Impact of Large penetration of DERs on conventional Distribution Network

BSES Rajdhani Power Ltd.

BSES is a JV of Reliance Infrastructure (51%) and Govt. of Delhi (49%)
BRPL Profile

- BRPL is the largest Discom in Delhi, covering 750 sq. km of area (West and South) with a population density of ~3000 per sq km.
- More than 2.4 Million customers
- JV between Govt. of Delhi (49%) and Reliance Infrastructure Ltd (51%).
- Met peak demand of over 3200 MW in summer 2019

- BSES caters to 2/3rd of Delhi
- South & West Delhi by BRPL
Pre-privatization: Delhi Power Situation

- Age Old Network
- Unprofessional Culture
- Outdated Technology
- Poor Consumer Service
- Equipment Burn outs
- High Corruption
- Inadequate Investment
- High Theft

Business inheritance marred by multiple maladies
Delhi Distribution Model

BSES Rajdhani

BSES Yamuna

TPDDL (earlier NDPL)

The Delhi Restructuring

GoNCTD

HOLDING CO

Equity Sale 51%

PRIVATE Cos.

GENCO

TRANS CO

DISCOM 1 (BYPL)

DISCOM 2 (BRPL)

DISCOM 3 (TPDDL)

TATA Power owned

Reliance Group owned
Steep Loss reduction post - privatization

Pre privatisation era

Post privatisation era

<table>
<thead>
<tr>
<th>Discom</th>
<th>FY 02</th>
<th>FY 18*</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRPL</td>
<td>51.5%</td>
<td>9.44%</td>
<td>42%</td>
</tr>
<tr>
<td>BYPL</td>
<td>63.1%</td>
<td>10.41%</td>
<td>52%</td>
</tr>
<tr>
<td>TPDDL</td>
<td>51.3%</td>
<td>8.50%</td>
<td>42%</td>
</tr>
</tbody>
</table>

~42% reduction in losses post takeover as against 20% rise in a decade up-to privatization

* Provisional: Subject to DERC approval
Multi-Pronged approach taken for Loss Reduction

<table>
<thead>
<tr>
<th>BSES</th>
<th>FY 03</th>
<th>FY 17*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Loss</td>
<td>35%</td>
<td>3%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BSES</th>
<th>FY 03</th>
<th>FY 17*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Loss</td>
<td>22%</td>
<td>9%</td>
</tr>
</tbody>
</table>

* Provisional ; Subject to DERC approval
BSES successfully serves 67% of Delhi’s Power Demand.

Delhi met 7016 MW on 10th July 2018.

Delhi Power Demand is:
- ~70% more than Mumbai
- ~3 times of Kolkata
- ~4 Times of Chennai

> 103% growth in Peak Load served since privatization
Ever Improving Customer Services Journey...

A Progressive and Sustainable Journey towards Improving Customer Service

BSES Rajdhan Power Ltd.

C-SAT: Customer Satisfaction
QMS: Queue Management System
CHD: Customer Helpdesk
SLCC: Small Load Consumer Category
MLCC: Medium Load Consumer Category
KCC: Key Consumer Category
RTGS: Real Time Gross Settlement
CAS: Consumer Application System
IVRS: Interactive Voice Response System
Green Initiatives

- Renewable energy
- RTSPV Net Metering
- Low carbon homes / Smart Homes
- Waste to Energy Plants
- Sustainable agriculture / Solar Water Pumps
- Demand Aggregation for RE & EE Projects
- E-bikes/e-rickshaws Charging
- Electric/ Internal Fleet of Cars
- Electric charging & Battery Swapping Station
- Electric Buses Charging Depots
- DISCOM’s ESCO Model
  - Low carbon businesses and industries

BSES Rajdhani Power Ltd.
BRPL’s Rooftop Journey till YTM Jun19

- 1468 Installations completed, 47.47 MWp; Another 18.30 MWp in Progress
- Capacity of Solar 47.47 MWp against sanctioned load of 155.1 MW (~31%)
No. of net-meter installations in FY18-19 is higher than cumulative no. of installations in last 3 FYs

Waste-to-Energy, Hybrid Solar, Wind Plants in Pipeline
Facility to submit online Net-metering application commenced
Major issues for DER integration

• GoI has set a target of 175 GW of Solar PV with 40 GW of Rooftop solar by 2022

• As the distribution grid was designed as load-only grid with unidirectional power flow, the integration of PV at 11kV feeder and lower voltage levels needs to be studied

• The major challenges for the distribution grid network and its operations are, also considered and discussed in the study report are:
  • Voltage Regulation
  • Overcurrent Protection
  • Reverse Power Flows
  • Violation of Operational Parameters
  • Impact on Dispatch and Power System Operation
Voltage Regulation Practices

- Conventional distribution System assume no power sources on the system other than substations
- All power flows are uni-directional from Substation towards end of feeders
- Voltage limits specified as
  - ±6% in case of low tension
  - +6% to -9% in case of high tension
- With DER / RTS PV in the network, basic assumption of no other source in the network fails
- Voltage problems can ensue if the capacity of the added source is significant with respect to the distribution feeder capacity
- Varying output of PV sources can cause cyclic voltage excursions on the feeder that lead to hunting of tap changers or capacitor-switching devices
Overcurrent Protection

