June 26, 2023

Ref: 15225.01

Mr. Michael King, Chair
Wareham Planning Board
54 Marion Road
Wareham, MA 02571

Re: Application for Site Plan Review – Wareham PV I, LLC
Proposed Large Ground-Mounted Solar Energy Facility
0 Route 25 (Map 115, Lot 1000), Wareham, MA

Dear Mr. King,

On behalf of the Applicant, Wareham PV I, LLC, VHB respectfully submits this application for Site Plan Review for a proposed ±3.5-megawatt AC large ground-mounted solar energy facility (the Project) located at 0 Route 25 (Map 115, Lot 1000) in Wareham, Massachusetts. The Project is designed to comply with the applicable requirements of the Zoning By-Laws of the Town of Wareham as last revised in October 2019 and April 2023 (the Zoning By-Laws). Under Section 590: Solar Energy Generation Facilities of the Zoning By-Laws, the Project is subject to Site Plan Review by the Planning Board.

Enclosed, please find fourteen (14) copies of the following application materials (including one set of original signed application forms) as required per the applicable sections of the Zoning By-Laws:

- Site Plan Review Application
- Project Narrative
- Construction Schedule
- Existing Site Photographs
- Solar Documentation

The following application materials are being provided under separate cover:

- Site Plans titled "Proposed Solar Array – 0 Route 25", prepared by VHB, dated June 26, 2023
- Stormwater Report prepared by VHB, dated June 2023

Should you need any additional information please do not hesitate to reach out to me at 617-607-1833 or by email at sebaugh@vhb.com.

Sincerely,

Sarah Ebaugh, PE
VHB

SITE PLAN REVIEW APPLICATION

Proposed Large Ground Mounted Solar Energy Facility

0 Route 25
Wareham, MA

PREPARED FOR

Wareham PV I, LLC
330 Congress Street, 6th Floor
Boston, MA 02210
617.377.4301

PREPARED BY

101 Walnut Street
PO Box 9151
Watertown, MA 02471
617.924.1770

June 26, 2023

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Site Plan Checklist
Certified Abutters List
Tax Verification Form
Application Fees (Checks #379557, 379072, 379080)

APPLICATION FOR SITE PLAN REVIEW

Page 1

Applicant: Name: Wareham PV I, LLC

Mailing address: 330 Congress Street, 6th Floor
Boston, MA 02210

Telephone: (617) 377-4301

Project: Street & Number: 0 Route 25

Assessor's Map: 115 Lot(s) 1000

Dwelling Units # 0

Parking Spaces # 0

Acres: 22.4 Square Feet Commercial Space: 0

Briefly describe project:
A 3.5+/- MW (AC) Large Ground-Mounted Solar Energy Facility (the Project) located at 0 Route 25 in Wareham, MA, consisting of approximately 4.1 acres of solar panels, utility infrastructure, fencing, and stormwater management systems and related amenities to support the proposed use. The Project will use an existing gravel road with an existing curb cut off of Charge Pond Road for access.

Date: 06/26/2023

Signature of Applicant: Michael A. Alvarez
COO

APPLICATION FOR SITE PLAN REVIEW

List of abutters:

Please list the names of all abutters, owners of land directly opposite on any public or private street or way, and abutters to the abutters within three hundred feet of the property line of the petitioner as they appear on the most recent applicable tax list.

113-1011	Cape Solar, LLC,	PO Box 1300,	Onset, MA	02558
113-1012	Sure Cran Services, Inc.	PO Box 448,	Wareham, MA	02571
113-1029	Town of Wareham	54 Marion Road	Wareham, MA	02571
113-7-11	Daniel A Bazinet, Patricia A Bazinet Trustees	122 Charge Pond Road	Wareham, MA	02571
113-7-13	David A St Jacques	124 Charge Pond Road	Wareham, MA	02571
113-7-8	Charge Pond LLC	172 Charge Pond Road	Wareham, MA	02571
115-1000	David Fletcher	PO Box 892	Plymouth, MA	02362

SITE PLAN REVIEW CHECKLIST

Plans shall be prepared by a registered architect, landscape architect, or Professional Engineer. 14 complete sets are required with the following information included:

1. GENERAL INFORMATION

__X__ Developer name, address, telephone number

__X__ Property owner name, address, telephone number, legal relationship between developer and property owner

__X__ Date of application

__X__ Statement briefly describing project

__X__ Locus map (1" = 2,000')

__X__ Location of property to surrounding area (this plan shall show at a scale of not less than 1" = 100' the general characteristics of all lands within 200' of the proposed site and shall include structures, parking areas, driveways, pedestrian ways and natural characteristics)

__X__ Zoning district (square feet within each district if more than one district)

__X__ Total area of project in square feet to include wetland and 100 year flood plain (both in square feet)

__X__ All contiguous land owned by the applicant or by the owner of the property. At the discretion of the Planning Board photographs of the site at size 8" x 10"

2. EXISTING FEATURES

Plans shall be accurately drawn to a scale of 1" = 20, 1" = 40', or 1" = 100' where practical and appropriate to the size of the proposal and shall show all existing natural, manmade, and legal features of the site. Such plans are to include but not be limited to the following:

__X__ Tree line of wooded area

__N/A__ Individual trees 18" dbh or over

__X__ Bogs or agricultural areas

X All wetlands protected under CMR 10.02 (1) (a-d)

N/A Flood plain (100 years) with base flood elevation data

X Contour lines (2' intervals)

X General soil types

2b. EXISTING MANMADE FEATURES

N/A Vehicle accommodation areas

X Street, roads, private ways, walkways

N/A Curbs, gutters, curb cuts, drainage grates

N/A Storm drainage facilities, including manholes

N/A Utility lines, including water, sewer, electric, telephone, gas, cable TV

N/A Fire hydrants and location of dumpsters

N/A Building, structures, and signs (free standing), including dimensions of each

N/A Existing light fixtures

2C. EXISTING LEGAL FEATURES

X Zoning of property (district lines)

X Property lines (with dimensions identified)

X Street right of way lines

X Utility or other easement lines

X Monuments

3. THE DEVELOPMENT PLAN

The development plan shall show proposed changes in the (a) existing natural features; (b) existing man made features and (c) existing legal features.

The Development Plan shall include:

N/A Square feet in every new lot

X Lot dimensions

X Location and dimensions of all buildings and free standing signs as well as the distances from all buildings to lot lines, streets, or street right of way

N/A Building elevations (side, front, and back for a typical unit) showing building height and any proposed wall signs

N/A Location, dimensions, and designated use for all recreation areas

N/A Location and dimension of all open space; indicate whether open space is to be dedicated to public use or to remain private

N/A Streets (including street names) which conform to the design standards of the Planning Board's Rules and Regulations Governing the Subdivision of Land

N/A Curbs and gutters, curb cuts, drainage grates

X Drainage facilities including manholes, pipes, drainage ditches, and retention ponds

N/A Sidewalks and walkways showing widths and materials

N/A Outdoor illumination with lighting fixture size and type identified

X Utilities; water, sewer, electric, telephone, gas, cable TV

N/A Fire hydrant location

N/A Dumpster (trash collection facilities)

X New contour lines resulting from earth movement (at 2' intervals) and indications of types of ground cover and other precautions to stabilize slopes

X Vehicle parking, loading, and circulation areas showing dimensions

X Proposed new plantings by size and location or construction of other devices to comply with screening and shading requirements

4. IMPACT STATEMENT

In order to evaluate the impact of the proposed development to Town services and the welfare of the community, there shall be submitted an impact statement in two parts.

_X_ All applicable Town services including but not limited to schools, sewer services, water systems, parks, fire, and police.

_N/A_ The roads in the immediate vicinity of the proposed development (including an estimate of both peak and average daily counts)

_X_ The ecology of the area within the site and any significant off-site impacts

Part Two shall describe what actions have been taken to mitigate the impacts described in Part One

This application constitutes the applicant's willingness to work under the Town of Wareham's Zoning Bylaws. Any errors or omissions from this checklist or the Zoning Bylaw may result in the application not being placed on a Planning Board Agenda or denial of the Site Plan.

Site Plan Review
Application Checklist

Note to Applicant(s): The following checklist serves as an instrument to help ensure that all necessary information and materials are submitted with the application for Site Plan Review. Please verify that all related items listed below have been accounted for in your submission. (Refer to Article 15 of the Zoning By-Law of the Town of Wareham, Massachusetts, adopted October 2004).

Name of site: 0 Route 25 Wareham, MA Date: 06/26/2023
Owner(s): David Fletcher
Address: PO Box 829, Plymouth, MA 02362
Telephone Number: (508) 509-6178 Cell Phone: _____

Developer(s): Wareham PV I, LLC
Address: 330 Congress Street 6th Floor Boston, MA 02210
Telephone Number: (617) 377-4301 Cell Phone: _____

Relationship between Developer & Property Owner: _____
Wareham PV I, LLC will be leasing land from Site Owner.

Surveyor: VHB
Engineer: VHB
Architect: N/A
Landscape Architect: VHB

ITEM	Complete
Application for Site Plan Review – Special Permit filed with Planning Board	X
(14 copies of application and supplementary materials)	X
Application for Special Permit – Residential Cluster Development filed with Planning Board	N/A
(11copies of application and supplementary materials)	N/A
Copies filed with Town Clerk	X
Filing Fees	X
GENERAL INFORMATION	
Developer Name, address, telephone number	X
Property Owner Name, address, telephone number	X
Date of Application	X
Statement briefly describing project	X
Locus Map (1" = 2,000')	X
Location of property to surrounding area (scale should be no less than 1" = 100') and general characteristics of all lands within 200' of the proposed site including structures, parking areas, driveways, pedestrian ways, and natural characteristics	X

Zoning district (sq. feet within each district if more than one)	X
Total area of project to include wetland and 100 year floodplain (both in sq. feet)	N/A
All contiguous land owned by the applicant or by owner of property	X
Photographs of site (8" by 10") – at discretion of Permitting Authority	X
List of abutters, certified by Board of Assessors	X
Number of dwellings which could be constructed by means of a conventional development plan, considering the whole tract, exclusive of water bodies and land prohibited from development by legally enforceable restrictions, easements, or covenants. This includes: • Any bank, freshwater wetland, coastal wetland, beach, dune, flat, marsh, or swamp bordering the ocean, any estuary, creek, river, stream, pond, or lake • Lake under any of the water bodies listed above; • Land subject to tidal action • Land subject to coastal storm flowage or slopes in excess of fifteen (15) percent are not to be counted in figuring the number of permissible units of conventional development.	N/A
EXISTING FEATURES	
(Scale 1" = 20', 1" = 40',or 1" = 100' where practical and appropriate to the size of the proposal) Must include a minimum of the following:	X
1. Existing Natural Features a. Tree line of natural area; b. Individual trees 18" dbh or over; c. Bogs or agricultural areas; d. All wetlands protected under 310 CMR 10.01 (1) (a-d); floodplain (100 year) with base flood elevation data; e. Contour lines (2' intervals); f. General soil types.	X
2. Existing Man-Made Features a. Vehicle accommodation areas; streets, roads, private ways, walkways; b. Curbs, gutters, curb cuts, drainage grates; c. Storm drainage facilities including manholes; d. Utility lines including water, sewer, electric, telephone, gas, cable TV; e. Fire hydrants and location of dumpsters; f. Buildings, structures, and signs (free standing) including dimensions of each; g. Exterior lighting features.	X
3. Existing Legal Features a. Zoning of property (district lines); b. Property lines (with dimensions identified); c. Street right-of-way lines; d. Utility or other easement lines; e. Monuments.	X

DEVELOPMENT PLAN	
Proposed changes to existing natural features, existing man-made features, and existing legal features including the following;	X
• Area of each new lot in square feet;	N/A
• Lot dimensions;	X
• Location and dimensions of all buildings and freestanding signs as well as the distances from all buildings to lot lines, streets, or street;	N/A
• Location, dimension, and designated use for all recreation areas;	N/A
• Location and dimension of all open space (indicate whether such open space is to be dedicated to public use or remain private);	N/A
• Streets (including street names) which conform to the design standards of the Planning Board's Rules and Regulations Governing the Subdivision of Land;	N/A
• Curbs and gutters, curb cuts, drainage grates;	N/A
• Drainage facilities including manholes, pipes, drainage ditches, and retention ponds;	X
• Sidewalks and walkways showing widths and materials;	N/A
• Outdoor illumination with lighting fixture size and type identified;	N/A
• Utilities – Water, sewer, electric, telephone, gas, cable TV;	X
• Fire hydrant locations;	N/A
• Dumpster (trash collection facilities);	N/A
• New contour lines resulting from earth movement (2' intervals) and indications of types of ground cover and other precautions to stabilize slopes;	X
• Vehicle parking, loading, and circulation areas showing dimensions and layout of parking spaces, travel lanes, aisles, and driveways;	N/A
• Proposed new plantings by size and location or construction of other devices to comply with screening and shading requirements.	X
IMPACT STATEMENT	
Part One: Description of neighborhood and impact of proposed development on all applicable town services including but not limited to schools, sewer service, water system, parks, fire, and police protection;	X
Traffic report of existing and future traffic within and adjacent to proposed development. (Include estimate of both peak and average daily traffic count);	N/A
Analysis of site in regards to wetlands, coastal wetlands, slopes, soil conditions, 100 year flood plain, and other natural features as Planning Board may request;	X
Environmental Impact Assessment Report relating to proposed plan and copy of environmental impact report if otherwise required in order to illustrate the ecology of the area within the site and any significant off-site impacts;	X
Evaluation of open land proposed within cluster, with respect to size, shape, location, natural resource value, and accessibility by residents of the Town or of the cluster;	N/A

Part Two: Description of actions that have been taken to mitigate the impacts described in Part One.	X

TOWN OF WAREHAM
ANR/SUBIDIVISION/SITE PLAN REVIEW FORM

Check one: ANR _____ Form B _____ Form C _____ Site Plan Review __X__

Date stamped in _____ Date decision in due _____

Applicant's name(s) Wareham PV I, LLC

Applicant's address 330 Congress Street 6th Floor Boston, MA 02210

Telephone number (617) 377-4301

Address of property 0 Route 25 Wareham, MA

Landowner's name David Fletcher

Owner's address PO Box 829, Plymouth, MA 02362

Telephone number (508) 509-6178

Contact person Lindsey Kester Telephone (385) 312-3938

Map # 115 Lot # 1000 Zone R-130

Date Approved _____ Date Denied _____

Comments (state reasons for denial or stipulations of approval)

_____
_____
_____
_____
_____
_____
_____
_____

Conditions for: _____

_____
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_____

RECORD OF PLANNING BOARD PROCEEDINGS AND DECISIONS
Town of Wareham Planning Board

Name of Subdivision or Project: Proposed Large Ground-Mounted Solar Energy Facility, 0 Route 25, Wareham, MA

APPLICATION: FORM A _____ FORM B _____ FORM C _____
SITE PLAN REVIEW ___X_____ OTHER _____

DATE SUBMITTED: _____

DATE DECISION IS DUE: _____

DATE OF PUBLIC HEARING(S): _____

DECISION DATE: _____

DATE DECISION SENT TO TOWN CLERK: _____

DATE APPEALS PERIOD BEGINS _____ ENDS _____

PLANNING BOARD DECISIONS: (yes or no or abstention) if abstaining, appropriate recusal form should accompany decision.

FORM A:
M. Baptiste _____ S. Quirk _____ M. King _____ J. Gleason _____
S. Corbitt _____ C. Schulz _____ A. Slavin _____

FORM B:
M. Baptiste _____ S. Quirk _____ M. King _____ J. Gleason _____
S. Corbitt _____ C. Schulz _____ A. Slavin _____

FORM C:
M. Baptiste _____ S. Quirk _____ M. King _____ J. Gleason _____
S. Corbitt _____ C. Schulz _____ A. Slavin _____

SITE PLAN:
M. Baptiste _____ S. Quirk _____ M. King _____ J. Gleason _____
S. Corbitt _____ C. Schulz _____ A. Slavin _____

COMMENTS OR STIPULATIONS ON DECISION: _____

_____

_____

STREET NAME PROPOSED AND ACCEPTED: _____

_____

Conditions for: _____

_____

_____

_____

_____

_____

Submission #156

View | Delete

Welcome to the website. For Help Documentation & Videos, please visit our Municipal User Center or, for schools, visit our Schools User Center. **It is recommended you write down the following credentials to login to the User Center - Username: "CivicOpen" and Password: "ClientUser10!"**

Previous submission Next submission

Print Resend e-mails

Submission information

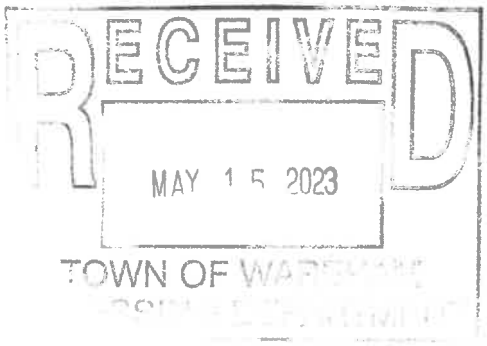
Form: Abutter Request Form - Online
Submitted by Anonymous (not verified)
May 15, 2023 - 4:32pm
73.218.178.36

Contact Information
Sarah Ebaugh

Phone Number:
6176071833

Email Address:
sebaugh@vhb.com

Date of Request:
May 15, 2023



Owners Name:
David Fletcher

Property Location:
0 Route 25, Wareham, MA

Map/Lot
Map 115, Lot 1000

Distance Required
300'

Which Board are you appearing before?
Planning Board

Previous submission Next submission

TOWN OF WAREHAM ABUTTERS

MAP 115 LOT 1000 300'

OWNER DAVID FLETCHER

MAP & LOT	OWNERS	STREET ADDRESS	TOWN & STATE	ZIP CODE
113-0-1011	CAPE SOLAR LLC,	PO BOX 1300,	ONSET, MA	02558
113-0-1012	SURE-CRAN SERVICES INC,	PO BOX 448,	WAREHAM, MA	02571
113-0-1029	TOWN OF WAREHAM,	54 MARION RD,	WAREHAM, MA	02571
113-0-7-11	BAZINET DANIEL A, BAZINET PATRICIA A TRUSTEES	122 CHARGE POND RD,	WAREHAM, MA	02571
113-0-7-13	STJACQUES DAVID A,	124 CHARGE POND RD,	WAREHAM, MA	02571
113-0-7-8	CHARGE POND LLC	172 CHARGE POND RD	WAREHAM, MA	02571
115-0-1000	FLETCHER DAVID,	PO BOX 892	PLYMOUTH, MA	02362

CERTIFIED ABUTTERS AS THEY APPEAR ON

OUR TAX ROLLS AS OF 5/16/2023

M. Renee Akins

ASSESSORS OFFICE

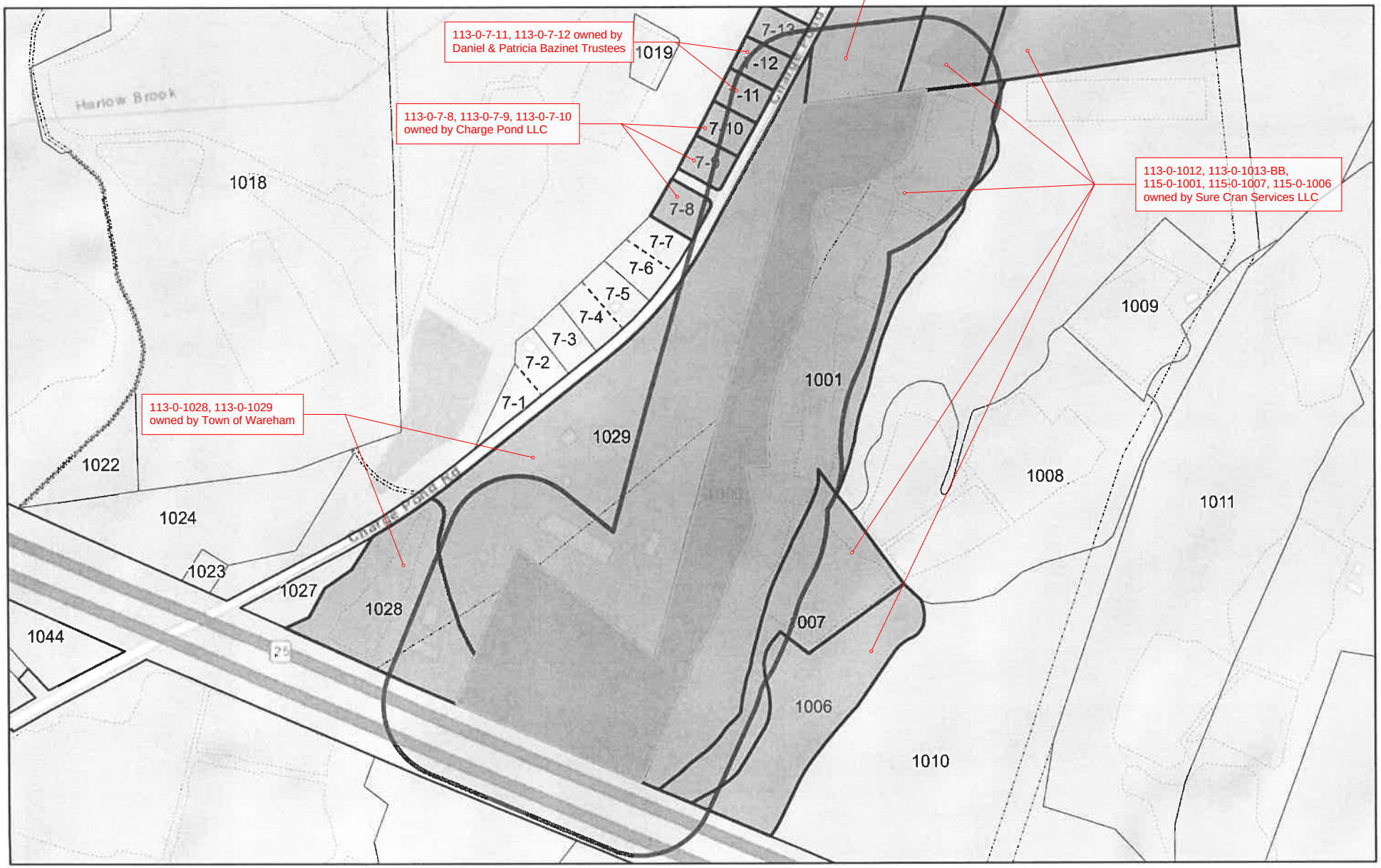
REQUESTED BY

SARAH EBAUGH

617 607-1833

SEBAUGH@VHB.COM

ArcGIS Web Map



5/16/2023, 8:38:43 AM

1:9,028

0 0.05 0.1 0.2 mi

0 0.07 0.15 0.3 km

Esri, HERE, Garmin, INCREMENT P, Intermap, NGA, USGS

Parcels with CAMA Data

Parcel Lines

Property Line

Public Road

Common Line

MiscPolys

Private Road ROW

Right of Way

Miscellaneous Lines

Utility

Wetland

Web AppBuilder for ArcGIS

Esri, HERE, Garmin, INCREMENT P, Intermap, NGA, USGS | FEMA, MassGIS | MassDEP |

PLANNING BOARD
TAX VERIFICATION FORM

This verifies that David Fletcher (name of applicant) is up-to-date on the taxes for the property(ies) he/she owns in Wareham. If the applicant is not the current owner of the property that the application addresses, the current owner David Fletcher (name of property owner) is up-to-date on taxes and on all properties he/she owns in the Town of Wareham.

Danielle Cambra

John Foster, Tax Collector

2

Project Narrative

Overview

The Applicant, Wareham PV I, LLC, is proposing to construct a ±3.5-megawatt (AC) large ground-mounted solar energy facility (the Project) located at 0 Route 25 in Wareham, Massachusetts (the Site). See Figure 1. The 22.4-acre parcel comprising the Site is identified by the Town of Wareham Assessor's Office as Map 115, Lot 1000 and is currently owned by David Fletcher (Owner).

According to the Town of Wareham Zoning Map, the Site is located within the Residential 130 (R-130) Zoning District. The Zoning By-Laws of the Town of Wareham as last revised in October 2019 and April 2023 (the Zoning By-Laws), which apply to the Project and the Site, allow large ground-mounted solar energy facilities, subject to Site Plan Review by the Planning Board, in the R-130 Zoning District.[1] The Project is designed to comply with the applicable requirements of the Zoning By-Laws.

Site Description

The Site is currently vacant land, bounded by Route 25 to the south, woodlands, wetland resource areas and cranberry bogs to the east, municipal buildings to the west and woodlands to the north. The southern end of the site is wooded, while land in the northern portion of the Site is already heavily disturbed as a result of historic sand extraction activities and consists primarily of exposed dirt/ sand.

Access to the Site is via an existing gravel access road with an existing curb cut off of Charge Pond Road. This gravel road, which bisects the Site and continues east, is located within an existing 20-foot wide access easement held by the Owner and owners of properties to the east of the Site. The road is currently in use by those property owners and their lessees for the operation and maintenance of existing cranberry bog

[1] Although the Zoning By-Laws were amended effective April 24, 2023, the Site is the subject of an Approval Not Required Plan (the ANR Plan) that was submitted to the Planning Board (along with the required written notice of plan submission to the Wareham Town Clerk) prior to June 12, 2021. The Planning Board voted to endorse the ANR Plan on July 12, 2021, thereby effecting a three-year "plan freeze" that shields the Site from the zoning changes effective June 12, 2021 to the extent such changes constitute (1) changes to zoning use regulations under the Zoning By-Laws, or (2) changes to zoning dimensional regulations or any other requirements of the Zoning By-Laws where the impact of such changes, as a practical matter, would nullify the use protection. The April 2023 zoning amendment increased the number of required parking spaces for motor vehicle repair facilities and has no bearing on the Project.

operations and four existing large ground-mounted solar energy facilities already approved by the Town of Wareham.

Wetland resource areas present on or near the Site and subject to jurisdiction under the Massachusetts Wetlands Protection Act (WPA) or the Wareham Wetland Protective By-Law include Bordering Vegetated Wetlands (BVW), Isolated Vegetated Wetlands (IVW), Bank and Riverfront Area (RFA). A Request for Determination of Applicability was submitted to the Conservation Commission, and a negative determination was issued on October 27, 2022.

According to the most recently available data provided by the Massachusetts Natural Heritage and Endangered Species Program (NHESP), no portion of the Site is located within Priority Habitat of Rare Species or Estimated Habitat of Rare Wildlife, nor are there any Certified Vernal Pools on the Site.

The Site does not lie within any Area of Critical Environmental Concern (ACEC). According to the most recent information provided by MassDEP, the Site is not located in an area designated as an Outstanding Resource Water, and no portion of the Site is located within a Zone II Interim Wellhead Protection Area.

The most recently issued Flood Insurance Rate Maps (FIRM) for the area produced by the Federal Emergency Management Agency (FEMA) indicate that no portion of the Site is within mapped 100-year floodplain.

The Natural Resources Conservation Service (NRCS) soil survey has mapped the majority of the Site as Windsor loamy sand, with 3 to 8 percent slopes. The northern tip of the Site is mapped as Carver coarse sand, with 3 to 8 percent slopes.

Topography within the southern portion of the Site generally slopes from west to east with slopes between 2 and 15%. In the northern portion of the site, topography is flatter in areas where earthwork activities previously occurred and contains isolated low points. Steep grades are present along the western property boundary.

Project Description

The Project will consist of approximately 4.1 acres of solar panels mounted on a fixed racking system at a specific angle for maximum exposure to the sun. The racking system will be supported by driven piles into the ground. All of the proposed solar panels and foundation structures will be located outside of the Wareham Wetland Protective By-Law's No Activity Zone as well as outside of the 100' wetland Buffer Zone.

Solar panels and associated infrastructure, including pad-mounted transformers and utility cabinets, will occupy both the north and south portions of the Site. The north portion of the Site was previously cleared and heavily disturbed as a result of historic sand extraction activities and consists primarily of exposed dirt/sand. Construction in the south portion of the Site will require tree clearing within the Project footprint, removal and stockpiling of existing topsoil for re-spreading, and minimal grading to provide a relatively constant slope across the panel array. Following grading and leveling of the land, the topsoil will be re-spread and the foundation piles or posts will be driven into the ground. The disturbed area will then be hydro-seeded with the requested Wareham, MA Northeast Solar Pollinator 3' Mix –

ERNMX-612. The Operation and Maintenance Plan for the Project prohibits the use of any chemical or pesticides on the Site.

Access to the Site is via an existing gravel access road with an existing curb cut off Charge Pond Road. This gravel road, which bisects the Site and continues east, is located within an existing 20-foot-wide access easement held by the Owner and owners of properties to the east of the Site. The road is currently in use by those property owners and their lessees for the operation and maintenance of existing cranberry bog operations and four existing large ground-mounted solar energy facilities already approved by the Town of Wareham. No improvements to the access will be necessary within the Charge Pond Road right of way. The portion of the existing gravel access road on the Site will be improved to the minimum width necessary for emergency access and suitable material to support the truck traffic that will be generated during the construction of the Project. Following construction, there will be minimal traffic to and from the Project, consisting mainly of a maintenance truck on occasion to address any issues. Within the Site, access to all major equipment pads will be provided via 20-foot-wide gravel drives with turnarounds at each equipment pad location. No impervious driveways are being proposed for the construction of the Project. These interior access drives will be inspected during the regular maintenance visits to the facility and gravel will be replaced and re-graded as necessary to provide proper access. The Applicant anticipates coordinating with a local snow removal contractor to perform snow removal operations.

The Project will be totally enclosed by fencing for safety purposes and to eliminate trespassing and potential issues with vandalism. In addition, signs will be posted on the perimeter fence around the Project and at the entrance gates to the north and south portions of the Site with emergency contact information.

The Project will be connected to the existing electric distribution wires running within the Charge Pond Road right of way. New underground conduits will be installed from the Site boundary, within the existing 20-foot-wide access easement, to a point approximately 100 feet from the edge of Charge Pond Road, at which point the infrastructure will transition above ground on new utility poles.

The Project has been designed to comply with the Massachusetts Stormwater Management Standards in accordance with the WPA Regulations (310 CMR 10.00). More detailed information is provided in the Stormwater Report that is included as an attachment to this application.

Compliance with Zoning By-law

The Project complies with the applicable sections of the Town of Wareham Zoning By-laws. Specially, the Project complies with the following sections as noted below:

Section 590 – Solar Energy Generation Facilities

- 593.1: Landscape Plan including sizes, types and numbers of plantings and details. Existing vegetation and other unique land features shall be preserved where feasible.

The location of existing treed areas and details regarding the proposed seed mix have been provided on the Site Plans. As noted above, the Site is bounded by Route 25 to the south, woodlands, wetland resource areas and cranberry bogs to the east, municipal buildings to the west and woodlands to the north. A 50-foot vegetated buffer has been provided on all property lines. Additional plantings are proposed along the western property boundary to supplement existing vegetation.

The Project has been designed to limit earthwork and tree/vegetation clearing to the maximum extent feasible. Extremely limited clearing is proposed in the north portion of the Site, which is already heavily disturbed as a result of historic sand extraction activities and consists primarily of exposed dirt/sand. An area of clearing in the south portion of the Site is required to accommodate the proposed solar arrays, and other areas of clearing beyond the arrays is required to accommodate stormwater facilities, and to avoid shading impacts to the arrays. These areas are depicted on the Site Plans.

- 593.2: Plans of the large ground-mounted solar energy facility signed by a PE licensed to practice in the Commonwealth of Massachusetts showing the proposed layout of the system and any potential shading from nearby structures.

  Site Plans stamped and signed by a Massachusetts registered Professional Engineer (the Site Plans) have been prepared in accordance with this requirement and are included as an attachment to this application. As noted above, an area of clearing in the south portion of the Site is required to accommodate the proposed solar arrays, and other areas of clearing beyond the arrays is required to accommodate stormwater facilities, and to avoid shading impacts to the arrays. These areas are depicted on the Site Plans.

- 593.3: Proposed changes to the landscape of the site, grading, vegetation clearing and planting, exterior lighting, screening vegetation & structures.

  This information is provided on the Site Plans. No lighting is proposed.

- 594.4: A Stormwater management plan detailing the hydrologic conditions of the site, proposed alterations of the site and proposed components of drainage system and any measures for the detention, retention or infiltration of water for the protection of water quality and protection from flooding.

  A stormwater management report (the Stormwater Report) has been prepared in accordance with this requirement and included as an attachment to this application.

- 593.5: Description of the solar energy facility and the technical, economic and other reasons for proposed location and the design shall be prepared and signed by a registered professional engineer.

  Please refer to the "Project Description" section above for a description of the facility. The Applicant acquired the Project from Galehead Development in January 2021. Given the scarcity of available land for greenfield solar development, as well as the lengthy interconnection timeframes, the Applicant saw value in acquiring a mid-stage development asset with an established interconnection and land position. The Applicant views the location off of Charge Pond Road as highly appropriate for solar development given the proximity of several other operating large ground-mounted solar energy facilities, the lack of residential abutters, and the fact that the land

in the northern portion of the Site is already heavily disturbed as a result of historic sand extraction activities and consists of exposed dirt/sand. The sandy soils on the Site also make for a less expensive build as the land is already quite level with no need to pre-drill holes to accept supporting piles—they can just be driven into the ground.

The Project design was prepared, and the Site Plans depicting that design were signed, by a Massachusetts registered Professional Engineer.

- 593.6: Confirmation prepared and signed by a registered professional engineer that the large ground mounted solar energy facilities comply with all applicable Federal and State standards.

  The Project will comply with all applicable federal and state standards. The Site Plans are stamped and signed by a registered Professional Engineer. The final electrical and structural plans to be submitted with the Building Permit application will also be stamped and signed by a registered Professional Engineer.

- 593.7: One- or three-line electrical diagram detailing the solar photovoltaic installation, associated components, and electrical interconnection methods, with all National Electrical Code compliant disconnects and over current devices.

  Refer to Section 5 of this document.

- 593.8: Documentation of the major system components to be used, including panels, mounting system, inverters.
  Refer to Section 5 of this document.

- 593.9: Documentation of the major system components to be used, including panels, mounting system, inverters.

  Refer to Section 5 of this document.

- 593.10: An Operations & Maintenance Plan (see section 595 on decommissioning)
  Refer to Section 5 of this document.

- 593.11: The Planning Board may require the proponent to pay for professional services to evaluate the proposal.
  Acknowledged.

Section 594.1 & 3 – Design Standards

- 594.1.1: Be sited on a parcel of land at least three (3) acres in size.
  The Site is approximately 22.4-acres in size, therefore meeting the requirement.

- 594.1.2: Meet the requirements and standards for industrial uses found in Article 7: Design Standards and Guidelines of this Zoning By-law.

  The Project meets the requirements as listed in Article 7: Design Standards and Guidelines of this Zoning By-law.

- 594.1.3-5: Have front, side, rear yard depths that comply with the R-130 district requirements, which are 20-feet, 10-feet and 10-feet, respectively. That is unless the parcel either abuts a residential district, in which all setbacks shall be a minimum of 50-feet or is across the street from a residential district or residential development.

  The Project neither abuts a residential district nor is across the street from either a residential district or residential development. However, a 50-foot setback has been provided on all property lines to the proposed fence line.

- 594.1.6: All large ground-mounted solar energy facilities shall be fenced for security. Fencing that is visible from the right-of-way or residences shall be a type of fence acceptable to the permit grading authority. All fencing shall be designed to blend into the landscape.

  Security fencing is proposed around the perimeter of the facility. No fencing is visible from the public right of way or residences.

- 594.1.7: The project proponent shall submit a plan for the operation and maintenance of the large ground-mounted solar energy facility, which shall include measures for maintain safe access to the installation, stormwater controls as well as general procedures for operational maintenance of the installation.

  An operations & maintenance (O&M) plan has been provided in Section 5 of this document. O&M measures specific to stormwater management have been included as an appendix to the Stormwater Report.

- 594.1.8: No large ground-mounted solar energy facilities shall be approved or constructed until evidence has been given to the permit granting authority that the utility company that operates the electrical grid where the installation is to be located has been informed of the large ground-mounted solar energy facilities owner or operator's intent to install an interconnected customer owned generator. Off-grid systems shall be exempt from this requirement.

  This information has been provided as an attachment.

- 594.3.1: Screening of appurtenant structures, but not limited to equipment shelters, storage facilities, transformers and substations from the view of persons not on the parcel, public rights of way and all residential districts shall be provided.

  Much of the property is naturally screened by surrounding woodlands or like uses.. Additional plantings along the western property boundary are provided to supplement the existing vegetation for screening.

- 594.3.2: Lighting shall be consistent with state and federal law. Lighting of appurtenant structures shall be limited to that required for safety and operational purposes and reasonable shielded from abutting properties. Where feasible, lighting of the solar photovoltaic installation shall be directed downward and shall incorporate full cut-off fixtures to reduce light pollution.

No lighting is proposed.

- 594.3.4: Place all utility connections underground except to the extent the Planning Board reasonably determines that 'underground utilities are not feasible'.

  All utility connections are proposed underground, until the point of interconnection at Charge Pond Road. At this point, utilities transition to above grade in order to connect to the existing overhead wires within Charge Pond Road.

- 594.3.5: Inverters and transformers shall be sited so as to minimize sound impacts to residences.

  The Project is not located near residences. Sound generation documentation has been provided in Section 5.

- 594.3.6: Minimize the clear cutting of trees and natural vegetation to the minimum necessary for construction, operation, and maintenance of the facility.

  The Project has been designed to meet this requirement to the maximum extent feasible. Extremely limited clearing of natural vegetation is proposed in the north portion of the Site, which is already heavily disturbed as a result of historic sand extraction activities and consists primarily of exposed dirt/sand. An area of clearing in the south portion of the Site is required to accommodate the proposed solar arrays, and other areas of clearing beyond the arrays is required to accommodate stormwater facilities, and to avoid shading impacts to the arrays. These areas are depicted on the Site Plans.

- *595. Abandonment or Decommissioning:*

  The Project will comply with the abandonment and decommissioning requirements described in Section 595. A Decommissioning Evaluation and Cost Estimate has been included attached herein.

Section 1534: Development Impact Statement

- Description of neighborhood and impact of proposed development on all applicable town services including but not limited to schools, sewer, water, parks, fire and police.

  The Project is located in an agricultural area containing cranberry bogs, other solar developments and adjacent to the Town's Department of Public Works (DPW) maintenance yard and it is not anticipated that the solar use will create adverse impacts on Town resources. The proposed use does not require sewer or water services. Police and fire support would only be required in response to emergencies.

- Traffic Report of existing traffic within and adjacent to proposed development.

  The proposed use is not anticipated to generate additional traffic on surrounding roadways within the vicinity of the Project and does not warrant the preparation of a traffic report. The Applicant respectfully requests a waiver to this requirement.

- Ecology of the area within the site and any significant off-site impacts.

The project will not create any adverse on-site or off-site impacts. A Request for Determination of Applicability was submitted to the Conservation Commission, and a negative determination was issued on October 27, 2022. The Project has been designed to not impact any wetland resource areas including buffer zones and riverfront area.

According to the most recently available data provided by the Massachusetts Natural Heritage and Endangered Species Program (NHESP), no portion of the Site is located within Priority Habitat of Rare Species or Estimated Habitat of Rare Wildlife, nor are there any Certified Vernal Pools on the Site.

The Site does not lie within any Area of Critical Environmental Concern (ACEC). According to the most recent information provided by MassDEP, the Site is not located in an area designated as an Outstanding Resource Water, and no portion of the Site is located within a Zone II Interim Wellhead Protection Area.

The most recently issued Flood Insurance Rate Maps (FIRM) for the area produced by the Federal Emergency Management Agency (FEMA) indicate that no portion of the Site is within 100-year floodplain.

The Natural Resources Conservation Service (NRCS) soil survey has mapped the majority of the Site as Windsor loamy sand, with 3 to 8 percent slopes. The northern tip of the Site is mapped as Carver coarse sand, with 3 to 8 percent slopes.

Topography within the southern portion of the Site generally slopes from west to east with slopes between 2 and 15%. In the northern portion of the site, topography is flatter in areas where earthwork activities previously occurred and contains isolated low points. Steep grades are present along the western property boundary.

- Proposed Mitigation

  Currently, no mitigation is proposed as part of this project. The solar array will provide a renewable source of energy and it is not anticipated to have any adverse impacts on the environment and/or municipal services that would require mitigation.

Waiver Requests

The Applicant respectfully requests waivers from the following sections of the Zoning By-law:

- 1532.1.2: Such plans are to include the location of existing individual trees 18"dbh or over.

  Given the large size of the parcel, locating each individual tree 18" or larger is infeasible.

- 1534.2.2: Include an estimate of both peak and average daily traffic counts.

  Applicant requests a waiver from this requirement on the grounds that following construction, there will be minimal traffic to and from the Project, consisting mainly of a maintenance truck on occasion to address any issues. Therefore, a study of proposed conditions comparedto existing conditions is not warranted.

\\vhb.com\gis\proj\Wat-EVL\14668.02 Galehead Env- Wareham\Project\NOI Figures 021121.aprx

0 175 350 700 Feet

Proposed Wareham Solar | Wareham, MA

Legend

Project Location

Figure 1 - Locus Map

Source Info: USGS, MassGIS, VHB

3

Construction Schedule

WAREHAM SOLAR-CONST. SCHEDULE

Activity	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12
Preconstruction/Engineering												
Geotech Investigation & Pile Load Tests												
Preliminary Engineering												
Finalize EPC Contracting												
Civil & Structural*												
Vegetation Clearing												
Grading/Roads												
Perimeter Fence Install												
Struct - Pile Installation												
Struct - Equipment Fdns												
Struct - Rack Installation												
Planting/Restoration/Reseeding												
Electrical (Plant)**												
MV Collection/Inverter Install												
DC Install (wire and equipment)												
Module Deliveries												
Module Install												
DC Wiring												
Battery System Install												
Testing & Commissioning												
Electrical (Overhead Line)												
Vegetation Clearing/Access												
Set Structures/String Conductor												
Planting/Reseeding/Restoration												
Plant Completion/Operations Handoff												

4

Existing Site Photographs

vhb Engineers | Scientists | Planners | Designers

Photographic Log

Client Name: Longroad Energy | **Site Location:** 0 Route 25, Wareham, MA | **Project No**: 15225.01

Photo No.: 1 | **Date:** 4/29/21

Location: Northeast corner of site

Description: Existing access path adjacent to abutting property

vhb Engineers | Scientists | Planners | Designers

Photographic Log

Client Name: Longroad Energy | **Site Location:** 0 Route 25, Wareham, MA | **Project No**: 15225.01

Photo No.: 2 | **Date:** 4/29/21

Location: Northeast corner of site

Description: Existing stockpiles within cleared area of site

vhb Engineers | Scientists | Planners | Designers

Photographic Log

Client Name: Longroad Energy	**Site Location:** 0 Route 25, Wareham, MA	**Project No**: 15225.01

Photo No.: 3 **Date:** 1/28/21

Location: Southern boundary of site

Description: Wetland to southeast of site, facing west

vhb Engineers | Scientists | Planners | Designers

Photographic Log

Client Name: Longroad Energy	**Site Location:** 0 Route 25, Wareham, MA	**Project No**: 15225.01

Photo No.: 4 **Date:** 3/17/21

Location: Central portion of Site

Description:

Mainly unvegetated area within most of the central portion of the Site.

Engineers | Scientists | Planners | Designers

Photographic Log

Client Name: Longroad Energy | **Site Location:** 0 Route 25, Wareham, MA | **Project No**: 15225.01

Photo No.: 5 **Date:** 3/17/21

Location: Central portion of Site

Description:
Mainly unvegetated area within most of the central portion of the Site.

Engineers | Scientists | Planners | Designers

Photographic Log

Client Name: Longroad Energy | **Site Location:** 0 Route 25, Wareham, MA | **Project No**: 15225.01

Photo No.: 6 **Date:** 6/28/21

Location: Southern portion of Site

Description:
Forested area in the southern portion of the Site. Mainly pine canopy with dense shrub layer.

5

Solar Documentation

Operations & Maintenance Plan
Documentation of Site Control/ Access
Product Cut Sheets
Sound Generation
Decommissioning Plan/ Financial Surety
Interconnection Acknowledgement
One-Line Electrical Diagram

Project Inspection and Maintenance Program

During the operational phase of the Project, the following equipment inspection and maintenance activities will be implemented as scheduled below.

The following activities will be conducted in accordance with the Original Equipment Manufacturer (OEM) but in no case less than annually:

- Complete visual inspection
- Complete mechanical inspection
- Complete electrical testing
- Complete equipment maintenance
- Inspection and maintenance of racking system

Operations and Maintenance Capability

Longroad Energy Holdings, LLC (Longroad), of which Wareham PV I, LLC is a subsidiary, is an experienced operations and maintenance (O&M) manager of both large-scale solar and wind projects.

Longroad Energy Services, LLC (LES), also a subsidiary of Longroad, is currently contracted to manage 3.5 gigawatts (GW) of operating and under construction projects across the United States.

LES's O&M plan is designed to manage all operational and commercial matters related to the facility. Longroad will provide the following resources at or for the Project facility to ensure safety and complete readiness by the commercial operation date:

- Staff recruiting;
- Staff training and safety;
- Policy and procedure guidance and manuals;
- Operations and engineering readiness;
- Maintenance services readiness; and
- Install Supervisory Control and Data Acquisition (SCADA) and asset management systems.

LES employs a fully integrated, data-driven O&M strategy that maximizes project value. LES's in-house operations capabilities include real-time resource monitoring and analysis from its Portland, Maine-based Remote Operations Center (ROC), on-site and regional O&M personnel, and regional Commercial Asset Management staff.

A key to LES's success is early engagement in the development and construction process to ensure seamless transition to operations. The operations team works alongside Longroad project developers and construction managers from the earliest phases of project development.

