Distribution Protection
M-7651A D-PAC
Application: DER Interconnection Protection
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- North American Regional Manager for OMICRON starting in 1997.
- Regional Sales Manager with Beckwith Electric. He also served as National Sales Director for Substation Automation with AREVA T&D.
- Written numerous articles on substation maintenance testing, and has conducted numerous training sessions for substation technicians and engineers at utilities and universities across North America.
- 20 year Senior Member of IEEE-PES, has been a contributor on a number of PSRC working groups, and presented at a number of industry conferences specific to power system protection and control.
- Graduate of Fort Lewis College, Durango, CO, with a Bachelor’s degree in Business Administration.

Wayne is Beckwith Electric’s top strategist for delivering innovative technology messages to the Electric Power Industry through technical forums and industry standard development.

- Before joining Beckwith Electric, performed in Application, Sales and Marketing Management capacities at PowerSecure, General Electric, Siemens Power T&D and Alstom T&D.
- Provides training and mentoring to Beckwith Electric personnel in Sales, Marketing, Creative Technical Solutions and Engineering.
- Key contributor to product ideation and holds a leadership role in the development of course structure and presentation materials for annual and regional Protection & Control Seminars.
- Senior Member of IEEE, serving as a Main Committee Member of the Power System Relaying and Control Committee for over 25 years.
  - Chair Emeritus of the IEEE PSRC Rotating Machinery Subcommittee (’07–’10).
  - Contributed to numerous IEEE Standards, Guides, Reports, Tutorials and Transactions, delivered Tutorials IEEE Conferences, and authored and presented numerous technical papers at key industry conferences.
M-7651A D-PAC for DER Interconnection Protection

DER Interconnection Protection Overview

Conventional DER

- Industrial Gas Turbine
- Reciprocating Diesel
- Microturbine Gaseous Fuel
- Reciprocating Gaseous Fuel

Reciprocating aka: Internal Combustion Engine (ICE)
**Conventional DER**

Fuel Cell

![Fuel Cell Diagram]

**Renewable DER**

Solar (Thermal)

Solar (PV)

Small Hydro
Renewable DER

Wind
- May be induction or synchronous generator output
- May be mixture of generator and inverter output

Biogas

Biomass

Renewable DER

Biodiesel

Tidal
Renewable DER

Storage Battery

Protection Elements and Use

— “The Five Food Groups”
  • Loss of Parallel Operation (utility disconnected)
    • Anti-Islanding
  • Abnormal Power Flow
    • Anti-Islanding
  • Fault Backfeed Removal
  • Detection of Damaging System Conditions
  • Restoration

— Impact on interconnection protection
  • Interconnection transformer configuration
  • Various types of DERs
    – Induction, Synchronous, Asynchronous (Inverters)
Interconnection Protection

“The Five Food Groups”

- Loss of Utility Parallel (Anti-Islanding)
  - Voltage and frequency (27, 59, 81-U, 81-O)
  - Rate-of-change of frequency (81R, aka ROCOF)
    - Based on load (real and reactive) not equaling generation

- Abnormal Power Flow (Anti-Islanding)
  - Power (32F, 32R-U)
    - Based on power flow violations across the PCC

Low Import Power: 32R-U

- 32R-U Relay pickup set to at least 5% of total connected generator rated KVA
- 32R-U Relay programmed to trip when imported power falls below the pickup level
- Switching off a large amount of facility load may cause nuisance tripping
- Generator Control should have proper bias power margin set
Bias is made in the genset controller to ensure import of 40kW when paralleled.

32R-U is set lower with appropriate margin (trips if import goes below genset control setpoint).

Interconnection Protection
“The Five Food Groups”

- Fault Backfeed Detection
  - Phase and overcurrent (51V, 51), grounded systems
    - Directional overcurrent (67) or impedance (21) may be used
  - Ground overcurrent (50N/51N) for grounded systems
    - Directional ground overcurrent (67N) may be used
  - Ground over/under voltage (27N, 27N/59N) for ungrounded systems
  - Negative sequence overcurrent (46)
  - Based on abnormally high current or abnormally low/high voltage as a result of faults
When applying non-directional phase or ground elements for fault backfeed protection (50P, 50N, 51P, 51N), they must be coordinated for faults in the facility and on the utility.

