2nd International Conference on “Large-Scale Grid Integration of Renewable Energy in India, New Delhi

Grid loss protection for solar-wind hybrid inverter

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Outline

• Inverter market
• About grid connected solar inverters
• Anti-islanding protection
• Test setup, procedure and results
• Other important safety protections
• Case studies- Inverters tested in laboratory & on-site
Photovoltaic INVERTER
Market segments

- Grid-connected systems
  - Residential applications
  - Commercial and industrial applications
  - Large power plants

- Off-grid systems
  - Rural applications
  - Industrial solutions
  - Consumer systems

Solar energy systems
Grid tied Inverter (GTI)

- Presence of utility
- Voltage, frequency and phase - Match to utility
- Disconnection from the grid if the utility goes down.

What is Islanding?

- The so called “distributed generation systems” contribute electricity by providing continuous supply of power, thus creating a situation wherein the DGS will act as an island of power feeding into the unpowered grid.
Problems of Islanding

• **Safety Concern:** Safety is the main concern, as the grid may still be powered in the event of a power outage due to electricity supplied by distributed generators, as explained earlier. This may confuse the utility workers and expose them to hazards such as shocks.

• **Damage to customer’s appliances:** Due to islanding and distributed generation, there may be a *bi-directional flow of electricity*. This may cause severe damage to electrical equipment, appliances and devices. Some devices are more sensitive to voltage fluctuations than others and should always be equipped with surge protectors.

• **Inverter damage:** In the case of large solar systems, several inverters are installed with the distributed generators. Islanding could cause problems in proper functioning of the inverters.
20 kW
Solar – Wind Hybrid Inverter
Objective

• The primary objective was to validate the effectiveness of grid loss protection function in a solar-wind hybrid inverter.

• Effectiveness was determined by
  – the speed with which the inverter detects & ceases to energize the utility.
20 kW SOLAR WIND HYBRID INVERTER

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Facilities (Solar PV Simulator)
Facilities (DC source)
Facilities (GRID Simulator)
Facilities (200 kW RLC Load)
ANTI-ISLANDING TEST PROCEDURE
IEC 62116/ IS 16169

3 test cases (P & V)
- 100% (< 75%)
- 50-66% (40 – 60%)
- 25-33% (< 20%)

Two sets of conditions
- 31 test cases
- 47 test cases

Safety
- prevent contact with unexpectedly energized lines

Protection
- prevent out-of-phase reclosure

Conclusion:
T ≤ 2 s
Disconnection times tested as per IS 16169

<table>
<thead>
<tr>
<th>P(EUT), %</th>
<th>Balanced Condition</th>
<th>Un-balanced Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>499.46</td>
<td>637.607</td>
</tr>
<tr>
<td>66</td>
<td>305.73</td>
<td>237.336</td>
</tr>
<tr>
<td>33</td>
<td>396.56</td>
<td>207.146</td>
</tr>
</tbody>
</table>
Disconnection time

Trip time= 499.46 ms

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Inverter Behavior

Volt-var characteristics

Volt- watt characteristics

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20 kW hybrid inverter on site in Bengaluru
20 kW hybrid inverter on site in Bengaluru
20 kW hybrid inverter generation for 24 hours
Solar

Power, Watts

Time, Hours

Wind

Power, Watts

Time, Hours

20 kW hybrid inverter generation for 24 hours
Cumulative Power

Power, Watts

Time, Hours

20 kW hybrid inverter generation for 24 hours
OTHER PROTECTIONS
## Over/under Voltage

<table>
<thead>
<tr>
<th>Voltage (at the point of utility connection)</th>
<th>Maximum trip time</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V &lt; \frac{V(\text{nominal})}{2}$</td>
<td>0.1 seconds</td>
</tr>
<tr>
<td>$[\frac{V(\text{nominal})}{2}] &lt; V &lt; [0.85 \times V(\text{nominal})]$</td>
<td>2.0 seconds</td>
</tr>
<tr>
<td>$[0.85 \times V(\text{nominal})] &lt; V &lt; [1.1 \times V(\text{nominal})]$</td>
<td>Continuous operation</td>
</tr>
<tr>
<td>$[1.1 \times V(\text{nominal})] &lt; V &lt; [1.35 \times V(\text{nominal})]$</td>
<td>2.0 seconds</td>
</tr>
<tr>
<td>$[1.35 \times V(\text{nominal})] &lt; V$</td>
<td>0.05 seconds</td>
</tr>
</tbody>
</table>

Voltage drop between inverter and utility point of connection should be included.
Over/under Frequency

- 51 Hz
- 50 Hz
- 49 Hz

**Frequency**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Maximum Trip time</th>
</tr>
</thead>
<tbody>
<tr>
<td>If frequency (50 Hz or 60 Hz) goes outside the range of ± 1 Hz</td>
<td>0.2 seconds</td>
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SAFETY/ PROTECTION TEST
IEC 62109-1 & -2/ IS 16221-1 & -2

- Capacitor discharge test
- Electrical tests related to shock hazard
- Humidity conditioning test (48 hrs)
- Ingress protection test
- Creepage and clearance Measurement
- Single fault test
- Thermal test
- UV conditioning test

Array ground insulation resistance test
Array residual current detection test
Backfeed voltage/current test
Temperature rise

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### OVERVIEW OF TESTS

<table>
<thead>
<tr>
<th>IEC 62109-1</th>
<th>IEC 62109-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Thermal test</td>
<td>• Single fault condition</td>
</tr>
<tr>
<td>• Single fault condition test</td>
<td>• Electrical rating</td>
</tr>
<tr>
<td>• Rating</td>
<td>• Array insulation resistance</td>
</tr>
<tr>
<td>• Marking &amp; documentation</td>
<td>• Residual current test</td>
</tr>
<tr>
<td>• Electric shock</td>
<td>• Residual current disconnection time (GTI only)</td>
</tr>
<tr>
<td>• Mechanical hazard</td>
<td>• Marking &amp; documentation</td>
</tr>
<tr>
<td>• Fire hazard</td>
<td></td>
</tr>
<tr>
<td>• Sonic pressure hazard</td>
<td></td>
</tr>
<tr>
<td>• Liquid hazard</td>
<td></td>
</tr>
<tr>
<td>• Chemical hazard</td>
<td></td>
</tr>
<tr>
<td>• Physical requirements</td>
<td></td>
</tr>
<tr>
<td>• Components</td>
<td></td>
</tr>
<tr>
<td>• Software functions</td>
<td></td>
</tr>
</tbody>
</table>

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Similar Case studies

• 27.6 kW GTI solar inverter
• 60 kW GTI solar inverter
• 1 kW GTI solar inverter
• 3 kW GTI solar inverter
• 100 kW GTI solar inverter
Tested 27.6 kVA grid connected solar inverter

Due to partial shading effect

OPTIMIZER
FIXED dc VOLTAGE
Low generation due to cloudy weather

Grid is lost

Reconnected to grid due to inbuilt – Anti Islanding function
Lot of variations are due to solar radiation.
Successful reconnection after islanding

This inverter does not have grid loss protection function

Failed to reconnect to the grid
100 kW Solar GTI energy generation plot

Power generation (kW)

LOW RADIATION

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THANK YOU

- ORGANIZERS
- MINISTRY OF POWER
- MNRE
- CPRI
- AUDIENCE

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