During the operations phase, LES combines advanced performance monitoring and analysis from the ROC project financial data to continually optimize site performance. LESutilizes cloud-based data management platforms to manage data and optimize project operational and financial performance. Through the use of these tools, decisions are made with a complete understanding of the short- and long-term financial implications to the projects LES manages. In addition to an experienced in-house staff, LES partners with Tier 1 suppliers of major equipment such as modules, trackers, inverters, and transformers to ensure high performance throughout each project's expected life.

Safety

Longroad's first priority is the safety of its personnel and those who work on its projects. Each operational review meeting begins with a review of safety lessons learned, and every operating decision is made within the framework of the LES Safety Program and Site Safety Plan. Longroad's safety culture begins with the hiring decisions made in staffing its teams and continues through each phase of development, construction, and operation of our projects.

All new employees must complete Longroad's onboarding safety training before reporting to their duties. Longroad continually updates its employee safety training. Annual safety refresher training of all site employees is accomplished through monthly or as-needed safety meetings, tailgate meetings, and formal training sessions. Topics reviewed in these sessions include high voltage work, electrical safety, arc flash protection, and live work. Other areas of training include confined space entry, environmental considerations, CPR/first aid, forklift safety, crane safety, safe lifting practices, and safe driving.

Vegetation Management

Ground cover within the array areas will be monitored for growth and mowed as needed to maintain a safe work environment. Vegetation growth will be maintained under and around the solar installation at levels needed to reduce the risk of ignition from the electrical system while minimizing mowing.

The Project site will be inspected for evidence of erosion and rilling in slopes. If such conditions are observed, they will be corrected and revegetated as needed.

Growth of trees or other vegetation shading the arrays will be trimmed as needed. Excessive vegetation growth, including saplings, shrubs, large weeds, within the array areas will be removed.

Stormwater Management Features and Access Roads

Stormwater management features will be inspected for evidence of erosion and sediment settling. If erosion has occurred or sediment has accumulated in stormwater management features, such conditions will be corrected. Refer to the Long Term Pollution Prevention Plan provided as an attachment within the Stormwater Management Report for additional information pertaining to inspection and maintenance of stormwater management features.

The gravel access roads and roadside swales will be inspected for evidence of erosion, rilling, and clogging. If such conditions are observed, they will be corrected.

Solar Panel Recycling

All broken solar panels will be promptly contained and removed from the project site. Panels requiring disposal during operations or at decommissioning will be recycled.

SECOND AMENDMENT TO OPTION AGREEMENT

THIS SECOND AMENDMENT TO OPTION AGREEMENT (this "*Amendment*") is entered into and is effective as of May 17, 2023 (the "*Amendment Effective Date*") by and between David H. Fletcher ("*Owner*") and Wareham PV I, LLC ("*Optionee*"). Owner and Optionee may also be referred to hereafter collectively as the "Parties" or each a "Party." Capitalized terms used in this Amendment that are not defined herein will have the meanings described to them in the Agreement (defined below).

A. Owner and Optionee previously entered into an Option Agreement dated May 16, 2019, a Memorandum of which was recorded on October 7, 2019 in the Plymouth County Registry of Deeds, Massachusetts in Book 51755, Page 206, and amended by that certain Amendment to Option Agreement dated as of May 16, 2021, a Memorandum of which was recorded on August 5, 2021 in the Plymouth County Registry of Deeds, Massachusetts in Book 55430, Page 314 (the "*Agreement*").

B. The Parties desire to modify and amend the Agreement in certain respects, as more particularly set forth herein, so as to extend the option term period to lease the Property from Owner.

For and in consideration of the premises, including the recitals above, and other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged, the Parties agree as follows:

1. **Amendments**. The Agreement is hereby amended as follows:

   a. The last three sentences of Section 2 of the Agreement are hereby deleted and replaced with the following:

   "Prior to the expiration of the Seventh Option Period, Optionee may extend the Option for an additional one (1) year (the "Eighth Option Period") upon written notice to Owner and payment by Optionee of an additional fee of [redacted] ("Eighth Option Fee"). Prior to the expiration of the Eighth Option Period, Optionee may extend the Option for an additional one (1) year (the "Ninth Option Period") upon written notice to Owner and payment by Optionee of an additional fee of [redacted] ("Ninth Option Fee"). Prior to the expiration of the Ninth Option Period, Optionee may extend the Option for an additional one (1) year (the "Tenth Option Period") upon written notice to Owner and payment by Optionee of an additional fee of [redacted] ("Tenth Option Fee"). Prior to the expiration of the Tenth Option Period, Optionee may extend the Option for an additional one (1) year (the "Eleventh Option Period") upon written notice to Owner and payment by Optionee of an additional fee of [redacted] ("Eleventh Option Fee"). Together, the First Option Fee, Second Option Fee, Third Option Fee, Fourth Option Fee, Fifth Option Fee, Sixth Option Fee, Seventh Option Fee, Eighth Option Fee, Ninth Option Fee, Tenth Option Fee, and Eleventh Option Fee are referred to herein as "Option Fees", which shall be nonrefundable except as otherwise expressly set

D.H.F.

forth herein. Together, the First Option Period, Second Option Period, Third Option Period, Fourth Option Period, Fifth Option Period, Sixth Option Period, Seventh Option Period, Eighth Option Period, Ninth Option Period, Tenth Option Period, and Eleventh Option Period are referred to herein as "Option Periods". Optionee shall have the right to terminate this Option, as to all or any part of the Property, at any time and for any reason, with immediate effect during the Option Periods [redacted]

b. Section 9(a) is hereby deleted in its entirety and replaced with the following:

"a. the initial term shall be for twenty-five (25) years ("Initial Term") commencing on the date of Commercial Operation as defined below. Prior to the end of the Initial Term, Optionee may request from Owner the right to a five (5) year extension term upon mutually agreeable terms and conditions (the "First Extension Term"). Prior to the end of the First Extension Term (if applicable), Optionee may request from Owner the right to a second five (5) year extension term upon mutually agreeable terms and conditions (the "Second Extension Term"). Prior to the end of the Second Extension Term (if applicable), Optionee may request from Owner the right to a third five (5) year extension term upon mutually agreeable terms and conditions (the "Third Extension Term"). The date of Commercial Operation means the date the Facility has been interconnected to the utility electric grid and sale of energy on a commercial basis has commenced ("Commercial Operation");

c. The following is hereby added as Section 9(h) to the Agreement:

"h. prior to the Fifth (5th) anniversary of the Operations Date Optionee shall retain an independent contractor to provide a good faith estimate of the total cost to restore any changes made to the Property by Optionee to substantially the same condition as immediately prior to the execution of the Lease, less the salvage value of the Facility, if any (the "Reclamation Estimate"). Within ten (10) business days of its receipt of the Reclamation Estimate, Optionee shall deliver a copy of the Reclamation Estimate to Owner. No later than sixty (60) days after such delivery, Optionee shall deliver to Owner credit support ("Removal Bond") for the amount of the Reclamation Estimate. Further Optionee shall not be obligated to provide the Removal Bond if any governmental agency imposes a bonding or financial security arrangement as part of the condition of the permit with respect to the Project which covers decommissioning costs, and such credit

D.H.F.

support shall be deemed to be satisfied by the bond or financial security arrangement supplied pursuant to such permit. Optionee shall comply with all decommissioning requirements that are contained in the permit that is ultimately issued for the Project. To the extent that the Reclamation Estimate is zero (or negative), the Removal Bond shall not be required; and"

d. The following is hereby added as Section 9(i) to the Agreement:

"Owner shall fully cooperate with Optionee in connection with obtaining and complying with any land use, environmental or other governmental approvals required for the financing, construction, installation, relocation, replacement, maintenance, operation or removal of the Facility, including without limitation execution of applications for such governmental approvals. [redacted]

2. The Parties hereby acknowledge that as of the Amendment Effective Date, the parties have entered into the Eighth Option Period.

3. **Miscellaneous**. As expressly modified by this Amendment, the Agreement is hereby ratified and confirmed by Owner and Optionee.

4. **Successors and Assigns**. This Amendment is binding upon and inures to the benefit of each of the Parties and their respective directors, managers, officers, employees, stakeholders, principals, agents, representatives, heirs, successors, assigns, and family members.

5. **Memorandum**. This Amendment shall not be recorded except with the express written consent of Owner and Optionee. Owner and Optionee shall execute an Amendment to the Memorandum of Option Agreement (the "Memorandum") in the form attached hereto as Exhibit A, for filing of record in the official public records of Plymouth County Registry of Deeds, Massachusetts. The recording of such Memorandum of shall be binding upon Owner and Optionee, and their respective successors, legal representatives and assigns, the same as if this Amendment was filed of record in its complete text.

6. **Counterparts.** This Amendment and the Memorandum as provided for above may be executed and delivered by fax or electronic mail and in multiple counterparts, each of which shall be deemed an original to the same effect as if all parties had executed the same instrument, and all of which together shall constitute one and the same instrument.

[The signature pages to this Amendment follow on the next pages]

This Amendment is executed by Owner and Optionee to be effective as of the Amendment Effective Date.

OWNER:

DAVID H. FLETCHER

[Signature pages continue]

OPTIONEE:

WAREHAM PV I, LLC,
a Delaware limited liability company

By: Michael U. Alvarez
Name: Michael U. Alvarez
Title: Chief Operating Officer

Exhibit A

(attached)

After recording return to:
Longroad Energy
Attn: Vanessa Kwong
220 Montgomery Street, Suite 860
San Francisco, CA 94104

SECOND AMENDMENT TO MEMORANDUM OF OPTION AGREEMENT

This SECOND AMENDMENT TO MEMORANDUM OF OPTION AGREEMENT (this "Memorandum") is entered into as of the 17th day of May, 2023, by and between David H. Fletcher ("Owner") and Wareham PV I, LLC, a Massachusetts limited liability company ("Optionee"). Owner and Optionee are sometimes referred to herein individually as a "Party" and collectively as the "Parties."

RECITALS

A. Owner and Optionee previously entered into an Option Agreement (the "Agreement") dated May 16, 2019, a Memorandum of which was recorded on October 7, 2019 in the Plymouth County Registry of Deeds, Massachusetts in Book 51755, Page 206, and amended by that certain Amendment to Option Agreement dated as of May 16, 2021, a Memorandum of which was recorded on August 5, 2021 in the Plymouth County Registry of Deeds, Massachusetts in Book 55430, Page 314, covering certain land located in County of Plymouth, State of Massachusetts, as more particularly described on Exhibit A attached hereto and incorporated herein by reference (the "Property").

B. The Parties have amended the Agreement pursuant to an Amendment to Option Agreement of even date herewith (the "Amendment") to amend certain terms of the Agreement as further described below, among other terms. The Parties desire to execute this Memorandum to put the public on notice of certain terms of the Amendment.

NOW, THEREFORE, in consideration of the mutual promises set forth in the Agreement and the Amendment, and of other good and valuable consideration, the receipt and sufficiency of which is hereby acknowledged, the Parties agree as follows:

1. **Amendments.**

   The Agreement was amended to allow Optionee the right to exercise the options granted in the Option Agreement at any time on or before, May 17, 2027.

2. **Miscellaneous.**

i. Interpretation. Nothing contained in this Memorandum or the Amendment shall be construed as modifying the Agreement except as specifically provided pursuant to the Amendment. Capitalized terms used but not otherwise defined in the Amendment shall have the same meanings assigned to them in the Agreement. The purpose of this Memorandum is to give public notice of the existence of the Amendment. In the event of any inconsistency between this Memorandum and the terms and conditions of the Amendment, the Amendment shall prevail.

ii. Ratification. The Agreement, as amended by the Amendment, is hereby ratified and confirmed, and shall continue in full force and effect.

iii. Counterparts. This Memorandum may be executed in multiple counterparts, all of which shall be considered one and the same agreement and each of which shall be deemed an original.

[*Signature pages follow*]

P.H.F.

IN WITNESS WHEREOF, the parties have executed this Memorandum to be effective as of the date first set forth above.

OWNER:

DAVID H. FLETCHER,

By: David H. Fletcher

STATE OF MASS. §

§

COUNTY OF PLYMOUTH §

The foregoing instrument was acknowledged before me this 7 day of June, 2023 by David H. Fletcher.

[seal of Notary]

Elizabeth A. Morrison

Notary Public

[*Signature pages continue*]

Elizabeth A. Morrison
NOTARY PUBLIC
Commonwealth of
Massachusetts
My Commission Expires
2/14/2025

OPTIONEE:

WAREHAM PV I, LLC,

a Delaware limited liability company

By:_____

Name: Charles Spiliotis

Title: Chief Operating Officer

ACKNOWLEDGMENT

A notary public or other officer completing this certificate verifies only the identity of the individual who signed the document to which this certificate is attached, and not the truthfulness, accuracy, or validity of that document.

State of California

County of San Francisco

On June 14, 2023, before me, Jocelyn Koo, Notary Public, personally appeared Charles Spiliotis, who proved to me on the basis of satisfactory evidence to be the person whose name is subscribed to the within instrument and acknowledged to me that he executed the same in his authorized capacity, and that by his signature on the instrument the person, or the entity upon behalf of which the person acted, executed the instrument.

I certify under PENALTY OF PERJURY under the laws of the State of California that the foregoing paragraph is true and correct.

WITNESS my hand and official seal.

Signature_____

JOCELYN KOO
Commission No. 2302816
NOTARY PUBLIC-CALIFORNIA
ALAMEDA COUNTY
My Comm. Expires SEPTEMBER 19, 2023

EXHIBIT A

Legal Description of the Property:

Located in Plymouth County, Massachusetts and more particularly described as follows:

All that certain lot, containing 22.4 +/- acres of land with improvements thereon, located on Route 25 in Wareham, Plymouth County, MA 02571, identified as Lot No. 1000 in Plan of Land in Wareham, Mass, as recorded on August 30, 2016 in Plan Book 60, page 872 in the Plymouth County Registry of Deeds, a copy of which is attached hereto at Exhibit B.

BEING part of the same premises which Frank C. Arcadipane by his deed dated May 8, 2007 and recorded in the Plymouth County Register of Deeds in Book Volume 34514, pages 232-234, granted and conveyed to David Fletcher.

D.F. D.F.

SEL-651R-2 Recloser Control

Advanced Recloser Control

New Features

The following features were added for intertie protection and control, compliant with IEEE Standard 1547-2018 "IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power System Interfaces."

- **Fast Rate-of-Change-of-Frequency and Vector Shift Elements.** Swiftly detect islanding conditions and disconnect distributed energy resources (DER) before any possible autoreclosing of the electric power system (EPS).
- **Longer Seconds-Based Time Delays for Frequency Elements.** Frequency elements have adequate time-delay setting range for qualifying tripping for abnormal EPS frequency. Similarly, return of normal EPS frequency is qualified before the intertie (recloser) is closed. Seconds-based timing is immune to frequency changes and allows tripping time to be absolute.
- **Additional Voltage Elements.** Adequate number of voltage elements allows for qualifying tripping for abnormal EPS voltage. Similarly, return of normal EPS voltage is qualified before the intertie (recloser) is closed.
- **Autosynchronism Element Works in Tandem With Synchronism-Check Element.** Autosynchronism element frequency and voltage control outputs automatically bring DER (versus EPS) slip frequency, phase angle, and voltage magnitude differences within allowable limits for synchronism-check closing of the intertie (recloser).

Key Features and Benefits

- **Single-Phase Tripping/Reclosing.** Interrupt, then restore service on the faulted phase, rather than affecting all three phases. When load levels vary from phase to phase, set trip levels independently for each phase.
- **Multi-Recloser Interface.** Support a number of reclosers from different manufacturers with one common control cable interface.
- **Wide-Range Recloser Compatibility.** Use the SEL-651R-2 Advanced Recloser Control with control cable interfaces for many different reclosers. Learning the settings and operation of just the SEL-651R-2 enables you to operate a wide range of reclosers.
- **ACSELERATOR QuickSet® SEL-5030 Software.** Use the eight settings groups to easily configure multiple group settings to fit operational situations. Apply custom application designs and create design templates that can be stored on the recloser control for your specific applications.
- **Low-Energy Analog (LEA) Inputs.** Reduce costs and save space with as many as six LEA voltage inputs.
- **Enclosure Options.** Choose the extra space and easy access of the dual-door enclosure or the more compact size of the single-door option. For the dual- or single-door options, select the painted cold-rolled steel enclosure (NEMA 3R rated) for normal applications or the painted type 304 stainless steel enclosure (NEMA 3RX rated) to reduce corrosion in harsh environments. Both enclosure styles also achieve an IP45 rating for solids and water ingress resistance.
- **Ethernet Communications.** Provide DNP, Modbus®, IEC 61850, File Transfer Protocol (FTP), and Simple Network Time Protocol (SNTP) capabilities through use of single fiber, dual copper, or fiber-optic Ethernet ports. A built-in web server makes firmware upgrades over Ethernet quick and secure.
- **Communications Flexibility.** Order the SEL-651R-2 with one USB port, four serial ports (three EIA-232 and one EIA-485), one Ethernet port (fiber-optic), or two Ethernet ports (copper or fiber-optic). The front-panel USB port retrieves events, settings, and templates faster than traditional EIA-232 ports.
- **Automatic Network Reconfiguration (ANR).** Improve reliability with ANR by isolating faulted line sections and restoring service to unaffected areas of the system.
- **Configurable Power Elements.** Determine power flow or VAR flow direction and magnitude with configurable power elements. Apply at system intertie points or at capacitor bank installations.
- **Total Harmonic Distortion (THD).** Monitor the system power quality based on THD with harmonic metering as high as the 16th harmonic, following IEEE 519-2014.
- **Built-In Power Supply.** Power demanding 12 Vdc accessories easily with a built-in 40 W continuous (60 W surge) auxiliary power supply.
- **Digitally Signed Firmware Upgrade.** Upload digitally signed firmware over Ethernet or serial connection. Secure algorithms guarantee the validity of the firmware file.
- **Second-Harmonic Blocking.** Secure the recloser control during transformer energization.
- **Rate-of-Change-of-Frequency Elements.** Detect rapid frequency changes to initiate load shedding or network decoupling.
- **Event Data and Fast Sampling Rate.** See more pre-fault and post-fault data with 60-cycle-length event reports. Gain better resolution with 128-samples/cycle analog data.
- **COMTRADE Event Reports.** Capture standard and high-impedance event reports in COMTRADE standard file format.
- **Synchrophasors.** Gather power system information and monitor wide-area performance with IEEE C37.118 synchrophasors.
- **High-Impedance Fault Detection.** Apply SEL Arc Sense™ technology in detecting more high-impedance faults than conventional protection for more reliable operation of distribution systems.

Compatibility Overview

Multi-Recloser Interface

An SEL-651R-2 Recloser Control ordered with the Multi-Recloser Interface is compatible with the following reclosers on one common interface:

- G&W Viper-ST
- G&W Viper-LT
- ABB Elastimold MVR
- Tavrida OSM Al_4
- ABB Gridshield (32-pin and 42-pin versions)
- Eaton NOVA NX-T

Three-Phase Reclosers With Single-Phase Tripping Capability

An SEL-651R-2 Recloser Control connects to the following three-phase reclosers with single-phase tripping capability:

- G&W Viper-ST
- G&W Viper-LT
- ABB Elastimold MVR
- ABB OVR-3/VR-3S (24-pin, 15 and 27 kV models)
- ABB Joslyn TriMod 600R
- ABB Gridshield (32-pin and 42-pin versions)
- Eaton NOVA-TS or NOVA-STS Triple-Single
- Eaton NOVA NX-T
- Tavrida OSM Al_4
- Siemens SDR Triple-Single

Three-Phase Reclosers

The SEL-651R-2 Recloser Control connects to the following three-phase reclosers:

- G&W Viper-S
- G&W Control Power Viper-S
- Eaton
  - CXE
  - Auxiliary-Powered Eaton NOVA
  - RE
  - RVE
  - RXE
  - VSA
  - VSO
  - VWE
  - VWVE 27
  - VWVE 38X
  - WE
  - WVE 27
  - WVE 38X
  - Control-Powered Eaton NOVA
- Whipp & Bourne GVR (when equipped with interface module)
- Tavrida OSM Al_2
- Siemens SDR Three-Phase

Certification

The current IEEE C37.60 test certificates are available at selinc.com.

Product Overview or Functional Overview

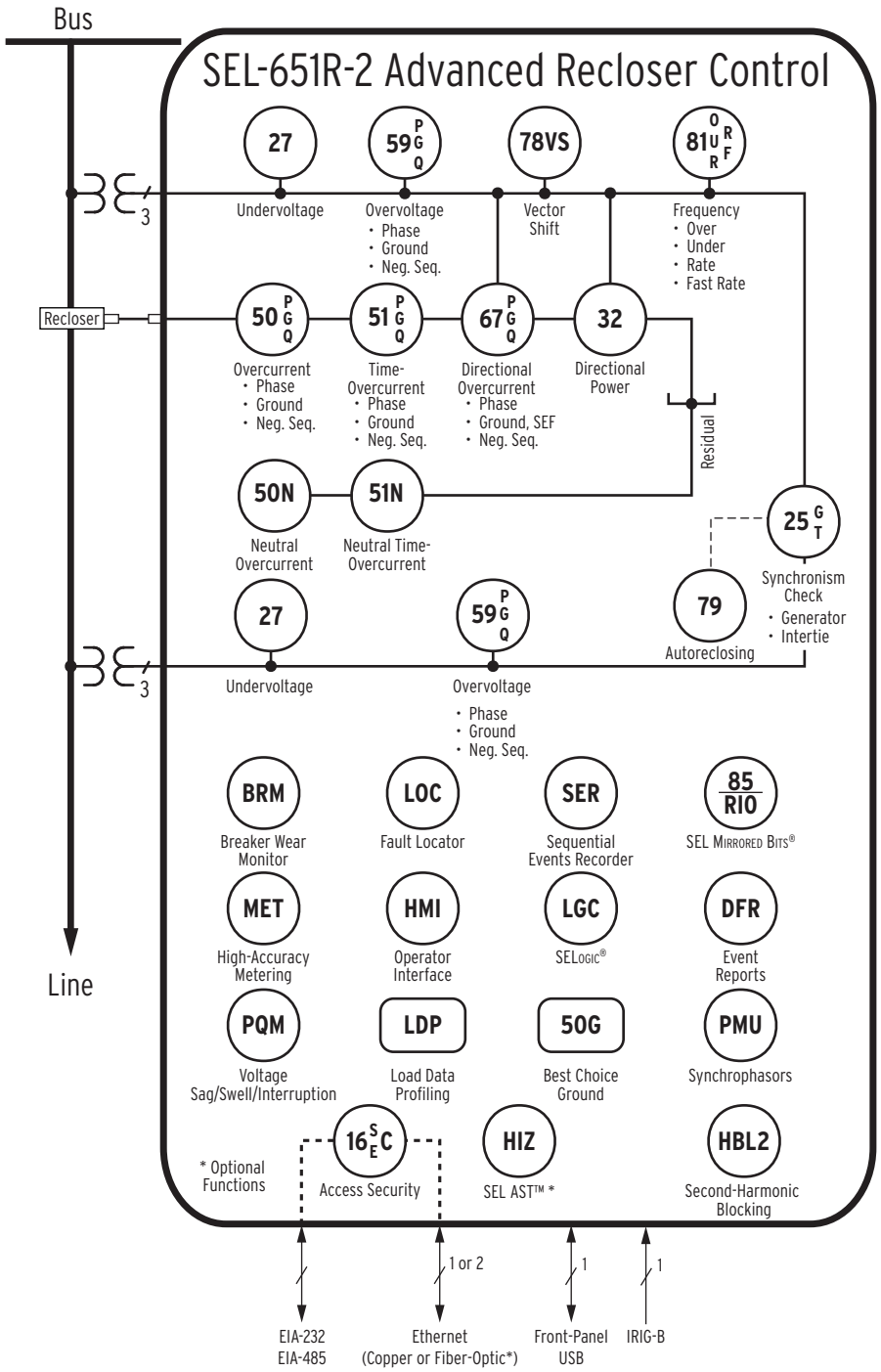


Figure 1 Functional Diagram

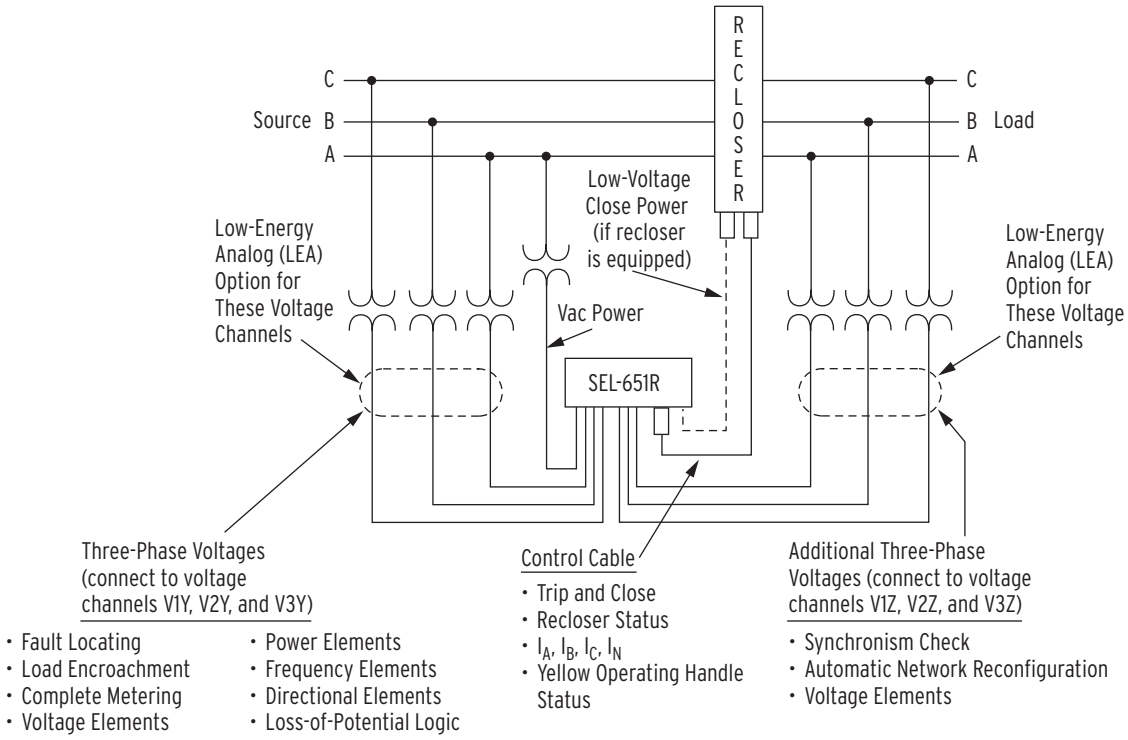


Figure 2 Connect Three-Phase Load and Source Voltages to SEL-651R-2

Control Cable

The control cable brings secondary current, recloser status, yellow operating handle status, and, in some cases, LEA voltages to the SEL-651R-2 and takes trip/close signals out to the recloser (see *Figure 3*). The control cable connects to the SEL-651R-2 via a control cable receptacle/interface at the bottom of the enclosure.

Note: Select the appropriate control cable interface when ordering.

Voltage Inputs

Connect voltages on both sides of the recloser, as shown in *Figure 2*, for such schemes as Automatic Network Reconfiguration (*Figure 12*) and synchronism check. Select the three-phase voltage channel (VY or VZ) to operate features such as the following (*Figure 2*):

- ➤ Fault locating
- ➤ Load encroachment
- ➤ Power elements
- ➤ Voltage sag/swell/interrupt recording

Order the VY and VZ voltage channels as optional LEA voltage inputs. This option allows you to connect the low-level voltage outputs from less-costly power system voltage transducers, including those built into many of the popular reclosers, to LEA voltage inputs on the SEL-651R-2.

Control Power Input

Order the control power input (shown as the Vac Power connection in *Figure 2*) as either 120 Vac, 230 Vac, 125 Vdc, or 48 Vdc.

The 120 Vac option includes a ground-fault circuit interrupter (GFCI) convenience outlet.

Use ac transfer switches (see *Figure 3*) to change to the alternate control power source when the primary control power source is unavailable. This ability is especially valuable in Automatic Network Reconfigurations such as those in *Figure 11* and *Figure 12*.

The incoming control power is converted to the following:

- ➤ 12 Vdc to run the control electronics
- ➤ Stored energy in capacitors in the power module to provide energy for the trip/close outputs of the relay module

If the incoming control power is unavailable, the 12 V battery provides energy to charge the capacitors and to run the control electronics.

The 125 Vdc and 48 Vdc power input options include a reduced level 12 V auxiliary supply for use in wetting contact inputs, but not for powering communications devices. These options do not include the battery charger, batteries, or GFCI convenience outlet.

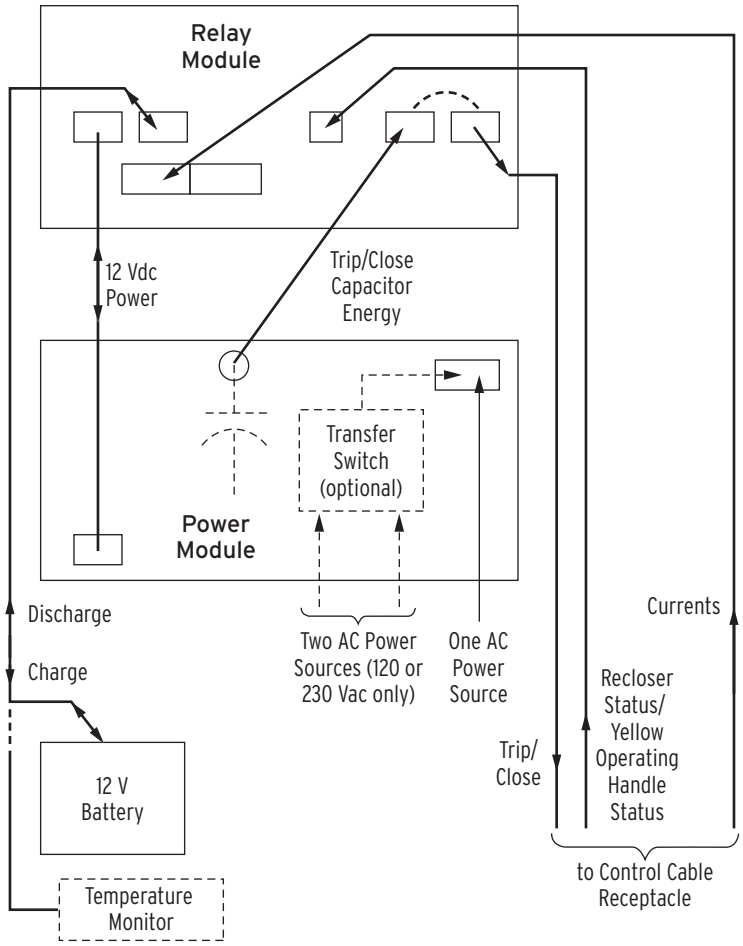


Figure 3 Major Interconnections Between SEL-651R-2 Components

Automation and Communication

Communications Connection Options

The base model SEL-651R-2 is equipped with one USB port, three independently operated EIA-232 serial ports, and one isolated EIA-485 port. Ethernet port ordering options include the following:

- Single 100BASE-FX optical Ethernet port
- Dual redundant 10/100BASE-T metallic Ethernet ports
- Dual redundant 100BASE-FX optical Ethernet ports

Note: The SEL-651R-2 Product Literature CD includes a special driver required for USB communication.

Establish communication by connecting computers, modems, protocol converters, data concentrators, port switchers, and communications processors. Connect multiple SEL-651R-2 controls to an SEL communications processor, an SEL real-time automation controller (RTAC), an SEL computing platform, or to an SEL synchrophasor vector processor for advanced data collection, protection, and control schemes (see *Figure 4*).

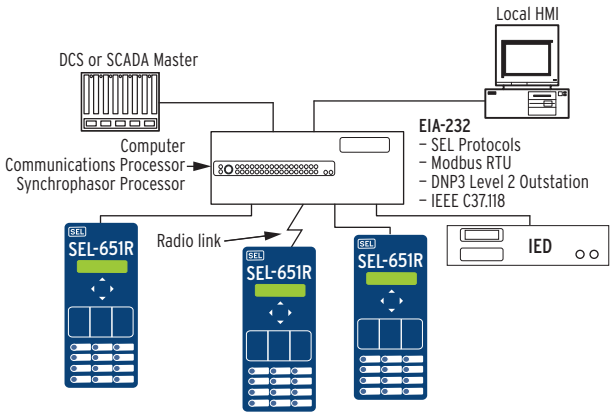


Figure 4 Typical Serial Communications Architecture

SEL manufactures a variety of standard cables for connecting SEL-651R-2 to many external devices. Consult your SEL representative for more information on cable availability. The SEL-651R-2 can communicate directly with SCADA systems, computers, and RTUs via serial or Ethernet port for local or remote communications (see *Figure 5*).

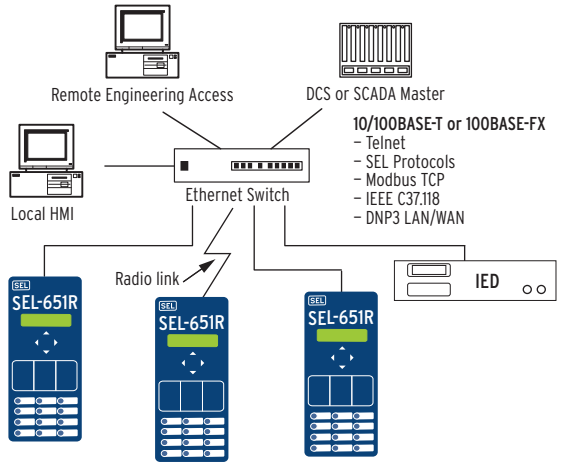


Figure 5 Typical Ethernet Communications Architecture

High-speed Ethernet ports are valuable for engineering access and control setup. Download a 60-cycle, 128 sample-per-cycle event report in as little as 40 seconds. Upgrade firmware in a scant 55 seconds from initiation to Relay Enabled.

Go beyond local engineering access and connect optional dual Ethernet ports to increase network reliability and availability (*Figure 6* and *Figure 7*). The configuration shown in *Figure 6* uses an Ethernet switch inside the control to bridge network connections and form a self-healing ring as part of a managed network. *Figure 7* shows how to connect the control for fully redundant fast-failover configuration. In either configuration, no single point of failure can prevent communication with the control. *Table 1* lists available protocols.

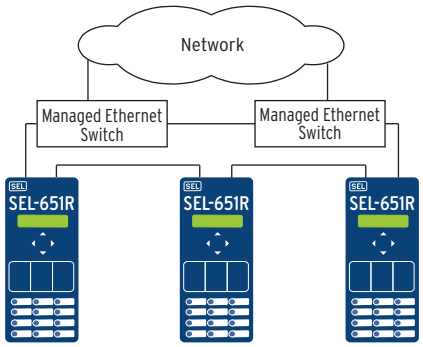


Figure 6 Self-Healing Ring Using Internal Ethernet Switch

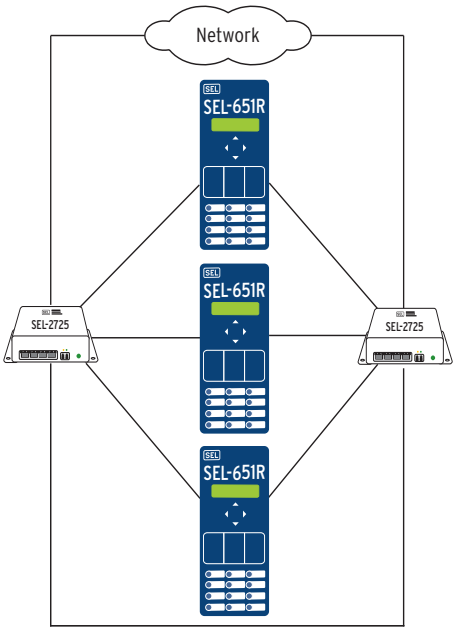


Figure 7 Failover Network Topology

Serial Communication

The SEL-651R-2 retains all the serial communications capability of previous SEL-651R models and adds an EIA-485 and Type B USB port for fast and convenient local access. Use any communications processor software that emulates a standard terminal system.

FTP

Provides the ability to read and write available settings files and read COMTRADE file format event reports from the recloser control over Ethernet.

Table 1 Open Communications Protocol

Type	Description
IEC 61850	Ethernet-based international standard for interoperability between intelligent devices in a substation. Operates remote bits, breaker controls, and input/output (I/O). Monitors Relay Word bits and analog quantities. Use MMS file transfer to retrieve COMTRADE file format event reports.
Simple ASCII	Plain language commands for human and simple machine communications. Use for metering, setting, self-test status, event reporting, and other functions.
Compressed ASCII	Comma-delimited ASCII data reports. Allows external devices to obtain relay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.
Fast SER Protocol	Provides serial or Ethernet SER data transfers with original time stamp to an automated data collection system.
Modbus RTU or TCP	Serial or Ethernet-based Modbus with point remapping. Includes access to metering data, protection elements, contact I/O, targets, relay summary events, and settings groups.
Extended Fast Meter and Fast Operate	Serial or Telnet binary protocol for machine-to-machine communications. Quickly updates SEL communications processors, RTUs, and other substation devices with metering information, relay element and I/O status, time-tags, open and close commands, and summary event reports. Data are checksum protected. Binary and ASCII protocols operate simultaneously over the same communications lines so binary SCADA metering information is not lost while an engineer or technician is transferring an event report or communicating with the relay using ASCII communications through the same relay communications port.
DNP3 Serial or LAN/WAN	Serial or Ethernet-based Distributed Network Protocol with point remapping. Includes access to metering data, protection elements, contact I/O, targets, SER, relay summary event reports, and settings groups.
IEEE C37.118	Serial or Ethernet Phasor Measurement Protocol. Streams synchrophasor data to archiving historian for post disturbance analysis, to visualization software for real-time monitoring, or to synchrophasor data processor for real-time control.

Flexible Control Logic and Integration Features

Use the SEL-651R-2 control logic to provide the following improvements:

- Replace traditional panel control switches
- Eliminate RTU-to-relay wiring
- Replace traditional latching relays
- Replace traditional indicating panel lights
- Replace external timers

Eliminate traditional panel control switches:

- 12 programmable operator-control pushbuttons
  - Use to implement your control scheme via SELOGIC control equations.
  - Change operator-control pushbutton labeling to suit your control scheme (*Figure 23*).
- 16 local control points
  - Set, clear, or pulse local control points via the front-panel human-machine interface and display (*Figure 23*).
  - Program the local control points to implement your control scheme via SELOGIC control equations.
  - Use the local control points for extra functions such as trip testing or scheme enabling/disabling.
- Define custom messages (e.g., SINGLE PHASE TRIP\ ENABLED) to report power system or relay conditions on the LCD.
- Control which messages are displayed via SELOGIC control equations by driving the LCD display via any logic point in the relay. Set as many as 32 programmable display messages.

Replace RTU-to-Relay Wiring Using 32 Remote Control Points

- Set, clear, or pulse remote control points via serial port commands.
- Incorporate these points into your control scheme via SELOGIC control equations
- Use them for SCADA-type control operations such as trip, close, and settings group selection.

Replace Traditional Latching Relays Using 32 Latching Control Points

- Use these points for functions such as remote control enable.
- Program latch set and latch reset conditions with SELOGIC control equations. The latching control points retain states when the relay loses power.
- Set or reset the latching control points via operator-control pushbuttons, control inputs, remote control points, local control points, or any programmable logic condition.

- In the factory settings, these latching control points give many of the operator-control pushbuttons their ENABLE/DISABLE or ON/OFF mode of operation, where each press of the pushbutton toggles the latch to the opposite state.

Replace Traditional Indicating Panel Lights With 24 Status and Target LEDs

Change LED labeling to suit your control scheme (*Figure 23*). Note that the aforementioned 12 programmable operator-control pushbuttons also have programmable LEDs associated with them.

Replace External Timers With 64 General Purpose Timers and 16 General Purpose Up/Down Counters

- Eliminate external timers for custom protection or control schemes with 64 general purpose SELOGIC control equation timers.
- Each timer has independent time-delay pickup and dropout settings.
- Program each timer input with any element (e.g., time-qualify a voltage element).
- Assign the timer output to trip logic or other control scheme logic.
- Use the 16 general purpose up/down counters to emulate the features of motor-driven timers, which can stall in place indefinitely and then continue timing when appropriate user-set conditions exist.

SELOGIC Control Equations With Expanded Capabilities

The SEL-651R-2 is factory set for use without additional logic in many situations. For complex or unique applications, expanded SELOGIC functions allow superior flexibility and put relay logic into the hands of the protection engineer.

With expanded SELOGIC control equations you can do the following:

- Assign the relay inputs to suit your application
- Logically combine selected relay elements for various control functions
- Assign outputs to your logic functions.

To program SELOGIC control equations, combine relay elements, inputs, and outputs with SELOGIC control equation operators (see *Table 2*). You can use any element in the Relay Word in these equations. Add programmable control functions to your protection and automation systems. New functions and abilities enable you to use analog values in conditional logic statements.

Table 2 SELOGIC Control Equation Operators

Operator Type	Operators	Comments
Boolean	AND, OR, NOT	Allows combination of measuring units
Edge Detection	F_TRIG, R_TRIG	Operates at the change of state of an internal function
Comparison	>, >=, =, <=, <, < >	
Precedence Control	( )	Allows multiple and nested sets of parentheses
Comment	#	Provides for easy documentation of control and protection logic

ACSELERATOR QuickSet SEL-5030 With Design Features

Use the ACSELERATOR QuickSet SEL-5030 Software to develop settings offline. The system automatically checks interrelated settings and highlights out-of-range settings. You can transfer settings created offline by using a PC communications link with the SEL-651R-2. The software also converts event reports to oscillograms with time-coordinated element assertion and phasor/sequence element diagrams. View real-time phasors via QuickSet.

With the licensed version of QuickSet, you can commission recloser controls using only the settings you need. This version allows users to create custom Application Designs. Use these designs to quickly implement advanced schemes, such as Automatic Network Reconfiguration and single-phase tripping/reclosing. Application Designs hide settings you do not want changed (such as SELOGIC control equations), while making visible just the minimum necessary settings (such as timer and pickup settings) to implement the scheme.

All settings can be aliased and manipulated mathematically for simple end-user interfacing. You can also define custom notes and settings ranges. The Application Designs enhance security by allowing access to only a specified group of settings. Create Application Designs that include the most commonly used relay features and settings (*Figure 8*) and watch commissioning times drop drastically. Design custom templates using QuickSet for your specific applications and then store the templates on the recloser control for easy access when making settings changes.

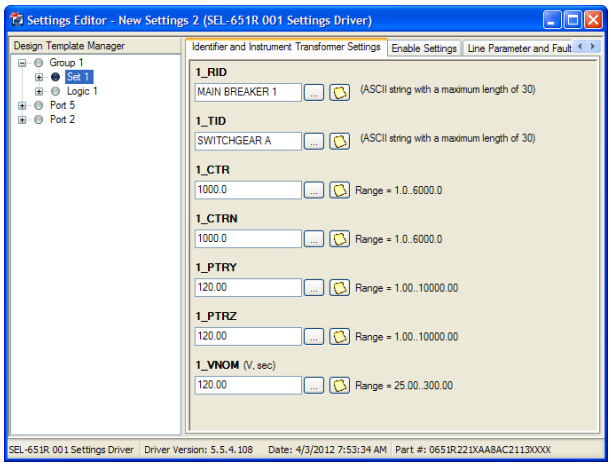


Figure 8 Example Application Designs

MIRRORED BITS Communications

The SEL-patented MIRRORED BITS® communications technology provides bidirectional recloser control-to-recloser control digital communications. MIRRORED BITS can operate independently on one or two EIA-232 serial ports on a single SEL-651R-2. With MIRRORED BITS operating on two serial ports, there is communication upstream and downstream from the SEL-651R-2 site.

This bidirectional digital communication creates eight additional virtual outputs (transmitted MIRRORED BITS) and eight additional virtual inputs (received MIRRORED BITS) for each serial port operating in the MIRRORED BITS mode (see *Figure 9*). Use these MIRRORED BITS to transmit/receive information between upstream relays and a downstream recloser control to enhance coordination and achieve faster tripping for downstream faults. MIRRORED BITS technology also helps reduce total scheme operating time by eliminating the need to assert output contacts to transmit information.

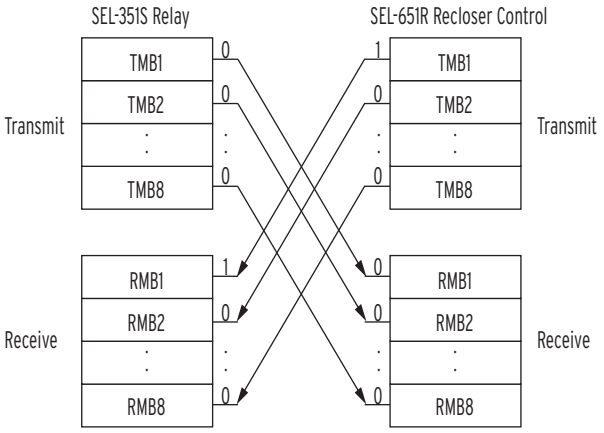


Figure 9 MIRRORED BITS Transmit and Receive Bits

Integrated Web Server

An embedded web server is included in every SEL-651R-2 recloser control. Browse to the recloser control with any standard web browser to safely read settings, verify recloser control self-test status, inspect meter reports, and read recloser control configuration and event history. The web server allows no control or modification actions at Access Level 1 or lower, so users can be confident that an inadvertent button press will have no adverse effects. *Figure 10* shows the settings display webpage.

The web server allows users with the appropriate engineering access level (2AC) to upgrade the firmware over an Ethernet connection. An Ethernet port setting enables or disables this feature, with the option of requiring front-panel confirmation when the file is completely uploaded.