This could lead to longer clearing times for utility faults.

To speed up response of utility faults, use of directional elements (67, 67N, 21P), set to only trip in the utility’s direction, will provide maximum trip speed.

Inverter-based DER produces very little fault current
- 1.0-1.3x rated current at full output
- Fault current even less when output is lower then rated
  - Solar PV late in day; low irradiance = low output

Fault backfeed protection (overcurrent) cannot be set below load for fear of nuisance tripping

Resultant large NDZ (non-detection zone)
- Transfer Trip anyone $$$$$$$ ?????
Focused Directional Overcurrent (FDO) Concept

- Use of focused directional overcurrent (FDO) elements (67P, 67Q, 67N) for Distributed Energy Resource (DER) Interconnection Protection (IP)

- Applicable at the PCC

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Traditional Directional Element

- For DER IP, directionalization is a reliability and security enhancement to control phase and ground overcurrent elements

- Used at the PCC, directionalization to the EPS blinds the overcurrent elements for load and faults in the DER's facility, thereby increasing the DER IP security

- In traditional 180° forward/reverse directional control, the overcurrent elements are subject to tripping on the DER's real power output.
• Increasing the MTA from 15° to 115° so the forward real power load region is ignored exposes the overcurrent element to trip for load flow and faults in the facility (reverse load area).

Traditional Directional Element

Inverter Fault Current Level

• Inverters typically develop fault current of 1.1-1.3x rated current
• To avoid tripping on normal power output, the overcurrent elements may be set above the DER’s rated output current
• For an inverter-based DER, this overcurrent pickup value is typically 1.2–1.4x the DER’s rated output current
Inverter Fault Current Level

- This tactic decreases sensitivity to detect DER fault infeed into the EPS
- This current value is essentially the same as load with margin for overload
- If the inverter-based DER is supplied by some variable source, such as a PV array, and as the PV output decreases below rated, the output current for both load and faulted EPS conditions also decreases below rated, making fault detection even more difficult.

![Inverter Fault Current Level Diagram](image)

Focused Directionality

- FDO allows the directional characteristic of overcurrent element to be tunable to other than the traditional 180° forward/reverse decision
- Ex., the overcurrent element response angle may be restricted to 45° forward, plus or minus 10°, for an effective response angle of 35° to 55°

![Focused Directionality Diagram](image)
FDO and Current Setting

- FDO elements allow settings as low as 0.15A secondary which should greatly improve the sensitivity of the overcurrent elements.
- The actual minimum primary current level detectable depends on the applied CT ratio.
- Ex., DER IP using a 500:5 CT and by employing a setting of 0.15 secondary amps on the FDO element yields a sensitivity of 15A primary amps.

FDO and Current Setting

- Sensitive overcurrent element pickup setting with a definite time characteristic will coordinate with transmission protection and allow ride-through.
  - Transmission protection is typically definite time Z with transfer trip aided clearing times of 20-25 with 50BF margin.

\[ t = \text{transmission protection time} + \text{pilot delay time} + \text{transmission interrupter clearing time} + \text{margin} \]
LEB is **not** a proxy for FDO.

**Application Considerations**

- An inverter, at its terminals, can only provide positive sequence current.
- Transformer winding and grounding at the PCC and EPS energization status at the DER IP play pivotal roles in directionization and application of FDO.
- **Ground Faults (67N):**
  - In order to apply FDO for ground faults, the interconnection transformer winding at the Utility-side of the point-of-common coupling must be a grounded wye
Interconnection Protection
“The Five Food Groups”

- Damaging System Conditions
  - Open phase condition or load imbalance (46, 47), negative sequence current and voltage
  - Phase sequence reversal (47), negative sequence voltage
  - Loss of synchronism (78)
  - Instantaneous overvoltage (59)
    - Based on current or voltage imbalance (including reverse phase rotation), power system and DER going out-of-step, or ferroresonance

