Renewable Energy Impact to Distribution Network Performance and Reliability

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1. RE Integration and changes in the Electric Distribution System
2. Technical issues of integrating RE
3. Distribution Impact Studies
4. Recommendations to accommodate RE interconnections
Introduction to RE Integration

Traditional Electric Power System

- Delivering electricity from bulk generating power plants to end-use customers
- Power moves in a single direction from generation through transmission and distribution lines to the end-users.
Evolving landscape of the distribution network

- Embedded RE resources leading to decentralized generation.
- “Prosumers” exporting power to the distribution network, causing bidirectional flows.
**Embedded Generating (EG) Plant**
- refers to Generating Units that are connected to a Distribution System and has no direct connection to the Grid
- often used **renewable energy resources** such as solar, wind, biomass, small hydro, and geothermal energy.

**Categories of RE technologies:**

A. Dispatchable RE sources
   - Hydro, Biomass, Geothermal

B. Variable RE sources (non-dispatchable)
   - Primarily Solar and Wind
Variable Renewable Energy (VRE) are generating facilities where electric energy is produced from a source that is renewable, cannot be stored by the facility owner or operator and has inherent variability that is beyond the control of the facility owner or operator.

Characteristics of VRE:

1. Variability – due to temporal availability of resources (wind and solar power output vary over time).
2. Uncertainty – due to unexpected changes in resource availability (factors: wind speed, cloud cover, etc.).
3. Location-specific – due to the geographical availability of resources.
4. Low marginal costs – since the resources are freely available.

Reference:
IRENA, Renewable Energy Integration in Power Grids: Technology Brief
Philippine Renewable Energy Act of 2008

**Republic Act 9513** or “Renewable Energy Act of 2008”

A policy framework has been created to facilitate the implementation of renewable energy projects. The law encourages the establishment of various incentive and supportive schemes in order to stimulate investments in renewable energies.

- Net Metering – a consumer-based renewable energy incentive scheme wherein electric power generated by an end-user from an eligible on-site RE generating facility, with a maximum aggregate capacity of **100 kW**, and delivered to the local distribution network may be used to offset electric energy provided by the DU to the end-user during the applicable period.
Technical Issues of RE Integration

The integration of embedded RE generation at the distribution level poses a unique set of benefits and challenges for the customers and the utility.

Potential adverse impacts of RE integration at the distribution level.

**Thermal Loading**

The current carrying capacity of the equipment. Loading an equipment beyond its thermal rating may lead to permanent damage.

**Voltage Regulation**

Embedded generation can be used for voltage support, in some cases, but often makes voltage control more complex in the distribution system.

**Power Quality**

The high DER penetration may affect adversely power quality, raising issues such as voltage variation, frequency variation, flicker severity, and harmonics.

**Fault level**

Every point in a distribution network has a particular fault level, which is a measure of the maximum fault current expected at that point.

**Control/Safety**

Island forms when a generator continues to supply the load in a part of the network disconnected from the upstream distribution system.
Technical Issues of RE integration

Thermal Loading

RE integration has the effect of changing current flows in the distribution network, which may lead to the overloading of feeders and transformers, especially during maximum generation and minimum loading conditions.

**Distribution level Criteria**

The loading levels of all distribution lines and distribution equipment should not exceed 70% of the maximum continuous ratings of phase conductors and transformers.

**Subtransmission level Criteria**

Subtransmission line loading should not exceed 90% of the conductor’s thermal rating while delivery point power transformer(s) should not exceed 100% of their rated capacity during N-1 conditions.
Technical Issues of RE integration

Voltage Profile

1.0 pu  1.05 pu  0.95 pu

Distribution Transformer

Voltage Regulation

RE integration may also result in changes in voltage profile along a feeder and may exceed the statutory voltage limits.

DU Criteria: Voltage present at any Connection Point shall be within **5%** of nominal voltage during normal conditions and within **10%** during N-1 condition.
Technical Issues of RE integration

Power Quality

Four aspects of power quality issues that must be observed:

- **Flicker Severity** impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time.
  