The SEL-651R-2 firmware files contain cryptographic signatures that enable the SEL-651R-2 to recognize official SEL firmware. A digital signature, computed using the SHA-256 Secure Hash Algorithm, is appended to the compressed firmware file. Once the firmware is fully uploaded to the relay, the relay verifies the signature by using a Digital Signature Algorithm security key that SEL stored on the device. If the signature is valid, the firmware is upgraded in the relay. If the relay cannot verify the signature, it reverts to the previously installed firmware.

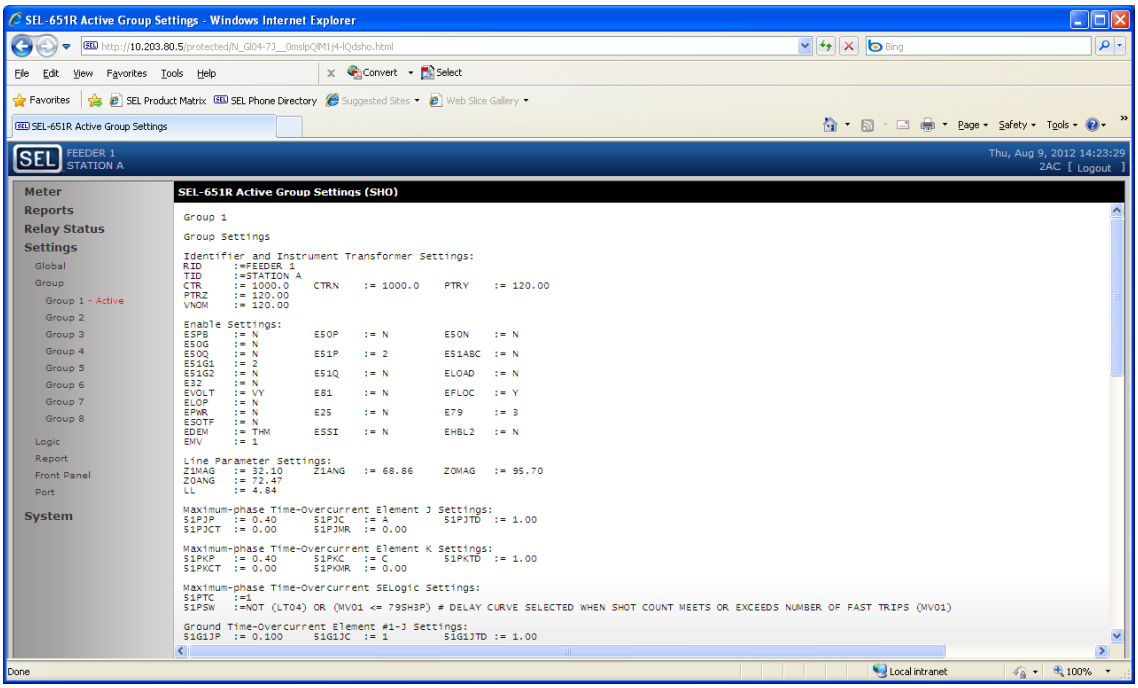


Figure 10 Settings Display Webpage

Applications

Automatic Network Reconfiguration

Automatic Network Reconfiguration augments system reliability by automatically isolating faulted line sections and restoring service to the unaffected areas of the system. In the simple Automatic Network Reconfiguration implementation in *Figure 11*, there is no direct communication between the recloser control sites and there is minimal voltage sensing. For the sample fault in *Figure 11*, system isolation and restoration is methodically accomplished with the following:

- Sectionalizing recloser tripping on sensed dead feeder (for line section isolation).
- Midpoint recloser control changing settings (for better backfeed coordination).
- Tie recloser closing into dead line sections (for restoration of unfaulted line sections from adjacent feeder).

The advanced Automatic Network Reconfiguration shown in *Figure 12* includes both source-side and load-side voltages into the SEL-651R-2 Recloser Controls and Mirrored Bits communications (via fiber optics or radio) between the recloser sites. These enhancements greatly speed up Automatic Network Reconfiguration. Automatic Network Reconfiguration is especially valuable in urban areas and for critical loads where there are tie points available to other feeders for system restoration.

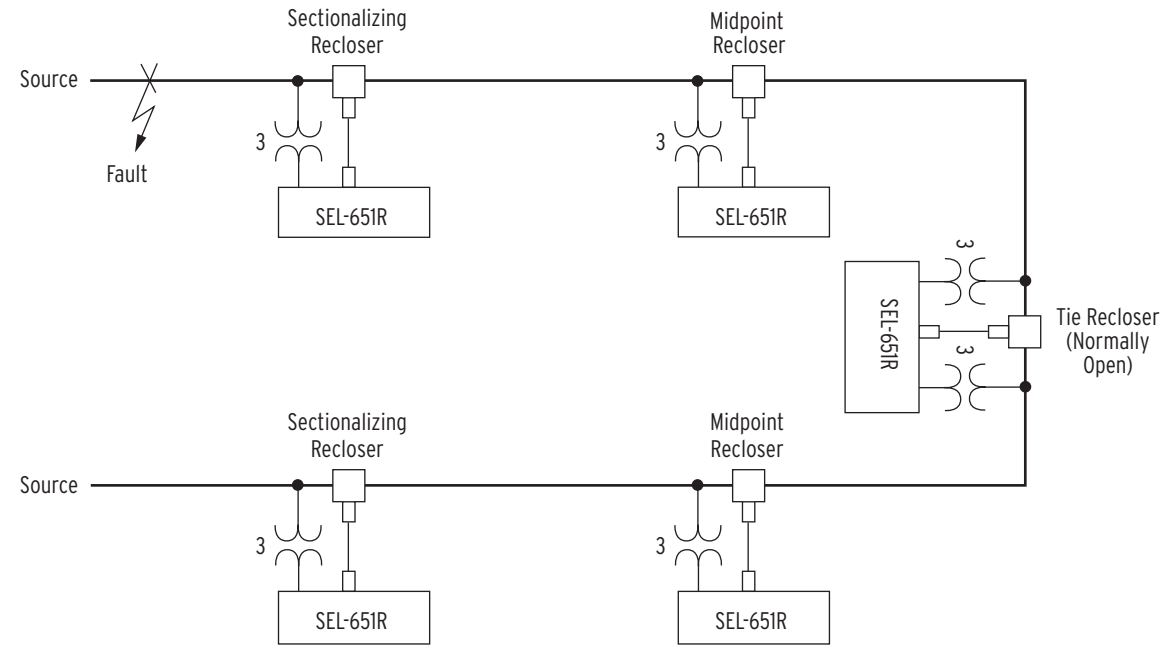


Figure 11 Simple Automatic Network Reconfiguration

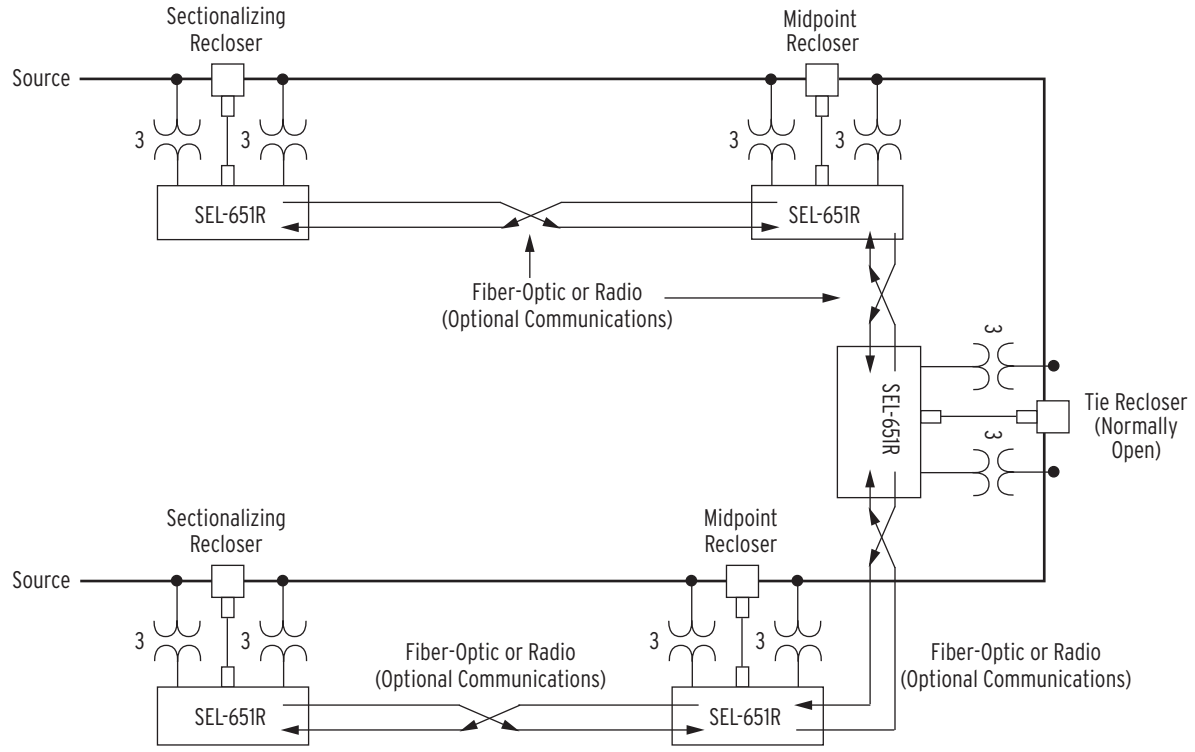


Figure 12 Advanced Automatic Network Reconfiguration

Distributed Energy Resource Interconnection

Reclosers are ideal for interconnecting microgrids and DER to area electric power systems (Area EPS). In these applications, they are commonly specified with six LEA voltage sensors built into the recloser. Utilities, consultants, microgrid owners, and DER owners use these turnkey recloser solutions at the Point of Common Coupling (PCC) as defined in IEEE 1547. *Figure 13* demonstrates autosynchronism control of the DER, resulting in eventual synchronism-check closing of the recloser when slip frequency, phase angle, and voltage magnitude differences are all within allowable limits.

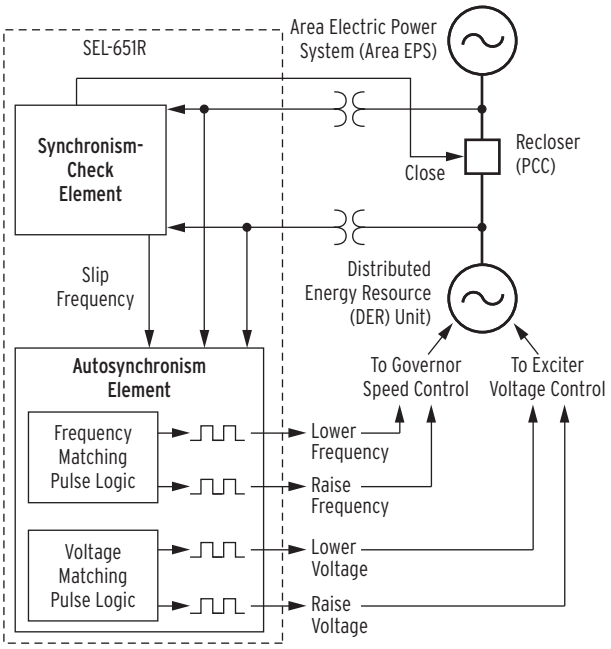


Figure 13 Distributed Energy Resource Intertie

Single-Phase Tripping/Reclosing

Single-phase tripping/reclosing also improves system reliability by keeping customers in service who are not on the faulted phase of a feeder. In *Figure 14*, a permanent fault occurs on the middle phase. Because single-phase tripping/reclosing is enabled, only the middle pole of the recloser opens for the fault. In this case, reclosing does not restore service because the fault is permanent, but only the customers on the middle phase are left without power, rather than customers on all three phases.

Available trip-reclose-lockout operation modes for the single-phase reclosers are as follows:

- Three-phase trip/reclose, three-phase lockout
- Single-phase trip/reclose, three-phase lockout
- Single-phase trip/reclose, single-phase lockout
- Single-phase trip/reclose, single-phase lockout (three-phase lockout if two or more phases involved)

Three-phase tripping is still available for all single-phase trip modes. Apply single-phase operation to rural areas where many loads are single-phase and restoration can take longer because of travel distance. Switch between single-phase and three-phase operation depending upon seasonal needs. When the load levels differ from phase to phase, set the trip levels for each phase independently.

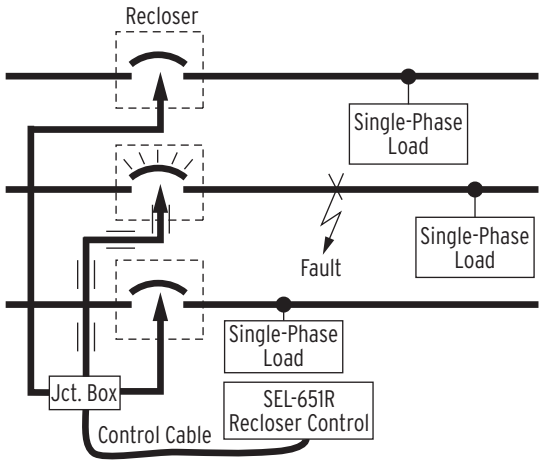


Figure 14 Single-Phase Tripping Isolates Only the Faulted Phase

Protection Features

Overcurrent Protection

Use any combination of fast and delay curves (see *Figure 15*) for phase, ground, and negative-sequence overcurrent protection. For a nominal recloser CT ratio of 1000:1, these curves can be set to levels as sensitive as 100 A primary for phase-to-ground overcurrent protection and 5 A primary for ground overcurrent protection.

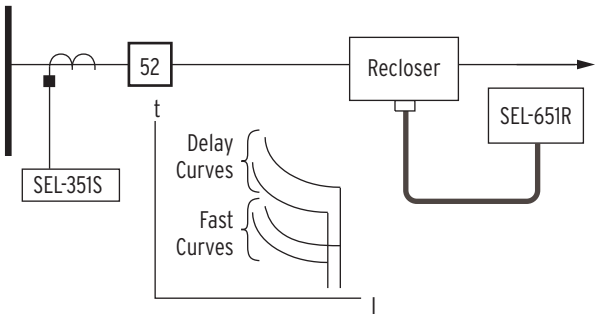


Figure 15 Coordinate the SEL-651R-2 With Other Devices

Any fast or delay curve can be set with any of the curves in *Table 3*. The U.S. and IEC curves conform to IEEE C37.112-1996, IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays. The traditional recloser curve choices in *Table 3* are listed using the older electronic control designations.

Table 3 Curve Choices Resident in the SEL-651R-2

Curve Type	Curve Choices
All Traditional Recloser Curves	A, B, C, D, E, F, G, H, J, KP, L, M, N, P, R, T, V, W, Y, Z, 1, 2, 3, 4, 5, 6, 7, 8, 8PLUS, 9, KG, 11, 13, 14, 15, 16, 17, 18
U.S. Curves	Moderately inverse, inverse, very inverse, extremely inverse, short-time inverse
IEC Curves	Class A (standard inverse), class B (very inverse), class C (extremely inverse), long-time inverse, short-time inverse

You can also specify traditional recloser curves in a curve setting by using the newer microprocessor-based control designations (the SEL-651R-2 works with either designation). For example, a given traditional recloser curve has these two designations:

- Older electronic control designation: A
- Newer microprocessor-based control designation: 101

Traditional Recloser Curve A and 101 are the same curve.

Fast and delay curves (including U.S. or IEC curve choices) can be modified with these traditional recloser control curve modifiers:

- Constant time adder—adds time to curve
- Vertical multiplier (time dial)—shifts whole curve up or down in time
- Minimum response time—holds off curve tripping for minimum time

Instantaneous overcurrent trip, definite-time overcurrent trip, and high-current lockout variations are also available.

The SEL-651R-2 has two reset characteristic choices for each time-overcurrent element. One choice resets the elements if current drops below pickup for at least one cycle. The other choice emulates electromechanical induction disk elements, where the reset time depends on the time dial setting, the percentage of disk travel, and the amount of post-fault load current.

Load Encroachment

Load-encroachment logic (*Figure 16*) prevents operation of phase overcurrent elements under high load conditions. This unique SEL feature permits load to enter a predefined area (shown in the impedance plane in *Figure 16*) without causing a trip, even though load current is above phase minimum trip.

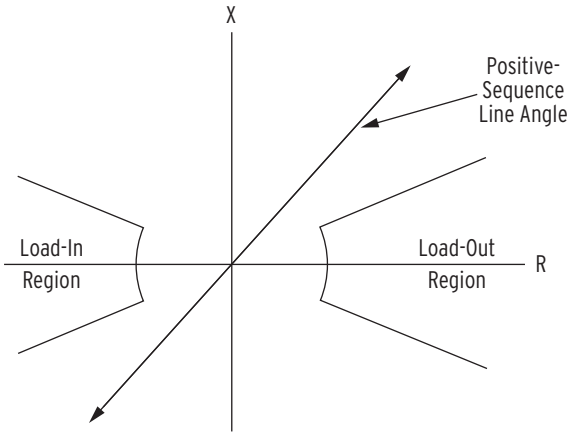


Figure 16 Load-Encroachment Logic Defines Load Zones (No Trip Zones)

Directional Elements Increase Sensitivity and Security

Phase and ground directional elements are standard. An automatic setting mode sets all directional thresholds based on replica line impedance settings. Phase directional elements provide directional control to the phase-overcurrent and negative-sequence overcurrent elements. Positive-sequence and negative-sequence directional elements work together. The positive-sequence directional element memory provides a reliable output for close-in, and forward- or reverse-bolted three-phase faults where each phase voltage is zero. The negative-sequence directional element uses the same patented principle proven in the SEL-351 Relay. Apply this directional element in virtually any application regardless of the amount of negative-sequence voltage available at the recloser control location.

Ground directional elements provide directional control to the ground overcurrent elements. The following directional elements work together to provide ground directionality:

- Negative-sequence voltage-polarized element
- Zero-sequence voltage-polarized element

Our patented Best Choice Ground Directional Element® logic selects the best ground directional element for the system conditions. This scheme eliminates directional element settings. You can also override this automatic setting feature for special applications.

Loss-of-Potential Logic Supervises Directional Elements

Voltage-polarized directional elements rely on valid input voltages to make correct decisions. The SEL-651R-2 includes loss-of-potential logic that detects one, two, or three blown potential fuses and disables the

directional elements. For example, in a loss-of-potential condition, you can enable forward-set overcurrent elements to operate nondirectionally. This patented loss-of-potential logic is unique, because it only requires a nominal setting and is universally applicable.

Reclosing

The SEL-651R-2 can reclose as many as four (4) times. This allows for as many as five operations of any combination of fast and delay curve overcurrent elements. The SEL-651R-2 verifies that adequate close power is available before issuing an autoreclose. Reset timings for an autoreclose and for a manual/remote close from lockout are set separately. Traditionally, the reset time for a manual/remote close from lockout is set less than the reset time for an autoreclose. Front-panel LEDs track the control state for autoreclosing: 79 RESET, 79 CYCLE, or 79 LOCKOUT (see *Figure 23* and *Table 5*). Sequence coordination logic is enabled to prevent the SEL-651R-2 from tripping on its fast curves for faults beyond a downstream recloser. Customize reclosing logic by using SELOGIC control equations. Use programmable timers, counters, latches, logic functions, and analog compare functions to optimize control actions.

Power Elements

Four independent directional three-phase power elements are available in the SEL-651R-2. Each enabled power element can be set to detect real power or reactive power. With SELOGIC control equations, the power elements provide a wide variety of protection and control applications. Typical applications include the following:

- Overpower and/or underpower protection and control
- Reverse power protection and control
- VAR control for capacitor banks

Harmonic Blocking Elements Secure Protection During Transformer Energization

Transformer inrush can cause sensitive protection to operate. Use the second-harmonic blocking feature to detect an inrush condition and block selected tripping elements until the inrush subsides. Select the blocking threshold as a percentage of fundamental current, and optimize security and dependability with settable pickup and dropout times. Use the programmable torque control equation to only enable the blocking element immediately after closing the breaker.

Fast Rate-of-Change-of-Frequency Protection for Fast Islanding Protection

The fast rate-of-change-of-frequency protection, 81RF, provides a faster response compared to frequency (81) and rate-of-change-of-frequency (81R) elements. Fast operating speed makes the 81RF element suitable for detecting islanding conditions. The element uses a characteristic (see *Figure 18*) based on the frequency deviation from nominal frequency (DF = FREQ – NFREQ) and the rate-of-change of frequency (DFDT) to detect islanding conditions.

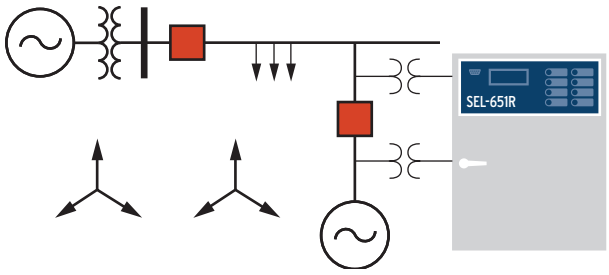


Figure 17 Fast Islanding Detection

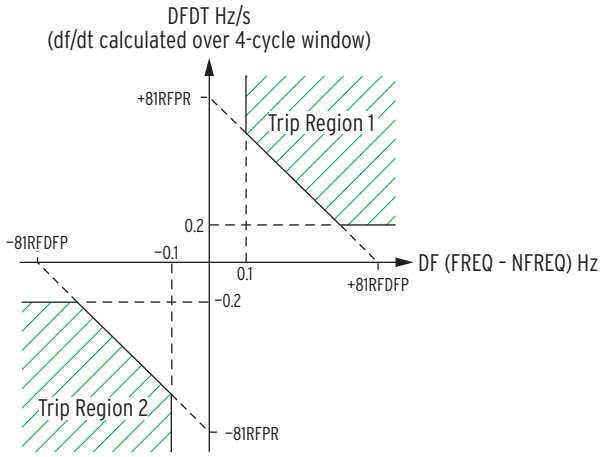


Figure 18 81RF Characteristics

Under steady-state conditions, the operating point is close to the origin. During islanding conditions, depending on the islanded system acceleration, the operating point enters Trip Region 1 or Trip Region 2 of the characteristic. 81RFDFP (in Hz) and 81RFRP (in Hz/sec) are the settings used to configure the characteristic.

Vector Shift (78VS) Protection

When distributed generators (DG) are connected in the utility network, the vector shift (78VS) element is used to detect islanding conditions and trip the DG. Failure to trip islanded generators can lead to problems such as personnel safety, out-of-synchronization reclosing, and deg-

radation of power quality. Based on the change in the angle of the voltage waveform, the islanding condition can be detected by the vector shift function.

Use the vector shift element with the 81RF element as a backup for fast and secure islanding detection. The vector shift element operates within three cycles, which is fast enough to prevent reclosing out-of-synchronism with the network feeders to avoid generator damage.

Fault Locating

The SEL-651R-2 provides an accurate estimate of fault location even during periods of substantial load flow. The fault locator uses fault type, replica line impedance settings, and fault conditions to develop an estimate of fault location without communications channels, special instrument transformers, or pre-fault information. This feature contributes to efficient line crew dispatch and fast service restoration. The fault locator requires three-phase voltage inputs.

High-Impedance Fault Detection

High-impedance faults are short-circuit faults with fault currents smaller than what a traditional overcurrent element can detect.

The SEL-651R-2 with Arc Sense technology includes logic that can detect HIF signatures without being affected by loads or other system operation conditions. High-impedance fault event reports are stored in both Compressed ASCII and COMTRADE file format.

The SEL-651R-2 offers another method of detecting high-impedance faults. A ground overcurrent element is used to count the number of times the ground current exceeds a threshold in a given amount of time. If the count exceeds a set threshold, the relay asserts an alarm indicating a potential high-impedance fault.

Monitoring and Metering

Event Reporting and Sequential Events Recorder (SER)

Event Reports and Sequential Events Recorder features simplify post-fault analysis and help improve your understanding of both simple and complex protective scheme operations. These features also aid in testing and troubleshooting relay settings and protection schemes. Increase the availability of information by accessing settings, events, and other data over a single communications link.

Event Reporting and Oscillography

In response to a user-selected internal or external trigger, the voltage, current, and element status information contained in each event report confirms relay, scheme, and system performance for every fault. Decide how much detail is necessary when an event report is triggered: 4, 16, 32, or 128 samples/cycle resolution analog data. The relay stores the following:

- 40 event reports (when event report length is 15 cycles)
- 25 event reports (when event report length is 30 cycles)
- 15 event reports (when event report length is 60 cycles)

Reports are stored in nonvolatile memory and are available in Standard ASCII, Compressed ASCII, and COMTRADE file format. Relay settings operational in the relay at the time of the event are appended to each event report.

High-impedance fault event reports are also available in Compressed ASCII and COMTRADE file formats. The information used to determine if a high-impedance fault is present on the system is included in the report. The relay stores the following:

- 28 event reports (when event report length is 2 minutes)
- 14 event reports (when event report length is 5 minutes)
- 7 event reports (when event report length is 10 minutes)
- 3 event reports (when event report length is 20 minutes)

Demodulated IRIG-B time code can be input into either the IRIG-B BNC connector or Serial Port 2. Connect a high-quality time source such as the SEL-2401 Satellite-Synchronized Clock to the BNC IRIG-B connector to enable microsecond accurate time synchronization. Connect an SEL communications processor (combining data and IRIG signals) to Serial Port 2 on the SEL-651R-2 for millisecond accurate time synchronization.

The recloser control also synchronizes the internal clock to an NTP server via SNTP with 5 ms accuracy. Connect all possible time sources (IRIG, SNTP, DNP) and the recloser control automatically selects the most accurate.

The ACSELERATOR Analytic Assistant® SEL-5601 Software and QuickSet can read a Compressed ASCII or COMTRADE file format version of the event report, which contains even more information than the standard ASCII event report. Using Analytic Assistant and QuickSet, you can produce oscillographic traces and digital element traces on the PC display. A phasor analysis screen allows users to analyze the pre-fault, fault, and post-fault intervals, observing the directly measured inputs, as well as the calculated sequence component signals.

Event Summary

Each time the relay generates a standard event report, it also generates a corresponding Event Summary, a concise description of an event that includes the following information:

- Relay/terminal identification
- Event date and time
- Event type
- Fault location
- Recloser shot count at time of trigger
- System frequency at the start of the event report
- Front-panel fault targets at the time of trip
- Phase (IA, IB, IC), ground (IG = 3I0), and negative-sequence (3I2) current magnitudes in amperes primary measured at the largest phase current magnitude in the triggered event report

Set the relay to automatically send an Event Summary in ASCII text to one or more serial ports each time an event report is triggered.

Sequential Events Recorder (SER)

Use this feature to gain a broad perspective on relay element operation. Select items that trigger an SER entry including I/O change of state, element pickup/dropout, recloser state changes, etc. The relay SER stores the latest 1,024 entries.

Synchrophasor Measurements

Use the IEEE C37.118-2005 protocol to send synchrophasor data to SEL synchrophasor applications. These include the SEL-3373 Station Phasor Data Concentrator (PDC), SEL-3378 Synchrophasor Vector Processor (SVP), SEL-3530 Real-Time Automation Controller (RTAC), and SEL SYNCHROWAVE® software suite. The SEL-3373 Station PDC time correlates data from multiple SEL-651R-2 recloser controls and concentrates the result into a single-output data stream. The SEL-3378 SVP enables control applications based on synchrophasors, which allows users to do the following:

- Directly measure the oscillation modes
- Act on the results
- Properly control islanding of distributed generation using wide-area phase-angle slip and acceleration measurements
- Customize synchrophasor control applications based on unique power system requirements

You can then use SYNCHROWAVE software to archive and display wide-area system measurements, which are precisely time-aligned using synchrophasor technology.

The data rate of SEL-651R-2 synchrophasors is selectable, with a range of 1–60 messages per second. This flexibility is important for efficient use of communications capacity. The SEL-651R-2 phasor measurement accuracy meets the highest IEEE C37.118-2005 Level 1 requirement of 1 percent total vector error (TVE). Use the low-cost SEL-651R-2 in any application that otherwise would have required purchasing a separate dedicated phasor measurement unit (PMU).

Use the SEL-651R-2 with the SEL communications processors, or the SEL-3530 RTAC, to change nonlinear state estimation into linear state estimation. If all necessary lines include synchrophasor measurements, state estimation is no longer necessary because the system state is directly measured.

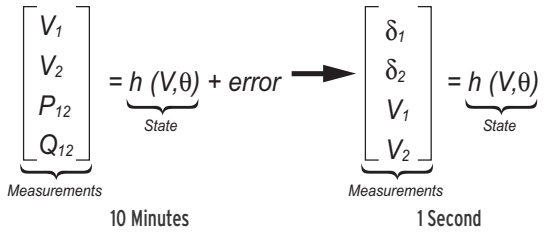


Figure 19 Synchrophasor Measurements Turn State Estimation Into State Measurement

Improve Situational Awareness

Improve information for system operators by using advanced synchrophasor-based tools to provide a real-time view of system conditions. Use system trends, alarm points, and preprogrammed responses to help operators prevent a cascading system collapse and maximize system stability. Awareness of system trends helps operators more accurately set system protection levels based on measured data.

Figure 20 Visualization of Phase Angle Measurements Across a Power System

Better information helps users do the following:

- Increase system loading while maintaining adequate stability margins
- Improve operator response to system contingencies such as overload conditions, transmission outages, or generator shutdown
- Increase system knowledge with correlated event reporting and real-time system visualization.
- Validate planning studies to improve system load balance and station optimization

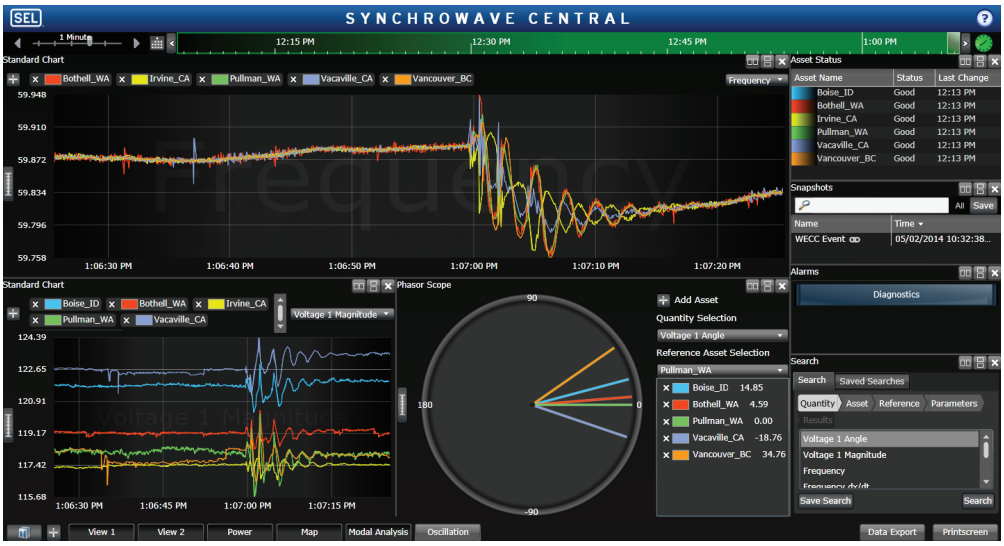


Figure 21 SEL-5078-2 SYNCHROWAVE Central Real-Time, Wide-Area Visualization Tool

Voltage Sag/Swell/Interrupt (VSSI) Report

The VSSI report captures power quality data related to voltage disturbances over a long period. Captured data include the magnitude of currents, one set of three-phase voltages, a reference voltage, and the status of the VSSI elements (Relay Word bits).

Use VSSI report information to analyze power quality disturbances or protective device actions that last longer than the time window of a conventional event report. The VSSI recording rate varies from fast to slow, depending on changes in the triggering elements. VSSI data (a minimum of 3855 entries) are stored to nonvolatile memory just after they are generated.

Recloser Wear Monitor

Reclosers experience mechanical and electrical wear every time they operate. The recloser wear monitor measures unfiltered ac current at the time of trip and the number of close-to-open operations as a means of monitoring this wear. Every time the recloser trips, the recloser control records the magnitude of the raw current in each phase. This current information is integrated on a per-phase basis.

When the integration exceeds the threshold set by the recloser wear curve (see *Figure 22*), the SEL-651R-2 asserts a logic point for the affected phase. Use the logic point for alarming or to modify reclosing. This method of monitoring recloser wear is based on breaker rating methods from switchgear manufacturers.

Figure 22 shows three set points needed to emulate a breaker wear curve. The set points in *Figure 22* can be programmed to customize the recloser wear curve. Predetermined set points are available for traditional reclosers, following recommendations for reclosers in ANSI C37.61-1973.

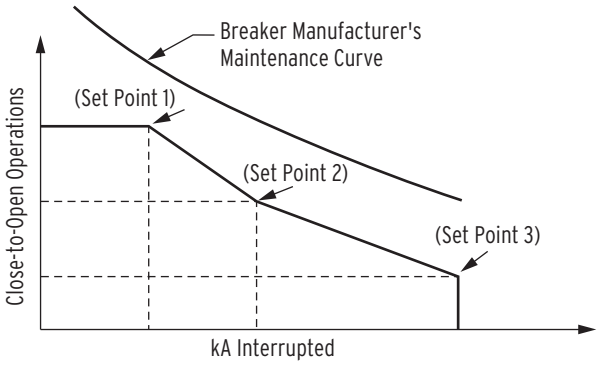


Figure 22 Recloser Contact Wear Curve and Settings

Load Profile

The load profile recorder in the SEL-651R-2 is capable of recording as many as 15 selectable analog quantities at a periodic rate (5, 10, 15, 30, or 60 minutes) and storing the data in a report in nonvolatile memory. Choose any of the analog quantities listed in *Table 4* (except peak demands). At a five-minute periodic recording rate and with 15 selected analog quantities, the SEL-651R-2 stores as many as 26 days of load profile data. More days of storage are available if you choose longer periodic recording rates or select fewer analog quantities.

Metering

The SEL-651R-2 provides extensive and accurate metering capabilities, as shown in *Table 4*. See *Specifications* for metering accuracies. The SEL-651R-2 reports all metered quantities in primary quantities (current in A primary and voltage in kV primary). Use the THD elements for the current and voltage channels for harmonics-based decisions or operations.

The phantom voltage feature creates balanced three-phase voltage values for metering from a single-phase voltage connection. These derived three-phase voltage values are also used in three-phase power and energy metering.

Table 4 Available Metering Quantities (Sheet 1 of 2)

Instantaneous Quantities	**Fundamental Values**
Currents	
$I_{A, B, C, N}$	Phase and neutral current channels
I_G	Ground (residual current)
I_1, $3I_2$, $3I_0$	Positive-, negative-, and zero-sequence
Voltages	Values for both VY and VZ three-phase voltage channels
$V_{A, B, C, AB, BC, CA}$	Line-to-neutral and line-to-line
V_1, V_2, $3V_0$	Positive-, negative-, and zero-sequence

Table 4 Available Metering Quantities (Sheet 2 of 2)

Power	
$MW_{A, B, C, 3P}$	Megawatts, single- and three-phase
$MVAR_{A, B, C, 3P}$	Megavars, single- and three-phase
$MVA_{A, B, C, 3P}$	Megavolt-amperes, single- and three-phase
$PF_{A, B, C, 3P}$	Power factor, single- and three-phase (with leading or lagging indication)
Demand Quantities	**Present and Peak (Fundamental Values)**
Currents	
$I_{A, B, C, N}$	Phase and neutral current channels
I_G	Ground (residual current)
$3I_2$	Negative-sequence
Power	
$MW_{A, B, C, 3P}$	Megawatts, single- and three-phase (in and out)
$MVAR_{A, B, C, 3P}$	Megavars, single- and three-phase (in and out)
$MVA_{A, B, C, 3P}$	Megavolt-amperes, single- and three-phase
Energy Quantities	**In and Out (Fundamental Values)**
$MWh_{A, B, C, 3P}$	Megawatt hours, single- and three-phase
$MVARh_{A, B, C, 3P}$	Megavar hours, single- and three-phase
Maximum/Minimum Quantities	**Fundamental Values**
Currents	
$I_{A, B, C, N}$	Phase and neutral current channels
I_G	Ground (residual current)
Voltages	Values for both VY and VZ three-phase voltage channels
$V_{A, B, C}$	Line-to-neutral
Power	
MW_{3P}	Megawatts, three-phase
$MVAR_{3P}$	Megavars, three-phase
MVA_{3P}	Megavolt-amperes, three-phase
RMS Quantities	
Currents	
$I_{A, B, C, N}$	Phase and neutral current channels
Voltages	Values for both VY and VZ three-phase voltage channels
$V_{A, B, C}$	Line-to-neutral
Power (average)	
$MW_{A, B, C, 3P}$	Megawatts, single- and three-phase
Harmonic Quantities and Total Harmonic Distortion (THD)	**Through the 16th Harmonic**
Currents	
$I_{A, B, C, N}$	Phase and neutral current channels
Voltages	Values for both VY and VZ three-phase voltage channels
$V_{A, B, C}$	Line-to-neutral

Additional Features

Status and Trip Target LEDs/ Operator Controls

The SEL-651R-2 includes 24 programmable status and trip target LEDs, as well as 12 programmable direct-action operator-control pushbuttons on the front panel. These targets are shown in *Figure 23* and explained in *Table 5*. Customize the versatile SEL-651R-2 front panel to fit your needs. Optional tricolor LEDs even allow you to customize color. Use SELOGIC control equations and slide-in configurable front-panel labels to change the function and identification of target LEDs and operator-control pushbuttons and LEDs. Functions are simple to configure using QuickSet. Print label sets using templates or write labels by hand.

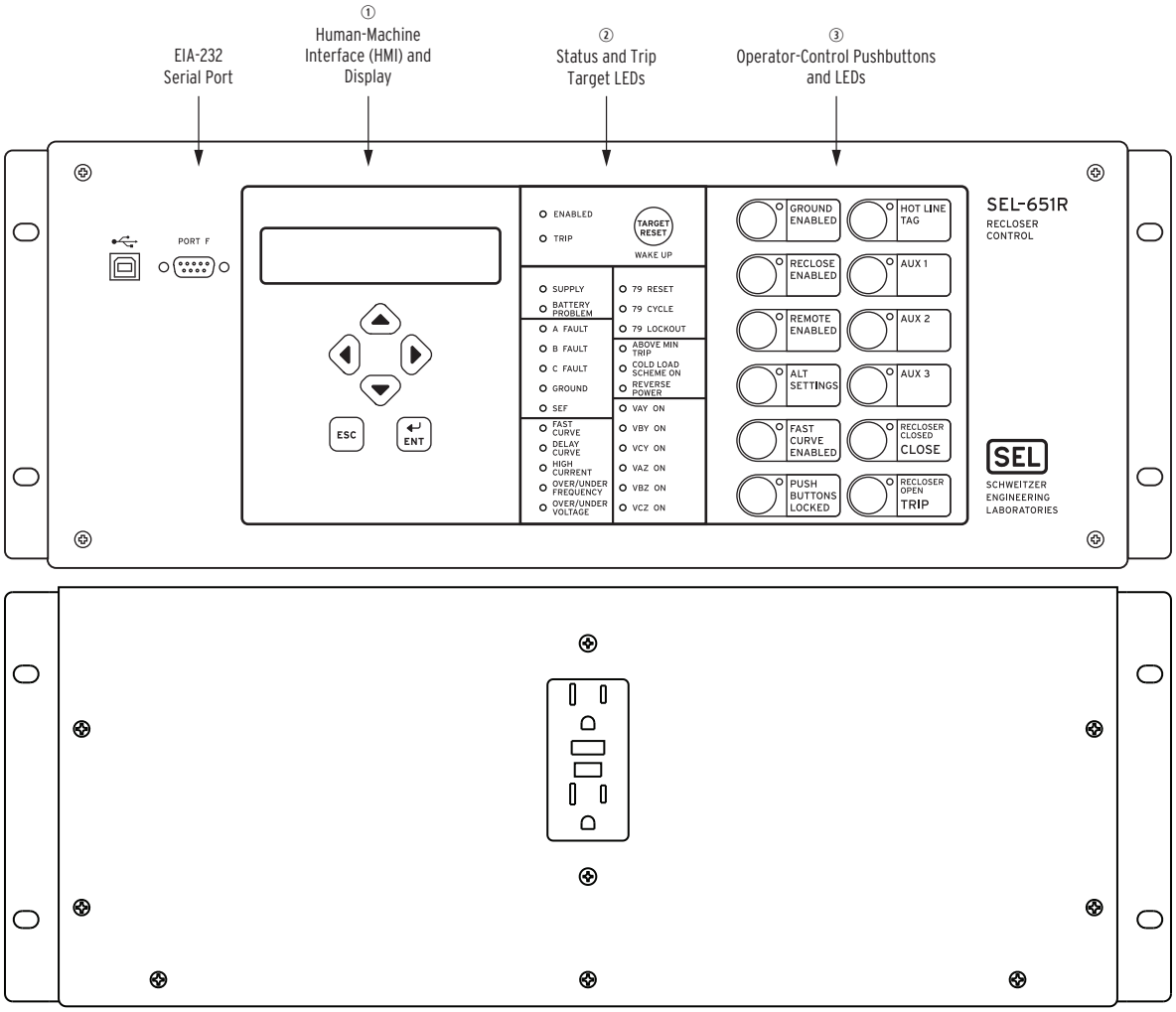


Figure 23 Front View of SEL-651R-2 Relay and Power Modules (Dual-Door Enclosure)

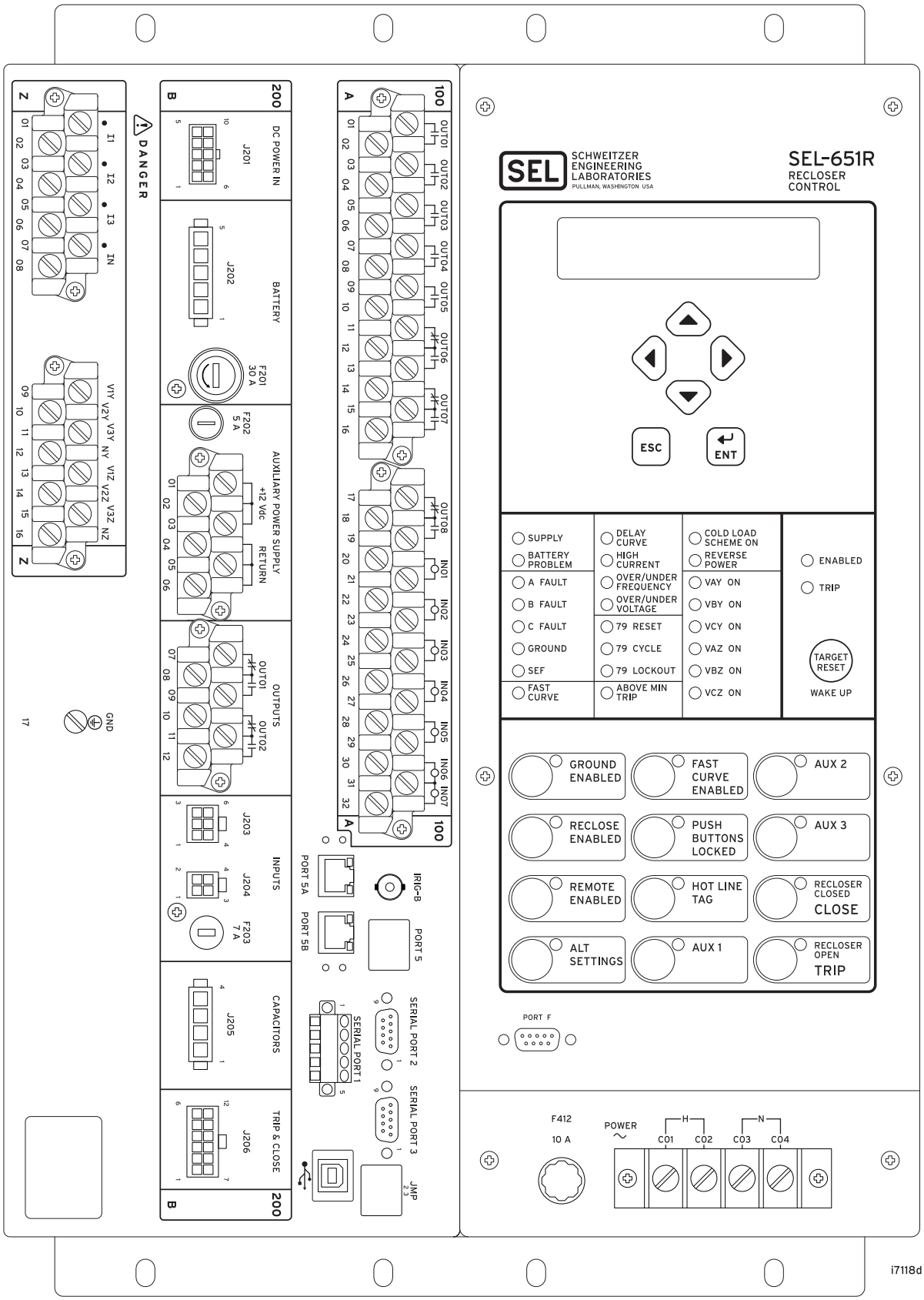


Figure 24 Front View of SEL-651R-2 Relay and Power Modules (Single-Door Enclosure)

Table 5 Factory-Default Front-Panel Interface Definitions (see *Figure 22*)

	Function	Definition
1	HMI Pushbuttons and Display	Navigate through the menu and various available functions (e.g., Metering, Event Summaries, Settings) by using the HMI pushbuttons and 2 x 16 LCD.
2	ENABLED[a]	SEL-651R-2 is powered correctly, functional, and has no self-test failures.
	TRIP[a]	Trip occurred.
	TARGET REST/WAKE UP Pushbutton[a]	Reset latched-in target LEDs; wake up the control after it has been put to sleep.
	SUPPLY	Supply power is present and OK.
	BATTERY PROBLEM	Indicates battery problems.
	A FAULT, B FAULT, C FAULT	Phases A, B, or C involved in fault.
	GROUND	Ground involved in fault.
	SEF	Sensitive earth fault overcurrent element trip (not set from factory).
	FAST CURVE	Fast curve overcurrent element trip.
	DELAY CURVE	Delay curve overcurrent element trip.
	HIGH CURRENT	High-set overcurrent element trip (not set from factory).
	OVER/UNDER FREQUENCY	Over- and underfrequency element trip (not set from factory).
	OVER/UNDER VOLTAGE	Over- and undervoltage element trip (not set from factory).
	79 RESET	The control is in the reset state, ready for a reclose cycle.
	79 CYCLE	The control is actively in the trip/reclose cycle mode.
	79 LOCKOUT	All reclose attempts were unsuccessful.
	ABOVE MIN TRIP	Current levels above minimum set overcurrent element pickup (not set from factory).
	COLD LOAD SCHEME ON	Cold Load Scheme active (not set from factory).
	REVERSE POWER	Reverse power flow exceeds power element set point (not set from factory).
	VAY, VBY, VCY ON	VY voltage channels energized.
	VAZ, VBZ, VCZ ON	VZ voltage channels energized (not set from factory).
3	GROUND ENABLED	Enable/disable ground overcurrent elements.
	RECLOSE ENABLED	Enable/disable autoreclosing.
	REMOTE ENABLED	Enable/disable remote control.
	ALTERNATE SETTINGS	Switch active setting group between main and alternate setting groups.
	FAST CURVE ENABLED	Enable/disable fast curve overcurrent element.
	PUSH BUTTONS LOCKED	Block the function of other operator controls (except WAKE UP and TRIP). Three-second delay to engage/disengage.
	HOT LINE TAG	No closing or autoreclosing can take place via the control.
	AUX 1	User programmable; e.g., program to Trip Test—test autoreclose logic without applying current.
	AUX 2	User programmable; e.g., program to enable/disable delay curve tripping.
	AUX 3	User programmable.
	RECLOSER CLOSED/CLOSE	Recloser status/close recloser.
	RECLOSER OPEN/TRIP	Recloser status/trip recloser (go to lockout).