- Facilitate proper restoration
  - All elements reset, voltage and frequency within limits
  - Reconnect timer (79) (all DER)
  - Sync check (25)
    - Synchronous generators and some self-commutating inverters

Conditions for Ferroresonance

- Feeder that DER is connected to must be isolated from the utility
  - (Islanded condition)
- KW load in the island must be less than 3 times DER rating
- Capacitance must be greater than 25% and less than 500% of DER rating
- There must be a transformer in the circuit to provide nonlinearity
Ferroresonance: Test Circuit Setup

New York Field Tests- 1989

Field Test Circuit

Conditions:
Wye-Wye Transformers, 100kVAr capacitance, 60kW generator, 12kW load

Advanced Convergent Protection Application

- Fault Backfeed Removal
- Damaging Conditions
- Loss of Utility Parallel (Anti-islanding)
- Abnormal Power Flow
- Restoration

Protection Element Usage
Usage:
- Feeder/Switchgear Protection
- Recloser Control
- DER Interconnection Protection

Protection Applications (example):
- Reverse Interlock (Fast Bus Protection)
- Maintenance Mode (fast, sensitive tripping of the Mains/Tie when personnel are working on the switchgear; decreases arc flash incident energy)
- Breaker Failure (Trip Mains/Tie when Feeder CB fails)
- Breaker Circuit Monitoring (Trip and Close Circuits)
- Alternate Settings for Backfeeding
- Directional Protection (Ph. & Gnd.) to prevent motor fault backfeed nuisance tripping

Metering, PQ Monitoring & Protection Applications:
- All measure quantities
- Complex calculated quantities (W, VAR, kVA, kVAR)
- Energy and Demands (+W/Hr, -W/Hr, Min., Max.)
- Harmonic Spectra Recording to 63rd (Graphic and Tabular)
- THD Alarm (%)
- THD Trip (%)
- TDD Alarm (%)
- TDD Trip (%)
- ITIC Curve Plotting for all Trips

Communication Based Protection Solutions
- Peer-to-Peer for Transfer Trip, Breaker Failure, Interlocking
- DMS to Relay for Profile Changes, Setpoint Changes
- IEC 61850, DNP, MODBUS
Why New Protection and Why Now?

Key Reasons:

1. **Information for Operations and Analysis** made possible thanks to technological advances in software microprocessors and memory.
   - Advanced Metering, PQ, DME DFR Records, High Visibility SOE, Data Storage, Data Filtering, Data Presentation, etc.

2. **Demand for Advanced Communications**
   - True Ethernet, Dual MAC, IEC 61850, SD, USB

3. **Regulatory Compliance**
   - NERC & IEEE Cyber Security Compliance

4. **Simplicity to Execute Complex Applications**

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Applications: Feeder, Switchgear, Recloser, DER

- Provide Full Suite of Voltage, Current, Directional Current, Directional Power, Load Shed and Restoration Elements
- Simple to Apply Preprogrammed Distribution Protection Schemes
- Complex Scheme Graphical Logic for Custom Applications
- Seamless Integration into Existing and Future Practices
- Voltage/Current Inputs available on the M-7651A:

<table>
<thead>
<tr>
<th>Voltage/Current Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Voltage Inputs (100 V Max)</td>
</tr>
<tr>
<td>High Voltage Inputs (100 V Max)</td>
</tr>
<tr>
<td>Low Voltage Inputs (200 V Max)</td>
</tr>
<tr>
<td>High Voltage Inputs (200 V Max)</td>
</tr>
<tr>
<td>Low Voltage Inputs (300 V Max)</td>
</tr>
<tr>
<td>High Voltage Inputs (300 V Max)</td>
</tr>
<tr>
<td>Low Voltage Inputs (500 V Max)</td>
</tr>
<tr>
<td>High Voltage Inputs (500 V Max)</td>
</tr>
</tbody>
</table>

- Contact Sensing Inputs & Contact Outputs

- Four programmable inputs (DI) and four programmable outputs (DO) (2 Form “A” & 2 Form “C”)
  - Inputs are externally wetted and can be individually configured for high or low voltage
  - Low Voltage, 18~60V, or, High Voltage, 80~300V