  **Criteria:** Flicker Severity at any point shall not exceed 1.0 for short term and 0.8 for long term.

- **Harmonics** are sinusoidal voltages and currents having frequencies that are integral multiples of the fundamental frequency.
  
  **Criteria:** THD of the voltage and the TDD of the current shall not exceed 5% during normal operating conditions.

- **Frequency Variation** The nominal frequency shall be 60 Hz.
  
  **Criteria:** The DU shall design and operate its system to assist the System Operator in maintaining the fundamental frequency within the limits of 59.7 Hz and 60.3 Hz during normal conditions.

- **Voltage Variation** the deviation of the RMS value of the voltage from its nominal value. This may exists as voltage swell/voltage sag/dip, over/undervoltage.
Technical Issues of RE integration

Fault Level

Installation of new RE generating plant in the distribution networks will potentially increase fault levels in the network.

Fault contribution from EG might trip the feeder breaker and recloser.

The impact of EG fault current contributions on system protection coordination must be considered.

Criteria: The maximum short circuit current should not exceed 90% of the interrupting capability of protective equipment and should not greatly impact the existing protection scheme.
Technical Issues of RE integration

Control & Safety Issues

The DG interconnection system shall detect an *islanded condition* during the operation of automatic sectionalizing equipment and shall cease to energize the system within **two seconds** after the formation of an island*

Adverse impact of unintentional islanded operation
- Unstable network (large frequency or voltage variations will occur when DG unit tries to supply the load in the island).
- Power quality and reliability (potential damage to equipment) is worsening.
- Safety problems to utility crews.

Reference:
*IEEE 1547 Standard for Conducting DIS for Distributed Resource Interconnection*
Distribution Impact Studies

In compliance with Article II, Section 2.9.4 of the Distribution Services and Open Access Rules (DSOAR)

Definition in the Distribution Service and Open Access (DSOAR) Rules:
Distribution Impact Studies (DIS) – A study performed to assess the ability of the Distribution System to accommodate a proposed Connection Agreement and any upgrades that may be required.

Definition in the Philippine Distribution Code:
Distribution Impact Studies (DIS) – A set of technical studies which are used to assess the possible effects of a proposed expansion, reinforcement, or modification of the Distribution System or a User Development and to evaluate Significant Incidents.
## Type of RE Generator Applications

<table>
<thead>
<tr>
<th>Connection Types</th>
<th>Description</th>
<th>Generator Aggregate Capacity</th>
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</thead>
<tbody>
<tr>
<td>1. Net Metering</td>
<td>Renewable Energy (RE) generators used to offset electric energy provided by the DU to the end-user</td>
<td>Pout ≤ 100 kW</td>
</tr>
<tr>
<td>2. Load Displacement/Own-Use/Parallel Operation</td>
<td>No export of power is allowed to the DU</td>
<td>(a) Pout ≤ 100 kW (distribution voltage)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) 100 kW &lt; Pout ≤ 10 MW (distribution voltage)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(c) Above 10 MW (sub-transmission voltage)</td>
</tr>
<tr>
<td>3. Export of Power</td>
<td>Generator output is exported to the facilities owned by the Distribution Utility (DU)</td>
<td>(a) 100 kW &lt; Pout ≤ 10 MW (distribution voltage)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) Above 10 MW (sub-transmission voltage)</td>
</tr>
</tbody>
</table>
**Distribution Impact Studies**

**Rationale and Importance of Impact Studies**

1. To determine the potential effect of the customer’s EG to the DU’s sub-transmission and distribution system.

2. To come-up with the appropriate connection scheme.

3. To determine the required asset reinforcements, if there is any.

4. To define the asset boundaries.
Distribution Impact Studies

**Scope of DIS**

1. **Thermal Loading and Voltage**
   - **Thermal Assessment**
   - **Voltage Assessment**

2. **Fault Level and Protection System**
   - **Short Circuit Duty**

3. **Power Quality**
   - **Power Quality Evaluation**
     - Impact of RE interconnection on the Power Quality

4. **Technical Support Capabilities and Additional Requirements**
   - **Technical Support Capability Requirements**
     - Active power support/curtailment, reactive power support, frequency withstand capability and low voltage ride through capability.
Distribution Impact Studies