[a] These indicated LEDs and the operator control have fixed functions. All other LEDs and operator controls (with corresponding status LEDs) can change function by programming at a higher logic level.

Control Inputs and Outputs

The basic SEL-651R-2 includes the following control inputs and outputs:

- Dedicated trip/close outputs that exit the SEL-651R-2 on a control cable receptacle/interface at the bottom of the enclosure (see *Figure 3*).
- Two Form C (normally closed/normally open) standard interrupting output contacts: OUT201 and OUT202 (row 200; *Figure 25*). OUT201 is factory-programmed as an alarm output.

Order the following additional I/O (row 100; *Figure 25*):

- Optoisolated inputs IN101–IN107 (12 Vdc rating; IN106 and IN107 share a common terminal)
- Form A (normally open) standard interrupting output contacts OUT101–OUT105
- Form C (normally closed/normally open) standard interrupting output contacts OUT106–OUT108

Assign the optoisolated inputs for control functions, monitoring logic, and general indication. Set input debounce time independently for each input. Each output contact is programmable using SELOGIC control equations.

Rear-Panel Diagrams

See *Figure 23* and *Figure 24* for the front views of the SEL-651R-2 Relay module.

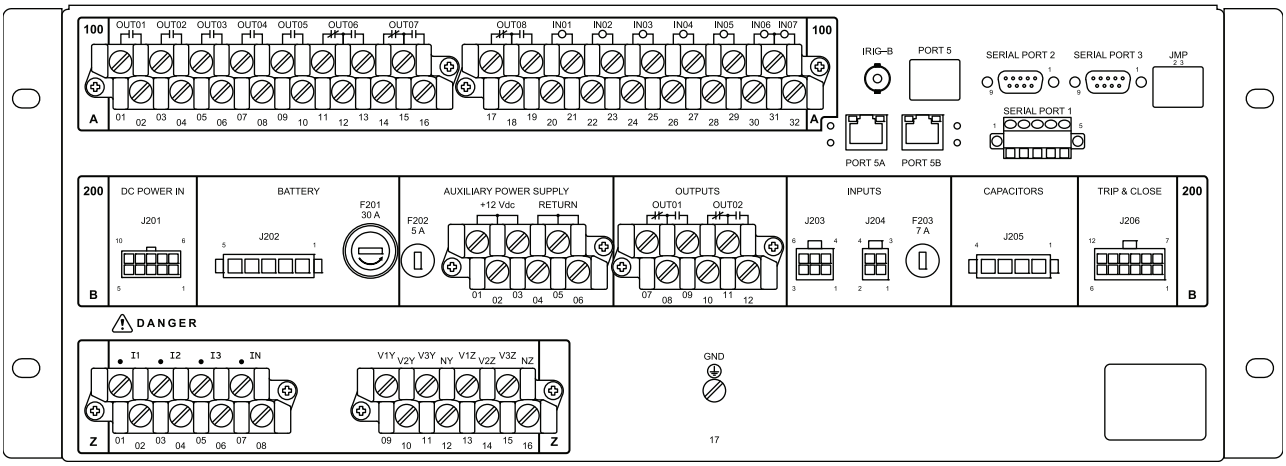


Figure 25 Rear View of the SEL-651R-2 Relay Module

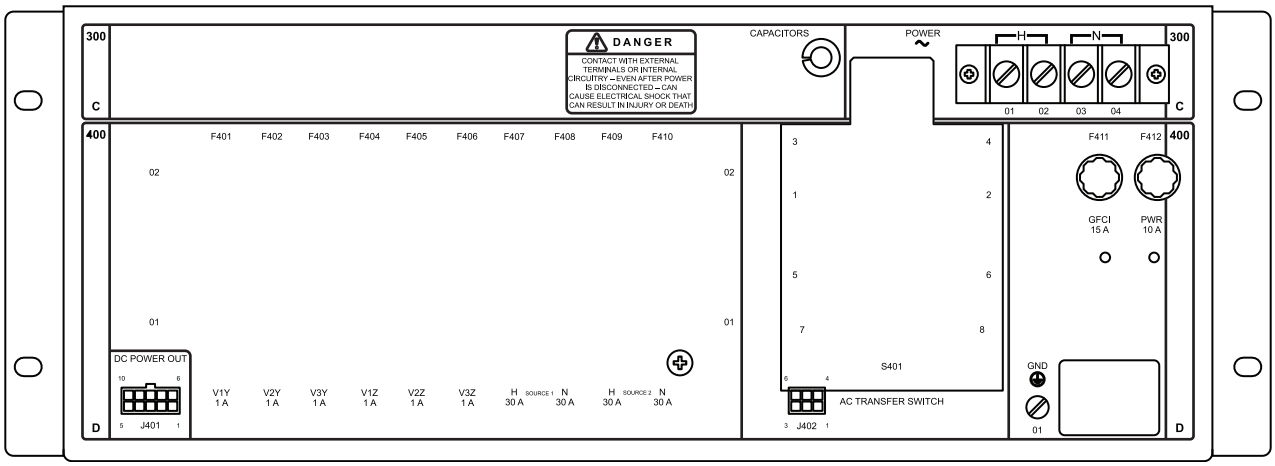
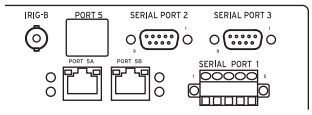
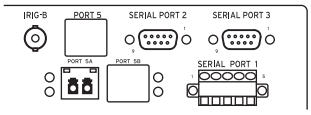


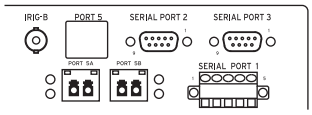
Figure 26 Rear View of the SEL-651R-2 Power Module (Dual-Door Enclosure)



Optional dual redundant 10/100BASE-T metallic Ethernet ports (5A and 5B) with EIA-485 serial Port 1



Optional single 100BASE-FX fiber Ethernet port (5A) with EIA-485 serial Port 1



Optional dual redundant 100BASE-FX Ethernet ports (5A and 5B) with EIA-485 serial Port 1

Figure 27 SEL-651R-2 Rear-Panel Communications Port Configurations

Enclosure Dimensions

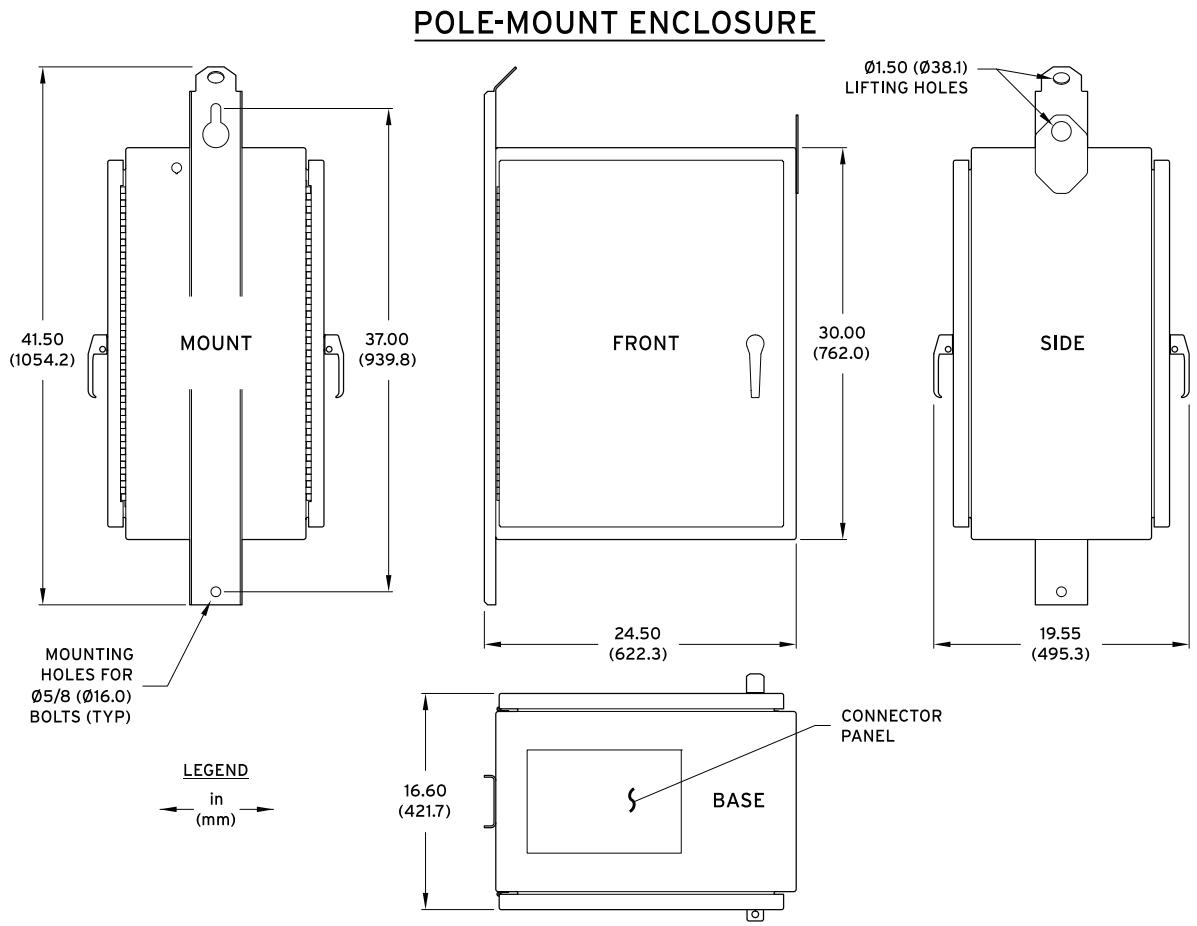


Figure 28 SEL-651R-2 Dimensions and Mounting Drill Plan (Dual-Door Enclosure)

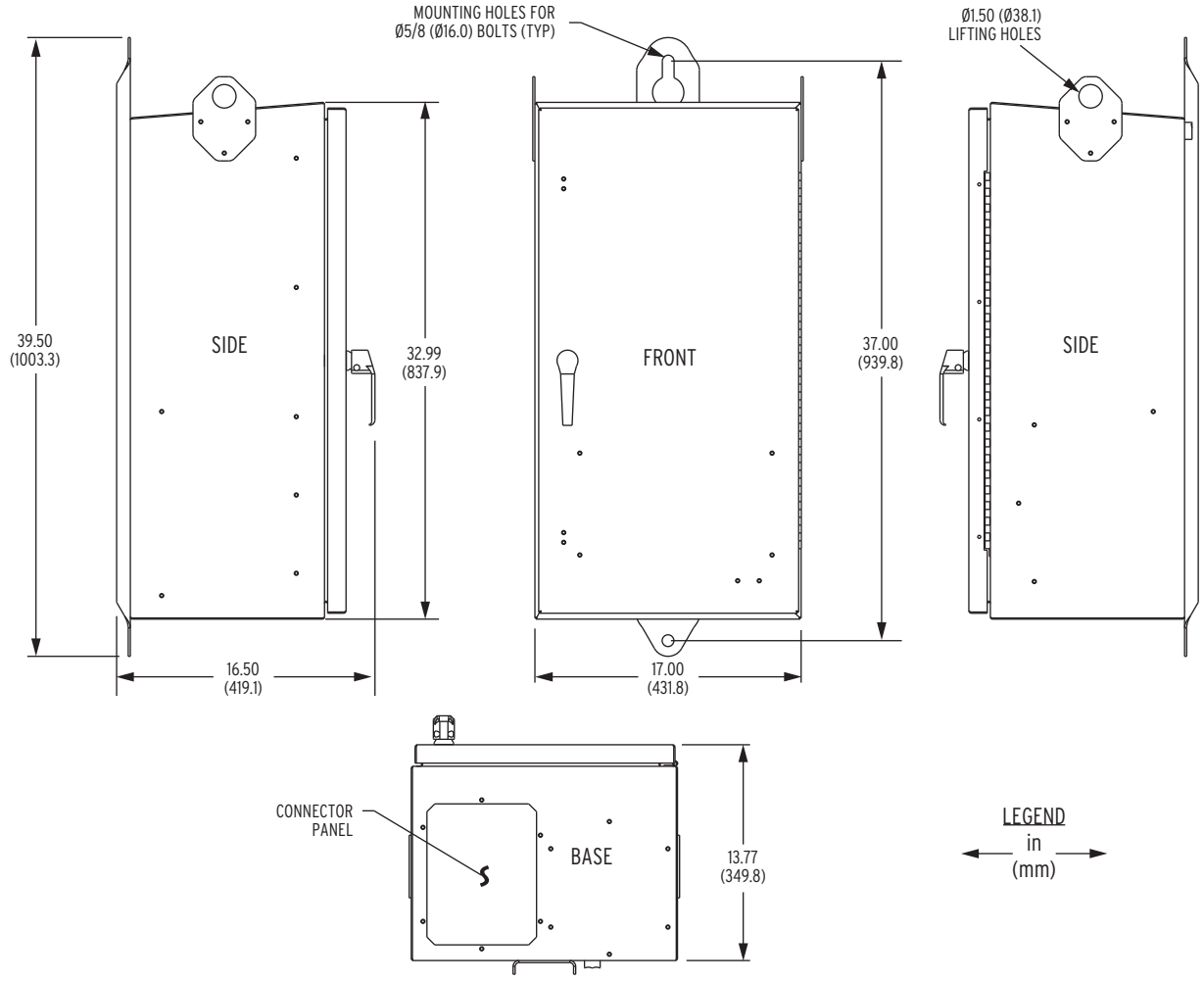


Figure 29 SEL-651R-2 Dimensions and Mounting Drill Plan (Single-Door Enclosure)

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

General

AC Current Inputs

Channels IA, IB, IC

1 A Nominal:	3 A continuous (4 A continuous at 55°C), linear to 20 A symmetrical; 100 A for 1 s; 250 A for 1 cycle
Burden:	0.13 VA @ 1 A, 1.31 VA @ 3 A

Channel IN

0.2 A Nominal:	15 A continuous, linear to 5.5 A symmetrical; 100 A for 1 s; 250 A for 1 cycle
Burden:	<0.5 VA @ 0.2 A

AC Voltage Inputs

300 V (PT):	300 V_{L-N} continuous (ideally connect voltage no higher than 240 Vac nominal, thus providing 60 Vac margin for accurately measuring overvoltage conditions); 600 Vac for 10 s.
Burden:	<0.03 VA @ 67 V <0.06 VA @ 120 V <0.80 VA @ 300 V
8 V LEA:	8 V_{L-N} continuous (ideally connect voltage no higher than 6.5 Vac nominal, thus providing 1.5 Vac margin for accurately measuring overvoltage conditions); 300 Vac for 10 s.
Burden:	Relay Input Z = 1 MΩ

Common Mode Voltage

Operation:	3 Vac
Without Damage:	50 Vac

Eaton NOVA LEA:	37 V_{L-N} continuous (ideally connect voltage no higher than 29.6 Vac nominal, thus providing 7.4 Vac margin for accurately measuring overvoltage conditions); 250 Vac for 10 s.
Burden:	Relay Input Z = 165 kΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	53 Vac
Lindsey SVMI LEA:	200 V_{L-N} continuous (ideally connect voltage no higher than 160 Vac nominal, thus providing 40 Vac margin for accurately measuring overvoltage conditions); 250 Vac for 10 s.
Burden:	Relay Input Z = 1 MΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	25 Vac
Siemens LEA:	8.49 V_{L-N} continuous (ideally connect voltage no higher than 6.79 Vac nominal, thus providing 1.7 Vac margin for accurately measuring overvoltage conditions); 155 Vac for 10 s.
Burden:	Relay Input Z = 24.22 kΩ
Common Mode Voltage	
Operation:	3 Vac
Without Damage:	50 Vac

Frequency and Rotation

Note: 60/50 Hz system frequency and ABC/ACB phase rotation are user-settable.

Frequency Tracking Range:	40–66 Hz
Maximum Rate of Change:	~20 Hz/s (The relay will not measure faster-changing frequencies and will revert to nominal frequency if the condition is maintained for longer than 0.25 s)

Note: Voltage V*n*Y or V*n*Z (where *n* = 1, 2, or 3) required for frequency tracking, depending upon Global setting FSELECT.

Power Supply

120 Vac Nominal

Rated Range:	85–132 Vac
Frequency Range:	40–65 Hz
Maximum Burden:	250 VA average, 500 VA peak
Inrush:	<100 A (I^2t < 24 A^2 – s)

230 Vac Nominal

Rated Range:	170–265 Vac
Frequency Range:	40–65 Hz
Maximum Burden:	250 VA average, 500 VA peak
Inrush:	<50 A (I^2t < 6 A^2 – s)

125 Vdc Nominal

Rated Range:	110.0–137.5 Vdc
Maximum Burden:	25 W continuous, 300 W for 1.5 s

48 Vdc Nominal

Rated Range:	43–60 Vdc
Maximum Burden:	25 W continuous, 300 W for 1.5 s

12 V Accessory Power Supply

For Models With AC Power Supply

12 Vdc ±10%, 40 W continuous, 60 W for 6 s every 60 s

For Models With DC Power Supply

12 Vdc ±10%, 3 W (0.25 A) continuous

Note: Some models momentarily dip to 9 Vdc during trip/close operations.

Output Contacts (Except Trip and Close)

Make:	30 A per IEEE C37.90-2005, Section 5.8
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
MOV Protection:	270 Vac, 360 Vdc, 40 J
Pickup Time:	<5 ms
Update Rate:	1/8 cycle

Breaking Capacity (10,000 Operations):

24 V	0.75 A	L/R = 40 ms
48 V	0.50 A	L/R = 40 ms
125 V	0.30 A	L/R = 40 ms
250 V	0.20 A	L/R = 40 ms

Cyclic Capacity (1 Cycle/Second):

24 V	0.75 A	L/R = 40 ms
48 V	0.50 A	L/R = 40 ms
125 V	0.30 A	L/R = 40 ms
250 V	0.20 A	L/R = 40 ms

Note: Per IEC 60255-0-20:1974, using the simplified assessment method.

AC Output Ratings

Maximum Operational Voltage (U_E) Rating:	240 Vac
Insulation Voltage (U_I) Rating (Excluding EN 61010-1):	300 Vac
Utilization Category:	AC-15 (control of electromagnetic loads >72 VA)
Contact Rating Designation:	B300 (B = 5 A, 300 = rated insulation voltage)
Voltage Protection Across Open Contacts:	270 Vac, 40 J
Rated Operational Current (I_E):	3 A @ 120 Vac 1.5 A @ 240 Vac
Conventional Enclosed Thermal Current (I_{THE}) Rating:	5 A
Rated Frequency:	50/60 ± 5 Hz
Electrical Durability Make VA Rating:	3600 VA, cos φ = 0.3
Electrical Durability Break VA Rating:	360 VA, cos φ = 0.3

Trip and Close Outputs

Traditional Interface Rating

Coil Voltage:	24 ± 2.4 Vdc
Coil Current:	15.5 A (Close), 12.2 A (Trip)

G&W Viper-ST/-LT, ABB Elastimold MVR, and ABB Gridshield (32-Pin and 42-Pin Versions) Rating

Coil Voltage:	155 + 5, –3 Vdc
Coil Current:	12–17 A (Close), 4 A (Trip) (per phase)
Pulse Duration:	52–55 ms (Close), 27–30 ms (Trip)

ABB OVR-3/VR-3S (24-Pin, 15 and 27 kV Models) Rating

Coil Voltage:	48 + 5, –3 Vdc
Pulse Duration:	85 ms (Close), 45 ms (Trip)

Control-Powered Eaton NOVA Rating

Coil Voltage:	48 + 5, –3 Vdc

ABB Joslyn TriMod 600R Rating

Coil Voltage:	155 + 5, –3 Vdc
Pulse Duration:	35 ms (Close), 14 ms (Trip)

Eaton NOVA-TS or NOVA-STS Triple-Single Rating

Coil Voltage:	48 + 5, –3 Vdc

Tavrida OSM AI_2 Rating

Coil Voltage:	155 + 5, –3 Vdc
Pulse Duration:	60 ms (Close), 15 ms (Trip)

Tavrida OSM AI_4 Rating

Coil Voltage:	155 + 5, –3 Vdc
Pulse Duration:	60 ms (Close), 15 ms (Trip)

Siemens SDR Triple-Single Rating

Coil Voltage:	155 + 5, –3 Vdc
Pulse Duration:	65 ms (Close), 40 ms (Trip)

Siemens SDR Three-Phase Rating

Coil Voltage:	155 + 5, –3 Vdc
Pulse Duration:	65 ms (Close), 40 ms (Trip)

Eaton NOVA NX-T Rating

Coil Voltage:	155 + 5, –3 Vdc
Pulse Duration:	45 ms (Close), 10 ms (Trip)

Note: Supports an entire trip-close-trip-close-trip-close-trip-close-trip-lockout sequence every minute.

Optoisolated Inputs (Optional)

When Used With DC Control Signals

125 Vdc:	On for 105–150 Vdc; off below 75 Vdc
12 Vdc:	On for 9.6–27 Vdc

When Used With AC Control Signals

125 Vdc:	On for 89.6–150.0 Vac; off below 53.0 Vac

Note: AC mode is selectable for Inputs IN101 and IN102 when ordered with 125 Vdc options via Global settings IN101D and IN102D. AC input recognition delay from time of switching: 0.75 cycles maximum pickup, 1.25 cycles maximum dropout.

Note: All optoisolated inputs draw less than 10 mA of current at nominal voltage or AC rms equivalent.

Status Inputs

DC Dropout Range:	0–4 Vdc
DC Pickup Range:	8–28 Vdc
Current Draw:	1–10 mA

Communications Ports

EIA-232:	One front, two rear
EIA-485:	One rear with 2100 Vdc of isolation
Per Port Data Rate Selections:	300, 1200, 2400, 4800, 9600, 19200, 38400, 57600
USB:	One front port (Type B connector, CDC class device)
Ethernet:	One 10/100BASE-T rear port (RJ45 connector) (discontinued option) Two 10/100BASE-T rear ports optional (RJ45 connector) One or two 100BASE-FX rear ports optional (LC connectors multimode) Internal Ethernet switch included with second Ethernet port

Time-Code Inputs

Recloser Control accepts demodulated IRIG-B time-code input at Port 2 or the BNC input.

Port 2, Pin 4 Input Current:	1.8 mA typical at 4.5 V (2.5 kΩ resistive)
BNC Input Current:	4 mA typical at 4.5 V (750 Ω resistive when input voltage is greater than 2 V)

Synchronization Accuracy

Internal Clock:	±1 µs
Synchrophasor Reports (e.g., **MET PM**, **EVE P**, **CEV P**):	±10 µs
All Other Reports:	±5 ms

Simple Network Time Protocol (SNTP) Accuracy

Internal Clock:	±5 ms

Unsynchronized Clock Drift

Relay Powered:	2 minutes per year typical

Operating Temperature

Relay Module:	–40° to +85°C (–40° to +185°F)
Batteries:	–40° to +80°C (–40° to +176°F)
Entire SEL-651R-2 unit:	–40° to +55°C (–40° to +131°F)

Note: LCD contrast impaired for temperatures below –20°C (–4°F). The entire SEL-651R-2 unit is operationally tested to +70°C (+158°F). The 15°C (27°F) difference between the +55°C rating and +70°C is for direct sunlight temperature rise.

Weight

<114 kg (<250 lb)

Battery Specifications

Base Version Requirements

Normal Capacity:	16 ampere-hours @ 25°C
Run Time (Relay Electronics Operate Plus One Trip/Close Cycle):	≥9.6 hours @ 25°C ≥3.2 hours @ –40°C
Recharge Time (Deep Discharge to Fully Charged):	≤9.6 hours @ 25°C
Estimated Life:	≥4 years @ 25°C ≥1 year @ +80°C

Extended Capacity Option Requirements

Normal Capacity:	40 ampere-hours @ 25°C
Run Time (Relay Electronics Operate Plus One Trip/Close Cycle):	≥24 hours @ 25°C ≥8 hours @ –40°C
Recharge Time (Deep Discharge to Fully Charged):	≤24 hours @ 25°C
Estimated Life:	≥4 years @ 25°C ≥1 year @ +80°C

Processing Specifications and Oscillography

AC Voltage and Current Inputs

128 samples per power system cycle, 3 dB low-pass filter cut-off frequency of 3 kHz.

Digital Filtering

Digital low-pass filter then decimate to 32 samples per cycle followed by one-cycle cosine filter.
Net filtering (analog plus digital) rejects dc and all harmonics greater than the fundamental.

Protection and Control Processing

Most Elements:	Four times per power system cycle
Time-Overcurrent Elements:	Two times per power system cycle

Oscillography

Length:	15, 30, or 60 cycles
Total Storage:	11 s of analog and binary
Sampling Rate:	128 samples per cycle unfiltered 32 and 16 samples per cycle unfiltered and filtered 4 samples per cycle filtered
Trigger:	Programmable with Boolean expression
Format:	ASCII and Compressed ASCII Binary COMTRADE (128 samples per cycle unfiltered)
Time-Stamp Resolution:	1 µs when high-accuracy time source is connected (**EVE P** or **CEV P** commands)
Time-Stamp Accuracy:	See *Time-Code Inputs* in these specifications.

Sequential Events Recorder

Time-Stamp Resolution:	1 ms
Time-Stamp Accuracy (With Respect to Time Source):	±5 ms

Control Element Settings Ranges and Accuracies

Instantaneous/Definite-Time Overcurrent Elements (50)

Current Pickup Range (A Secondary)

Phase and Neg.-Seq.:	0.05–20.00 A, 0.01 A steps
Ground:	0.005–20.000 A, 0.001 A steps
Neutral:	0.005–2.500 A

Steady-State Pickup Accuracy

Phase and Neg.-Seq.:	±0.01 A plus ±3% of setting
Ground:	±0.001 A plus ±3% of setting (IN < 4.7 A) ±0.010 A plus ±3% of setting (IN ≥ 4.7 A)
Neutral:	±0.001 A plus ±3% of setting
Transient Overreach:	±5% of pickup
Pickup/Dropout Time:	1.25 cycles
Time Delay Range:	0.00–16,000.00 cycles, 0.25–cycle steps
Time Delay Accuracy:	±0.25 cycle plus ±0.1% of setting

Time-Overcurrent Elements (51)

Current Pickup Range (A Secondary)

Phase and Neg.-Seq.:	0.05–3.20 A, 0.01 A steps
Ground:	0.005–3.200 A, 0.001 A steps
Neutral:	0.005–0.640 A, 0.001 A steps

Steady-State Pickup Accuracy

Phase and Neg.-Seq.:	±0.01 A plus ±3% of setting
Ground:	±0.001 A plus ±3% of setting (IN < 4.7 A) ±0.010 A plus ±3% of setting (IN ≥ 4.7 A)
Neutral:	±0.001 A plus ±3% of setting

Time Dials

U.S.:	0.5–15.0, 0.01 steps
IEC:	0.05–1.00, 0.01 steps
Recloser Curves:	0.10–2.00, 0.01 steps
Curve Timing Accuracy:	±1.50 cycles plus ±4% of setting, between 2 and 30 multiples of pickup

Second-Harmonic Blocking Elements

Pickup Range:	5% to 100% of fundamental, 1% steps
Steady-State Pickup Accuracy:	2.5 percentage points
Pickup/Dropout Time:	<1.25 cycles
Time Delay:	0.00–16,000.00 cycles, 0.25-cycle steps
Timer Accuracy:	±0.25 cycle and ±0.1% of setting

Undervoltage (27) and Overvoltage (59)

Pickup Ranges (V Secondary)

300 V Maximum Inputs

Phase:	1.00–300.00 V, 0.01 V steps
Phase-to-Phase:	1.76–520.00 V, 0.02 V steps
Sequence:	2.00–300.00 V, 0.02 V steps

8 V LEA Maximum Inputs

Phase:	0.03–8.00 V[a]
Phase-to-Phase:	0.05–13.87 V[a]
Sequence:	0.05–8.00 V[a]

Eaton NOVA LEA Inputs (37 Vac Maximum)

Phase:	0.12–37.09 V[a]
Phase-to-Phase:	0.21–64.24 V[a]
Sequence:	0.25–37.09 V[a]

Lindsey SVMI LEA Inputs (200 Vac Maximum)

Phase:	1.00–200.00 V
Phase-to-Phase:	1.76–346.00 V
Sequence:	2.00–200.00 V

Siemens LEA Inputs (8.49 Vac Maximum)

Phase:	0.03–8.49 V[a]
Phase-to-Phase:	0.05–14.72 V[a]
Sequence:	0.05–8.00 V[a]

Steady-State Pickup Accuracy

300 V Maximum

Phase:	±0.5 V plus ±1% of setting
Phase-to-Phase:	±1 V plus ±2% of setting
Sequence:	±1.5 Vac plus ±3% of setting @ 12.5–300 Vac

8 V LEA Maximum[a]

Phase:	±10 mV plus ±1% of setting
Phase-to-Phase:	±20 mV plus ±2% of setting
Sequence:	±30 mVac plus ±3% of setting @ 0.33–8.00 Vac

Eaton NOVA LEA[a]

Phase:	±60 mV plus ±1% of setting
Phase-to-Phase:	±120 mV plus ±2% of setting
Sequence:	±180 mVac plus ±3% of setting @ 1.55–37.09 Vac

Lindsey SVMI LEA[a]

Phase:	±0.5 V plus ±1% of setting
Phase-to-Phase:	±1 V plus ±2% of setting
Sequence:	±1.5 Vac plus ±3% of setting @ 12.5–200 Vac

Siemens LEA[a]

Phase:	±10 mV plus ±1% of setting
Phase-to-Phase:	±20 mV plus ±2% of setting
Sequence:	±30 mVac plus ±3% of setting @ 0.33–8.49 Vac

Transient Overreach:	±5%
Pickup/Dropout Time:	<1.25 cycles

Vector Shift (78VS)

Pickup Range:	2.0°–30.0°, 0.1-degree increment
Accuracy:	±1.5°, ±10% of setting
Pickup Time:	<3 cycles

Synchronism-Check Elements (25)

Slip Frequency Pickup Range:	0.005–0.500 Hz, 0.001 Hz steps
Slip Frequency Pickup Accuracy:	±0.003 Hz
Phase Angle Range:	0–80°, 0.01° steps
Phase Angle Accuracy:	±4°

Under- and Overfrequency Elements (81)

Frequency Range:	40.00–66.00 Hz, 0.01 Hz steps
Frequency Accuracy:	±0.01 Hz

Cycle-Based Delay Timers

Time Delay Range:	2.00–16,000.00 cycles, 0.25-cycle steps
Time Delay Accuracy:	±0.25 cycle plus ±0.1%

Seconds-Based Delay Timers

Time Delay Range:	0.10–1000.00 s, 0.01 s steps
Time Delay Accuracy:	±6 ms plus ±0.1% of setting

Undervoltage Frequency Element Block Range

300 V Inputs:	12.50–300.00 V[a]

Rate-of-Change-of-Frequency Element (81R)

Pickup Range:	0.10–15.00 Hz/s, 0.01 Hz/s steps
Dropout:	95% of pickup
Pickup Accuracy:	±100 mHz/s and ±3.33% of pickup
Pickup Time:	See *Equation 4.7* in the *SEL-651R-2 Instruction Manual.*
Pickup Time Delay:	0.10–60.00 s, 0.01-second steps
Dropout Time Delay:	0.00–60.00 s, 0.01-second steps
Timer Accuracy:	±6 ms and ±0.1% of setting

Autosynchronizing

Frequency Matching

Speed (Frequency) Control Outputs

Raise:	Digital output, adjustable pulse duration and interval
Lower:	Digital output, adjustable pulse duration and interval

Frequency Synchronism

Timer:	5–3600 s, 1 s increments
Frequency Adjustment Rate:	0.01–10.00 Hz/s, 0.01 Hz/s increment
Frequency Pulse Interval:	1–120 s, 1 s increment
Frequency Pulse Minimum:	0.02–60.00 s, 0.01 s increment
Frequency Pulse Maximum:	0.10–60.00 s, 0.01 s increment
Kick Pulse Interval:	1–120 s, 1 s increments
Kick Pulse Minimum:	0.02–2.00 s, 0.01 s increments
Kick Pulse Maximum:	0.02–2.00 s, 0.01 s increments

Voltage Matching

Voltage Control Outputs

Raise:	Digital output, adjustable pulse duration and interval
Lower:	Digital output, adjustable pulse duration and interval
Voltage Synchronized Timer:	5–3600 s, 1 s increments
Voltage Adjustment Rate (Control System):	0.01–30.00 V/s, 0.01 V/s increment
Voltage Pulse Interval:	1–120 s, 1 s increment
Voltage Control Pulse Minimum:	0.02–60.00 s, 0.01 s increment
Voltage Control Pulse Maximum:	0.10–60.00 s, 0.01 s increment
Timing Accuracy:	±0.5% plus ±1/4 cycle

Power Elements[b]

Minimum Current:	0.01 A
Minimum Voltage:	40 V
Steady-State Pickup Accuracy:	0.58 W plus ±5% of setting at unity power factor
Pickup/Dropout Time:	<3.75 cycles
Time Delay Accuracy:	±0.25 cycle plus ±0.1% of setting

Load Encroachment[b]

Minimum Current:	0.1 A
Minimum Voltage:	12.5 Vac
Forward Load Impedance:	0.5–640.0 Ω secondary
Forward Positive Load Angle:	–90° to +90°
Forward Negative Load Angle:	–90° to +90°
Negative Load Impedance:	0.50–640 Ω secondary
Negative Positive Load Angle:	+90° to +270°
Negative Negative Load Angle:	+90° to +270°

Pickup Accuracy

Impedance:	±3%
Angle:	±2°

SELOGIC Control Equation Variable Timers

Pickup Ranges

0.00–999,999.00 Cycles:	0.25-cycle steps (programmable timers)
Pickup/Dropout Accuracy:	±0.25 cycle plus ±0.1% of setting

Metering Accuracies

Accuracies specified at 20°C and at nominal system frequency unless noted otherwise.

Instantaneous and Maximum/Minimum Metering

Voltages

VAY, VBY, VCY, VAZ, VBZ, VCZ:	±0.2% (50–300 V), ±0.5° for PTs ±0.2% (0.67–8.00 V), ±0.5° for 8 V LEAs ±0.2% (3.09–37.09 V), ±0.5° for Eaton NOVA LEAs ±0.2% (25–200.00 V), ±0.5° for Lindsey SVMI LEAs ±0.2% (0.71–8.49 V), ±0.5° for Siemens SDR LEAs
VABY, VBCY, VCAY, VABZ, VBCZ, VCAZ:	±0.4% (50–300 V), ±1.0° for PTs ±0.4% (1.16–13.86 V), ±1.0° for 8 V LEAs ±0.4% (5.35–64.28 V), ±1.0° for Eaton NOVA LEAs ±0.4% (43.30–346.41 V), ±1.0° for Lindsey SVMI LEAs ±0.4% (1.22–14.70 V), ±1.0° for Siemens SDR LEAs
3V0Y, V1Y, V2Y, 3V0Z, V1Z, V2Z:	±0.6% (50–300 V), ±1.0° for PTs ±0.6% (0.67–8.00 V), ±1.0° for 8 V LEAs ±0.6% (3.09–37.09 V), ±1.0° for Eaton NOVA LEAs ±0.6% (25.00–200.00 V), ±1.0° for Lindsey SVMI LEAs ±0.6% (0.71–8.49 V), ±1.0° for Siemens SDR LEAs

Currents

IA, IB, IC[c]:	±0.5 mA plus ±0.1% of reading (0.1–2 A), ±0.5°
IN:	±0.08 mA plus ±0.1% of reading (0.005–4.5 A), ±1°
3I1, 3I0, 3I2:	±0.01 A plus ±3% of reading (0.1–2 A), ±1°

Power

Apparent (MVA)

MVAA, MVAB, MVAC, MVA3P:	±1.2% (V_{phase} > 50 Vac[d], I_{phase} > 0.1 A)

Real (MW)

MWA, MWB, MWC, MW3P:	±0.7% @ PF = 1, ±1.0% @ PF > 0.87 (V_{phase} > 50 Vac[d], I_{phase} > 0.1 A)

Reactive (MVAR)

MVARA, MVARB, MVARC, MVAR3P:	±0.7% @ PF = 0, ±1.0% @ PF < 0.50 (V_{phase} >50 Vac[d], I_{phase} > 0.1 A)

Energy

Megawatt Hours (In and Out)

MWhA, MWhB, MWhC, MWh3P:	+1.2% @ PF = 1, (V_{phase} > 50 Vac[d], I_{phase} > 0.1 A)

Megavar Hours (In and Out)

MVARhA, MVARhB, MVARhC, MVARh3P:	+1.2% @ PF = 0, (V_{phase} > 50 Vac[d], I_{phase} > 0.1 A)

Demand Metering

Currents

IA, IB, IC:	±0.25% (0.1–2 A)
IN (Measured):	±0.25% (0.005–4.5 A)
3I2, 3I0 (IG):	±3% ± 0.01 A, (0.1–20.0 A)

Synchrophasor Accuracy

Maximum Data Rate in Messages per Second

IEEE C37.118 Protocol:	60 (nominal 60 Hz system) 50 (nominal 50 Hz system)
SEL Fast Message Protocol:	1
IEEE C37.118-2005 Accuracy:	Level 1 at maximum message rate when phasor has the same frequency as A-phase voltage, frequency-based phasor compensation is enabled (PHCOMP := Y), and the narrow band filter is selected (PMAPP := N). Out-of-band interfering frequency (Fs) test, 10 Hz ≤ Fs ≤ (2 • NFREQ).
Current Range:	(0.2–2.0) • I_{nom} (I_{nom} = 1 A phase, 0.2 A neutral)
Frequency Range:	±5 Hz of nominal (50 or 60 Hz)
Voltage Range:	30–250 V for PTs 0.8–8.0 V for 8 V LEA inputs 3.71–37.09 V for Eaton NOVA LEA inputs 30–300 V for Lindsey SVMI LEA inputs 0.85–8.49 V for Siemens SDR LEA inputs
Phase Angle Range:	–179.99° to +180.00°

Harmonic Metering

Voltages

VAY, VBY, VCY, VAZ, VBZ, VCZ:	Accuracies valid for THD <100%, 30 V < fundamental < 200 V sec, 50 Hz or 60 Hz
Fundamental Magnitude:	±5%
02–16 Harmonic Percentage:	±5 percentage points[e]

Currents

IA, IB, IC:	Accuracies valid for THD < 100%, fundamental voltage < 200 V, 50 Hz or 60 Hz
1 A and 0.2 A Nominal:	0.02 A < fundamental current < 1 A sec
Fundamental Magnitude:	±5%
02–16 Harmonic Percentage:	±5 percentage points[e]

RMS Metering

Voltages

VAY, VBY, VCY, VAZ, VBZ, VCZ:	±1.2% V_{phase} > 50 Vac[d] for PTs

Currents

IA, IB, IC:	±0.5 mA plus ±0.2% (0.1–2.0 A)
IN (Measured):	±0.08 mA plus ±0.20% (0.005–4.500 A)

Average Real Power (MW)

MWA, MWB, MWC, MW3P:	±2.0% @ PF = 1 (V_{phase} > 50 Vac[c], I_{phase} > 0.1 A)

Type Tests

Recloser Type Tests

IEEE C37.60-2003, Section 6.13 Control Electronic Elements Surge Withstand Capability (SWC) Tests

6.13.1 Oscillatory and fast transient surge tests (a control-only test, performed in accordance with IEEE C37.90.1-2002)

6.13.2 Simulated surge arrester operation test (performed with the control connected to the following reclosers)

G&W Viper-ST:	27 kV, 12.5 kA interrupting, 800 A continuous 38 kV, 12.5 kA interrupting, 800 A continuous
ABB Elastimold MVR:	15/17 kV, 12.5 kA interrupting, 800 A continuous 38 kV, 12.5 kA interrupting, 800 A continuous

Eaton NOVA:	27 kV, 12.5 kA interrupting, 630 A continuous
Eaton Recloser Type "WVE-27":	38 kV, 8 kA interrupting, 560 A continuous
ABB OVR-3:	27 kV, 12.5 kA interrupting, 630 A continuous
Eaton NOVA-TS:	15.5 kV, 8 kA interrupting, 400 A continuous
Eaton NOVA (Control Powered):	27 kV, 12.5 kA interrupting, 630 A continuous
Tavrida OSM Al_2:	27 kV, 12.5 kA interrupting, 600 A continuous
Tavrida OSM Al_4:	27 kV, 12.5 kA interrupting, 600 A continuous

IEC 62271-111:2012/IEEE C37.60-2012, Section 6.111 Control Electronic Elements Surge Withstand Capability (SWC) Tests

6.111.2 Oscillatory and fast transient surge tests

6.111.3 Simulated surge arrester operation test

Both performed with the control connected to the following reclosers:

G&W Electric Viper-ST, Solid Dielectric

Voltage Rating:	38 kV
Current Break Rating:	12.5 kA
Continuous Current Rating:	800 A

Eaton Type NOVA 15, Aux. Power

Voltage Rating:	15.5 kV
Current Break Rating:	12.5 kA
Continuous Current Rating:	630 A

Tavrida OSM25_Al_2(630_150_2)

Voltage Rating:	27 kV
Current Break Rating:	12.5 kA
Continuous Current Rating:	630 A

ABB Gridshield TS Recloser (32-Pin)

Voltage Rating:	27 kV
Current Break Rating:	12.5 kA
Continuous Current Rating:	1000 A

Electromagnetic Compatibility Emissions[f]

Radiated and Conducted Emissions:	EN/IEC 60255-26:2013, Section 7.1 CISPR 22:2008 EN 55022:2010 + AC:2011 CISPR 11:2009 + A1:2010 EN 55011:2009 + A1:2010 FCC 47 CFR:2014, Part 15.107 FCC 47 CFR:2014, Part 15.109 Severity Level: Class A

Electromagnetic Compatibility Immunity[f]

Radiated RF Immunity:	EN/IEC 60255-26:2013, Section 7.2.4 IEC 61000-4-3:2006 + A1:2007 + A2:2010 EN 61000-4-3:2006 + A1:2008 + A2:2010 Severity Level: 10 V/m IEEE C37.90.2-2004 Severity Level: 20 V/m (average) 35 V/m (peak)
Conducted RF Immunity:	EN/IEC 60255-26:2013, Section 7.2.8 IEC 61000-4-6:2008 EN 61000-4-6:2009 Severity Level: 10 Vrms
Electrostatic Discharge Immunity:	EN/IEC 60255-26:2013, Section 7.2.3 IEC 61000-4-2:2008 Levels 2, 4, 6, and 8 kV contact; Levels 2, 4, 8, and 15 kV air IEEE C37.90.3-2001 Levels 2, 4, and 8 kV contact; Levels 4, 8, and 15 kV air
Electrical Fast Transient Burst Immunity:	EN/IEC 60255-26:2013, Section 7.2.5 EN/IEC 61000-4-4:2012 4 kV, 5 kHz on power supply, I/O, and ground 2 kV, 5 kHz on communications ports
Surge Immunity[g, h]:	EN/IEC 60255-26:2013, Section 7.2.7 Severity Level: Zone A Severity Level: Zone B on IRIG-B IEC 61000-4-5:2005 EN 61000-4-5:2006 Severity Level 4: 2 kV line-to-line 4 kV line-to-earth Severity Level 3 on IRIG-B: 2 kV line-to-earth
Surge Withstand Capability:	EN/IEC 60255-26:2013, Section 7.2.6 IEC 61000-4-18:2006 + A1:2010 EN 61000-4-18:2007 + A1:2010 Severity Level: Power supply and I/O 2.5 kV common mode 1.0 kV differential mode Communications ports 1.0 kV common mode IEEE C37.90.1-2012 2.5 kV oscillatory 4.0 kV fast transient

Environmental

Cold[f]:	IEC 60068-2-1:2007 Test Ad: 16 hours at –40°C
Damp Heat, Cyclic[f]:	IEC 60068-2-30:2005 Test Db: 25° to 55°C, 6 cycles, Relative Humidity: 95%
Dry Heat[f]:	IEC 60068-2-2:2007 Test Bd: Dry heat, 16 hours at +85°C
Vibration[f]:	IEC 60255-21-1:1988 EN 60255-21-1:1995 Severity Level: Endurance Class 1 Response Class 2 IEC 60255-21-2:1988 EN 60255-21-2:1995 Severity Level: Shock Withstand, Bump Class 1 Shock Response Class 2 IEC 60255-21-3:1993 EN 60255-21-3:1995 Severity Level: Quake Response Class 2
Enclosure Ingress Protection[i]:	IEC 60529:2001 + CRGD:2003 [BS EN 60529 Second Edition—1992 + REAF:2004] IP45

Safety[f]

Insulation Coordination

IEC 60255-27:2013, Section 10.6.4
EN 60255-27:2014, Section 10.6.4
IEEE C37.90-2005, Section 8
Severity Level—HiPot:
2.5 kVac on optoisolated inputs, contact outputs, CTs, and PTs
0.75 kVdc on IRIG-B, EIA-485, and Ethernet ports
3.6 kVdc on power supply
Type tested for one minute
Severity Level—Impulse:
5.0 kV on optoisolated inputs, contact outputs, CTs, PTs, and power supply
0.8 kV on IRIG-B, EIA-485, and Ethernet ports

[a] See Section 9: Settings in the SEL-651R-2 Instruction Manual for details on how to set voltage elements when using LEA inputs.
[b] Voltage, Power, and Impedance values listed for 300 Vbase (PT) inputs.
[c] Accuracies specified with balanced phase voltages at 120 Vac.
[d] Voltage threshold for given accuracy is 0.67 Vac for 8 V LEA inputs, 1.70 Vac for Eaton NOVA LEA inputs, 14.00 Vac for Lindsey SVMI LEA inputs, and 0.60 Vac for Siemens SDR LEA inputs.
[e] For example, for a particular harmonic value applied at 10% of fundamental, the harmonic value meters in the range of 5% to 15%.
[f] SEL enclosure excluded from test.
[g] Serial cable (non-fiber) lengths assumed to be <3 m.
[h] The following pickup/dropout delays are used:
Under- and overvoltage elements: 0.0/0.0 cycles
(Eaton NOVA and Lindsey LEAs required 6.0/6.0 cycles)
Phase instantaneous overcurrent elements: 0.5/1.0 cycles
Neutral instantaneous overcurrent elements: 0.0/4.0 cycles
Digital inputs: 0.5/0.5 cycles
[i] SEL enclosure included in test.

Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

Schweitzer Engineering Laboratories, Inc.
2350 NE Hopkins Court
Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

SCHWEITZER ENGINEERING LABORATORIES, INC.
2350 NE Hopkins Court • Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.332.1890 • Fax: +1.509.332.7990
selinc.com • info@selinc.com

PDS651R-02

SG125HV

String Inverter for 1500 Vdc System

SUNGROW
Clean power for all

HIGH YIELD

- Patented five-level topology, max. efficiency 98.9 %, European efficiency 98.7 %, CEC efficiency 98.5 %
- Full power operation without derating at 50 ℃
- Patented anti-PID function

EASY O&M

- Virtual central solution, easy for O&M
- Compact design and light weight for easy installation

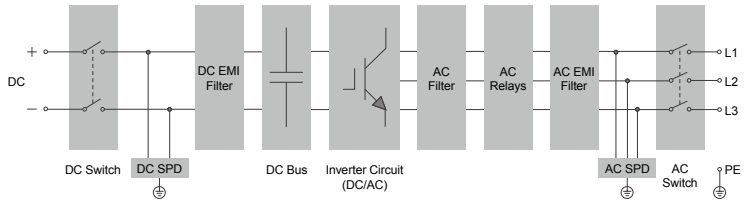
SAVED INVESTMENT

- DC 1500V,AC 600V, low system initial investment
- 1 to 5MW power block design for lower AC transformer and labor cost
- Max.DC/AC ratio up to 1.5

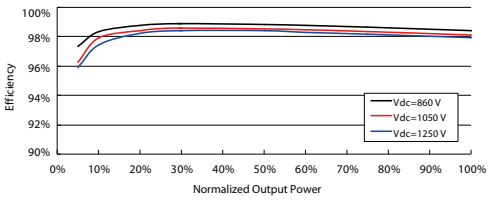
GRID SUPPORT

- Compliance with both IEC and UL safety,EMC and grid support regulations
- Low/High voltage ride through(L/HVRT)
- Active & reactive power control and power ramp rate control

CIRCUIT DIAGRAM



EFFICIENCY CURVE



Type designation	SG125HV
Input (DC)	
Max. PV input voltage	1500 V
Min. PV input voltage / Start-up input voltage	860 V / 920 V
Nominal PV input voltage	1050 V
MPP voltage range	860 – 1450 V
MPP voltage range for nominal power	860 – 1250 V
No. of independent MPP inputs	1
No. of DC inputs	1
Max. PV input current	148 A
Max. DC short-circuit current	250 A
Output (AC)	
AC output power	125 kVA @ 50 ℃
Max. AC output current	120 A
Nominal AC voltage	3 / PE, 600 V
AC voltage range	480 – 690 V
Nominal grid frequency / Grid frequency range	50 Hz / 45 – 55 Hz, 60 Hz / 55 – 65 Hz
THD	< 3 % (at nominal power)
DC current injection	< 0.5 % In
Power factor at nominal power / Adjustable power factor	> 0.99 / 0.8 leading - 0.8 lagging
Feed-in phases / connection phases	3 / 3
Efficiency	
Max. efficiency / European efficiency	98.9% / 98.7%
CEC efficiency	98.5%
Protection	
DC reverse connection protection	Yes
AC short-circuit protection	Yes
Leakage current protection	Yes
Grid monitoring	Yes
DC switch	Yes
AC switch	Yes
Q at night function	No
Anti-PID function	Yes
Overvoltage protection	DC Type II / AC Type II
General Data	
Dimensions (W*H*D)	670*902*296 mm 26.4''*35.5''*11.7''
Weight	76 kg 167.5 lb
Isolation method	Transformerless
Degree of protection	IP 65 NEMA 4X
Night power consumption	< 4 W
Operating ambient temperature range	-30 to 60 ℃ (> 50 ℃ derating) -22 to 140 ℉ (> 122 ℉ derating)
Allowable relative humidity range (non-condensing)	0 – 100 %
Cooling method	Smart forced air cooling
Max. operating altitude	4000 m (> 3000 m derating) 13123 ft (> 9843 ft derating)
Display / Communication	LED, Bluetooth+APP / RS485
DC connection type	OT or DT terminal (Max. 185 mm² 350 Kcmil)
AC connection type	OT or DT terminal (Max. 185 mm² 350 Kcmil)
Compliance	UL1741, UL1741SA, IEEE1547, IEEE1547.1, CSA C22.2 107.1-01-2001, FCC Part15 Sub-part B Class A Limits, California Rule 21, IEC 62109-1/-2, IEC 61000-6-2/-4, IEC 61727, IEC62116, BDEW, EN50549,VDE-AR-N 4110:2018, VDE-AR-N 4120:2018, UNE 206007-1:2013, P.O.12.3, UTE C15-712-1:2013, CEI 0-16:2017, IEC 61683, PEA, NTCO
Grid Support	LVRT, HVRT, ZVRT, active & reactive power regulation, PF control, soft start/stop

Three-phase pad-mounted compartmental type transformer

General

At Eaton, we are constantly striving to introduce new innovations to the transformer industry, bringing you the highest quality, most reliable transformers. Eaton's Cooper Power series Transformer Products are ISO 9001 compliant, emphasizing process improvement in all phases of design, manufacture, and testing. In order to drive this innovation, we have invested both time and money in the Thomas A. Edison Technical Center, our premier research facility in Franksville, Wisconsin. Such revolutionary products as distribution-class UltraSIL™ Polymer-Housed Evolution™ surge arresters and Envirotemp™ FR3™ fluid have been developed at our Franksville lab.

With transformer sizes ranging from 45 kVA to 12 MVA and high voltages ranging from 2400 V to 46 kV, Eaton has you covered. From fabrication of the tanks and cabinets to winding of the cores and coils, to production of arresters, switches, tap changers, expulsion fuses, current limit fuses, bushings (live and dead) and molded rubber goods, Eaton does it all. Eaton's Cooper Power series transformers are available with electrical grade mineral oil or Envirotemp™ FR3™ fluid, a less-flammable and bio-degradable fluid. Electrical codes recognize the advantages of using Envirotemp™ FR3™ fluid both indoors and outdoors for fire sensitive applications. The bio-based fluid meets Occupational Safety and Health Administration (OSHA) and Section 450.23 NEC Requirements.

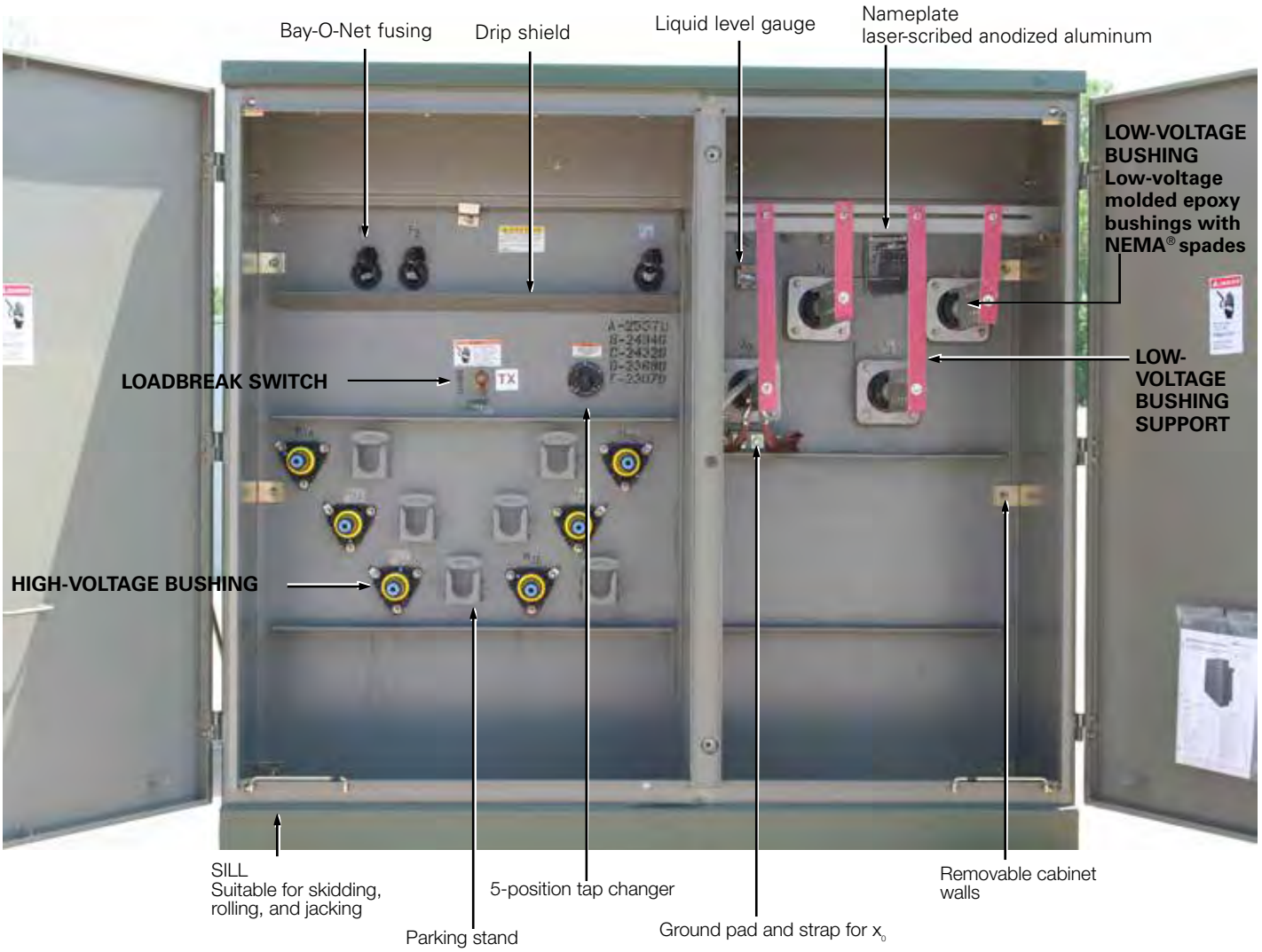


Figure 1. Three-phase pad-mounted compartmental type transformer.

Table 1. Product Scope

Type	Three Phase, 50 or 60 Hz, 65 °C Rise (55 °C, 55/65 °C), 65/75 °C, 75 °C
Fluid Type	Mineral oil or Envirotemp™ FR3™ fluid
Coil Configuration	2-winding or 4-winding or 3-winding (Low-High-Low), 3-winding (Low-Low-High)
Size	45 – 10,000 kVA
Primary Voltage	2,400 – 46,000 V
Secondary Voltage	208Y/120 V to 14,400 V
Specialty Designs	Inverter/Rectifier Bridge
	K-Factor (up to K-19)
	Vacuum Fault Interrupter (VFI)
	UL® Listed & Labeled and Classified
	Factory Mutual (FM) Approved®
	Solar/Wind Designs
	Differential Protection
	Seismic Applications (including OSHPD)
	Hardened Data Center

Table 2. Three-Phase Ratings

Three-Phase 50 or 60 Hz
kVA Available[1]:
45, 75, 112.5, 150, 225, 300, 500, 750, 1000, 1500, 2000, 2500, 3000, 3750, 5000, 7500, 10000

[1]Transformers are available in the standard ratings and configurations shown or can be customized to meet specific needs.

Table 3. Impedance Voltage

	Low-voltage rating		
Rating (kVA)	**≤ 600 V**	**2400 Δ through 4800 Δ**	**6900 Δ through 13800GY/7970 or 13800 Δ**
45-75	2.70-5.75	2.70-5.75	2.70-5.75
112.5-300	3.10-5.75	3.10-5.75	3.10-5.75
500	4.35-5.75	4.35-5.75	4.35-5.75
750-2500	5.75	5.75	5.75
3750	5.75	5.75	6.00
5000		6.00	6.50

Note: The standard tolerance is ± 7.5%

Table 4. Audible Sound Levels

	NEMA® TR-1 Average
Self-Cooled, Two Winding kVA Rating	**Decibels (dB)**
45-500	56
501-700	57
701-1000	58
1001-1500	60
1501-2000	61
2001-2500	62
2501-3000	63
3001-4000	64
4001-5000	65
5001-6000	66
6001-7500	67
7501-10000	68

Table 5. Insulation Test Levels

KV Class	Induced Test 180 or 400 Hz 7200 Cycle	kV BIL Distribution	Applied Test 60 Hz (kV)
1.2	Twice Rated Voltage	30	10
2.5		45	15
5		60	19
8.7		75	26
15		95	34
25		125	40
34.5		150	50

Table 6. Temperature Rise Ratings 0-3300 Feet (0-1000 meters)

	Standard	Optional
Unit Rating (Temperature Rise Winding)	65 °C	55 °C, 55/65 °C, 75 °C
Ambient Temperature Max	40 °C	50 °C
Ambient Temperature 24 Hour Average	30 °C	40 °C
Temperature Rise Hotspot	80 °C	65 °C

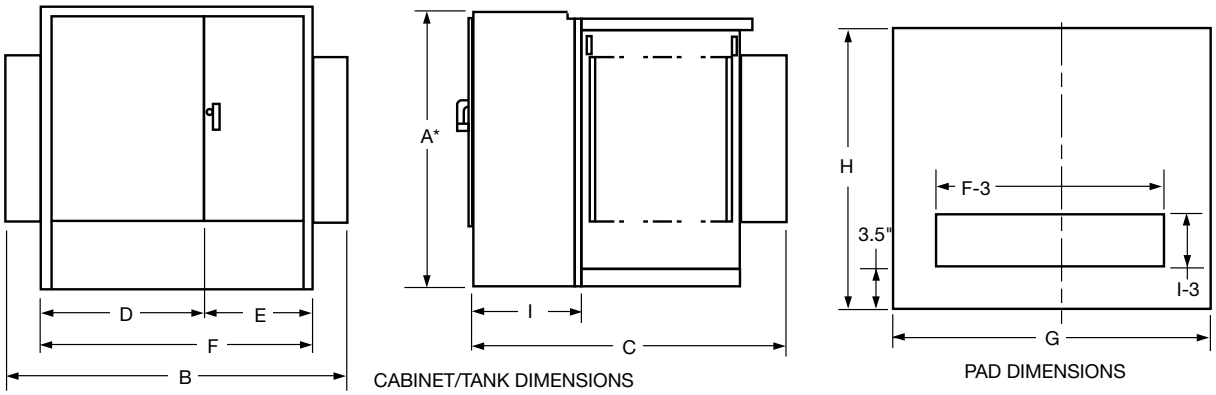


Figure 2. Transformer and pad dimensions.

* Add 9" for Bay-O-Net fusing.

Table 7. Fluid-filled—aluminum windings 55/65 °C Rise[1]

65° Rise	DEAD-FRONT—LOOP OR RADIAL FEED—BAY-O-NET FUSING OIL FILLED—ALUMINUM WINDINGS										
	OUTLINE DIMENSIONS (in.)									Gallons of Fluid	Approx. Total Weight (lbs.)
kVA Rating	A*	B	C	D	E	F	G	H	I		
45	50	68	39	42	26	68	72	43	20	110	2,100
75	50	68	39	42	26	68	72	43	20	115	2,250
112.5	50	68	49	42	26	68	72	53	20	120	2,350
150	50	68	49	42	26	68	72	53	20	125	2,700
225	50	72	51	42	30	72	76	55	20	140	3,150
300	50	72	51	42	30	72	76	55	20	160	3,650
500	50	89	53	42	30	72	93	57	20	190	4,650
750	64	89	57	42	30	72	93	61	20	270	6,500
1000	64	89	59	42	30	72	93	63	20	350	8,200
1500	73	89	86	42	30	72	93	90	24	410	10,300
2000	73	72	87	42	30	72	76	91	24	490	12,500
2500	73	72	99	42	30	72	76	103	24	530	14,500
3000	73	84	99	46	37	84	88	103	24	620	16,700
3750	84	85	108	47	38	85	88	112	24	660	19,300
5000	84	96	108	48	48	96	100	112	24	930	25,000
7500	94	102	122	54	48	102	100	126	24	1,580	41,900

1 Weights, gallons of fluid, and dimensions are for reference only and not for construction. Please contact Eaton for exact dimensions.

* Add 9" for Bay-O-Net fusing.

Table 8. Fluid-Filled—Copper Windings 55/65 °C Rise[1]

65° Rise	DEAD-FRONT—LOOP OR RADIAL FEED—BAY-O-NET FUSING OIL FILLED—COPPER WINDINGS										
	OUTLINE DIMENSIONS (in.)									Gallons of Fluid	Approx. Total Weight (lbs.)
kVA Rating	A*	B	C	D	E	F	G	H	I		
45	50	64	39	34	30	64	69	43	20	110	2,100
75	50	64	39	34	30	64	69	43	20	115	2,350
112.5	50	64	49	34	30	64	69	53	20	115	2,500
150	50	64	49	34	30	64	69	53	20	120	2,700
225	50	64	51	34	30	64	73	55	20	140	3,250
300	50	64	51	34	30	64	75	55	20	160	3,800
500	50	81	53	34	30	64	85	57	20	200	4,800
750	64	89	57	42	30	72	93	61	20	255	6,500
1000	64	89	59	42	30	72	93	63	20	300	7,800
1500	73	89	86	42	30	72	93	90	24	410	10,300
2000	73	72	87	42	30	72	76	91	24	420	11,600
2500	73	72	99	42	30	72	76	103	24	500	14,000
3000	73	84	99	46	37	84	88	103	24	720	18,700
3750	84	85	108	47	38	85	88	112	24	800	20,500
5000	84	96	108	48	48	96	100	112	24	850	25,000
7500	94	102	122	54	48	102	100	126	24	1,620	46,900

[1] Weights, gallons of fluid, and dimensions are for reference only and not for construction. Please contact Eaton for exact dimensions.

* Add 9" for Bay-O-Net fusing.

Standard features

Connections and neutral configurations

- Delta - Wye: Low voltage neutral shall be a fully insulated X0 bushing with removable ground strap.
- Grounded Wye-Wye: High voltage neutral shall be internally tied to the low voltage neutral and brought out as the H0X0 bushing in the secondary compartment with a removable ground strap.
- Delta-Delta: Transformer shall be provided without a neutral bushing.
- Wye-Wye: High voltage neutral shall be brought out as the H0 bushing in the primary compartment and the low voltage neutral shall be brought as the X0- bushing in the secondary compartment.
- Wye-Delta: High voltage neutral shall be brought out as the H0 bushing in the primary compartment. No ground strap shall be provided (line to line rated fusing is required).

High and low voltage bushings

- 200 A bushing wells (15, 25, and 35 kV)
- 200 A, 35 kV Large Interface
- 600 A (15, 25, and 35 kV) Integral bushings (dead-front)
- Electrical-grade wet-process porcelain bushings (live-front)

Tank/cabinet features

- Bolted cover for tank access (45-2500 kVA)
- Welded cover with hand hole (>2500 kVA)
- Three-point latching door for security
- Removable sill for easy installation
- Lifting lugs (4)
- Stainless steel cabinet hinges and mounting studs
- Steel divider between HV and LV compartment
- 20" Deep cabinet (45-1000 kVA)
- 24" Deep cabinet (1500-7500 kVA)
- 30" Deep cabinet (34.5/19.92 kV)
- Pentahead captive bolt
- Stainless steel 1-hole ground pads (45-500 kVA)
- Stainless steel 2-hole ground pads (750-10,000 kVA)
- Parking Stands (dead-front)

Valves/plugs

- One-inch upper filling plug
- One-inch drain plug (45-500 kVA)
- One-inch combination drain valve with sampling device in low voltage compartment (750-10,000 kVA)
- Automatic pressure relief valve

Nameplate

- Laser-scribed anodized aluminum nameplate

Figure 3. Drain valve with sampler.

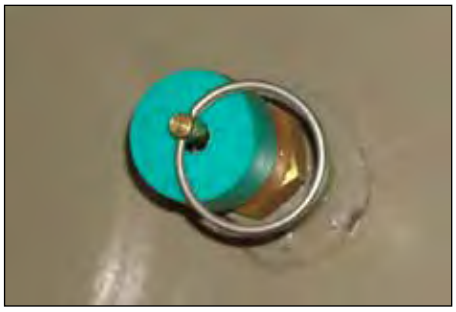


Figure 4. Automatic Pressure relief valve.

Figure 5. Liquid level gauge.

Figure 6. External Gauges.

Figure 7. External visible break with gauges.

Optional features

High and low voltage bushings

- 200 A (15, 25 kV) bushing inserts
- 200 A (15, 25 kV) feed thru inserts
- 200 A (15, 25 kV) (HTN) bushing wells with removable studs
- High-voltage 600 A (15, 25, 35 kV) deadbreak one-piece bushings
- Low voltage 6-, 8-holes spade
- Low voltage 12-, 16-, 20-holes spade (750-2500 kVA)
- Low voltage bushing supports

Tank/cabinet features

- Stainless steel tank base and cabinet
- Stainless steel tank base, cabinet sides and sill
- 100% stainless steel unit
- Service entrance (2 inch) in sill or cabinet side
- Touch-up paint (domestic)
- Copper ground bus bar
- Kirk-Key provisions
- Nitrogen blanket
- Bus duct cutout

Special designs

- Factory Mutual (FM)
- UL® Classified
- Triplex
- High altitude
- K-Factors
- Step-up
- Critical application
- Modulation transformers
- Seismic applications (including OSHPD)

Switches

- One, two, or three On/Off loadbreak switches
- 4-position loadbreak V-blade switch or T-blade switch
- Delta-wye switch
- 3-position V-Blade selector switch
- 100 A, 150 A, 300 A tap changers
- Dual voltage switch
- Visible break with VFI interrupter interlock
- External visible break (15, 25, and 35 kV, up to 3 MVA)
- External visible break with gauges (15, 25, and 35 kV, up to 3 MVA)

Gauges and devices

- Liquid level gauge (optional contacts)
- Pressure vacuum gauge (optional contacts and bleeder)
- Dial-type thermometer (optional alarm contacts)
- Cover mounted pressure relief device (optional alarm contacts)
- Ground connectors
- Hexhead captive bolt
- Molded case circuit breaker mounting provisions
- External gauges in padlockable box

Overcurrent protection

- Bay-O-Net fusing (Current sensing, dual sensing, dual element, high amperage overload)
- Bay-O-Net expulsion fuse in series with a partial range under-oil ELSP current limiting fuse (below 23 kV)
- Cartridge fusing in series with a partial range under-oil ELSP current limiting fuse (above 23 kV)
- MagneX™ interrupter with ELSP current-limiting fuse
- Vacuum Fault Interrupter (VFI)
- Visible break window
- Fuse/switch interlock

Valves/plugs

- Drain/sampling valve in high-voltage compartment
- Globe type upper fill valve

Overvoltage protection

- Distribution-, intermediate-, or station-class surge arresters
- Elbow arresters (for dead-front connections)

Metering/fan/control

- Full metering package
- Current Transformers (CTs)
- Metering Socket
- NEMA® 4 control box (optional stainless steel)
- NEMA® 7 control box (explosion proof)
- Fan Packages

Testing

- Customer test witness
- Customer final inspection
- Zero Sequence Impedance Test
- Heat Run Test
- ANSI® Impulse Test
- Audible Sound Level Test
- RIV (Corona) Test
- Dissolved Gas Analysis (DGA) Test
- 8- or 24-Hour Leak Test

Coatings (paint)

- ANSI® Bell Green
- ANSI® #61 Light Gray
- ANSI® #70 Sky Gray
- Special paint available per request

Nameplate

- Stainless steel nameplate

Decals and labels

- High voltage warning signs
- Mr. Ouch
- Bi-lingual warning
- DOE compliant
- Customer stock code
- Customer stenciling
- Shock and arc flash warning decal
- Non-PCB decal

Construction

Core

The three-legged, step-lap mitered core construction is manufactured using a high-quality cutting machine. For maximum efficiency, cores are precisely stacked, virtually eliminating gaps in the corner joints.

Five-legged wound core or shell-type triplex designs are used for wye-wye connected transformers, and other special transformer designs.

Cores are manufactured with precision cut, burr-free, grain-oriented silicon steel. Many grades of core steel are available for optimizing core loss efficiency.

Coils

Pad-mounted transformers feature a rectangular coil configuration with wire-wound, high-voltage primaries and sheet-wound secondaries. The design minimizes axial stress developed by short circuits and provides for magnetic balancing of tap connections.

Coils are wound using the highest quality winding machines providing exacting tension control and conductor placement for superior short-circuit strength and maximum efficiency.

Extra mechanical strength is provided by diamond pattern, epoxy-coated paper insulation, used throughout the coil, with additional epoxy at heavy stress points. The diamond pattern distribution of the epoxy and carefully arranged ducts, provide a network of passages through which cooling fluid can freely circulate.

Coil assemblies are heat-cured under calculated hydraulic pressure to ensure performance against short-circuit forces.

Core and coil assemblies

Pad-mounted transformer core and coil assemblies are braced with heavy steel ends to prevent the rectangular coil from distorting under short-circuit conditions. Plates are clamped in place using presses, and welded or bolted to form a solid core and coil assembly. Core and coil assemblies exceed ANSI® and IEEE® requirements for short-circuit performance. Due to the rigidity of the design, impedance shift after short-circuit is comparable to that of circular wound assemblies.

Tanks

Transformer tanks are designed for high strength and ease of handling, installation, and maintenance. Tanks are welded using precision-cut, hot rolled, pickled and oiled steel. They are sealed to protect the insulating fluid and other internal components.

Transformer tanks are pressure-tested to withstand 7 psig without permanent distortion and 15 psig without rupture.

Tank finish

An advanced multi-stage finishing process exceeds IEEE Std C57.12.28™-2014 standards. The eight-stage pre-treatment process assures coating adhesion and retards corrosion. It converts tank surfaces to a nonmetallic, water insoluble iron phosphate coating.

The paint method consists of two distinct layers of paint. The first is an epoxy primer (E-coat) layer which provides a barrier against moisture, salt and corrosives. The two-component urethane final coat seals and adds ultraviolet protection.

Vacuum processing

Transformers are dried and filled with filtered insulating fluid under vacuum, while secondary windings are energized. Coils are heated to drive out moisture, ensuring maximum penetration of fluid into the coil insulation system.

Insulating fluid

Eaton's Cooper Power series transformers are available with electrical-grade mineral insulating oil or Envirotemp™ FR3™ fluid. The highly refined fluids are tested and degassed to assure a chemically inert product with minimal acid ions. Special additives minimize oxygen absorption and inhibit oxidation. To ensure high dielectric strength, the fluid is re-tested for dryness and dielectric strength, refiltered, heated, dried, and stored under vacuum before being added to the completed transformer.

Eaton's Cooper Power series transformers filled with Envirotemp™ FR3™ fluid enjoy unique fire safety, environmental, electrical, and chemical advantages, including insulation life extending properties.

A bio-based, sustainable, natural ester dielectric coolant, Envirotemp™ FR3™ fluid quickly and thoroughly biodegrades in the environment and is non-toxic per acute aquatic and oral toxicity tests.

Building for Environmental and Economic Sustainability (BEES) total life cycle assessment software, utilized by the US Dept. of Commerce, reports its overall environmental performance impact score at 1/4th that reported for mineral oil. Envirotemp™ FR3™ fluid has also earned the EPA Environmental Technology Verification of transformer materials.

With a fire point of 360 °C, Envirotemp™ FR3™ fluid is FM Approved® and Underwriters Laboratories (UL®) Classified "Less-Flammable" per NEC® Article 450-23, fitting the definition of a Listed Product per NEC®.

Figure 8. VFI transformer with visible break.

Pad-mounted VFI transformer

Eaton's Cooper Power series VFI transformer combines a conventional distribution transformer with the proven Vacuum Fault Interrupter (VFI). This combination provides both voltage transformation and transformer over current protection in one space saving and money saving package. The pad-mounted VFI transformer protects the transformer and provides proper coordination with upstream protective devices. When a transformer fault or overload condition occurs, the VFI breaker trips and isolates the transformer.

The three-phase VFI breaker has independent single-phase initiation, but is three-phase mechanically gang-tripped. A trip signal on any phase will open all three phases. This feature eliminates single-phasing of three phase loads. It also enables the VFI breaker to be used as a three-phase load break switch.

Due to the resettable characteristics of the VFI breaker, restoring three-phase service is faster and easier.

The sealed visible break window and switch is an option that can be installed to provide visible break contact. This feature provides enhanced safety and allows an operator to see if the loadbreak switch contacts are in an open or closed position before performing maintenance.

Envirotran™ FM Approved special protection transformer

Eaton's Cooper Power series Envirotran™ transformer is FM Approved and suitable for indoor locations. Factory Mutual Research Corporation's (FMRC) approval of the Envirotran transformer line makes it easy to comply with and verify compliance with Section 450.23, 2008 NEC, Less-Flammable Liquid-Filled Transformer Requirements for both indoor and outdoor locations.

Envirotran FM Approved transformers offer the user the benefit of a transformer that can be easily specified to comply with NEC, and makes FM Safety Data Sheet compliance simpler, while also providing maximum safety and flexibility for both indoor and outdoor installations.

Because the "FM Approved" logo is readily visible on the transformer and its nameplate, NEC compliance is now easily verifiable by the inspector.

Envirotran FM Approved transformers are manufactured under strict compliance with FMRC Standard 3990 and are filled with FM Approved Envirotemp™ FR3™ fluid, a fire-resistant dielectric coolant.

FM
APPROVED

Special application transformers

Data Center transformer

With focus rapidly shifting from simply maximizing uptime and supporting demand to improving energy utilization, the data center industry is continually looking for methods to increase its energy efficiency and reliability. Utilizing cutting edge technology, Eaton's Cooper Power series Hardened Data Center (HDC) transformers are the solution. Designed with special attention given to surge protection, HDC liquid-filled transformers provide superior performance under the harshest electrical environments. Contrary to traditional dry-type units, HDC transformers provide unsurpassed reliability, overloadability, operational life, efficiency, thermal loading and installed footprint. These units have reliably served more than 100 MW of critical data center capacity for a total of more than 6,000,000 hours without any reported downtime caused by a thermal or short-circuit coil failure.

The top priority in data center operations is uninterrupted service. Envirotran HDC transformers from Eaton, having substantially higher levels of insulation, are less susceptible to voltage surges. Eaton has experienced zero failures due to switching transients. The ANSI® and IEEE® standard impulse withstand ratings are higher for liquid-filled transformers, making them less susceptible to insulation failure. The Envirotran HDC transformer provides ultimate protection by increasing the BIL rating one level higher than standard liquid-filled transformer ratings. The cooling system of liquid-filled transformers provides better protection from severe overloads—overloads that can lead to significant loss of life or failure.

Data center design typically includes multiple layers of redundancy, ensuring maximum uptime for the critical IT load. When best in class transformer manufacturing lead times are typically weeks, not days, an unexpected transformer failure will adversely affect the facility's reliability and profitability. Therefore, the ability to determine the electrical and mechanical health of a transformer can reduce the probability of costly, unplanned downtime. Routine diagnostic tests, including key fluid properties and dissolved gas analysis (DGA), can help determine the health of a liquid-filled transformer. Although sampling is not required for safe operation, it will provide the user with valuable information, leading to scheduled repair or replacement, and minimizing the duration and expense of an outage. With a dry-type transformer, there is no reliable way to measure the health or likelihood of an impending failure.

Solar transformer

As a result of the increasing number of states that are adopting aggressive Renewable & Alternative Energy Portfolio Standards, the solar energy market is growing—nearly doubling year over year. Eaton, a key innovator and supplier in this expanding market, is proud to offer its Cooper Power series Envirotran transformers specifically designed for Solar Photovoltaic medium-voltage applications. Eaton is working with top solar photovoltaic developers, integrators and inverter manufacturers to evolve the industry and change the way we distribute power.

In accordance with this progressive stance, every Envirotran Solar transformer is filled with non-toxic, biodegradable Envirotemp™ FR3™ dielectric fluid, made from renewable seed oils. On top of its biodegradability, Envirotemp™ FR3™ fluid substantially extends the life of the transformer insulation, saving valuable resources. What better way to distribute green power than to use a green transformer. In fact, delaying conversion to Envirotran transformers places the burden of today's environmental issues onto tomorrow's generations. Eaton can help you create a customized transformer, based on site specific characteristics including: temperature profile, site altitude, solar profile and required system life. Some of the benefits gained from this custom rating include:

- Reduction in core losses
- Improved payback on investment
- Reduction in footprint
- Improved fire safety
- Reduced environmental impact

For the solar photovoltaic industry, Eaton is offering standard step up transformers and dual secondary designs, including 4-winding, 3-winding (Low-High-Low) and 3-winding (Low-Low-High) designs.

Wind transformer

Eaton is offering custom designs for renewable energy power generation. Eaton manufactures its Cooper Power series Generator Step-Up (GSU) transformers for installation at the base of every wind turbine. Additionally, grounding transformers are available for wind power generation.

DOE efficiency

The United States Department of Energy (DOE) has mandated efficiency values for most liquid type, medium voltage transformers. As a result, all applicable Eaton's Cooper Power series transformers 2500 kVA and below conform to efficiency levels as specified in the DOE ruling "10 CFR Part 431 Energy Conservation Program".

Underwriters Laboratories® (UL®) Listed and Labeled/ Classified

The Envirotran transformer from Eaton can be specified as UL® Listed & Labeled, and/or UL® Classified. Underwriters Laboratories (UL®) listing is a verification of the design and construction of the transformer to the ANSI® and IEEE® standards. UL® listing generally is the most efficient, cost-effective solution for complying with relevant state and local electrical codes. UL® Combination Classification/Listing is another way in which to comply with Section 450.23, 2008 NEC® requirements. This combines the UL® listed transformer with a UL® Classified Less-Flammable Liquid and complies with the use restrictions found within the liquid Classification.

c UL US
LISTED

K-Factor transformer

With a drastic increase in the use of ferromagnetic devices, arcing devices, and electric power converters, higher frequency loads have increased significantly. This harmonic loading has the potential to generate higher heat levels within a transformer's windings and leads by as much as 300%. Harmonic loading has the potential to induce premature failure in standard-design distribution transformers.

In addition to standard UL® "K-Factor" ratings, transformers can be designed to customer-provided specifications detailing precise loading scenarios. Onsite measurements of magnitude and frequency, alongside harmonic analysis of the connected load can be performed by Eaton engineers or a third party consultant. These field measurements are used to determine exact customer needs and outline the transformer specifications.

Eaton will design harmonic-resistant transformers that will be subjected to the unique harmonic loads. These units are designed to maintain normal temperature rise under harmonic, full-load conditions. Standard UL® "K-Factor" designs can result in unnecessary costs when the "next-highest" K-Factor must be selected for a calculated design factor. To save the customer these unnecessary costs, Eaton can design the transformer to the specific harmonic spectrum used in the application. Eaton's Cooper Power series K-factor transformers are filled with mineral oil or Envirotemp™ FR3™ fluid and enjoy the added benefits of dielectric cooling such as higher efficiencies than dry-type transformers.

Modulation transformer

Bundled with an Outboard Modulation Unit (OMU) and a Control and Receiving Unit (CRU), a Modulation Transformer Unit (MTU) is designed to remotely achieve two way communication.

The use of an MTU reduces travel time and expense versus traditional meter reading performed by high voltage electricians. Additionally, with MTU it is possible to manage and evaluate energy consumption data, providing reduced metering costs and fewer tenant complaints.

An MTU utilizes existing utility infrastructure, therefore eliminating the need to engineer and construct a dedicated communication network.

Figure 9. Modular transformer.

Inverter/rectifier bridge

Eaton complements its range of applications for transformers by offering dual winding designs. These designs are intended for connection to 12-pulse rectifier bridges.

Product attributes

To set us apart from other transformer manufactures, Eaton includes the following guarantees with every three-phase pad-mounted transformer.

Engineered to order (ETO)

Providing the customer with a well developed, cost-effective solution is the number one priority at Eaton. Using customer specifications, Eaton will work with the customer from the beginning to the end to develop a solution to fit their needs. Whether it is application specific, site specific, or a uniquely specified unit, Eaton will provide transformers with the best in class value and performance, saving the customer time and money.

Made in the U.S.A.

Eaton's three-phase pad-mounted transformers are produced right here in the United States of America. Our manufacturing facilities are positioned strategically for rapid shipment of products. Furthermore, should the need arise, Eaton has a broad network of authorized service repair shops throughout the United States.

Superior paint performance

Protecting transformers from nature's elements worldwide, Eaton's E-coat system provides unrivaled transformer paint life, and exceeds IEEE Std C57.12.28™-2014 and IEEE Std C57.12.29™-2005 standards. In addition to the outside of the unit, each transformer receives a gray E-coat covering in the interior of the tank and cabinet, providing superior rust resistance and greater visibility during service.

If the wide range of standard paint selections does not suit the customer's needs, Eaton will customize the paint color to meet their requirements.

Rectangular coil design

Eaton utilizes a rectangular coil design. This winding technique results in a smaller overall unit footprint as well as reducing the transformer weight. The smaller unit size does not hinder the transformer performance in the least. Units have proven short circuit withstand capabilities up to 10 MVA.

Testing

Eaton performs routing testing on each transformer manufactured including the following tests:

- Insulation Power Factor: This test verifies that vacuum processing has thoroughly dried the insulation system to required limits.
- Ratio, Polarity, and Phase Relation: Assures correct winding ratios and tap voltages; checks insulation of HV and LV circuits. Checks entire insulation system to verify all live-to-ground clearances.
- Resistance: This test verifies the integrity of internal high-voltage and low-voltage connections; provides data for loss upgrade calculations.
- Routine Impulse Tests: The most severe test, simulating a lightning surge. Applies one reduced wave and one full wave to verify the BIL rating.
- Applied Potential: Applied to both high-voltage and low-voltage windings, this test stresses the entire insulation system to verify all live-to-ground clearances.
- Induced Potential: 3.46 times normal plus 1000 volts for reduced neutral designs.
- Loss Test: These design verification tests are conducted to assure that guaranteed loss values are met and that test values are

within design tolerances. Tests include no-load loss and excitation current along with impedance voltage and load loss.

- Leak Test: Pressurizing the tank to 7 psig assures a complete seal, with no weld or gasket leaks, to eliminate the possibility of moisture infiltration or fluid oxidation.

Design performance tests

The design performance tests include the following:

- Temperature Rise: Our automated heat run facility ensures that any design changes meet ANSI® and IEEE® temperature rise criteria.
- Audible Sound Level: Ensures compliance with NEMA® requirements.
- Lightning Impulse: To assure superior dielectric performance, this test consists of one reduced wave, two chopped waves and one full wave in sequence, precisely simulating the harshest conditions.

Thomas A Edison Research and Test Facility

We are constantly striving to introduce new innovations to the transformer industry, bringing you the highest quality transformer for the lowest cost. Eaton's Cooper Power series Transformer Products are ISO 9001 compliant, emphasizing process improvement in all phases of design, manufacture, and testing. We have invested millions of dollars in the Thomas A. Edison Technical Center, our premier research facility in Franksville, Wisconsin affirming our dedication to introducing new innovations and technologies to the transformer industry. This research facility is fully available for use by our customers to utilize our advanced electrical and chemical testing labs.

Three-phase pad-mounted compartmental type transformer

Eaton
1000 Eaton Boulevard
Cleveland, OH 44122
United States
Eaton.com

Eaton's Cooper Power Systems Division
2300 Badger Drive
Waukesha, WI 53188
United States
Eaton.com/cooperpowerseries

Printed in USA
Publication No. CA202003EN

For Eaton's Cooper Power series three-phase transformer product information call 1-877-277-4636 or visit: www.eaton.com/cooperpowerseries.

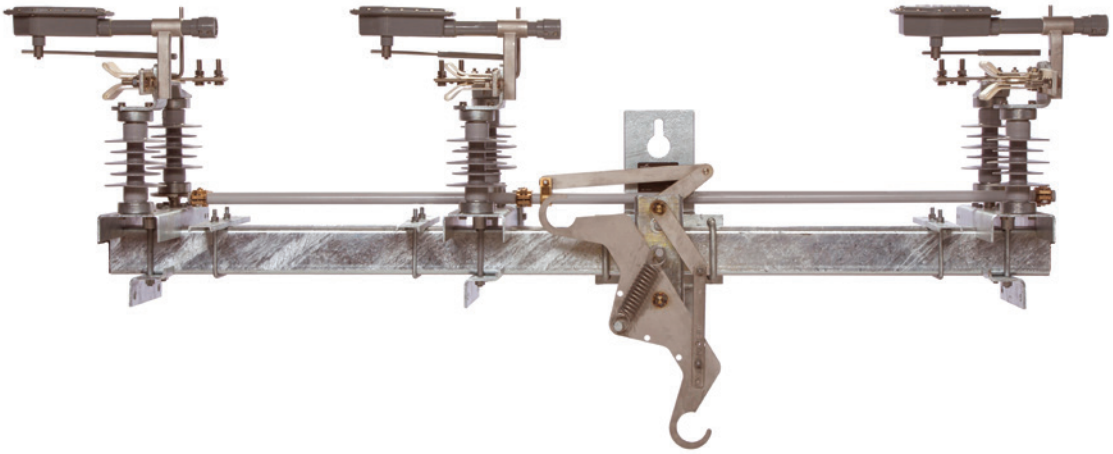
Powering Business Worldwide

Switches and Disconnects
CA008004EN

Effective March 2020
Supersedes January 2016

COOPER POWER SERIES

M-Force™ three-phase switch



Description

Eaton's Cooper Power™ series M-Force™ switch is a distribution-class, gang-operated, factory unitized three-phase overhead loadbreak switch. The M-Force switch is offered in distribution voltage classifications of 15.5 kV, 27 kV, and 38 kV. The M-Force switch may be used for line sectionalizing, paralleling, by-passing, or isolating.

M-Force stands for "Magnetic Force". Eaton has the only reverse loop contacts found on distribution-class sidebreak switches; a contact usually reserved for higher priced transmission switches. The reverse loop contacts utilize high current magnetic forces for added reliability. The reverse loop design allows for high contact pressure to be maintained during fault conditions. This feature prevents pitting and distorting of the switch blade and contacts even under severe momentary overload.

Powering Business Worldwide

Basic concept

Current-carrying conductors that are parallel to each other and have current flowing in the same direction, attract each other due to the magnetic forces acting on them (See Figure 1A).

Current-carrying conductors that are parallel to each other and have current flowing in the opposite direction, repel due to the magnetic forces acting on them (See Figure 1B).

Current flows through the two parallel inner segments of the reverse loop contacts in the same direction, thus these two segments attract each other, initiating contact pressure. Current flow through the inner segment and the outer segment is in opposite directions, which causes a repelling force that amplifies the contact pressure.

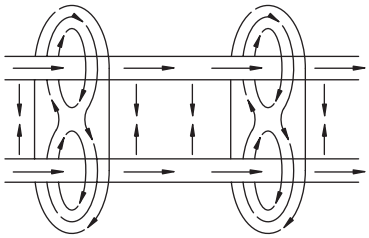


Figure 1A. Current flowing in same direction.

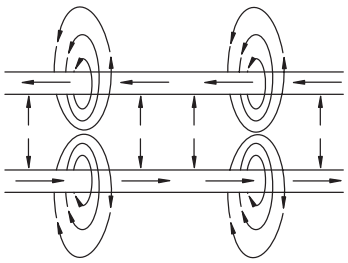


Figure 1B. Current flowing in opposite direction.