- Extended I/O (optional) adds additional 8 programmable inputs (DI) plus 8 programmable outputs (DO) (4 Form “A” & 4 Form “C”)
Two power inputs

- Main power supply (P/S) available in two ranges
  - Low V: 18~62V DC
  - High V: 80~325V AC/DC
- Independent backup power input: 12V DC
  - Common voltage employed in radios used for communications
**Advanced Communications**

- **Protocols Supported:**
  - Modbus, Modbus over TCP/IP
  - DNP3.0, DNP over TCP & UDP
  - IEC-61850 (Optional)
  - IEC-60870-5-104 (Optional)
  - 2179 (Optional)
- Dual MAC Ethernet port offers full auto-negotiable 10/100Mbps auto-detect communication with multi user and multi protocol support
- IRIG-B; Demodulated, TTL Level, Isolation 1,500V

**Protocols**

Serial Ports – MODBUS®, DNP3.0
Ethernet Ports – MODBUS over TCP/IP and UDP, DNP3.0 over TCP/IP and UDP, IEC 61850, ModbusP (Peer to Peer), IEC 60870-5-104 (optional)

**Overall Software Flow**

Show creating a file and connecting to the relay
Set Up

“Relay’s Environment”
“Relay’s Environment”

Can mix high and low voltages
Setting Profiles: 8

- These can be invoked by contact input, communication input, button input or measured parameter levels (ex., 32F vs. 32R)
- Each profile may be labeled for Operator and Technician use
- 7679 only; When role modes are changed, protection menus change to match the role
  - Recloser
  - Switch
  - Sectionalizer

User Profile Identification
Elements in a Profile

Profile and Elements
8 Profiles
User names will be displayed here

Element Programming by Clicking Element Number

Operating Modes

7679 Profiles to Change
Operating Modes
8 Profiles
User names will be displayed here

Roles include Recloser, Switch, Sectionalizer
Elements available to match mode selected
Global Settings

Programming

Element: 51P
Show setting 51P
Directional Overcurrent

67P, 67Q, 67N (67P shown below)
67P, 67Q, 67N (67P shown below)

Phase Directional Characteristic
Output I/O Map helps minimize logic programming by visually displaying which function and which setpoints are programmed to each output and which inputs are programmed to block.

- I/O Map tool allows copying of logics to other profiles.
- For testing purposes, individual protection elements can be disabled without deleting their programming. In this case, the functions will be greyed out.
- Custom IPSlogics also appear here.

Custom Schemes: IPSlogic
Custom Schemes: IPSlogic

Open IPSlogic, add gate, show state simulator
Backstory:

- Four 27 elements are set
- 27/4 is set at 0.7pu, 20 cycles
- 27/1, 2, 3 are set closer to nominal, but with longer time delays
- Voltage on Phase A is dropped to 0.5pu.
- 27/4 trips; all other 27’s in pickup on Phase A as long as low voltage is present and CB status indicates closed
Demand & Energy Metering

- Demand
- Demand and Energy
  - Present
  - Historical
  - Min/Max
  - All with date and time stamping

Energy (Bidirectional Registers)

Set Rated Load for TDD Metering

Set Up Oscillography Triggers
Secondary Metering: Loadflow at 1.0pf

- **Note V Sequence sets:**
  - V1 = Total Current
  - V2 = 0
  - V0 = 3

- **Note I Sequence sets:**
  - I1 = Total Current
  - I2 = 0
  - I0 = 3

- **Powers**
  - Watts = KVA
  - VAR = 0

---

Primary Metering: Loadflow at 1.0pf

- **Note V Sequence sets:**
  - V1 = Total Current
  - V2 = 0
  - V0 = 3

- **Note I Sequence sets:**
  - I1 = Total Current
  - I2 = 0
  - I0 = 3

- **Powers**
  - Watts = KVA
  - VAR = 0
Vector Diagram: Loadflow at 1.0pf

Vector Diagram: Loadflow at 0.8 pf lag
- Vector Diagram: Loadflow at 1.0pf,
  - “C” Phase Current Rolled