Connection Schemes (for subtransmission and distribution level)

**Determination of Connection Point:**

- EG Applicant’s location
- Proposed service entrance
- EG Applicant’s Timetable
- Available circuits within the EG Applicant’s Site
- Existing load of circuits and power transformers
- Circuit performances
- Plans affecting the proposed circuits and banks
- Other EG applications in the recommended circuit
Distribution Impact Studies

Simplified Process Flow for the Conduct of DIS

**Gather Customer Input Data**
- Initial requirements:
  - Letter of Application/Intent for Connection from Connection Applicant.
  - Plant Parameters Form of proposed RE interconnection.

**Offer Service for DIS**
- Assess the completeness of the plant parameters form and other requirements to commence with the conduct of the DIS.

**Conduct of DIS**
- Conduct of the following:
  - Power Flow Analysis (Thermal Assessment and Voltage Assessment)
  - Short Circuit Analysis
  - Evaluation of Power Quality
  - Technical Evaluation of support capabilities

**Release of DIS results**
- Presentation of DIS result to the Connection Applicant (CA).
  CA signing a conforme letter.
## Distribution Impact Studies

### Responsibilities of generator applicant and DU

<table>
<thead>
<tr>
<th><strong>EG Applicant</strong></th>
<th><strong>DU</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Submit Letter of Intent indicating aggregate capacity of its Generator Plant</td>
<td>1. Determines the DIS Fee amount.</td>
</tr>
<tr>
<td>2. Submit complete Plant Parameters and other requirements (e.g. SLDs and Energy Forecasts)</td>
<td>2. Conducts DIS</td>
</tr>
<tr>
<td>3. Submit Technical Documents and Certifications of Equipment in compliance with operational and connection requirements for VRE plants</td>
<td>3. Evaluate submitted Technical Documents and Certifications of Equipment if compliant with operational and connection requirements for VRE plants</td>
</tr>
<tr>
<td>4. Pay DIS Fee</td>
<td>4. Submit to EG Applicant the DIS report</td>
</tr>
<tr>
<td>5. Provide copy of NGCP Grid Impact Study (GIS) or certification/letter that NGCP is not requiring a GIS (for large generator or power plant)</td>
<td>5. Present results of DIS to EG Applicant</td>
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<td></td>
<td>6. Submit Letter of Offer to conduct Distribution Asset Study (DAS)</td>
</tr>
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<td></td>
<td>7. Provide EG Applicant template of Interconnection Agreement (ICA) and Distribution Wheeling Service and Metering Agreement</td>
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## Recommendations to accommodate RE interconnections

Conduct of **Distribution Asset Studies** to determine all distribution assets and costs necessary to accommodate a proposed interconnection.

<table>
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<th>Technical Issues</th>
<th>Recommended Actions/Projects</th>
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<td><strong>Thermal Loading</strong></td>
<td>- Network Reinforcement through the construction and/or reconductoring of subtransmission/distribution lines</td>
</tr>
<tr>
<td><strong>Voltage Regulation</strong></td>
<td>- Network Reinforcement, Installation of AVR (Automatic Voltage Regulators) and capacitors, Resetting of On-load tap changers (OLTC)</td>
</tr>
<tr>
<td><strong>Power Quality</strong></td>
<td>- Installation of PQ compensating equipment (e.g. static var compensators, harmonic filters, etc.)</td>
</tr>
<tr>
<td><strong>Fault Level</strong></td>
<td>- Uprating of power circuit breakers, installation of fault current limiting fuses (CLF) on DTs, resetting of protective relays.</td>
</tr>
<tr>
<td><strong>Control/Safety</strong></td>
<td>- Installation of Direct Transfer Trip (DTT) schemes, Installation of SCADA, teleprotection equipment, and comm. links for status monitoring and control</td>
</tr>
<tr>
<td><strong>Other Requirements</strong></td>
<td>- Installation of synchro-check relay, delta-wye interface transformer, installation of line switches, and metering facilities (w/ import &amp; export billing), etc.</td>
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END OF PRESENTATION

THANK YOU FOR LISTENING

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