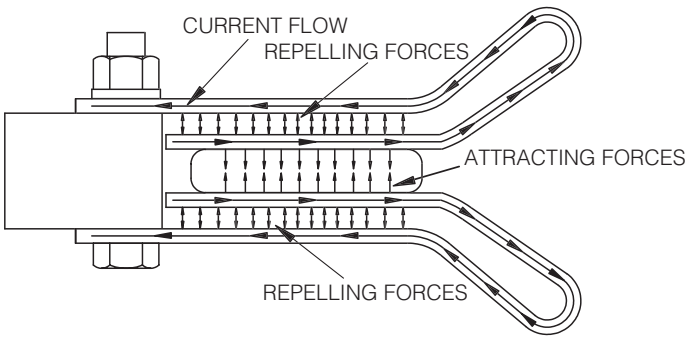


Figure 2. Magnetic forces acting on contacts.

Design features

Reverse loop contacts

The reverse loop contacts utilize high current magnetic forces for added reliability. The reverse loop contacts were adapted from Eaton's Cooper Power series KPF Line Tension Switch and have been field-proven for over 80 years. The reverse loop design allows for high contact pressure to be maintained during fault conditions. This feature prevents pitting and distorting of the switch blade and contacts even under severe momentary overload. These contacts originally designed for high voltage transmission switches also maintain extremely cool temperatures even under the rated full load. The max temperature rise allowed per IEEE Std 1247™-2005 standard for the blade and contact area is 65 °C. The max temperature rise observed on the reverse loop contact area was 38 °C, less than half of the allowed temperature. These types of test results, along with the proven field performance, undoubtedly make the Reverse Loop Contacts found in the M-Force switch the premiere choice in the industry.

Insulators

The M-Force switch comes standard with polymer (silicone rubber) insulators. These non-porcelain insulators offer exceptional dielectric and mechanical characteristics adding to the reliability of the M-Force switch, while lowering the weight. The M-Force switch can be provided in cycloaliphatic epoxy and porcelain housings. Insulators come standard with 2.25" bolt circles at 15 and 25 kV. Insulators require a 3.00" bolt circle at 35 kV.

Extended bearing assembly

The stainless steel shaft on the rotating insulator bearing assembly has been extended to four inches. This extra length will prevent horizontal movement of the rotating insulator during operation which ensures proper blade/contact alignment which is essential for smooth operation. Another feature of the bearing assembly is the oil-impregnated bushings that provide maintenance-free operation for the life of the switch.

Insulated Reliabreak™ arm

The Reliabreak™ Pick-up Arm on the M-Force switch is insulated on one side, which isolates the interrupter from the current path during a close operation. This feature allows for a wide range of adjustments between the Reliabreak arm and the blade catch finger. This increased tolerance removes the possibility of misalignment during operation which ensures proper load interruption.

Positive locking dead-end brackets

The dead-end brackets on the M-Force switch are of a positive locking design. This design allows for dead-ending at an angle without any distortion of the brackets. This allows for a more flexible switch that can be used in a wider variety of installation requirements.

New inter-phase clamps

The inter-phase control rod clamps on the M-Force switch are designed with a jam nut through the side of the casting which locks the clamps after factory alignment. This feature eliminates any possibility of accidental slippage of the control mechanism which ensures proper operation even under icy conditions.

Optional ice shields

The standard M-Force switch is capable of operating under a 3/8" ice build up. With the optional ice shields the M-Force switch is capable of opening and closing with a 3/4" ice build up.

The unique shields are designed to prevent ice from building up between the contact clips as well as removing the ice from the blade during the closing operation. Per IEEE Std C37.34™-1994, a chopping action is allowed during the close operation to break the ice. Due to the shearing action of the M-Force Ice Shields, the closing operation can be accomplished with one motion. No chopping is needed.

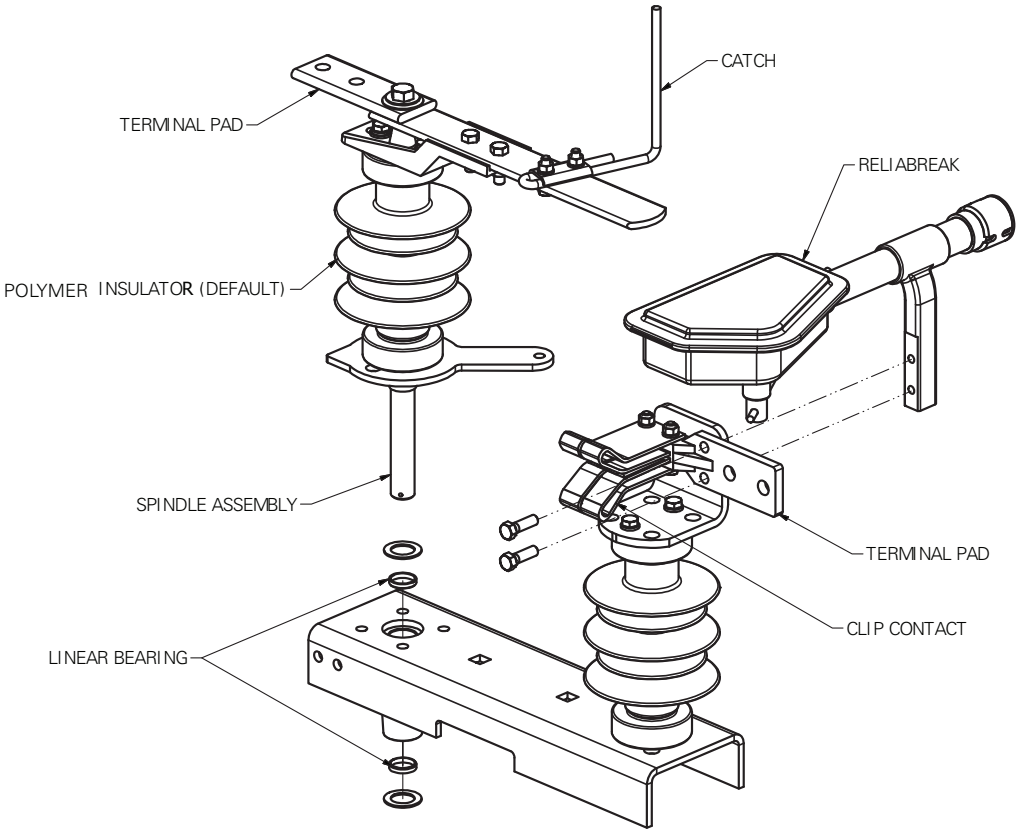


Figure 3. Illustration of M-Force switch.

M-Force switch dimensional data

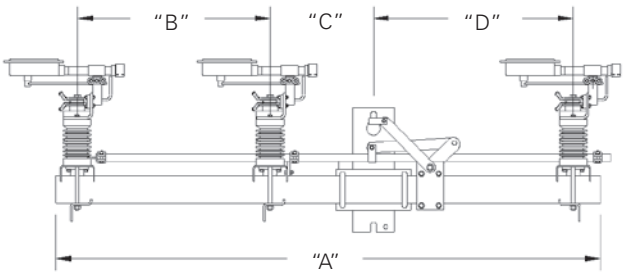


Figure 4. Horizontal switch configuration.

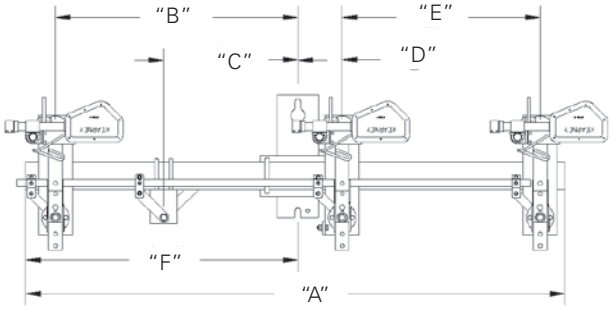


Figure 6. Vertical switch configuration.

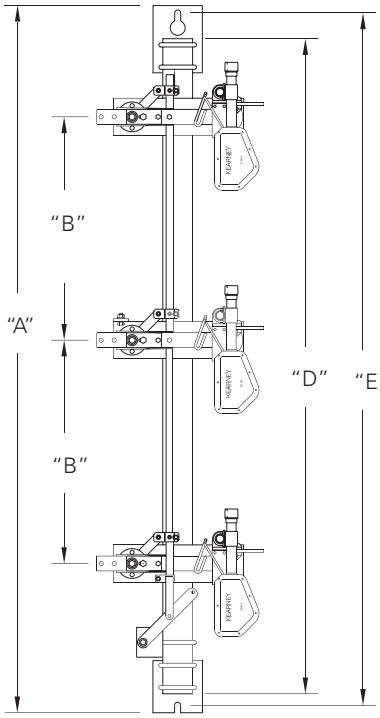


Figure 5. Phase-over-phase switch configuration.

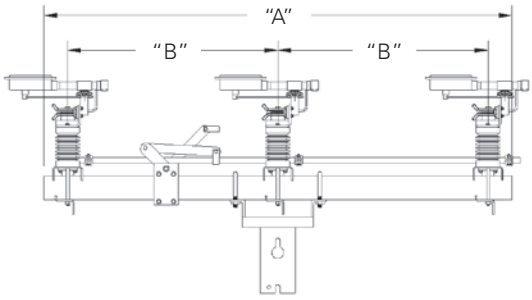


Figure 7. Horizontal Pole top switch configuration.

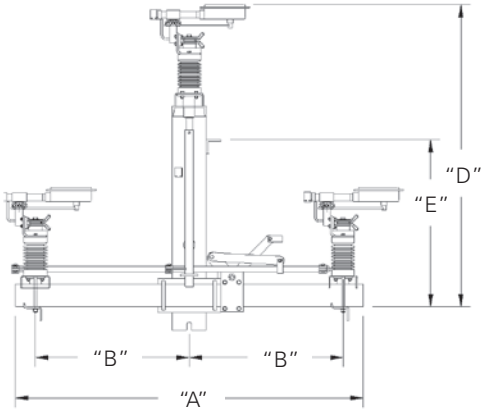


Figure 8. Triangular switch configuration.

Table 1. Dimensional Information

	Horizontal						Vertical (Riser)						Phase-over-Phase			Triangular		
	Standard			G095			Standard			G095								
Dim.	15.5 kV	27 kV	38 kV	15.5 kV	27 kV	38 kV	15.5 kV	27 kV	38 kV	15.5 kV	27 kV	38 kV	15.5 kV	27 kV	38 kV	15.5 kV	27 kV	38 kV
A	79"	88"	119"	97"	108"	126"	79"	88"	97"	108"	119"	126"	95"	104"	126"	61"	73"	79"
B	28"	33"	42"	28"	33"	42"	35.5"	40"	45"	49.5"	56"	54.5"	30"	34.5"	45.5"	27"	33"	36"
C	15"	15"	18"	24"	24"	24"	19.5"	19.5"	19.5"	19.5"	19.5"	19.5"	N/A	N/A	N/A	N/A	N/A	N/A
D	29"	33"	52"	38"	43.5"	52.5"	6.5"	6.5"	6.5"	22"	22.5"	22.5"	88"	97"	119"	58"	61"	73"
E	N/A	N/A	N/A	N/A	N/A	N/A	29"	33.5"	45"	29"	33.5"	42"	93"	102"	124"	34"	34"	42"
F	N/A	N/A	N/A	N/A	N/A	N/A	39.5"	45"	48.5"	53.5"	59.5"	58"	N/A	N/A	N/A	N/A	N/A	N/A

Horizontal Pole Top			
Standard			
Dim.	15.5 kV	27 kV	38 kV
A	79"	79"	97"
B	36"	36"	45"

Phase unit dimensions

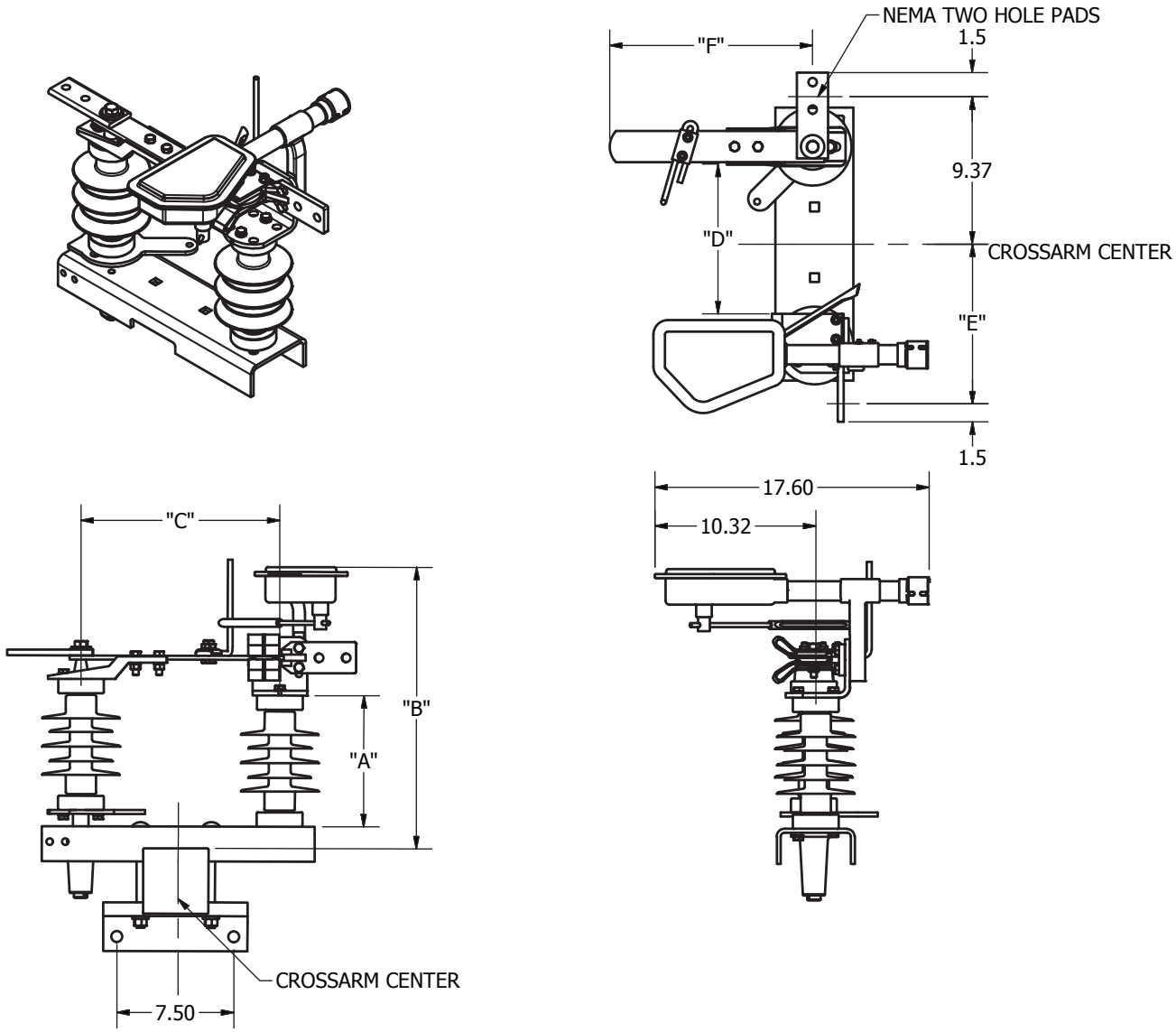


Figure 9. Phase unit breakdown.

Table 2. Phase Unit Dimensions

	Voltage Class	15.5 kV	27 kV	38 kV
Dim.	Insulator Material	2.25" Bolt Circle	2.25" Bolt Circle	3.00" Bolt Circle
A	Polymer	8.4"	10.8"	18.0"
	Epoxy	7.0"	10.0"	14.0"
	Porcelain	8.0"	10.0"	18.0"
B	B = A + 10.00"			
C		12. 8"	15.4"	20.0"
D		9.5"	12.1"	16.7"
E		10.0"	12.6"	17.3"
F		13.0"	15.6"	20.3"

Technical specifications

Table 3. Insulator Creep Distances

	2.25" Bolt Circle Insulators		3.00" Bolt Circle Insulators
	15.5 kV	27 kV	38 kV
Polymer Insulators	20.2"	28.0"	37.00"
Epoxy Insulators	18.3"	22.70"	37.69"
Porcelain Insulators	14.0"	17.38"	37.00"

Table 4. Electrical Characteristics

	Max	BIL	Cont. Current	Loadbreak	Momentary*	3 Second	Fault Close (ASM)
14.4 kV	15.5 kV	110 kV	900 A	50 @ 600 A/10 @ 900 A	40 kA Asy. rms	25 kA Sym. rms	1 @ 20 kA, 3 @ 15 kA
25 kV	27 kV	150 kV	900 A	50 @ 600 A/10 @ 900 A	40 kA Asy. rms	25 kA Sym. rms	1 @ 20 kA, 3 @ 15 kA
34.5 kV	38 kV	200 kV	900 A	10 @ 900 A	40 kA Asy. rms	25 kA Sym. rms	1 @ 20 kA, 3 @ 15 kA

* Momentary peak current is 65 kA.

Contacts

- The stationary contact is constructed of silver-plated hard drawn copper in a reverse loop configuration
- The reverse loop design ensures that pressure is applied to the blade when subjected to high fault currents

Blade

- The blade is constructed of silver-plated hard drawn copper of solid blade buss design
- The blade does not use a truss type design that requires backup springs to insure contact pressure
- The blade and contact design are self-wiping and capable of 20,000 mechanical operations without detrimental wear

Reliabreak interrupter

- The internal mechanism of the interrupter is manufactured from non-ferrous components ensuring long term resistance to corrosion in all environments
- The interrupter mechanism can handle 2500 successful mechanical operations
- The interrupter is capable of 10 successful 900 A interruptions or 50 successful 600 A interruptions at 15.5 kV and 27 kV
- The body of the interrupter is manufactured from UV stabilized Lexan® 103 material
- The interrupter operating arm is made of stainless steel (304) with UV stabilized Lexan® 103 insulation molded permanently onto the arm

Phase units

- All current-carrying parts are manufactured from copper
- Terminal pads are NEMA® two hole, silver or tin-plated
- The rotating insulator stack incorporates oil-impregnated bronze bearings to ensure maintenance free operation for life of the switch
- The spindle is manufactured from stainless steel and is supported by bushings spaced at four inches to eliminate rocking of the insulator and to ensure proper blade and contact alignment
- Each phase unit is secured to the crossarm with locking spacers to eliminate distortion of the phase unit base
- Dead-end brackets incorporate locking tabs that will eliminate movement under side forces present when conductor is dead-ended at an angle
- The switch is capable of opening or closing under a 3/8" ice layer without ice shields. The switch shall be capable of opening or closing under a 3/4" ice layer with ice shields.
- Insulator bolt pattern comes standard as 2.25" for 15 kV and 25 kV and 3.00" for 35 kV.

Table 5. Shipping Weights and Dimensions (2.25" Bolt Circle Polymer Insulators Standard, 3.00" on 35 kV)

	Voltage Class	15.5 kV		27 kV		38 kV	
	Crossarm	Steel	Fiberglass	Steel	Fiberglass	Steel	Fiberglass
Horizontal Upright	Crate L" x W" x H"	94" x 27" x 34"	94" x 27" x 34"	104" x 30" x 38"	104" x 30" x 38"	134" x 37" x 41"	134" x 37" x 41"
	Weight	381 lbs.	347 lbs.	414 lbs.	380 lbs.	478 lbs.	444 lbs.
Horizontal Pole Top	Crate L" x W" x H"	94" x 27" x 34"	94" x 27" x 34"	94" x 27" x 34"	94" x 27" x 34"	134" x 37" x 41"	134" x 37" x 41"
	Weight	377 lbs.	343 lbs.	410 lbs.	376 lbs.	474 lbs.	440 lbs.
Phase over Phase	Crate L" x W" x H"	100" x 27" x 34"	100" x 27" x 34"	110" x 30" x 38"	110" x 30" x 38"	140" x 37" x 41"	140" x 37" x 41"
	Weight	462 lbs.	428 lbs.	495 lbs.	461 lbs.	559 lbs.	525 lbs.
Vertical Riser	Crate L" x W" x H"	94" x 27" x 34"	94" x 27" x 34"	104" x 30" x 38"	104" x 30" x 38"	134" x 37" x 41"	134" x 37" x 41"
	Weight	402 lbs.	368 lbs.	435 lbs.	401 lbs.	499 lbs.	465 lbs.
Triangular	Crate L" x W" x H"	93" x 27" x 73"	94" x 27" x 73"	93" x 30" x 73"	93" x 30" x 73"	199" x 37" x 85"	99" x 37" x 85"
	Weight	471 lbs.	437 lbs.	504 lbs.	470 lbs.	568 lbs.	534 lbs.

Note: G095 spacing and special switch options will cause slight variations.

Table 6. Weight Adders

	15.5 kV		27 kV		38 kV
	2.25" B.C.	3.00" B.C.	2.25" B.C.	3.00" B.C.	3.00" B.C.
Polymer Insulators	–	14 lbs.	–	3 lbs.	–
Epoxy Insulators	9 lbs.	41 lbs.	14 lbs.	54 lbs.	57 lbs.
Porcelain Insulators	54 lbs.	114 lbs.	57 lbs	164 lbs.	199 lbs.

Table 7. M-Force Three-Phase Switch Catalog Number Configuration

M 1 H 11 T R 2 ?

Voltage Class
1 - 15.5 kV/110 kV BIL
2 - 27 kV/150 kV BIL
3 - 38 kV/200 kV BIL

Mounting Configuration
H - Horizontal Upright (Standard Option)
A - Horizontal Pole Top
P - Phase over Phase
R - Vertical Riser
G - Horizontal Upright (G095 Spacing)
S - Vertical Riser (GO95 Spacing)
T - Triangular
U - Underhung (GO95 Spacing)

Control Rod and Mechanism
Reciprocating Mechanism
11 - 28' Round Pipe 1.0" O.D. (Standard Option)
21 - 28' Round Fiberglass
41 - 28' 1" Pipe w/Fiberglass Top Section
51 - 28' Pipe w/Cycloaliphatic Insulator

Torsional Mechanism
A2 - 28' 1.5" Pipe (Steel Universal Section)
B2 - 28' 1.5" Pipe (Fiberglass Universal Section)
C2 - 28' 1.5" Pipe (Cycloaliphatic Insulator)

None
03- Hookstick operated (no control rod)

Crossarm Options
T - Steel with Single Point Lift (Standard Option)
S - Steel with Two Point Lift
G - Fiberglass with Single Point Lift
F - Fiberglass with Two Point Lift

Insulator Material
R - Polymer (Standard Option)
C - Cycloaliphatic Epoxy
P - Porcelain

Options (See Page 9 for details)
Note: More than one may be chosen.
Append codes in alphanumeric order.
B - Provisions for Crossarm Support Bracket
C - Captive Hardware on Terminal Pads (Incompatible with Option U below)
E - Extension Links (14")
F - Bonded Reciprocating Control Handle (Standard on Torsional Controls)
G - Reciprocating Handle with Interlocks
H - Lightning Arrester Brackets
I - Steel Interphase Rod
J - Provisions for Neutral Wire
K - Provisions for Sensors
R - Additional Nameplate on Handle
S - Ice Shields (3/4" Ice Break on Open or Close Operation)
T - Grounding Connector on Crossarm Mounting Bracket
U - Terminals, Copper, #2-500 MCM (Incompatible with Option C above)
V - Pole Mounting Band
1 - Extra 7' of Control Rod
2 - Extra 14' of Control Rod

Insulator Bolt Pattern
2 - 2.25" Bolt circle for 15 and 27 kV switches
3 - 3.00" Bolt circle for 35 kV switches

Consult factory for other bolt circle options.

Coastal M-Force Switches

Coastal M-Force switches utilize a corrosion- resistant fiberglass crossarm as a sturdy base for three robust phase units. Stainless steel components and bell crank assembly allow the switch to maintain reliable operation after exposure to salt, moisture and other environmental contaminants.

Coastal M-Force Three-Phase Switch Catalog Number Configuration

CM1 H 03 F R 2 H

CODE	VOLTAGE CLASS
1	15 kV/110 kV BIL
2	25 kV/150 kV BIL
3	35 kV/200 kV BIL

CODE	MOUNTING CONFIGURATION
H	Horizontal Upright (Standard Option)
R	Vertical Riser
P	Phase-over-Phase
G	Horizontal Upright (G095 Spacing)
S	Vertical Riser (GO95 Spacing)

CODE	OPERATING MECHANISM
03	Hookstick Bell Crank, no Rod

CODE	CROSSARM OPTIONS
F	Fiber Glass with Two Point Lift

CODE	INSULATOR MATERIAL
R	Polymer

CODE	INSULATOR BOLT PATTERN
2	15 or 25 kV
3	35 kV

CODE	OPTIONS - MORE THAN ONE MAY BE CHOSEN
C	Captive Hardware
H	Lightning Arrester Brackets
K	Provisions for Neutral Sensors
S	Ice Shield Kit
T	Ground Connector on Crossarm

Example: CM1H03SR2H – Coastal M-force, 15kV/110kV BIL, Hookstick/Bellcrank operation, Fiberglass crossarm with single point lift, silicone rubber insulator, 2.25" BC, Lightning arrester brackets

Definition of options

B–Provisions for crossarm support brackets

The "B" option supplies two adjustment mounting brackets on crossarm. This allows the customer to install support brackets/alley arms to the crossarm. The support brackets are not included.

C–Captive hardware on terminal pads

This option provides two 1-3/4" captive stainless steel studs on each NEMA® two-hole pad. These are usually used in conjunction with compression terminals. This option is incompatible with Option U.

E–Extension links

This option provides two 14" extension links on each conductor dead-end bracket, six per switch.

F–Bonded control handle

This option provides a grounding strap and connector that is attached to the manual operating handle. This is a standard feature on torsional control designs.

G–Reciprocating handles with interlocks

This option provides manual interlocks on switches and is available on switches sold in pairs only. When ordered with this option, end user information such as; utility name, contact person, address, and phone number will have to be provided prior to order input as required by the manufacturer of the interlocks.

H–Lightning arrester brackets

This option provides provisions for the mounting of six lightning arresters per switch.

I–Steel interphase rod

This provides a 1" O.D. steel interphase rod. The standard rod is UV inhibited fiberglass.

J–Provisions for neutral wire

This option provides a hole and spacing for a pin type insulator to be located on the crossarm to accommodate the neutral wire.

K–Provisions for sensors

This option provides longer phase unit bases that will accept sensors to be easily mounted if the manual switches are to be retrofitted for SCADA with a motor operator at a later date.

R–Additional nameplate on handle

This option provides a nameplate fixed to the manual control handle in addition to the nameplate mounted on the switch crossarm.

S–Ice shields

This option provides ice shields on each switch clip contact. This allows the switch to be opened or closed under a 3/4" ice build up.

T–Grounding connector

This option provides a grounding lug on the crossarm mounting bracket. This allows for the utility to ground the switch base to the pole ground.

U–Terminals

This option provides connectors on each two-hole NEMA® pad with a conductor range of #2-500 MCM. This option is incompatible with Option C.

V–Pole mounting band

This option provides the additional support of adjusting pole bands that are attached to the pole mounting bracket.

1–One additional control rod

2–Two additional control rods

Control rod options

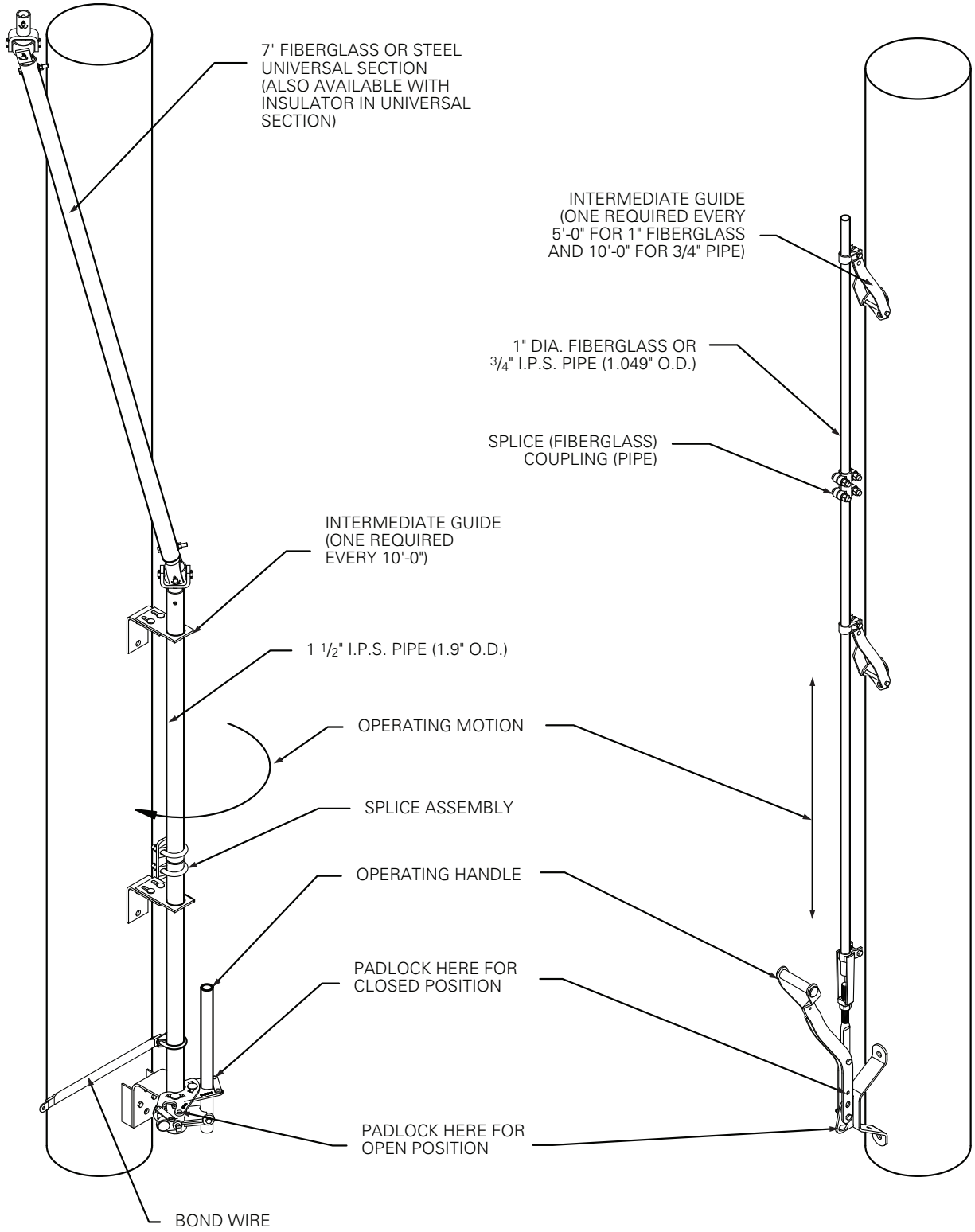


Figure 10. Torsional and Reciprocating control rod options.

Note: The standard length of control rod is 28'. Extra 7' lengths are available (see page 8 for options).

When one section of fiberglass is ordered for reciprocating control, the top section will be designated as that segment.

Eaton
1000 Eaton Boulevard
Cleveland, OH 44122
United States
Eaton.com

Eaton's Power Systems Division
2300 Badger Drive
Waukesha, WI 53188
United States
Eaton.com/cooperpowerseries

Powering Business Worldwide

Printed in USA
Publication No. CA008004EN/MCG

For Eaton's Cooper Power series product information call 1-877-277-4636 or visit: www.eaton.com/cooperpowerseries.

NX Horizon

Smart Solar Tracking System

Serving as the backbone on over 35 gigawatts of solar power plants around the world, the NX Horizon™ smart solar tracker system combines best-in-class hardware and software to help EPCs and asset owners maximize performance and minimize operational costs.

Flexible and Resilient by Design

With its self-aligning module rails and vibration-proof fasteners, NX Horizon can be easily and rapidly installed. The self-powered, decentralized architecture allows each row to be commissioned in advance of site power, and is designed to withstand high winds and other adverse weather conditions. On a recent 838 megawatt project in Villanueva, Mexico, these design features allowed for the project to go online nine months ahead of schedule.

TrueCapture and Bifacial Enabled

Incorporating the most promising innovations in utility scale solar, NX Horizon with TrueCapture™ smart control system can add additional energy production by up to six percent. Further unlocking the advantages of independent-row architecture and the data collected from thousands of sensors across its built-in wireless network, the software continuously optimizes the tracking algorithm of each row in response to site terrain and changing weather conditions. NX Horizon can also be paired with bifacial PV module technology, which can provide even more energy harvest and performance. With bifacial technology, NX Horizon outperforms conventional tracking systems with over 1% more annual energy.

Quality and Reliability from Day One

Quality and reliability are designed and tested into every NX Horizon component and system across our supply chain and manufacturing operations. Nextracker is the leader in dynamic wind analysis and safety stowing, delivering major benefits in uptime and long-term durability NX Horizon is certified to UL 2703 and UL 3703 standards, underscoring Nextracker's commitment to safety, reliability and quality.

Features and Benefits

5 years in a row

Global Market Share Leader (2015-18)

35 GW

Delivered on 5 Continents

Best-in Class

Software Ecosystem and Global Services

Up to 6%

Using TrueCapture Smart Control System

GENERAL AND MECHANICAL

Tracking type	Horizontal single-axis, independent row.
String voltage	1,500 V_{DC} or 1,000 V_{DC}
Typical row size	78-90 modules, depending on module string length.
Drive type	Non-backdriving, high accuracy slew gear.
Motor type	24 V brushless DC motor
Array height	Rotation axis elevation 1.3 to 1.8 m / 4'3" to 5'10"
Ground coverage ratio (GCR)	Configurable. Typical range 28-50%.
Modules supported	Mounting options available for virtually all utility-scale crystalline modules, First Solar Series 6 and First Solar Series 4.
Bifacial features	High-rise mounting rails, bearing + driveline gaps and round torque tube.
Tracking range of motion	Options for ±60° or ±50°
Operating temperature range	SELF POWERED: -30°C to 55°C (-22°F to 131°F) AC POWERED: -40°C to 55°C (-40°F to 131°F)
Module configuration	1 in portrait. 3 x 1,500 V or 4 x 1,000 V strings per standard tracker. Partial length trackers available.
Module attachment	Self-grounding, electric tool-actuated fasteners.
Materials	Galvanized steel
Allowable wind speed	Configurable up to 225 kph (140 mph) 3-second gust
Wind protection	Intelligent wind stowing with symmetric dampers for maximum array stability in all wind conditions
Foundations	Standard W6 section foundation posts

ELECTRONICS AND CONTROLS

Solar tracking method	Astronomical algorithm with backtracking. TrueCapture™ upgrades available for terrain adaptive backtracking and diffuse tracking mode
Control electronics	NX tracker controller with inbuilt inclinometer and backup battery
Communications	Zigbee wireless communications to all tracker rows and weather stations via network control units (NCUs)
Nighttime stow	Yes
Power supply	SELF POWERED: NX provided 30 or 60W Smart Panel AC POWERED: Customer-provided 120-240 V_{AC} circut

INSTALLATION, OPERATIONS AND SERVICE

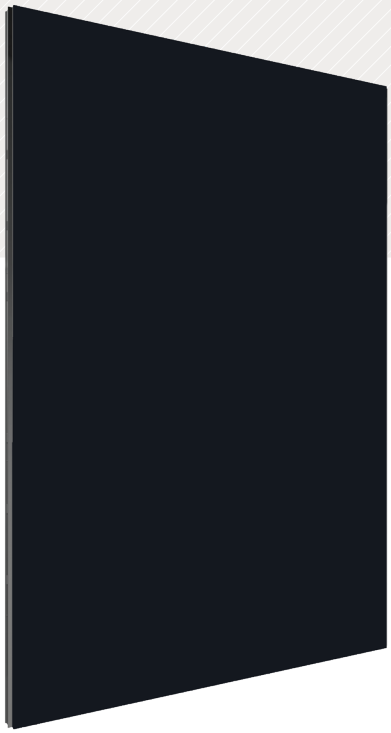
PE stamped structural calculations and drawings	Included
Onsite training and system commissioning	Included
Installation requirements	Simple assembly using swaged fasteners and bolted connections. No field cutting, drilling or welding.
Monitoring	NX Data Hub™ centralized data aggregation and monitoring
Module cleaning compatibility	Compatible with NX qualified cleaning systems
Warranty	10-year structural, 5-year drive and control components.
Codes and standards	UL 3703 / UL 2703 / IEC 62817

6200 Paseo Padre Parkway | Fremont, CA 94555 | USA | +1 510 270 2500 | nextracker.com

First Solar Series 6 CuRe

NEXT GENERATION THIN FILM SOLAR TECHNOLOGY

MODULE DATASHEET



HIGH-POWER PV MODULES

First Solar Series 6 CuRe photovoltaic (PV) modules set a new industry benchmark for lifetime energy production, optimized design and environmental performance. Series 6 CuRe modules are optimized for every stage of your application, significantly reducing balance of system, shipping, and operating costs.

440-470 Watts
Up to 19.0% Efficiency

HIGHEST LIFETIME ENERGY

- More real-world energy produced per nameplate watt: Improved temperature coefficient (-0.28%/C) from Series 6 (-0.32%/C) coupled with superior spectral response and shading behavior vs. c-Si
- Up to 10% more lifetime energy vs. the leading bifacial c-Si module, and up to 14% more than traditional c-Si modules
- Anti-reflective coated glass enhances energy production

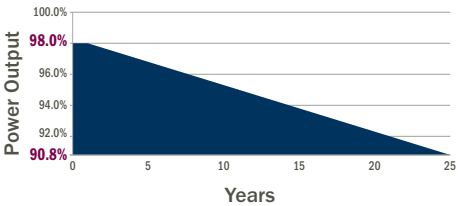
INNOVATIVE MODULE DESIGN

- Under-mount frame provides the cleaning and snow-shedding benefits of a frameless module while protecting edges against breakage
- Innovative SpeedSlots™ combine the robustness of bottom mounting with the speed of top clamping while utilizing fewer fasteners to achieve fastest installation times and lowest mounting hardware costs
- Dual junction box optimizes module-to-module connections and eliminates need for wire management

INDUSTRY'S BEST WARRANTED DEGRADATION RATE[1]

98% WARRANTY START POINT

0.3% WARRANTED ANNUAL DEGRADATION RATE



- 25-Year Linear Performance Warranty
- 10-Year Limited Product Warranty
- Industry's First and Only Hidden Cell Cracking Warranty

BEST IN-CLASS RELIABILITY & DURABILITY

- Manufactured under one roof with 100% traceable QA/QC
- Independently tested and certified for reliable performance that exceeds IEC standards in high temperature, high humidity, extreme desert and coastal applications
- Inherently immune to and warranted against hidden cell cracking power loss
- Durable glass/glass construction with market-leading hail impact certification

BEST ENVIRONMENTAL PROFILE

- Fastest energy payback time in the industry
- Produced using up to 6x less carbon and up to 24x less water than c-Si
- Global PV collection and recycling services available through First Solar or customer-selected third-party

FIRST SOLAR SERIES 6 CuRe

MODEL TYPES AND RATINGS AT STANDARD TEST CONDITIONS (1000W/m², AM 1.5, 25°C)[2]

NOMINAL VALUES		FS-6440-C FS-6440A-C	FS-6445-C FS-6445A-C	FS-6450-C FS-6450A-C	FS-6455-C FS-6455A-C	FS-6460-C FS-6460A-C	FS-6465-C FS-6465A-C	FS-6470-C FS-6470A-C
Nominal Power[3] (-0/+5%)	P_{MAX} (W)	440.0	445.0	450.0	455.0	460.0	465.0	470.0
Efficiency (%)	%	17.8	18.0	18.2	18.4	18.6	18.8	19.0
Voltage at P_{MAX}	V_{MAX} (V)	184.7	185.7	186.8	187.8	188.8	189.8	191.1
Current at P_{MAX}	I_{MAX} (A)	2.38	2.40	2.41	2.42	2.44	2.45	2.46
Open Circuit Voltage	V_{OC} (V)	220.0	220.4	221.1	222.0	222.9	223.8	224.3
Short Circuit Current	I_{SC} (A)	2.55	2.56	2.57	2.58	2.59	2.60	2.61
Maximum System Voltage	V_{SYS} (V)	1500[5]						
Limiting Reverse Current	I_R (A)	5.0						
Maximum Series Fuse	I_{CF} (A)	5.0						
RATINGS AT NOMINAL OPERATING CELL TEMPERATURE OF 45°C (800W/m², 20°C air temperature, AM 1.5, 1m/s wind speed)[2]								
Nominal Power	P_{MAX} (W)	332.4	336.0	339.9	343.6	347.3	351.3	355.0
Voltage at P_{MAX}	V_{MAX} (V)	173.1	174.1	175.2	176.2	176.3	177.4	179.3
Current at P_{MAX}	I_{MAX} (A)	1.92	1.93	1.94	1.95	1.97	1.98	1.98
Open Circuit Voltage	V_{OC} (V)	209.0	209.3	210.0	210.9	211.8	212.6	213.1
Short Circuit Current	I_{SC} (A)	2.06	2.06	2.07	2.08	2.09	2.10	2.10

TEMPERATURE CHARACTERISTICS

Module Operating Temperature Range	(°C)	-40 to +85
Temperature Coefficient of P_{MAX}	$T_K (P_{MAX})$	-0.28%/°C [Temperature Range: 25°C to 75°C]
Temperature Coefficient of V_{OC}	$T_K (V_{OC})$	-0.25%/°C
Temperature Coefficient of I_{SC}	$T_K (I_{SC})$	+0.04%/°C

MECHANICAL DESCRIPTION

Length	2009mm
Width	1232mm
Thickness	49mm
Area	2.47m²
Module Weight	34.5kg
Leadwire[6]	2.5mm², 720mm (+) & Bulkhead (-)
Connectors	MC4-EVO 2 or alternate
Bypass Diode	N/A
Cell Type	Thin film CdTe semiconductor, up to 271 cells
Frame Material	Anodized Aluminum
Front Glass	Heat strengthened
Back Glass	Heat strengthened
Encapsulation	Laminate material with edge seal
Frame to Glass Adhesive	Silicone
Load Rating[7]	2400Pa

PACKAGING INFORMATION

Modules Per Pallet	27	Pallet Dimensions (L x W x H)	2200 x 1300 x 1164mm (86 x 51 x 45.8in)
Pallet Weight	1032kg	Pallets per 40' Container	18

CERTIFICATIONS AND TESTS

IEC[4]

61215:2016 & 61730-1:2016[5], CE
61701 Salt Mist Corrosion
60068-2-68 Dust and Sand Resistance

UL[4]

UL 61730 1500V Listed[5]

REGIONAL CERTIFICATIONS[4]

MCS
InMetro
BIS
SII
FSEC
MyHijau

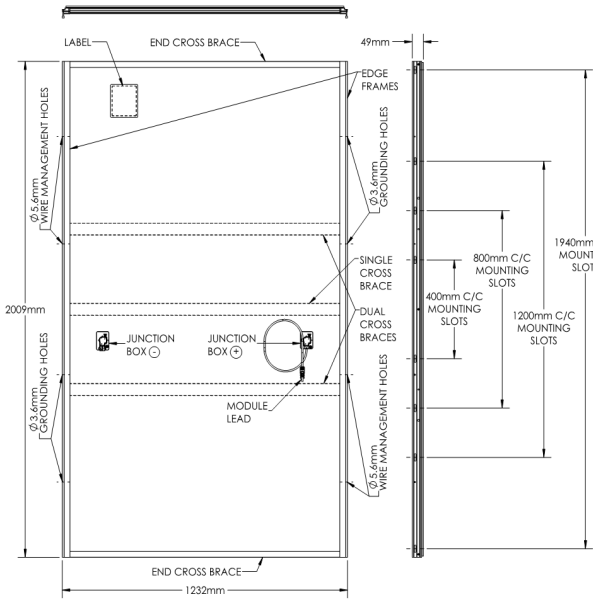
EXTENDED DURABILITY TESTS[4]

ANSI/CAN/CSA-C450-18
Long-Term Sequential Thresher Test
PID Resistant

QUALITY & EHS

ISO 9001:2015
ISO 14001:2015
ISO 45001:2018

MECHANICAL DRAWING



Install in portrait only

1 Limited power output and product warranties subject to warranty terms and conditions
2 All ratings ±10%, unless specified otherwise. Specifications are subject to change
3 Measurement uncertainty applies
4 Testing Certifications/Listings pending
5 IEC 61730-1: 2016 Class II | ULC 1703 1000V listed (CANADA)
6 Leadwire length from junction box exit to connector mating surface
7 1000Pa tentative design load rating for 1940mm mounting slots. Alternate or project-specific load ratings can be met with additional support, subject to evaluation

SUNGROW
Clean power for all

SG125HV

String Inverter for 1500 Vdc System

High Yield

- Patented five-level topology, max. efficiency 98.9 %, European efficiency 98.7 %, CEC efficiency 98.5 %
- Full power operation without derating at 50 ℃
- Patented anti-PID function optional

Easy O&M

- Virual central solution, easy for O&M
- Compact design and light weight for easy installation

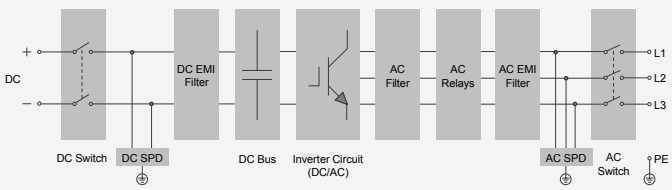
Saved Investment

- DC 1500V,AC 600V, low system initial investment
- 1 to 5MW power block design for lower AC transformer and labor cost
- Max.DC/AC ratio up to 1.5