SOE

SOE Showing Trip
Oscillography

Up to 8 Seconds per Record

Fault with DC Offset (Raw Waveform)

Inputs

Outputs
Oscillography

- Fault with DC Offset (Fundamental View)

\[ S_A, S_B, S_C \]
\[ V_{A'}, V_{B'}, V_{C'} \]
\[ I_{A'}, I_{B'}, I_{C'} \]

- Fault with DC Offset (RMS)

\[ S_A, S_B, S_C \]
\[ V_{A'}, V_{B'}, V_{C'} \]
\[ I_{A'}, I_{B'}, I_{C'} \]

Show Ph-Ph-G Fault with DC Offset; PG&E
Up to 8 Seconds per Record

M-7651A for DER
Element Testing
M-7651A: DER Interconnection Application

"Elements of Distinction"

- 32F-VAR: Inadvertent VAR Export for Exporting DER
- 32R-U: Minimal Import Power for Non-Exporting DER
- 32F-Watt: Inadvertent Forward Overpower
M-7651A Settings: DER Interconnection Application

- VTR = 115:1
- VT Type: 3Y-3Y
- Rated Secondary Voltage = 69V_LG
- CTR = 100:5 = 20 (3Y)
- Inverter Power = 1,000kVA
- Inverter FRA = \( I = \frac{kVA}{1.73\times kV} \)
  \[ = \frac{1,000}{1.73\times 13.8} \]
  \[ = I = 41.88A = 42A \]

Note: “FRA” = Full Rated Amps

M-7651A Settings: 32F-VAR DER Interconnection Application

- \( I_{FRA} = 42A \)
- \( I_{NOM} = \frac{I_{FRA}}{CTR} \)
  \[ = \frac{42}{20} \]
  \[ = 2.1A \]
- \( V_{NOM} = 69V \)
- Formula for “Relay \( P_{NOM} \)”
  - \( 3 \times 69 \times 2.1 = 434.7W_R = 435W_R = 1pu \)
M-7651A Settings: 32F-VAR
DER Interconnection Application

<table>
<thead>
<tr>
<th>Relay W= 435Wr</th>
<th>1pu</th>
<th>2.1 A</th>
</tr>
</thead>
<tbody>
<tr>
<td>INV &quot;S&quot; Out</td>
<td>pu</td>
<td>Secondary Current @ pu</td>
</tr>
<tr>
<td>1000</td>
<td>1.00</td>
<td>2.1</td>
</tr>
<tr>
<td>900</td>
<td>0.90</td>
<td>1.89</td>
</tr>
<tr>
<td>800</td>
<td>0.80</td>
<td>1.68</td>
</tr>
<tr>
<td>700</td>
<td>0.70</td>
<td>1.47</td>
</tr>
<tr>
<td>600</td>
<td>0.60</td>
<td>1.26</td>
</tr>
<tr>
<td>500</td>
<td>0.50</td>
<td>1.05</td>
</tr>
<tr>
<td>400</td>
<td>0.40</td>
<td>0.84</td>
</tr>
<tr>
<td>300</td>
<td>0.30</td>
<td>0.63</td>
</tr>
<tr>
<td>200</td>
<td>0.20</td>
<td>0.42</td>
</tr>
<tr>
<td>100</td>
<td>0.10</td>
<td>0.21</td>
</tr>
<tr>
<td>0</td>
<td>0.00</td>
<td>0</td>
</tr>
</tbody>
</table>

- Minimum sensitivity of relay is 0.01A
- We are good to 15% of inverter power

M-7651A:
CT Dimensioning

- CT Limitations

  - Minimum Sensitivity of Inverse Time Element: 67Q, N, P
  - 5A CT, 0.1$A_{\text{sec}}$
  - The relay in this application can detect faults to 10% of inverter rating (10% rating = 0.21$A_{\text{sec}}$)
M-7651A: CT Dimensioning