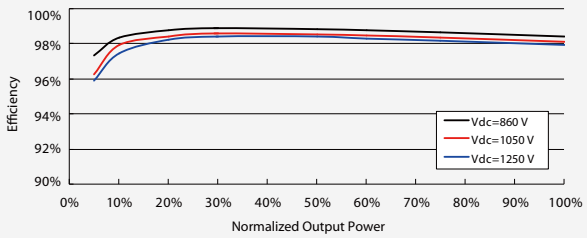
Grid Support

- Compliance with both IEC and UL safety,EMC and grid support regulations
- Low/High voltage ride through(L/HVRT)
- Active & reactive power control and power ramp rate control

Circuit Diagram



Efficiency Curve



Input (DC)	SG125HV
Max. PV input voltage	1500 V
Min. PV input voltage / Start-up input voltage	860 V / 920 V
Nominal PV input voltage	1050 V
MPP voltage range	860 – 1450 V
MPP voltage range for nominal power	860 – 1250 V
No. of independent MPP inputs	1
No. of DC inputs	1
Max. PV input current	148 A
Max. DC short-circuit current	240 A

Output (AC)	
AC output power	125000 VA @ 50 ℃
Max. AC output current	120 A
Nominal AC voltage	3 / PE, 600 V
AC voltage range	480 – 690 V
Nominal grid frequency / Grid frequency range	50 Hz / 45 – 55 Hz, 60 Hz / 55 – 65 Hz
THD	< 3 % (at nominal power)
DC current injection	< 0.5 % In
Power factor at nominal power / Ajustable power factor	> 0.99 / 0.8 leading - 0.8 lagging
Feed-in phases / connection phases	3 / 3

Efficiency	
Max. efficiency / European efficiency	98.9% / 98.7%
CEC efficiency	98.5%

Protection	
DC reverse connection protection	Yes
AC short-circuit protection	Yes
Leakage current protection	Yes
Grid monitoring	Yes
DC switch / AC switch	Yes / Yes
Night SVG function	No
Anti-PID function	Yes
Overvoltage protection	DC Type II / AC Type II

General Data	
Dimensions (W*H*D)	670*902*296 mm **26.4''*35.5''*11.7''**
Weight	76 kg **167.5 lb**
Isolation method	Transformerless
Degree of protection	IP 65 **NEMA 4X**
Night power consumption	< 4 W
Operating ambient temperature range	-25 to 60 ℃ (> 50 ℃ derating) **-13 to 140 ℉ (> 122 ℉ derating)**
Allowable relative humidity range (non-condensing)	0 – 100 %
Cooling method	Smart forced air cooling
Max. operating altitude	4000 m (> 3000 m derating) **13123 ft (> 9843 ft derating)**
Display / Communication	LED, Bluetooth+APP / RS485
DC connection type	OT or DT terminal (Max. 185 mm² **350 Kcmil**)
AC connection type	OT or DT terminal (Max. 185 mm² **350 Kcmil**)
Compliance	UL1741, UL1741SA, IEEE1547, IEEE1547.1, CSA C22.2 107.1-01-2001, FCC Part15 Sub-part B Class A Limits, California Rule 21, IEC 62109-1/-2, IEC 61000-6-2/-4, IEC 61727, IEC62116, BDEW, UNE 206007-1:2013, P.O.12.3, UTE C15-712-1:2013, CEI 0-16:2017, IEC 61683, PEA, NTCO
Grid Support	LVRT, HVRT, ZVRT, active & reactive power regulation, PF control, soft start/stop
Type designation	SG125HV-10

SUNGROW
Clean power for all

SG2500U

Turnkey Station for North America 1500 Vdc System

High Yield

- Advanced three-level technology, max. efficiency 98.8%, CEC efficiency 98.5 %
- Effective cooling, 1.1 overload capacity, no derating up to 122 ℉
- Max. DC/AC ratio more than 1.5

Easy O&M

- Integrated current and voltage monitoring function for online analysis and fast trouble shooting
- Modular design, easy for maintenance
- Convenient external LCD

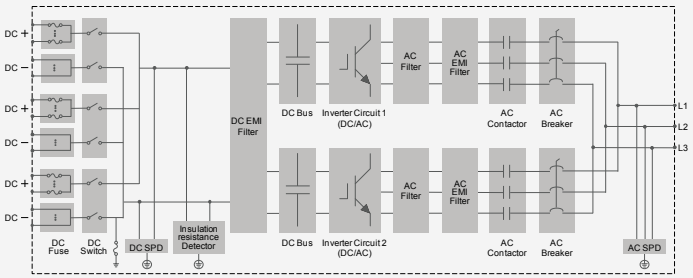
Saved Investment

- Low transportation and installation cost due to 10-foot container design
- 1500V DC system, low system cost
- Integrated LV auxiliary power supply

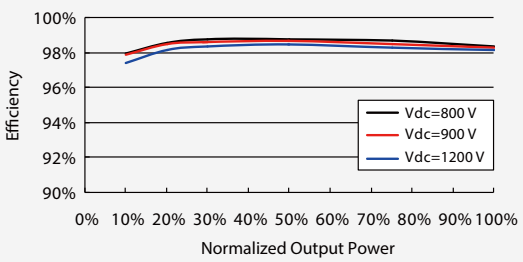
Grid Support

- Complies with UL 1741, UL 1741 SA, IEEE 1547, Rule 21 and NEC 2014/2017
- Grid support including L/HVRT, L/HFRT, power ramp rate control, active andreactive power support

Circuit Diagram



Efficiency Curve



Input (DC)	SG2500U
Max. PV input voltage	1500V
Min. PV input voltage / Startup input voltage	800 V / 840 V
MPP voltage range for nominal power	800 – 1300 V
No. of independent MPP inputs	1
No. of DC inputs	18 – 21
Max. PV input current	3508 A
Max. DC short-circuit current	4800 A
PV array configuration	Negative grounding

Output (AC)	
AC output power	2750 kVA @ 45 ℃ (113 ℉) / 2500 kVA @ 50 ℃ (122 ℉)
Max. AC output current	2886 A
Nominal AC voltage	550 V
AC voltage range	484 - 605 V
Nominal grid frequency / Grid frequency range	60 Hz / 55 – 65 Hz
THD	< 3 % (at nominal power)
DC current injection	< 0.5 % In
Power factor at nominal power / Adjustable power factor	> 0.99 / 0.8 leading – 0.8 lagging
Feed-in phases / Connection phases	3 / 3

Efficiency	
Max. efficiency / CEC efficiency	98.8 % / 98.5 %

Protection	
DC input protection	Load break switch + fuse
AC output protection	Circuit breaker
Overvoltage protection	DC Type II / AC Type II
Grid monitoring / Ground fault monitoring	Yes / Yes
Insulation monitoring	Optional
Night SVG function	Optional
Overheat protection	Yes

General Data	
Dimensions (W*H*D)	2991*2896*2438 mm **(117.8"*114.0"*96.0")**
Weight	6.9 T **(15211.9 lbs)**
Isolation method	Transformerless
Degree of protection	NEMA 3R
Auxiliary power supply	120 Vac, 5 kVA / Optional: 480 Vac, 30 kVA
Operating ambient temperature range	-30 to 60 ℃ (> 50 ℃ derating) **(-22 to 140** ℉ **(> 122** ℉ **derating))**
Allowable relative humidity range (non-condensing)	0 – 95 %
Cooling method	Temperature controlled forced air cooling
Max. operating altitude	4000 m (> 2000 m derating) **(13123 ft (> 6561 ft derating))**
Display	Touch screen
Communication	Standard: RS485, Ethernet; Optional: optical fiber
Compliance	UL 1741, IEEE 1547, UL1741 SA, NEC 2014/2017, CSA C22.2 No.107.1-01
Grid support	Night SVG function (optional), L/HVRT, L/HFRT, active & reactive power control and power ramp rate control, Volt-var, Frequency-watt

Viper®-S

Solid Dielectric, Three Phase Reclosers

Providing electronic three phase overcurrent protection for systems rated through 38kV, 800A continuous current, 12.5kA symmetrical interrupting

- Reliable performance
- Control flexibility including SEL-351 series, SEL-651R2, GE controls and more
- Operator safety with mechanical block
- Maintenance-free operation
- Overhead, substation and dead-front padmount designs
- Ease of installation
- Three internal current transformers
- Up to six internal voltage sensors
- Smart Grid/Lazer® solutions
- RUS accepted

G&W Engineered to order. Built to last.

Catalog O-vs19

Viper-S

Viper-S solid dielectric, three phase reclosers combine the time proven reliability of electronically controlled, vacuum fault interrupters with the maintenance benefits of a solid dielectric insulated device. The reclosers are designed for three phase automatic or manual trip operation providing overcurrent protection for systems rated up to 38kV maximum, 800A continuous, and 12.5kA rms symmetrical interrupting.

Features

Reliable Performance - Viper-S reclosers utilize G&W's time proven epoxy system to fully encapsulate the vacuum interrupters. This system provides excellent insulation properties while providing fully shielded, void-free construction. All modules are UV protected and 100% factory tested for partial discharge. The Viper-S recloser utilizes the latest in magnetic actuator technology. The interrupter and actuator assembly are tested annually for 10,000 mechanical operations to ensure a long service life. If main power is lost, the recloser has enough stored energy to trip once, after the control sends the trip command, within a 24 hour period.

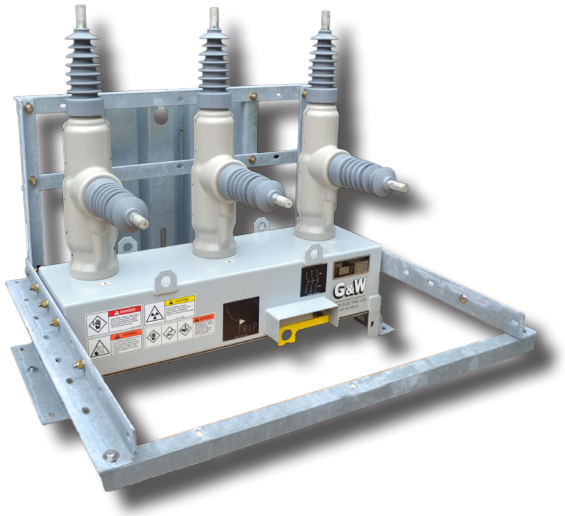
Control Flexibility - Viper-S reclosers are designed to work with a variety of different controls including SEL-351 series, SEL-651R2, GE controls and more.

Operator Safety - Vacuum interrupters are sealed within a solid dielectric insulation. A hookstick operable manual trip and lockout handle prohibits operation either from the control or remotely. A mechanical blocking device further assures against accidental close. An open and closed contact indicator verifies contact position. Contact status and lockout condition can also be verified at the control.

Maintenance-free - Solid dielectric insulation provides a maintenance-free installation. Electronic equipment associated with the operation of the magnetic actuator is located inside the Viper-S tank.

Ease of Installation - Mounting bracket with key hole and lifting provisions provide ease of installation. Site-ready designs provide all accessories including mounting bracket, arresters and voltage transformers preassembled prior to shipment significantly reducing installation time. The control cable brings all current, the handle status and trip/close information into the control.

Application Flexibility - Units are designed for overhead, substation and padmount applications. Pole mounted units can be equipped with either horizontal or vertical insulators. Removable silicone insulators are standard for overhead applications. This feature permits easy field replacement if an insulator is damaged. Higher external BIL rated insulators can also be retrofitted if necessary.



▲ 15kV Viper-S recloser with polemount center bracket and surge arrestor provisions.

Smart Grid / Lazer® Automation Solutions - The Viper-S is automation ready, simplifying conversion for any future automation requirements. A multi-ratio current transformer is encapsulated within the module. The current transformer is provided with 1000/500:1 ratios. A 400/200:1 dual ratio CT option is also available for lower current detection. Inputs to the control are field changeable.

CT accuracy is +/-1%. Capacitive voltage sensors encapsulated within each module permit voltage reading for network reconfiguration while eliminating the need for add-on sensors and cabling. When Low Energy Analog Voltage Sensors (LEA VS) are used, accuracy is +/-2% over the temperature range -20°C (-4°F) through +40°C (104°F) when tested as a system. The accuracy is +/-4% from -60°C (-76°F) through +65°C (149°F). The phase angle accuracy is +/-1° throughout the full temperature range. Two voltage ratios are available: a 10,000:1 for applications above 13.8 kV L-G and a 2,500:1 ratio below that voltage. External voltage and current sensors can also be used depending on application requirements.

Complete Lazer automation packages are available offering a pre-engineered solution for applications requiring intelligent automatic switching and power restoration. The packages feature one or more protective relays, equipped with distribution and communication capabilities. Available communication devices include fiber optic transceivers and wireless radio. The typical control paired with the Viper-S is the SEL-351R4.

Catalog Numbers

Voltage Class	Catalog Number
15.5kV	VIP378ER-12S
27kV	VIP388ER-12S
38kV	VIP398ER-12S

Approximate weight less bracket = 325 lbs. (148 kg).

Operation Options

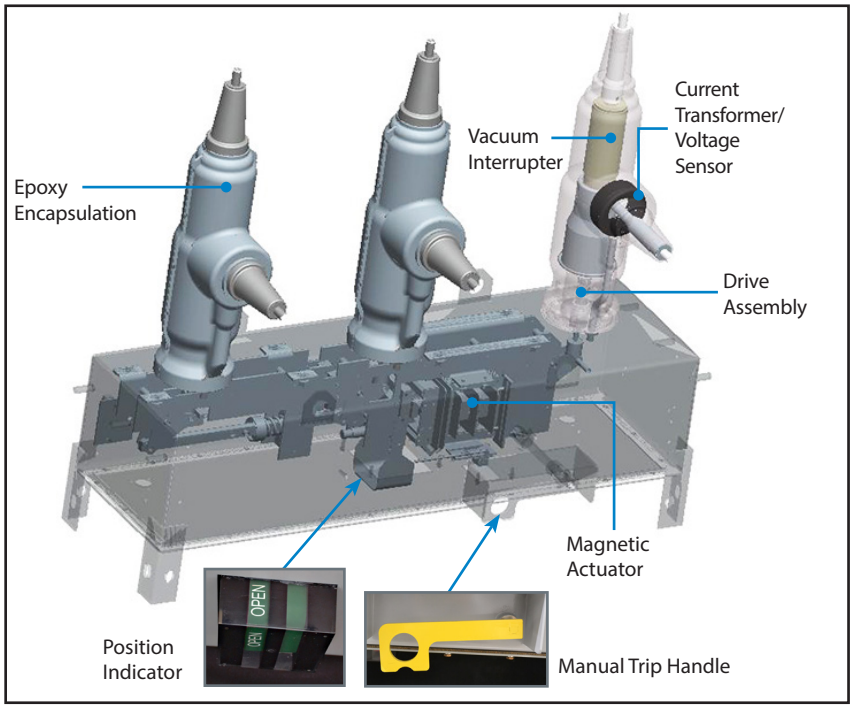
Dead-line Operation - Permits using the batteries located in the control for operation of the recloser when main control power is lost. A remote status signal reports the operational status of the interrupter power supply permitting remote indication of the control's capability to open or close the recloser.

Custom Relay Solutions (CRS) - The CRS option permits using 48VDC or 125VDC control logic voltage as an alternative to traditional 14-pin SEL, Cooper and GE controls which use 24VDC for control logic. Recloser power is not affected. This flexibility reduces installed cost for retrofit projects by limiting the need to change relays or replacing the input/output boards.

Internal Voltage Sensing - Permits voltage reading for network reconfiguration applications and provides a secondary analog 120V AC output accepted by most relays such as the SEL-351R family. Up to 3 or 6 optional internal voltage sensors are available. LEA VS can be used when the Viper-S is paired with the SEL-651R2.

Manual Trip Operation

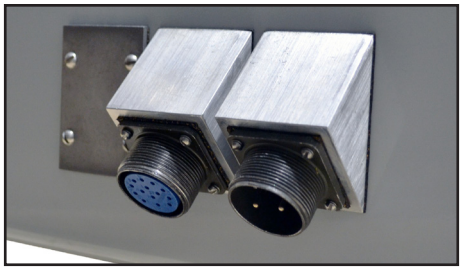
Operation of the hookstick operable manual trip handle trips and locks out the recloser. A contact position indicator is provided indicating open or closed status of the contacts. Module contact status is also displayed at the control. Operation of the manual trip handle disables any local or remote closing operation until the handle is reset. A mechanical blocking device further assures against accidental close. The handle is operable from ground level. Once reset, the recloser can be closed from the control.



◀ Isometric view of the Viper-S without insulators.

Control Connections

The traditional 14-pin recloser control connector design is the same as other Cooper reclosers permitting easy change out of previously installed controls and/or reclosers.



▲ 14-pin with 2-pin AC cable connectors.

Control Capabilities

Various style controls are available depending upon application requirements. Typical control settings include:

- Minimum trip for phase, ground and sensitive ground faults.
- Numerous pre-programmed and user-defined time current curves for sensing phase or ground faults.
- Three independent recloser interval times. Capable of up to four shots to lockout.
- Reset time.
- Sequence coordination.
- Cold load pickup.
- Advanced parameters. Refer to control specifications for more details.

▲ Schweitzer SEL-351R control

Viper-S

Control Power Viper-S

Many of today's reclosers require two to three cables between the control and the recloser to provide AC power to the recloser, control signals and commands, and in many cases, deadline operation. Now there is a cleaner, more efficient way to do the same tasks using G&W's Control Power Viper-S.

The Control Power Viper-S provides a single cable solution for all current, control, breaker status, and auxiliary power to operate the Viper-S. This package uses the power from the control to operate the Viper-S through a four-shot sequence. The power in the recloser control is backed up by batteries and provides an excellent solution for applications requiring deadline operation.

The Control Power Viper-S paired with the SEL-651R2 provides deadline operation which the 14-pin connector cannot provide. The Control Power Viper-S provides a more economical solution compared to the traditional SEL-651R2 14-pin configuration. This is accomplished by utilizing the SEL-651R2 power source to drive the Viper-S magnetic actuator and eliminate the AC/DC power supply within the Viper-S. The Control Power Viper-S has less electronics in the recloser than traditional 14-pin reclosers on the market today.

Features

The Control Power Viper-S utilizes the same magnetic actuators, with integrated trip spring, and the proven solid dielectric encapsulated dead tank modules with screw- on silicone insulators. The Viper-S has been upgraded to proficiently meet the growing demand of the SEL-651R2 recloser control for mechanically ganged applications.

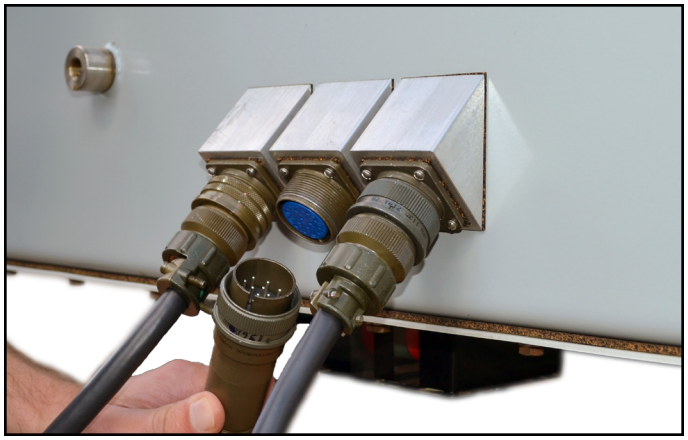
The Control Power Viper-S provides an alternative source of reclosers to use with existing recloser controls in the field.

With the addition of the 19-pin interface, the Viper-S is now compatible with many of the popular recloser controls. The chart of controls is a non-exhaustive list. Other relays can be integrated with the Viper-S using our Custom Relay Solution for 48 or 125 VDC I/O applications. Please contact your G&W representative for more details.

Viper-S Recloser Control Comparison Chart*

Manufacturer	Control	Connectors Accepted	
		14-pin	19-pin
SEL	351R/ 651RA	•	
	751-751A	•	
	651R2	•	•
Cooper	Form 6	•	•
	Form 5	•	•
	Form 4D	•	•
	Form 4C	•	•
	FXB	•	
GE	URC	•	
	R650	•	
Beckwith	M-7679	•	

*Special applications with SEL-311L; GE-845; and more. Consult factory for more information.



▲ Traditional configuration: 2-pin AC, 14-pin for control, and 8-pin 120VAC Voltage sensing connectors.

▲ Control powered solution: 8-pin quick-disconnect for LEA Voltage Sensors and 19-pin connector with integrated dead-line operation control.

▲ GE R650 recloser control with 14 pin interface

Interface Configurations

The Viper-S come with various interface configurations depending on the control used. The tables below give additional details of the connectors for each of the following configurations:

Viper-S, Traditional 14-pin, SEL-351R/651RA*		
Configuration	Type	Description
Required	14-pin, multi-turn	Control
	2-pin, multi-turn	AC (heaters, cap charging)
Optional	6-pin, multi-turn	Dead-line operation
	8-pin, multi-turn	Three 120VAC internal VS
	Hard-wired or connectorized	Additional aux. contacts

*Note: For additional compatible controls with these configurations see table on page 4.

Viper-S, 14-pin, SEL-651R2*		
Configuration	Type	Description
Required	14-pin, multi-turn	Control
	2-pin, multi-turn	AC (heaters, cap charging)
Optional	4-pin, 1/4 turn	3 LEA VS
	8-pin, 1/4 turn	3 or 6 LEA VS
	8-pin, multi-turn	Three 120VAC internal VS
	Hard-wired or connectorized	Additional aux. contacts

*Note: No Dead-line operation available with this configuration, use the 19-pin Control Powered version instead.

Viper-S, 19-pin, Custom Relay Solution (CRS)		
48 VDC or 125 VDC control powered		
Configuration	Type	Description
Required	19-pin, multi-turn	Control
	6-pin, multi-turn	AC: heaters* & DC: cap charging
Optional	8-pin, multi-turn	Three 120VAC internal VS
	Hard-wired or connectorized	Additional aux. contacts
Compatible controls with these configurations:		
SEL	351, 351S and 751A	

*Note: If AC is not available, optional heaters can work on DC. Mostly used for substation applications where only DC is available.

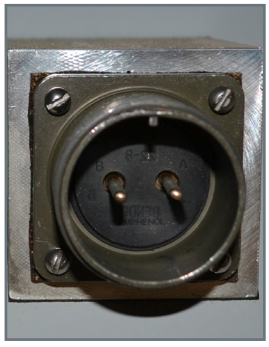
Viper-S, 19-pin, Control Powered SEL-651R2		
Configuration	Type	Description
Required	19-pin, multi-turn	Control*
Optional	4-pin, 1/4 turn	3 LEA VS
	8-pin, 1/4 turn	3 or 6 LEA VS
	8-pin, multi-turn	Three or Six 120VAC internal VS
	Hard-wired or connectorized	Additional aux. contacts

*Note: Control cable includes AC for heaters and dead-line operation feature if battery is provided.

VS = Voltage Sensors
LEA = Low Energy Analog

Traditional 14-pin configuration

▲ 14-pin connector



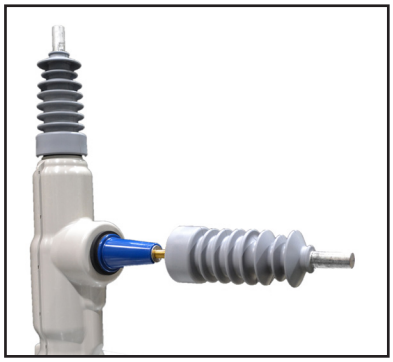
▲ 2-pin AC connector

▲Optional 6-pin dead-line operation connector

19-pin configuration

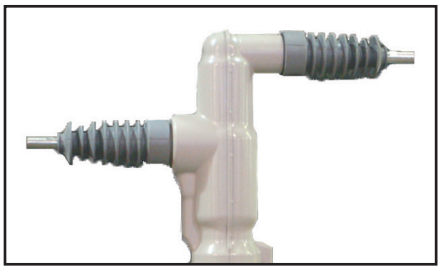
▲ 19-pin connector

Viper-S



Insulator Flexibility

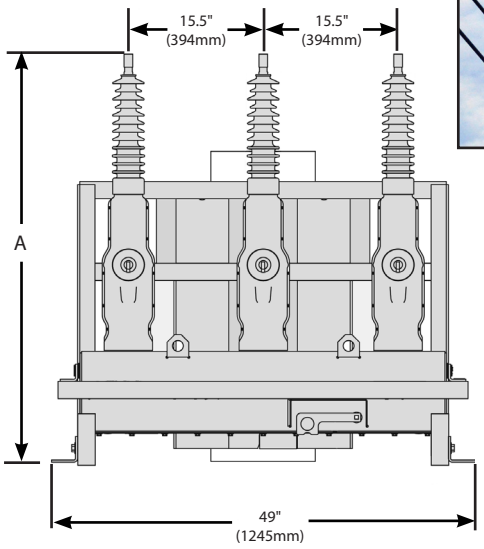
Polemounted units can be equipped with either horizontal or vertical insulators. Removable silicone insulators are standard for overhead applications. This feature permits easy field replacement if an insulator is damaged. Higher external BIL rated insulators can also be retrofitted if necessary. 3 or 6 internal VS are available in either L or Z modules.

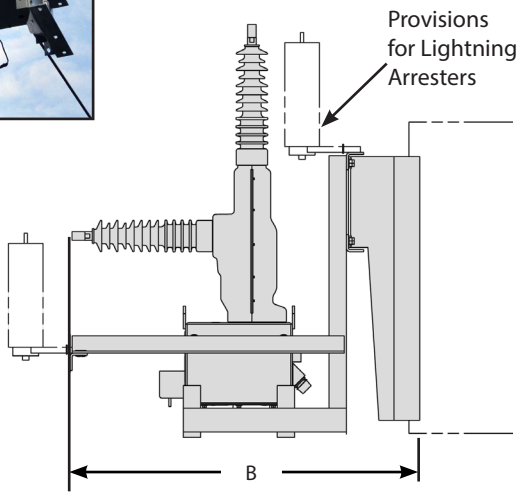


▲ Shown with horizontal insulator configuration (Z module)

Polemount Center Bracket*

Approx. Dimensions*- ins. (mm)			
	15.5kV	27kV	38kV
A	42 (1067)	47 (1204)	51 (1295)
B	39 (991)	44 (1118)	48 (1219)

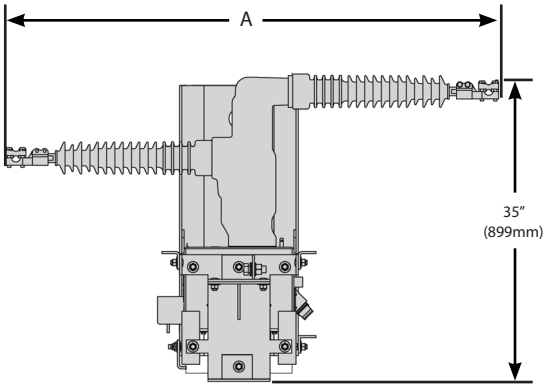




Polemount Alley-Arm*

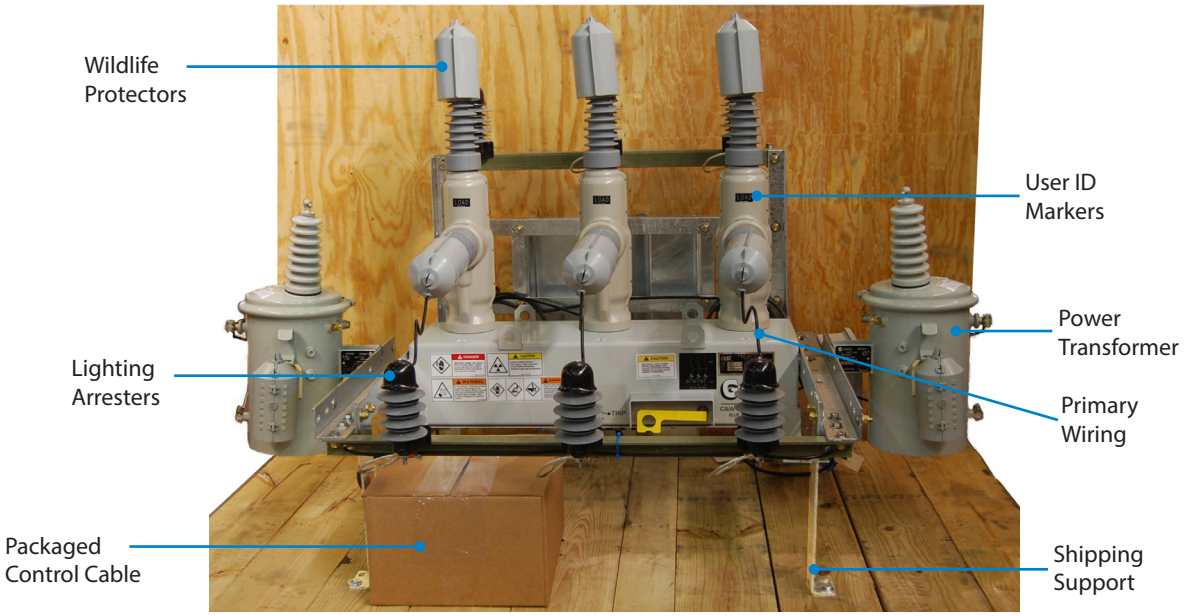
Horizontal Side Mounting Brackets with "Z" modules are ideal for overhead configurations where all three phase conductors are on one side of the pole.

Approx. Dimensions*- ins. (mm)			
	15.5kV	27kV	38kV
A	42 (1067)	50 (1270)	58 (1473)

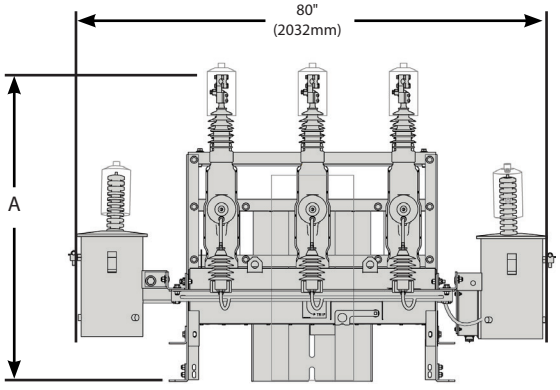


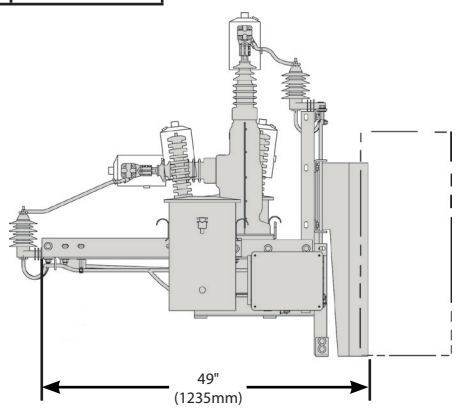
* Dimensions are approximate. Do not use for construction.
Galvanized steel bracket is standard. Stainless steel is available.

Polemount Site-Ready Assembly*
Preassembly of all auxiliary equipment significantly reduces recloser preparation time for product installation in the field. Includes potential transformers or voltage transformers, arresters, aerial lugs, terminal/junction boxes, wildlife protectors and all associated wiring. Control cables are connectorized on both ends and cut to length for a cleaner installation. User identification markers can be applied to each unit prior to shipment further reducing installation time.



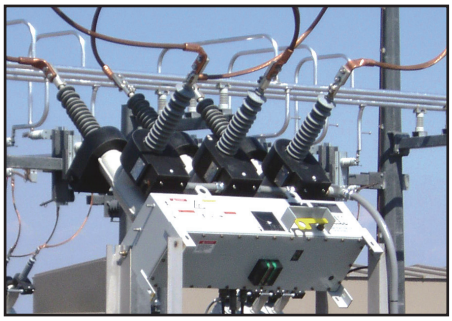
Approx. Dimensions*- ins. (mm)			
	15.5kV	27kV	38kV
A	54 (1378)	58 (1473)	62 (1575)





* Dimensions are approximate. Do not use for construction.
Galvanized steel bracket is standard. Stainless steel is available.

Substation Mount Recloser*



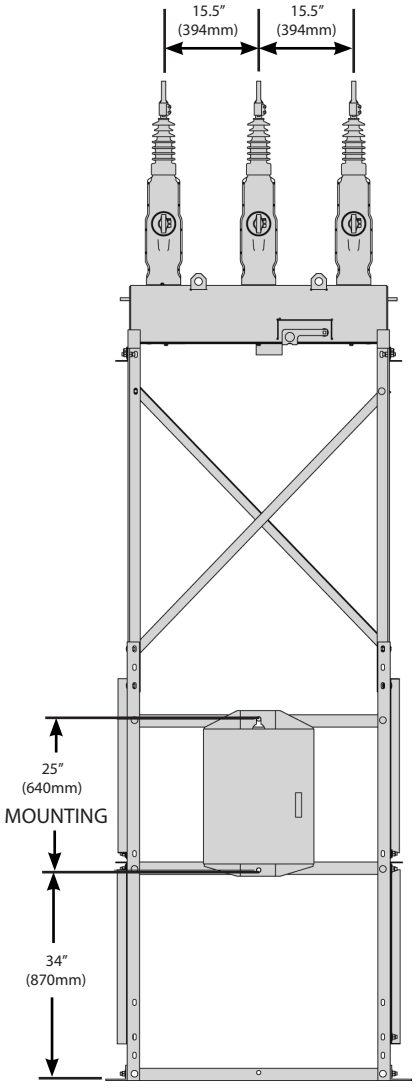
▲ 45° angle mounting for applications requiring the same load and line side connector height.

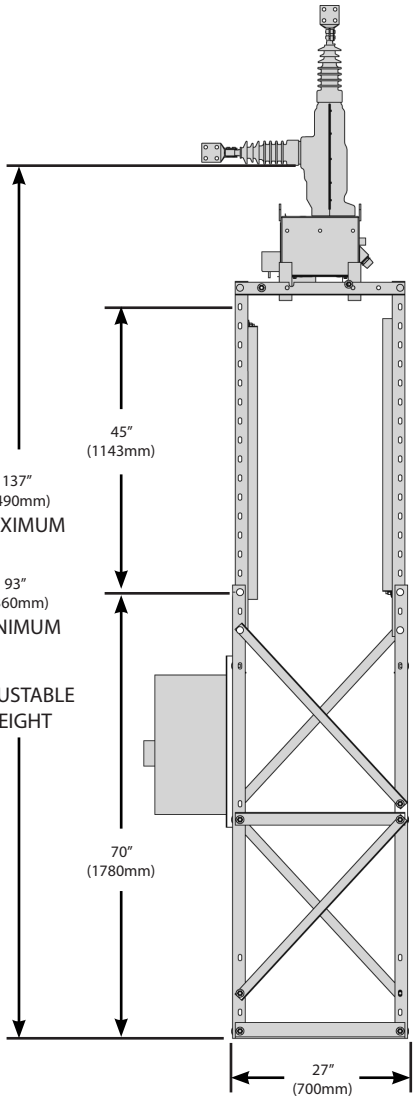
Substation frames are adjustable. Standard frames are galvanized. Stainless steel is available. Custom frames available including conversion for direct replacement of existing reclosers.

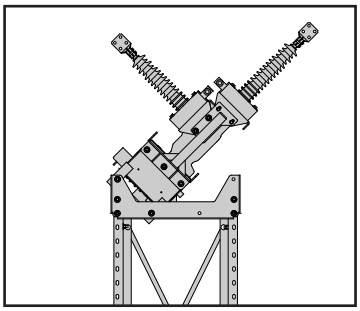
Dead-tank construction makes it ideal for substation circuit breaker applications and ensures the shielded solid dielectric module is grounded to earth potential.

For applications where extended creepage is required, larger insulators can be applied up to 940mm of creepage distance and 150kV BIL. External bushing CTs can be mounted at the base of the insulator where they can be used for metering or relay protection schemes like bus differential. The mechanism housing for substation applications is rated IP46 for maximum protection from water intrusion.

Externally mounted CTs - provide current monitoring on both the load and line side. Individual CTs and cabling are available.

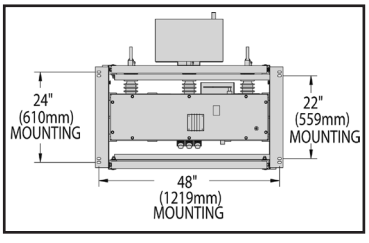






▲ Viper-S substation mount shown with CTs.

▲ Custom mounted frame required for replacement of previously installed oil filled equipment.



Bottom View

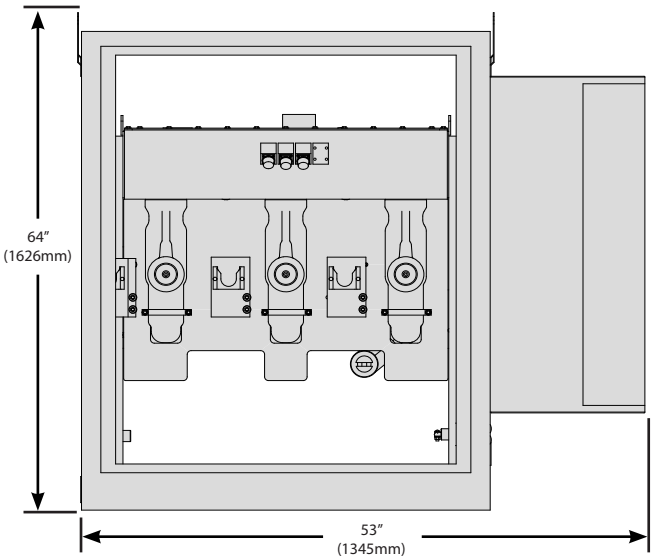
* Dimensions are approximate. Do not use for construction.

Padmount Applications

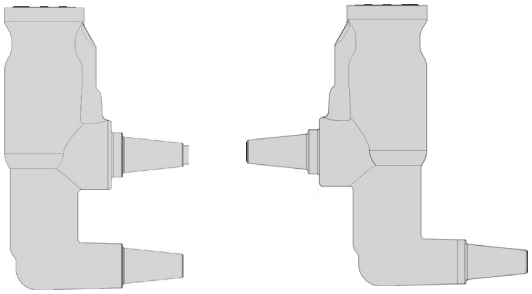
For applications where space is limited at the substation or where underground feeders require protection, Viper-S solid dielectric reclosers can provide an ideal solution using a dead-front padmount design. The padmounted Viper-S can be used as a breaker or as a tie-switch. Padmount applications can be considered for fenceless substations. In this configuration, the cable connections can be provided with either a standard IEEE 600A apparatus or 200A deepwell interface for elbow connectors. Separate compartments are provided for accessing the cables and operators. Controls can be mounted directly to the recloser frame or within a separate adjacent low voltage enclosure. Up to six internal LEA voltage sensors can be provided on padmounted designs with Z or C modules, perfect for tie points on FDIR schemes and automatic transfers.

Padmount Reclosers with Front / Back Access*

Padmount Reclosers are available with "Z" Modules for cable entrances front and back, or with "C" Modules for cable entrances in front. A galvanized steel enclosure is standard. 304 and 316 stainless steel are available. Photo above shows C module design. Drawing below shows Z module design.



Module Configurations



Padmounted Viper-S used in place of a circuit breaker in a solar generation intertie application ▶

* Dimensions are approximate. Do not use for construction.

Typical Specifications

A. GENERAL

This specification covers the requirements for an electronically controlled, mechanically ganged solid dielectric vacuum recloser for use on distribution systems through 38kV. The recloser shall be manufactured by G&W Electric Company designated as Viper-S solid dielectric recloser. Recloser configuration shall be (check one):

___ Polemount, center
___ Polemount, side horizontal (alley-arm)
___ Polemount, facing pole
___ Substation, 90° mount
___ Substation, 45° mount
___ Padmount, dead-front
___ Phase-over-phase

B. DESIGN RATINGS AND STANDARDS

Reclosers shall be designed, tested and built per IEEE C37.60 and IEC 62271-111 standards. Certified test reports shall be provided. The recloser shall be rated: (select column):

Voltage Class (kV)	15	25	35
Max System Voltage (kV)	15.5	27	38
BIL (kV)	110	125	150
Continuous Current (A)	800A*	800A*	800
8 Hr. Overload, at 20° C	960	960	960
60Hz Withstand, kV rms Dry, 1 min	50	60	70
60Hz Withstand, kV rms Wet, 10 sec	45	50	60
Interrupting Rating RMS (kA)	12.5	12.5	12.5
Making Current, RMS, asym, KA	20	20	20
Peak, asym (kA)	32	32	32
Short Circuit Current, kA sym, 3 second	12.5	12.5	12.5
Mechanical Operations	10k	10k	10k
Temperature range, -60°C to +65°C (-76°F to 150°F)			

*Consult factory for higher continuous current up to 1000A.

C. RECLOSER CONSTRUCTION

C1: Mechanism Enclosure

The magnetic actuator and corresponding linkage assembly shall be housed within a light gray painted stainless steel tank. A contact position indicator easily visible from the ground, a mechanical counter and air vent shall be provided.

C2. Operating Mechanism

The operating mechanism shall utilize a magnetic actuator for opening and closing of the vacuum interrupters. The magnetic actuator shall be powered by capacitors located in the recloser tank. The manual trip and lockout handle shall be made of stainless steel for maximum corrosion resistance. Vacuum interrupter contact position indication shall be accomplished using green (open) and red (closed) indicators located on the bottom of the tank and through LEDs inside the control.

C3. Vacuum Interrupters

Interruption of the fault or load currents shall be accomplished through vacuum interrupters located inside the solid dielectric modules.

C4. Solid Dielectric Modules

The solid dielectric modules shall utilize a time-proven solid dielectric epoxy insulation to fully encapsulate each of the three vacuum interrupters. The solid dielectric modules shall be fully shielded and incorporate a high impact poly-carbonate, track resistant, UV stable covering. The modules shall be dead tank or dead front technology and shall conduct a fault to ground through their external surface in case of a flash over. The operating temperature range shall be -60°C to +65°C. A 1000/500:1 or a 400/200:1 dual ratio current transformer and optional voltage sensor(s) shall be integrally molded into each module. CT accuracy shall be +/-1%. Modules shall be molded with one (1) source side and one (1) load side, IEEE apparatus bushing interfaces. The bushing interfaces shall accommodate either connection of an underground cable elbow for padmount applications or silicone insulators for pole top and substation applications.

C5. Bushings

Bushing types shall be (check one):

For Overhead design:
___ Air insulated, removable silicone insulators over an IEEE bushing interface

For Riser Pole:
___ Air insulated, silicone insulators on one side and elbow connectors on the other side.

For Padmount design:
___ 600A apparatus bushing
___ 200A deep well bushing

D. OPERATION

Monitoring of the circuit shall be accomplished using internal multi-ratio current transformers and voltage sensors. The unit shall be powered by an external 120/240 VAC or 48/125 VDC source. In the event main power is lost, the unit shall have trip/close operating capabilities through the battery located in the control.

Visit gwelec.com/specs.html for electronic versions of typical specifications.

The magnetic actuator shall use a permanent magnet to hold a solenoid plunger in the closed position while maintaining a charge on the opening spring. Trip/close operation shall be accomplished by energizing the trip coil which generates a magnetic flux in the opposite direction and releases the trip spring. The trip spring guarantees an open gap of the contacts inside the vacuum interrupter resulting in a fail-safe operation.

Recloser sequencing, tripping and overcurrent sensing, shall be an automatic function of the electronic control. Manual trip and lockout shall be provided by an external, hook-stick operable handle. Operation of the manual trip handle shall activate a mechanical block device, disabling any local or remote closing operation until the handle is reset.

E. SMART GRID / LAZER® AUTOMATION

The recloser shall be automation ready simplifying conversion for any future automation requirements. Up to 6 optional LEA (Low Energy Analog) capacitive voltage sensors shall be encapsulated within each recloser module permitting voltage reading for network reconfiguration while eliminating the need for add-on external sensors and cabling. LEA voltage sensing accuracy is +/-2% over the temperature range -20°C (-4°F) through +40°C (+104°F) when tested as a system. The accuracy is +/-4% from -40°C (-40°F) through +65°C (+149°F). The phase angle accuracy is +/-1° throughout the full temperature range. Two voltage ratios are available: a 10,000:1 for applications above 13.8 kV L-G and a 2,500:1 ratio below that voltage. External voltage and current sensors can also be used depending on application requirements.

F. PADMOUNT ENCLOSURE

Enclosures shall be made of 12 gauge galvanized or stainless steel and manufactured to IEEE C37.72 and C57.12.28 standards. The enclosure shall be mounted independently to facilitate cable installation, if desired or for future replacement. Enclosures shall be tamper-resistant incorporating hinged access door(s) with penta-head locking bolts(s) and provisions for padlocking. The enclosure shall be provided with lifting provisions and painted with a Munsell 7.0GY3.29/1.5 green finish. Front cable connections or front/back cable connections shall be available. 3 or 6 voltage sensors shall be internal to the modules.

G. ELECTRONIC CONTROLS

The standard recloser control shall be the Schweitzer model SEL-351R4, SEL-351R3 Falcon, or SEL-651RA. The 351 family of controls shall be used when up to (4) 0-300 VAC voltage inputs will be monitored. The SEL-651R2 shall be the control used for up to 6 voltage inputs. Other traditional 14-pin and 19-pin interfaces controls shall also be available upon request.

H. FACTORY PRODUCTION TESTS

Each individual recloser shall undergo a mechanical operation check verifying contact trip/close velocity, travel profile, timing and phase synchronicity. The recloser shall be AC hi-pot tested one minute phase-to-phase, phase-to-ground and across the open contacts. Circuit resistance shall be checked on all phases. Time overcurrent tests shall be conducted to verify minimum pick up level performance. System testing shall be performed on each Viper-S with their respective matching control and any other site-ready add-on such as lightning arrester and potential transformers.