- CT Limitations
  - SSA = 10kA (10,000A)
    - System SSA contribution is greater than Facility with DER
    - 10,000/40 = 250; <500A; OK
  - Max. Load of Facility with DER (DER off) = 2MW
    - 2MW = kVA/(1.73 * kV) = 2,000 / (1.73 * 13.8) = 83.8
    - 83.8 / 100 = 0.83A; OK

<table>
<thead>
<tr>
<th>AC Current</th>
<th>1 Nominal</th>
<th>I Continuous</th>
<th>I Short duration</th>
<th>Burden</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase Current</td>
<td>1 A</td>
<td>3 A</td>
<td>100 A for 1 second</td>
<td>&lt; 0.021 VA</td>
</tr>
<tr>
<td>Ground Current</td>
<td>1 A</td>
<td>3 A</td>
<td>100 A for 1 second</td>
<td>&lt; 0.021 VA</td>
</tr>
</tbody>
</table>

System Setup
System Setup

M-7651A Test Connections

For both connections, VA@0° with IA@0° & VB@-120° with IB@-120° & VC@-240° with IC@-240° = 100% forward real power flow

- Test Set Notes:
  - Each phase neutral connected together internally.
  - One common neutral for all phases available for external connection.

- Test Set Notes:
  - Each phase neutral available for connection.
  - Neutral should be externally connected together.
M-7651A D-PAC for DER Interconnection Protection

32F-VAR Element Application

M-7651A Settings: 32F-VAR DER Interconnection Application

RELAY POWER

- \( P_{\text{Nom}} = 3 \times 69 \times 2.10 \)
  \( = 438 \text{ VA} \) = 1pu
- Normal pf = +/- 0.9 (25 degrees)
  - \( \sin 25^\circ = 0.4226 \)
  - \( \cos 25^\circ = 0.9 \)
- kW at 0.9 = 438 \* \cos 25
  \( = 394 \text{W} \)
- VARs at 0.9 = 438 \* \sin 25
  \( = 185 \text{VAR} \)
- Normal VAR Export Max. = 185 VAR
- 20% Margin = 185 \* 1.2 = 222 VAR
- Setting = VAR / 1pu VA
  \( = 222 / 438 = 0.5077 = 0.51 \text{ pu} \)

Line-to-Ground Voltage:

- \( P_{\text{Nom}} = 3 \times V_{\text{Nom}} \times I_{\text{Nom}} \) (Secondary Nominal Power)
- Pickup = \( \frac{\text{Primary Power}}{P_{\text{Nom}} \times V_{\text{TRI}} \times CTR} \)
M-7651A Settings: 32F-VAR
 DER Interconnection Application

- +Q = Var into Utility
- -Q = Var into DER

DER Operating at Unity pf
DER Operating at -0.9 pf (Supplying VAR)

93

32F-VAR
 Setpoints

69VL-G
FORWARD
REVERSE

REAL POWER
REACTIVE

SSA = 10kA
Max Load = 2MW (2,000kA)

PV-based Inverter
1,000kVA, 0.9pf
480V
X"d = 1 (100%)
X"d = 1 (100%)
Xd = 1 (100%)

3/8/2019
Testing the 32F-VAR Element

\[
\text{Inom (2.1) X Vnom (69) = 144.9W} \\
144.9 \times 0.51 \text{ (PU) Pick up = 73.9W}
\]

- Rotate 3-ph currents
- Meter reactive VAR's in Secondary Metering
- Check pick up and trip time
- Output 1 will pulse

M-7651A D-PAC for DER Interconnection Protection

32R-U Element Application
**M-7651A Settings: 32R-U**

**DER Interconnection Application**

**RELAY POWER**

- \( P_{\text{Nom}} = 3 \times 69 \times 2.1 \)
  \[ = 438 \text{ VA} = 1 \text{pu} \]
- \( W_{\text{Nom}} = 3 \times 69 \times 2.1 \times (\cos 0^\circ) \)
  \[ = 438 \text{ VA} = 1 \text{pu} \]
- \( W_{\text{Nom}10\%} = 3 \times 69 \times 2.1 \times (\cos 0^\circ) \times (0.1) \)
  \[ = 43.5 \text{ W} \]
- \( I_{(W10\%)} \text{ at } 1.0 \text{pf} = \frac{43.5}{3 \times 69 \times \cos 0^\circ} \)
  \[ = 0.21 \text{ A} \]

- Desire to trip if real power imported into the Facility with DER is less then 10% of the DER’s rated output
- At unity pf, minimal amps coming into facility with DER must be equal or greater than 0.21A, or 21mA

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**M-7651A Settings: 32R-U**

**DER Interconnection Application**

**REVERSE UNDERPOWER**

- Negative Pickup
- Underpower

**EPS**

- Facility with DER
- PoC
- DER
- Load

- PV-based Inverter
- L200kVA, 0.9f
- \( \frac{X_{d}'}{X_{d}} = 1 (100\%) \)
- \( \frac{X_{d}'}{X_{d}} = 1 (100\%) \)
- \( X_{d} = 1 \text{ (100\%)} \)
- Max Load = 2MW (2,000kA)
Note:
Blocking Inputs 1 and 2 are used to block the 32R-U element if either the PPC CB or DER CBs are opened. Do not select blocking for "element only" testing.

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M-7651A Settings: **32R-U**  
**Test Procedure**

1) Pre-fault, Clears the Target
2) Ramp 3 ph. Currents down on 10mA steps
3) Verify trip time and function status
M-7651A D-PAC for DER Interconnection Protection

32F-Watt Element Application

M-7651A Settings: 32F-W DER Interconnection Application

**RELAY POWER**

- $P_{\text{NOM}} = 3 \times 69 \times 2.1$
  
  $= 438 \text{ VA} = 1\text{pu}$

- $W_{\text{NOM}} = 3 \times 69 \times 2.1 \times (\cos 0^\circ)$
  
  $= 438 \text{ VA} = 1\text{pu}$

- $W_{\text{NOM}25\%} = 3 \times 69 \times 2.1 \times (\cos 0^\circ) \times (0.25)$
  
  $= 108.6\text{W}$

- $I_{(W25\%)}$ at 1.0pf $= 108.6 / (3 \times 69 \times \cos 0^\circ)$
  
  $= 0.525\text{A}$

- Desire to trip if real power exported out of the Facility with DER is greater than 25% of the DER’s rated output
- At unity pf, maximum amps flowing into the EPS at unity pf must be equal or greater than 0.525A, or 525mA
M-7651A Settings: 32F-W
DER Interconnection Application

FORWARD OVERPOWER

100:5
CTR = 20
3Y
3Yg‐3Y
VTR = 115
13.8kV:480V

- PV-based Inverter
- 1,000kVA, 0.9pf
- 480V
- $X_d' = 100\%$
- $X_d = 100\%$
- $X_d = 100\%$

Max Load = 2MW
(2,000kA)

Setting is 25% of In (2.1)
Pre-fault values

In (2.1) x .25 = .525mA

Ramp up in 50mA steps, > 2 sec. per step
Verify trip time and pick-up

Annex:
Software Navigation Overview
Creating NEW File

Opening EXISTING File
Set Up System

Relay Setpoints
Display I/O Map

Setpoint Summary
SOE Set Up

3500 SOE stored in nonvolatile memory

Oscillography Set Up

100 OSC files stored in nonvolatile memory
Primary Metering And Component Metering

Secondary Metering, Components Metering, and Status
All corresponding voltages and currents in phase (loadflow at unity pf)

- All corresponding voltages and currents in phase (loadflow at unity pf)
- Phase A current wired 180° from Phase A voltage
- All currents lag corresponding voltage by 10°
- Loadflow with lagging power factor

- All currents lag corresponding voltages by 10°
- Phase A current is wired 180° out-of-phase with Phase A voltage
- Representative of balanced load at lagging pf
Function Status (Targets)

Reclose Status Monitor
Harmonics Monitoring

Retrieve SOE Record
Retrieve Oscillography Record

Retrieve Trip Sequence Events
Retrieve Fault Recorder Events

Email Support