I. STANDARD COMPONENTS

The following shall be included as standard:

1. Lifting provisions
2. Grounding provisions
3. Mechanical counter
4. Manual trip and lockout handle with true mechanical block
5. SEL-351R recloser control and associated control cable
6. Fail-safe mechanically ganged operations
7. Dead Tank solid dielectric epoxy modules with up to six internal voltage sensors and three dual ratio CT's
8. Arrester mounting provisions (overhead applications only)
9. Field changeable silicone insulators
10. AC connectorized cable for heaters and power source to the magnetic actuator circuitry
11. Galvanized center polemount frame

J. OPTIONS

The following options shall be supplied:
(Check as necessary)

___ NEMA 2-hole aerial lugs
___ NEMA 4-hole aerial lugs
___ Clamp style aerial lugs (#2- 500 kcmil)
___ Clamp style aerial lugs (250-750 kcmil)
___ 4/0 brass eyebolt ground lug
___ Stainless steel polemount center bracket with arrester provisions on the load and source side.
___ Stainless steel polemount side bracket (a.k.a. alley-arm frame) with arrester provisions on the load and source side.
___ Galvanized steel substation frame.
___ Polemount site-ready assembly
___ Lightning arresters
___ Dead-front padmounted design with stainless steel enclosure.
___ External 1.0 KVA oil potential transformer for 120 VAC supply power with hardware to mount on standard frame
___ External 0.75 KVA solid dielectric voltage transformer (0.3% accuracy) for 120 VAC supply power with hardware to mount on standard frame
___ High impact, UV stable wildlife protectors for source and load insulators
___ External CTs for current monitoring
___ Six internal voltage sensors

G&W offers a complete line of smart distribution voltage equipment including:

Lazer® Automation

- Multiple levels of protection
- Open, flexible communication
- Pre-engineered, factory tested
- Transfer, loop, and network applications

Solid Dielectric Switchgear

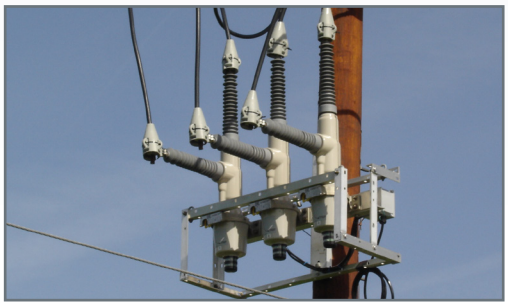
- To 38kV, 16kA interrupting
- Submersible vault and padmount
- Smart Grid / Lazer® solutions
- Single phase and three phase
- Integral Visible Break Designs

SF6 Insulated Switchgear

- To 38kV, 25kA interrupting
- Submersible vault and padmount
- Smart Grid / Lazer® solutions
- Load and Fault Interrupting

Solid Dielectric Reclosers

- To 38kV, 12.5kA interrupting
- To 27kV, 16kA interrupting
- Overhead, substation and padmount
- Smart Grid / Lazer® solutions
- Single phase and three phase
- Six voltage sensing available



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GW02-2018
Aug. 2018

SG125HV Noise Level Test Report

Version	Date	Author	Approved by
V10	2017,May, 28	Bale, Yang	Chen W

1.Introduction

This document describes the noise level test for SG125HV.The test is conducted in the Sungrow Testing Center, which is a WMT testing lab (Witnessed Manufacturer's Testing) accredited by TUV, CSA and UL.

The test procedures are in accordance with the standard ISO3746 and the sound pressure level fulfills the requirements in the IEC62109-1 standard.

2.Noise Level Test

The noise test was completed in the shielding room using the test platform shown below:

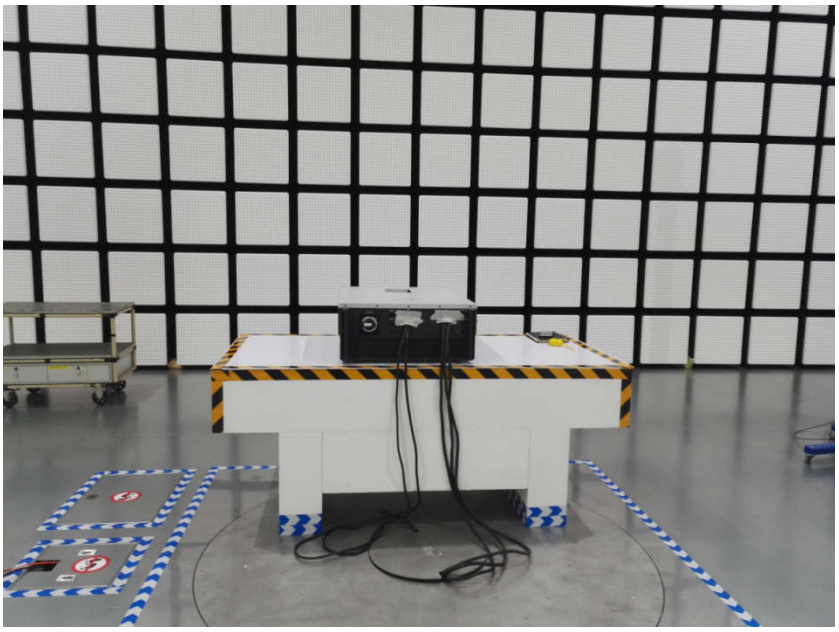

Fig-1 Noise Test Platform

During the test, the noise test instrument is located at a distance of 1m from the inverter, the inverter's operating DC voltage is 1050V and its output power is 125kW.The test data for the four directions and background noise are as follows:

Direction	**Test Data**
Bottom	61.6dB
Left Side	56.9dB
Top	53.7dB
Right Side	53.2dB
Background Noise	31.1dB

Appendix: Testing Pictures

Fig-2 Background Noise

Fig-3 Bottom Side

Fig-4 Left Side

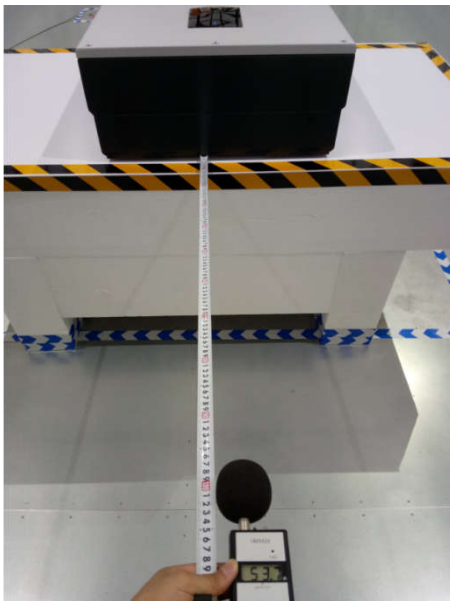

Fig-5Top Side

Fig-6Right Side

Decommissioning Plan
Wareham Solar Project
Plymouth County, Massachusetts

Prepared for:
Wareham PV I, LLC
330 Congress Street
6th Floor
Boston, Massachusetts 02210

Prepared by:
Stantec Consulting Services Inc.
1165 Scheuring Road
De Pere, Wisconsin 54115

Project No: 195602122
February 03, 2023
Revised June 26, 2023

This document entitled Decommissioning Plan Wareham Solar Energy Project, Plymouth County, Massachusetts, was prepared by Stantec Consulting Services Inc. ("Stantec") for the use of Wareham PV I, LLC (the "Client"), and the applicable regulatory agencies. Any reliance on this document by any other third party is strictly prohibited. The material in this document reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in this document are based on conditions and information existing at the time this document was published and do not take into account any subsequent changes.

Carl Broberg, PE
Civil Engineer

JoAnne J. Blank
Senior Associate

Matthew A Clementi, PE
Senior Project Engineer

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1.0 INTRODUCTION

Wareham PV I, LLC (Wareham PV I), a subsidiary of Longroad Energy Holdings, LLC (Longroad), is proposing to construct the Wareham Solar Energy Project in Plymouth County, Massachusetts. The proposed Wareham Solar Energy Project (the Project) is to be located within the Township of Wareham, Massachusetts. The Project will occupy approximately 18 acres of land (within perimeter fencing) and will have a maximum nameplate generating capacity of up to 3.5 megawatts (MW) alternating current (AC). Major components of the Project include solar modules, racking/tracking system, inverters, transformers, and a Project substation. Solar modules being considered include the First Solar Series 6 panels (475 watt) or other similar models.

This Decommissioning Plan (Plan) provides a description of the decommissioning and restoration phase of the Project. The decommissioning phase is assumed to include the removal of Project facilities, including the items listed in Section 1.1 and shown in Figure 1.

This Plan includes an overview of the primary decommissioning Project activities: dismantling and removal of facilities, and restoration of land. A summary of estimated costs and revenues associated with decommissioning the Project are included in Section 4.0. The summary statistics and estimates provided are based on an approximately 3.5-MW Project array design. Wareham PV I acknowledges that the revenue to be realized from resale or salvage of Project facilities will not be considered in calculation of the financial security, described in Sections 4.2 and 4.3.

1.1 SOLAR FACILITY COMPONENTS

The main components of the Project include:

- Solar panels and racking system
- Inverters and transformers
- Foundations and steel piles
- Electrical cabling and conduits (underground)
- Perimeter fencing
- Site access and internal roads
- Transmission generation tie-in line (overhead)

1.2 TRIGGERING EVENTS AND EXPECTED LIFETIME OF PROJECT

Project decommissioning may be triggered by events such as the end of a power purchase agreement or when the Project reaches the end of its operational life. The Project will be considered to be abandoned if the Project is non-operational for a period of twelve (12) consecutive months. If properly maintained, the expected lifetime of a solar project is approximately 40 years with an opportunity for a project lifetime of 50 years or more with equipment replacement and repowering. Depending on market conditions and Project viability, the solar arrays may be retrofitted with updated

components (e.g., panels, frame, racking system, etc.) to extend the life of the Project. In the event that the modules are not retrofitted, or at the end of the Project's useful life, the panels and associated components will be decommissioned and removed from the Project site (Site).

Components of the Project facility that have resale value may be sold in the wholesale market. Components with no resale value will be salvaged and sold as scrap for recycling or disposed of at an approved offsite licensed solid waste disposal facility (landfill). The resale value of components has not been considered in this Plan; however, the salvage value of the material scrap value has been estimated in Section 4. Decommissioning activities will include removal of the arrays and associated components as listed in Section 1.1 and described in Section 2.

1.3 DECOMMISSIONING SEQUENCE

Per Section 595 of the Town of Wareham Zoning By-Laws, Project facilities and components will be removed within 150 days of a Project which has reached the end of its useful life or has been abandoned. Monitoring and site restoration may extend beyond this period to ensure successful revegetation and rehabilitation. The anticipated sequence of decommissioning and removal is described below; however, overlap of activities is expected.

- Reinforce access roads, if needed, and prepare site for component removal
- Install temporary fencing and best management practices (BMPs) to protect sensitive resources
- De-energize solar arrays
- Dismantle panels and racking
- Remove frame and internal components
- Remove inverters and transformers
- Remove electrical cables and conduits
- Remove structural foundations and backfill sites
- Remove above ground transmission line unless retained for future use
- Remove access and internal roads and grade site
- De-compact subsoils (if required), restore and revegetate disturbed land to pre-construction conditions to the extent practicable

2.0 PROJECT COMPONENTS AND DECOMMISSIONING ACTIVITIES

The Project components and decommissioning activities necessary to restore the Project area, as near as practicable, to pre-construction conditions are described within this section.

2.1 OVERVIEW OF PROJECT EQUIPMENT

Wareham PV I anticipates utilizing approximately 7,356 solar modules, with a total nameplate generating capacity of up to approximately 3.5 $MW_{[AC]}$. On the approximately 18-acre Site. Statistics and cost estimates provided in this Plan are based on a First Solar Series 6, 475-watt or similar, module.

Electrical cabling will be removed, regardless of depth. Access roads may be left in place if requested and/or agreed to by the landowner. Public roads damaged or modified during the decommissioning and reclamation process will be repaired upon completion of the decommissioning phase.

Estimated quantities of materials to be removed and salvaged or disposed of are included in this section. Most of the materials described have salvage value; although, there are some components that will likely have none at the time of decommissioning. All recyclable materials, salvaged and non-salvage, will be recycled to the furthest extent possible. All other non-recyclable waste materials will be disposed of in accordance with state and federal law in an approved licensed solid waste facility.

Table 1 presents a summary of the primary components of the Project included in this decommissioning plan.

Table 1 Primary Components of Project to be Decommissioned

Component	Quantity	Unit of Measure
Solar Modules (approximate)	7,356	Each
Racking System (full equivalent racks)	154	Each
Steel Piles (racking)	1,386	Each
Inverters	32	Each
Solar and Grounding Transformer Pads	2	Each
Perimeter Fencing (approximate)	7,300	Lineal Foot (estimated)
Internal Access Roads (approximate)	3,865	Lineal Foot (estimated)
Above Ground Transmission Line	1,500	Lineal Foot (estimated)

2.2 SOLAR MODULES

Wareham PV I is considering the First Solar Series 6 (475-watt) module or similar model for the Project. Each module assembly (with frame) has a total weight of approximately 76.1 pounds. The modules are approximately 79 inches long and 49 inches in width and are mainly comprised of non-metallic materials such as silicon, glass, composite film, plastic, and epoxies, with an anodized aluminum frame.

At the time of decommissioning, module components in working condition may be refurbished and sold in a secondary market, yielding greater revenue than selling as salvage material. **The potential revenue associated with the sale of modules has not been used in the calculation of net decommissioning cost. Wareham PV I is committed to the responsible handling and recycling of Project facilities.** A cost of transportation and recycling of the solar panels has been included in the decommissioning costs (Table 3), although a net profit from resale would be expected during the first ten years of Project life.

2.3 RACKING SYSTEM AND SUPPORT

The solar modules will be mounted on a fixed tilt racking system, such as the Titan racking manufactured by APA Solar Racking. For purposes of cost estimating, equivalent racking approximately 32 meters (105 feet) in length, supporting 48 solar modules in two-in-portrait format, were assumed. Smaller racks will be employed at the edges of the layout, to efficiently utilize available space. The racking system is mainly comprised of galvanized and stainless steel; steel piles that support the system are comprised of structural steel.

The solar arrays will be deactivated from the surrounding electrical system and made safe for disassembly. Electronic components, and internal electrical wiring will be removed and salvaged. The steel piles will also be removed and salvaged.

2.4 INVERTERS AND TRANSFORMERS

Wareham PV I proposes to use the transformerless Sungrow inverters to be located within the arrays. The inverters will be deactivated, disassembled, and removed. Depending on condition, the equipment may be sold for refurbishment and re-use. Two concrete pads will be located in the central portion of the Project to support the solar and grounding transformers. The foundations will be removed at the time of decommissioning. If not re-used, the equipment will be salvaged or disposed of at an approved solid waste management facility. All oils, lubricants, and hazardous materials will be collected and disposed of at a licensed facility.

2.5 ELECTRICAL CABLING AND CONDUITS

The Project's underground electrical collection system will be placed at a depth of three feet (36 inches) or greater below the ground surface. In compliance with Section 595 of the Town of Wareham Zoning By-Laws, all above and below-surface Project components will be removed from the site.

2.6 PERIMETER FENCING, SITE ACCESS AND INTERNAL ROADS

The Wareham PV I facility will include a security fence around the perimeter of the site. An access road will allow access to the substation and solar equipment. Internal access roads will be located within the array to allow access to the equipment. The access roads will be approximately 20 feet wide and total approximately 3,800 linear feet (0.72 miles). To be conservative, the decommissioning estimate assumes that all access roads will be completely removed.

During installation of the Project facilities, site access road subgrade conditions will be stabilized by placement of geogrid reinforced granular fills over soft ground. This Plan assumes that eight inches of compacted gravel will be placed over geotextile fabric. The estimated quantities of these materials are provided in Table 2.

Table 2 Typical Access Road Construction Materials

Item	Quantity	Unit
Geotextile	8,589	Square Yards
Gravel or granular fill; 8-inch deep	1,909	Cubic Yards

Decommissioning activities include the removal and stockpiling of aggregate materials onsite for salvage preparation. It is conservatively assumed that all Geogrid and aggregate materials will be removed from the Project site and hauled up to five miles from the Project area. Following removal of aggregate and Geogrid, the access road areas will be graded, de-compacted with deep ripper or chisel plow (ripped to 18 inches), backfilled with native subsoil and topsoil, as needed, and land contours restored as near as practicable to preconstruction conditions.

3.0 LAND USE AND ENVIRONMENT

3.1 CURRENT LAND USE

The proposed solar facilities are predominantly located on vacant land, bounded by Route 25 to the south, woodlands, wetland resource areas and cranberry bogs to the east, municipal buildings to the west, and woodlands to the north. The southern end of the Site is wooded. The northern portion of the Site is previously disturbed as a result of historic sand extraction activities and consists primarily of exposed dirt/sand.

The areas of the Site that are disturbed by Project facilities and activities will be restored and revegetated in consultation with the owner(s) of the Property at the time of decommissioning and in compliance with regulations in place at that time.

3.2 RESTORATION, REVEGETATION AND SURFACE WATER DRAINAGE

Project sites that have been excavated and backfilled will be graded as needed to provide proper site drainage. Topsoil, if held in reserve from project construction, will be placed on disturbed areas and seeded with appropriate vegetation to reintegrate it with the surrounding environment. Soils compacted during de-construction activities will be de-compacted, as necessary, to restore the land to pre-construction land use.

Surface water conditions at the Project site will be reassessed prior to the decommissioning phase. Wareham PV I will obtain the required water quality permits from the Massachusetts Department of the Environmental Protection (MASSDEP) and the U.S. Army Corps of Engineers (USACE), if needed, before decommissioning of the Project. Storm water permits required at the time of decommissioning will be obtained. Work will be completed to comply with the Massachusetts Stormwater Management Standards in accordance with the Massachusetts Wetlands Protection Act (WPA) Regulations (310 CMR 10.00), as well as conditions agreed upon by Wareham PV I and Plymouth County, or as directed by regulations in effect at the time of decommissioning.

3.3 MAJOR EQUIPMENT REQUIRED FOR DECOMMISSIONING

The activities involved in decommissioning the Project include removal of the Project components: solar modules, racking, foundations and piles, inverters, transformers, access roads, and electrical cabling and conduits. Restoration activities include back-filling of pile and foundation sites; de-compaction of subsoils; grading of surfaces to pre-construction land contours and revegetation of the disturbed areas.

Equipment required for the decommissioning activities is similar to what is needed to construct the solar facility and may include, but is not limited to: small cranes, low ground pressure (LGP) track mounted excavators, backhoes, LGP track bulldozers and dump trucks, front-end loaders, deep rippers, water trucks, disc plows and tractors to restore subgrade conditions, and ancillary equipment. Standard dump trucks may be required to transport material removed from the site to disposal facilities.

4.0 DECOMMISSIONING COST ESTIMATE SUMMARY

Expenses associated with decommissioning the Project will be dependent on labor and equipment costs at the time of decommissioning. For the purposes of this report 2023 average market values were used to estimate labor and equipment expenses.

4.1 DECOMMISSIONING EXPENSES

Project decommissioning includes costs associated with removal of equipment, transfer of components to facilities for reuse or salvage and recycling or disposal of other solid waste. Materials designated as waste will be disposed of at a licensed facility, as required by local and state solid or hazardous waste regulations. Decommissioning costs also include backfilling, grading and restoration of the proposed Project site as described in Section 2.

Labor and equipment rates used to estimate the decommissioning costs are based on average 2023 rates acquired through RSMeans, an industry accepted construction cost estimating tool, that provides labor and equipment rates. Rates are updated annually. Major categories of labor include electricians, equipment operators and unskilled laborers. Rates include overhead and profit. Major equipment is described in Section 3.3. Table 3 summarizes the estimates for activities associated with the major components of the Project.

In addition to removal and restoration costs, Wareham PV I is committed to the responsible re-use and/or recycling of the decommissioned equipment. Solar modules will have substantial resale value within the first 10 years of the Project. The cost of solar module recycling ranges widely, and is dependent on variables such as the quantity, location, and the technology and processes in place at the time of recycling. No recycling cost is anticipated for the first 10 years of the Project, due to the value of the equipment. However, a conservative cost estimate of recycling fees, with transportation for solar panels, anticipated after the first 10 years from commencement of power generation is included in Table 3.

Table 3 Estimated Decommissioning Expenses

Activity	Unit	Number	Cost per Unit	Total
Overhead and management (includes estimated permitting required)	Lump Sum	1	$45,000	$45,000
Solar modules; disassembly and removal (increased handling of modules for resale)	Each	7,356	$9.90	$72,824
Racking system disassembly and removal	Each	154	$290	$44,660
Steel pile/post removal	Each	1,450	$13.75	$19,938

Activity	Unit	Number	Cost per Unit	Total
Inverters	Each	32	$450	$14,400
Transformers and foundations	Lump Sum	1	$5,210	$5,210
Access road excavation and removal	Lump Sum	1	$10,030	$10,030
Remove below surface electrical cabling	Linear Feet	4,650	$0.90	$4,185
Remove above ground transmission line	Linear Mile	0.28	$64,000	$17,920
Perimeter fence removal	Linear Feet	7,300	$3.10	$22,630
Topsoil replacement and rehabilitation of site	Lump Sum	1	$70,200	$70,200
Public road repairs	Lump Sum	1	$8,000	$8,000
Total Estimated Decommissioning Cost (Facility Removal and Site Restoration)				**$334,997**
Estimated Recycling Cost of Solar Panels (with Transportation)				$161,832
Total Estimated Decommissioning Cost with Recycling of Solar Modules				**$496,829**

4.2 DECOMMISSIONING REVENUES

Revenue from decommissioning the Project will be realized through the sale of the solar facility components and construction materials. As previously described, the value of the decommissioned components will be higher in the early stages of the Project and decline over time. Resale of components such as solar panels is expected to be greater than salvage (i.e., scrap) value for most of the life of the Project, as described below. **Wareham PV I acknowledges that the revenue to be realized from resale or salvage of Project facilities will not be considered in calculation of the financial security.**

Modules and other Project components can be sold within a secondary market for re-use. A current sampling of reused solar panels indicates a wide range of pricing depending on age and condition ($0.10 to $0.30 per watt). Future pricing of solar panels is difficult to predict at this time, due to the relatively young age of the market, changes to solar panel technology, and the ever-increasing product demand. A conservative estimation of the value of solar panels at $0.10 per watt, based on guaranteed purchase prices received on similar projects, would yield $349,400. Increased costs of removal, for resale versus salvage, are expected in order to preserve the integrity of the panels. These increased handling costs are reflected in the estimated costs provided in Table 3.

The main material of the racking system and piles is assumed to be salvageable steel. The resale value of components such as racking, may decline more quickly; however, the salvage value of the steel that makes up a large portion of the racking is expected to stay at or above a value that will provide revenue at the time of decommissioning.

Solar modules are expected to be resold if decommissioned during the first 10 years of the Project. At the end of Project life, the panels would be recycled or salvaged for the components such as glass, silicon with aluminum framing. Alternative and more efficient methods of recycling solar panels are anticipated before this Project is decommissioned, given the large number of solar facilities that are currently being developed.

4.3 DECOMMISSIONING COST SUMMARY

Table 4 provides a summary of the estimated cost to decommission the Project, using the information detailed in Sections 4.1 and 4.2. Estimates are based on average 2023 prices, with no market fluctuations or inflation considered.

Table 4 Decommissioning Cost Summary

Item	Cost/Revenue
Decommissioning Expenses (Facility Removal and Site Restoration)	$334,997
Estimated Recycling Cost of Solar Panels (with Transportation)	$161,832
Total Estimated Decommissioning Cost with Recycling of Solar Modules	**$496,829**
Gross Decommissioning with 25 Percent Contingency Added (i.e., 125% of Gross Estimated Decommissioning)	**$621,036[1]**
Stantec does not concur with the example per megawatt decommissioning costs provided in the National Renewable Energy Laboratory (NREL) table referenced in the December 12, 2022, Wareham Planning Board Meeting. We understand, however, that Wareham PV I (in consideration of the referenced NREL table) has agreed to use the following stipulated costs as initial estimated decommissioning costs, provided that the Planning Board (1) adopts the permit conditions proposed in the December 30, 2022 letter from applicant's counsel to the Board, (2) the applicant is permitted to provide financial assurance in the form of a surety bond, and (3) there is no prohibition on reduction of the financial assurance amount if a future review indicates a reduced estimated decommissioning cost. Total decommissioning costs are based on a 3.5 $MW_{[AC]}$ system. – $458,000/MW for the solar equipment decommissioning	**$1,603,000**
Gross Decommissioning with 25 Percent Contingency Added (i.e., 125% of Gross Estimated Decommissioning)	**$2,003,750[1]**

[1] Stantec understands that Wareham PV I has agreed to increase the financial assurance amount (or updated financial assurance amount, as applicable) by three (3) percent annually on the anniversary of the Project's commercial operation date.

4.4 FINANCIAL MECHANISM/ASSURANCE

Wareham PV I has indicated that it will comply with Section 595.3 of the Town of Wareham Zoning By-Laws (By-Laws):

> *Proponents of ground-mounted solar energy facilities shall provide a form of surety, either through escrow account, bond or otherwise, to cover the cost of removal in the event the town must remove the installation and remediate the landscape, in an amount and form determined to be reasonable by the Town, equivalent to 125 percent of the cost of removal and compliance with the additional requirements set forth herein. Such surety will not be required for municipal- or state-owned facilities. The project proponent shall submit a fully inclusive estimate of the costs associated with removal, prepared by a qualified engineer. The submission shall include a mechanism for calculating and adjusting the increased value of the surety removal costs due to inflation.*

Wareham PV I will post financial security as described in the By-Laws, in the amount of **$2,003,750**, which represents 125 percent of the total gross estimated removal and recycling costs, with no resale or salvage value considered. Wareham PV I also agrees that the surety amount will be increased by three (3) percent each year, on the annual anniversary of Project commissioning.

FIGURES

Figure 1 Project Layout

CHARGE POND ROAD

BLUE STAR MEMORIAL HIGHWAY (ROUTE 25)

10'x20' CONCRETE PAD FOR SOLAR TRANSFORMERS

8'x8' CONCRETE PAD FOR GROUNDING TRANSFORMER

0 20 40 Feet

vhb

Proposed Large-Scale Ground-Mounted Solar Photovoltaic Installation
0 Route 25
Wareham, MA

June 22, 2023

Draft Decommissioning Bond

BOND #_____

Surety Company
Annually Renewable Decommissioning Bond

KNOW ALL MEN BY THESE PRESENTS: That_____(hereinafter called the "Principal"), and Surety Company (hereinafter called the "Surety"), are held and firmly bound unto _____(hereinafter called the "Obligee"), initially in the full and just sum of _____($00.00) , the payment of which sum, well and truly to be made, the said Principal and Surety bind themselves, and each of their heirs, administrators, executors, and assigns, jointly and severally, firmly by these presents.

WHEREAS, the Principal has or will construct a commercial solar photovoltaic facility ("Solar Farm"), as that term is currently defined by the _____ (Property); and

WHEREAS, the Principal has been authorized to construct a Solar Farm by virtue of a legislative enactment by the Obligee and by other administrative approvals of Boards of the Obligee, all of which are conditioned upon the requirement that the Principal file security to cover the cost of decommissioning all facilities/structures which are part of the "Solar Farm" at the Property; and

WHEREAS, the Obligee has agreed to accept a bond guaranteeing the performance of said decommissioning pursuant to the terms and conditions of that certain bond agreement entered into between Obligee and Principal in connection with the Solar Farm (the "Bond Agreement").

NOW, THEREFORE, UPON EXECUTION BY THE PRINCIPAL AND SURETY AND UPON ACCEPTANCE BY THE OBLIGEE, THIS OBLIGATION SHALL BECOME EFFECTIVE AND SHALL REMAIN IN FULL FORCE AND EFFECT PURSUANT TO THE FOLLOWING EXPRESS PROVISIONS:

1. This bond is for the term beginning_____and ending _____. The bond may be extended for additional terms at the option of the surety, by continuation certificate executed by the Surety. Neither non-renewal by the surety, nor failure, nor inability of the Principal to file a replacement bond shall constitute a loss to the Obligee recoverable under this bond.
2. This Bond shall terminate prior to the term set forth above only upon receipt by Surety of an express, written statement by Obligee that the Solar Farm has been dismantled, in accordance with the decommissioning plan referenced and incorporated into the Bond Agreement, to the Obligee's satisfaction and that the Bond may be released by Surety.
3. In the event of default by the Principal, Obligee shall deliver to Surety by certified mail, a written statement of the facts of such default, within thirty (30) days of the occurrence. In the event of default, the Surety will have the right and opportunity, at its sole discretion, to either cure the default; or to tender to the Obligee funds sufficient to pay the cost of completion less the balance of the Contract price up to an amount not to exceed the penal sum of the bond. In no event shall the Surety be liable for fines, penalties, liquidated damages, or forfeitures assessed against the Principal.
4. No claim, action, suit or proceeding, except as hereinafter set forth, shall be had or maintained against the Surety on this instrument unless same be brought or instituted upon the Surety within one year from termination or expiration of the bond term.
5. No right of action shall accrue on this bond to or for the use of any person or corporation other than the Obligee named herein or the heirs, executors, administrator or successors of Obligee.
6. The aggregate liability of the surety is limited to the penal sum stated herein regardless of the number or amount of claims brought against this bond and regardless of the number of years this bond remains in force.
7. If any conflict or inconsistency exists between the Surety's obligations or undertakings as described in this bond and as described in the underlying document, then the terms of this bond shall prevail.
8. Nothing in this bond shall be construed to waive, release, or otherwise modify in any way the rights and obligations of Obligee or Principal under the Bond Agreement or any of the terms or conditions of the Bond Agreement.
9. This bond shall not bind the Surety unless the bond is accepted by the Obligee. The acknowledgement and acceptance of this bond is demonstrated by signing where indicated below. If this obligation is not accepted by way of signature of the Obligee below, this bond shall be deemed null and void.

Signed and sealed this_____day of_____, 2020.

PRINCIPAL:	SURETY:
_____(seal)	Surety Company (seal)
_____	_____
(name & title)	Attorney-in-Fact

THE ABOVE TERMS AND CONDITIONS OF THIS BOND HAVE BEEN REVIEWED AND ACCEPTED BY THE (OBLIGEE).

ACKNOWLEDGED AND ACCEPTED BY OBLIGEE:

BY: _____

PRINTED NAME/TITLE: _____

DATE: _____

PLEASE RETURN A COPY OF ACCEPTED BOND TO:

Exhibit - Group Study Agreement

This Agreement, dated **August 28, 2020**, is entered into by and between **Wareham PV I, LLC** ("Interconnecting Customer") and the Company, for the purpose of setting forth the terms, conditions and costs for conducting a Group Study relative to the Group Study Process as outlined in Section 3.4.1 of the Interconnection Tariff. This Group Study pertains to Application Number [redacted] (the Interconnecting Customer's application ID number). The Interconnecting Customer is part of the Group identified on Attachment 1 hereto. Terms used herein without definition shall have the meanings set forth in Sections 1.2 and 3.4.1 of the Interconnection Tariff which are hereby incorporated by reference.

1) The Interconnecting Customer's share of the Group Study fee of $ [redacted] is due in full prior to the execution of the Group Study. The Interconnecting Customer's share of the Group Study fee is a percentage of the Group Study cost for common studies on the basis of the aggregated system design capacity for each Group member's Facility (in MW AC) and the full cost for any study(ies) that are not common but performed for the Interconnecting Customer's Facility. The Company may reassess study costs subsequent to a change in composition of the Group, and any increase in such costs must be paid by the Interconnecting Customer and the remaining Group members (and any such increase shall not be subject to the cost cap under paragraph 8 below). The Interconnecting Customer shall not be eligible under Section 5.5 of the Interconnection Tariff for a payment plan for Group Study fee costs under this Agreement.

2) The Interconnecting Customer agrees to provide, in a timely and complete manner, all additional information and technical data necessary for the Company to conduct the Group Study not already provided in the Interconnecting Customer's application.

3) All work pertaining to the Group Study that is the subject of this Agreement will be approved and coordinated only through designated and authorized representatives of the Company and the Interconnecting Customer. Each party shall inform the other in writing of its designated and authorized representative, if different than what is in the application.

4) Where there are other potentially Affected Systems, and no single Party is in a position to prepare an Impact Study covering all potentially Affected Systems, the Company will coordinate but not be responsible for the timing of any additional studies required to determine the impact of the interconnection request on other potentially Affected Systems. The Interconnecting Customer will be directly responsible to the potentially Affected System operators for all costs of any additional studies required to evaluate the impact of the interconnection on the potentially Affected Systems. The Company will not proceed with this Group Study without the Interconnecting Customer's consent to have the other studies conducted.

5) The Group Study will determine the scope and produce an estimate for the cost of System Modifications to the Company's EPS within ±25%. A Group may request an Extended Group Study designed to produce an estimate for the cost of System Modifications to the Company's EPS within ±15%. The time allowed to perform an Extended Group Study may exceed the Time Frames provided for in Section 3.4.1(d) of the Interconnection Tariff. An Extended Group Study will only be performed upon unanimous consent of all Group members, evidenced by an executed Extended Group Study Consent Form. Interconnecting Customer will be responsible for all System Modification costs in accordance with Section

5 and Section 3.4.1 of the Interconnection Tariff.

6) The Group Study, together with any additional studies contemplated in Paragraph 4, shall form the basis for the Interconnecting Customer's proposed use of the Company EPS and shall be furthermore utilized in obtaining necessary third-party approvals of any required facilities and requested distribution services. The Interconnecting Customer understands and acknowledges that any use of study results by the Interconnecting Customer or its agents, whether in preliminary or final form, prior to ISO-NE approval, should such approval be required, is completely at the Interconnecting Customer's risk.

7) Confidentiality. Interconnecting Customer authorizes the Company to share the Interconnecting Customer's contact information and project details with other members of the Group, except for unredacted one-line diagrams, three-line diagrams, or any other design drawing. Interconnecting Customer shall provide the Company with appropriately redacted copies of diagrams and drawings that may be shared with other Group members at the Company's discretion.

8) The Company will, in writing, advise the Interconnecting Customer in advance of any cost increase for work to be performed up to a total amount of increase of 10% only. All costs that exceed the 10% increase cap will be borne solely by the Company. Any such changes to the Company's costs for the work shall be subject to the Interconnecting Customer's consent. The Interconnecting Customer shall, within thirty (30) days of the Company's notice of increase, authorize such increase and make payment, or the Company will suspend the work and the corresponding agreement will terminate.

9) Final Accounting. An Interconnecting Customer may request a final accounting report of any difference between (a) Interconnecting Customer's cost responsibility under this Agreement for the actual cost of the Group Study, and (b) Interconnecting Customer's previous aggregate payments to the Company for the Group Study within 120 Business days after completion of the construction and installation of the System Modifications described in an attached exhibit to the Interconnection Service Agreement. Upon receipt of such a request from an Interconnecting Customer, the Company shall have 120 Business days to provide the requested final accounting report to the Interconnecting Customer. To the extent that Interconnecting Customer's cost responsibility in this Agreement exceeds Interconnecting Customer's previous aggregate payments, the Company shall invoice Interconnecting Customer and Interconnecting Customer shall make payment to the Company within forty-five (45) Business Days. To the extent that Interconnecting Customer's previous aggregate payments exceed Interconnecting Customer's cost responsibility under this Agreement, the Company shall refund to Interconnecting Customer an amount equal to the difference within forty-five (45) Business Days of the provision of such final accounting report.

10) In the event this Agreement is terminated for any reason, any payments made to the Group Study are non-refundable.

11) Nothing in this Agreement shall be interpreted to give the Interconnecting Customer immediate rights to wheel over or interconnect with the Company's EPS.

12) Interconnecting Customer shall not voluntarily assign its rights or obligations, in whole or in part, under this Agreement without Company's written consent. Any assignment Interconnecting Customer purports to make without Company's written consent shall not be

valid. Company shall not unreasonably withhold or delay its consent to Interconnecting Customer's assignment of this Agreement. Notwithstanding the above, Company's consent will not be required for any assignment made by Interconnecting Customer to an Affiliate or as collateral security in connection with a financing transaction. In all events, the Interconnecting Customer will not be relieved of its obligations under this Agreement unless, and until the assignee assumes in writing all obligations of this Agreement and notifies the Company of such assumption.

13) Except as the Commonwealth is precluded from pledging credit by Section 1 of Article 62 of the Amendments to the Constitution of the Commonwealth of Massachusetts, and except as the Commonwealth's cities and towns are precluded by Section 7 of Article 2 of the Amendments to the Massachusetts Constitution from pledging their credit without prior legislative authority, Interconnecting Customer and Company shall each indemnify, defend and hold the other, its directors, officers, employees and agents (including, but not limited to, affiliates and contractors and their employees), harmless from and against all liabilities, damages, losses, penalties, claims, demands, suits and proceedings of any nature whatsoever for personal injury (including death) or property damages to unaffiliated third parties that arise out of, or are in any manner connected with, the performance of this Agreement by that party, except to the extent that such injury or damages to unaffiliated third parties may be attributable to the negligence or willful misconduct of the party seeking indemnification.

Notwithstanding the foregoing, the Interconnecting Customer hereby waives recourse against the Company and its Affiliates for, and releases the Company and its Affiliates from, any and all liabilities arising from or attributable to incomplete, inaccurate, or otherwise faulty information supplied by the Interconnecting Customer or the Group.

14) If either party materially breaches any of its covenants hereunder, the other party may terminate this Agreement by serving notice of same on the other party to this Agreement.

15) This Agreement shall be construed and governed in accordance with the laws of the Commonwealthof Massachusetts. This Agreement, including any attachments, is entered into pursuant to the Interconnection Tariff. Together the Agreement and the Interconnection Tariff represent the entire understanding between the Parties, their agents, and employees as to the subject matter of this Agreement. Each Party also represents that in entering into this Agreement, it has not relied on any promise, inducement, representation, warranty, agreement or other statement not set forth in this Agreement or in the Company's Interconnection Tariff. In the event of a conflict between this Agreement, the Interconnection Tariff, or the terms of any other tariff, Exhibit or Attachment incorporated by reference, the terms of the Interconnection Tariff, as the same may be amended from time to time, shall control.

16) All amendments to this Agreement shall be in written form executed by both Parties.

17) The terms and conditions of this Agreement shall be binding on the successors and assigns of either Party.

18) This Agreement may be terminated under the following conditions.

a) The Parties agree in writing to terminate the Agreement.

b) The Interconnecting Customer may terminate this Agreement at any time by

providing written notice to Company.

c) The Company may terminate this Agreement if the Interconnecting Customer either: (1) has not paid the fee or, (2) has not responded to requests for further information in accordance with provisions in the Interconnection Tariff, specifically Section 3.6.2; (3) has been removed from the Group in accordance with the Interconnection Tariff.

Interconnecting Customer: Wareham PV I, LLC

Signature: DocuSigned by: Matt Marino 4F6C019A71E54CA...

Name: Matt Marino

Title: Manager

Date: 9/18/2020

Company: Eversource

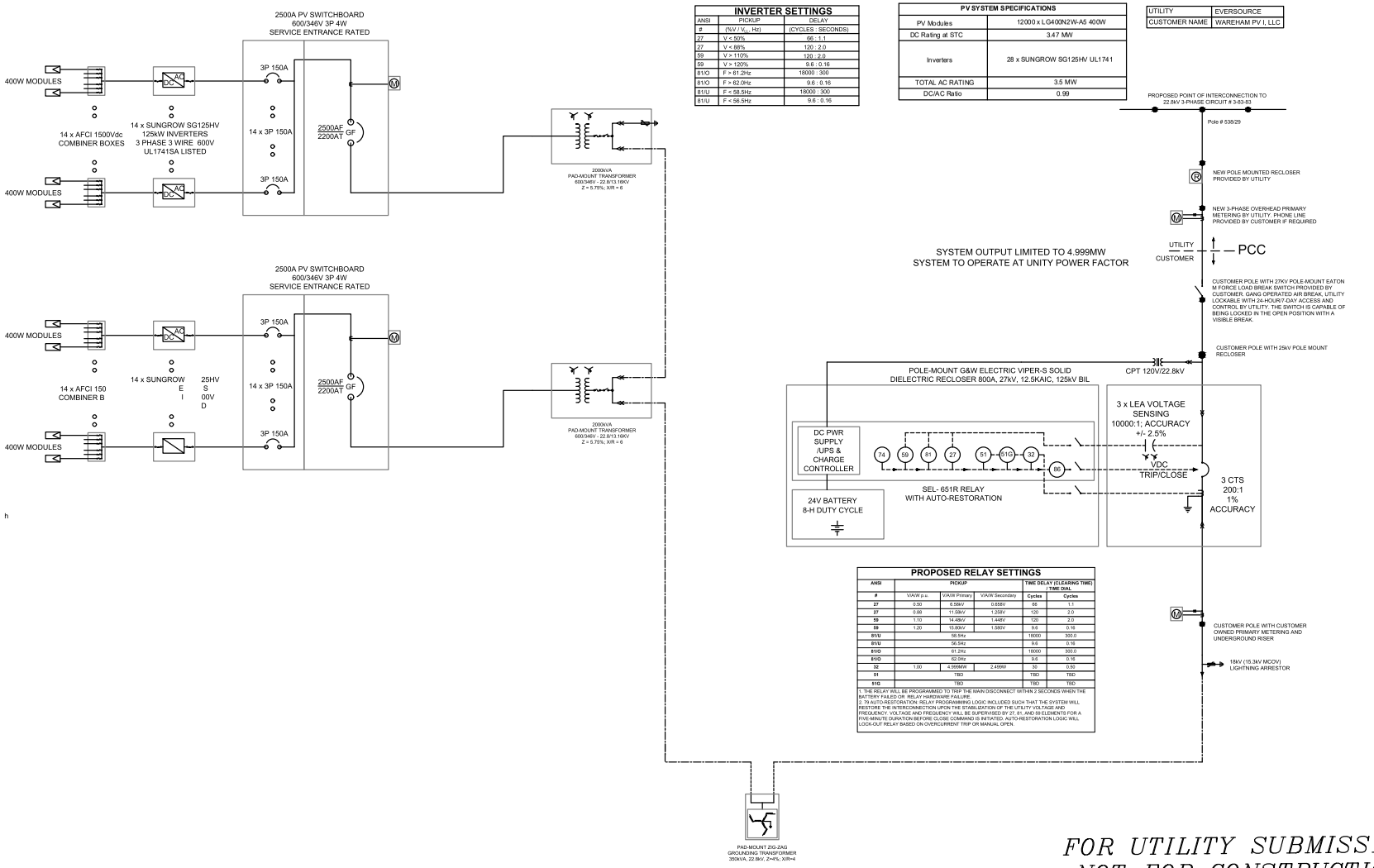
Signature: DocuSigned by: Melanie Khederian DA19E9377C72407...

Name: Melanie Khederian

Title: Account Executive

Date: 9/18/2020

Attachment 1: Group Composition and Study Cost Allocation
Attachment 2: Special Terms or Conditions for Group Study (*optional by Company*)



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INVERTER SETTINGS

ANSI	PICKUP	DELAY
#	(%V / V_{G}, Hz)	(CYCLES : SECONDS)
27	V < 50%	66 : 1.1
27	V < 88%	120 : 2.0
59	V > 110%	120 : 2.0
59	V > 120%	9.6 : 0.16
81/O	F > 61.2Hz	18000 : 300
81/O	F > 62.0Hz	9.6 : 0.16
81/U	F < 58.5Hz	18000 : 300
81/U	F < 56.5Hz	9.6 : 0.16

PV SYSTEM SPECIFICATIONS

PV Modules	12000 x LG400N2W-A5 400W
DC Rating at STC	3.47 MW
Inverters	28 x SUNGROW SG125HV UL1741
TOTAL AC RATING	3.5 MW
DC/AC Ratio	0.99

UTILITY	EVERSOURCE
CUSTOMER NAME	WAREHAM PV I, LLC

PROPOSED RELAY SETTINGS

ANSI	PICKUP			TIME DELAY (CLEARING TIME) / TIME DIAL	
#	V/A/W p.u.	V/A/W Primary	V/A/W Secondary	Cycles	Cycles
27	0.50	6.58kV	0.658V	66	1.1
27	0.89	11.58kV	1.258V	120	2.0
59	1.10	14.48kV	1.448V	120	2.0
59	1.20	15.80kV	1.58V	9.6	0.16
81/U		56.5Hz		18000	300.0
81/U		56.5Hz		9.6	0.16
81/O		61.2Hz		18000	300.0
81/O		62.0Hz		9.6	0.16
32	1.00	4.566MW	2.456W	30	0.50
51		TBD		TBD	TBD
51G		TBD		TBD	TBD

1. THE RELAY WILL BE PROGRAMMED TO TRIP THE MAIN DISCONNECT WITHIN 2 SECONDS WHEN THE BATTERY FAILED OR RELAY HARDWARE FAILURE.
2. 79 AUTO-RESTORATION RELAY PROGRAMMING LOGIC INCLUDED SUCH THAT THE SYSTEM WILL RESTORE THE INTERCONNECTION UPON THE STABILIZATION OF THE UTILITY VOLTAGE AND FREQUENCY. VOLTAGE AND FREQUENCY WILL BE SUPERVISED BY 27, 81, AND 59 ELEMENTS FOR A FIVE-MINUTE DURATION BEFORE CLOSE COMMAND IS INITIATED. AUTO-RESTORATION LOGIC WILL LOCK-OUT RELAY BASED ON OVERCURRENT TRIP OR MANUAL OPEN.

FOR UTILITY SUBMISSION
NOT FOR CONSTRUCTION

REVISIONS

REV	DESCRIPTION	DATE	DESIGN	REVIEWED

FLETCHER
CHARGE POND RD
WAREHAM MA, 02571

DWG NAME

DWG NO.

SIZE
D

SCALE:

DATE

6

Supplemental Plans & Reports (Under Separate Cover)

Site Plans
Stormwater Report