- Allows temporary faults to be quickly cleared from the system
- Permanent faults to be isolated in a manner minimizing the no. of customers affected & extent of any damage
- Involves coordinated operation of many devices, including circuit breakers, relays, reclosures, sectionalizing switches, and various types of fuses
- Devices are coordinated based on the various time-current response curves, relay pickup settings (where applicable), and fuse melting/damage curves.
- Presence of distribution-connected PV introduces new sources of fault currents that can change the direction of flow, introduce new fault-current paths, increase fault-current magnitudes, and redirect ground fault currents resulting into
  - Sympathetic Tripping
  - Fuse – CB coordination issue
Existing Protection Schemes

<table>
<thead>
<tr>
<th>S No</th>
<th>Voltage Level (kV)</th>
<th>Circuit Breaker Details</th>
<th>CT Primary</th>
<th>Relay Details</th>
<th>Protection Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.4</td>
<td>Outgoing ACB</td>
<td>50</td>
<td>400</td>
<td>R1</td>
</tr>
<tr>
<td>2</td>
<td>0.4</td>
<td>Incomer ACB</td>
<td>50</td>
<td>1250/2000</td>
<td>R2</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>DT CB (RMU)</td>
<td>18.4</td>
<td>75</td>
<td>R3</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>Outgoing CB</td>
<td>25</td>
<td>400</td>
<td>R4</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>Incomer CB</td>
<td>25</td>
<td>1200</td>
<td>R5</td>
</tr>
<tr>
<td>6</td>
<td>66</td>
<td>Power Trafo CB</td>
<td>31.5</td>
<td>200</td>
<td>R6</td>
</tr>
<tr>
<td>7</td>
<td>66</td>
<td>Incomer CB</td>
<td>31.5</td>
<td>1000</td>
<td>R7</td>
</tr>
</tbody>
</table>
Reverse Power Flow

- Maximum reverse power flow into the grid can be allowed based on two parameters:
  - Feeder/grid asset thermal capacity
  - Over-voltage at the point of interconnection

- Following formula is used to calculate the maximum reverse power flow on a feeder:

\[
P_{\text{reversed (max)}} = P_{\text{PV(max)}} - P_{\text{load(min)}}
\]

Where,

- \( P_{\text{reversed (max)}} \) = Maximum reversed power flow in the network
- \( P_{\text{reversed (max)}} \) = Maximum power from PV power plant at noon time (peak irradiance)
- \( P_{\text{load (min)}} \) = Minimum load at noon time when PV power at peak

- Maximum phase current in a feeder has been calculated using the following formula:

\[
I_{\text{phase}} = \frac{P_{\text{reversed(max)}}}{\sqrt{3}xU_r}
\]
Impact Assessment Study

- To assess the impact of RTS PV, Energynautics with the support of GIZ carried out scenario-based simulation study titled “Analysis of Indian Electricity Distribution Systems for the Integration of High Shares of Rooftop PV” for Delhi and Bhopal – Urban and Rural Feeder.
- Five Different scenarios built and studied for Urban and Rural feeders to understand and assess the unmanaged as well as managed hosting capacities of feeders.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Delhi Urban Scenarios</th>
<th>Delhi Rural Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PV equally distributed with normal load</td>
<td>PV power plant</td>
</tr>
<tr>
<td>2</td>
<td>PV equally distributed with adapted load</td>
<td>PV equally distributed with normal load</td>
</tr>
<tr>
<td>3</td>
<td>PV at the end of the feeder with normal load</td>
<td>PV equally distributed with adapted load</td>
</tr>
<tr>
<td>4</td>
<td>PV at the end of the feeder with adapted load</td>
<td>PV equally distributed with a 3.5 MW PV power plant</td>
</tr>
<tr>
<td>5</td>
<td>PV at the end of the feeder with lower line cross section</td>
<td>PV equally distributed with the network fully cabled</td>
</tr>
</tbody>
</table>
Key Findings

1. PV penetration levels of **75 % of distribution transformer capacity** and higher can be implemented without having to undertake any measures to contain voltage problems or overloading.

2. At very high penetration level (close to 100%), it could be observed that **Active Power Management Strategies** of either capping PV inverter capacity or the use of peak shaving storage performed best in resolving both voltage and loading issues.

3. **Automatic voltage control** by tap changing transformers at 132/33, 220/66 or 220/33 kV should be implemented in all distribution grids regardless of PV development. For lower voltage levels (66/11 or 33/11 kV level), this strategy is very beneficial, but not strictly required if the voltage control above is adequate.

4. Voltage problems in the distribution grid, caused by both load (under voltage) and PV (overvoltage) can be efficiently eliminated by the use of a **wide area voltage measurement** and control method i.e. measuring the voltage at multiple points in the grid and operating the voltage control by transformers accordingly.

5. The distribution grid codes need to be updated to require voltage control capability.
Forum of Regulators study

- **Safe limit** for network penetration by solar PV should be on **over-current (thermal capacity)** for symmetrically distributed solar photovoltaic systems, when permitted PV capacity (AC nominal power of inverter) is **not more than the sanctioned load/contract demand**.

- If solar PV penetration capacity is **more than the sanctioned load/contract demand**, aggregate or single PV power plant capacity (AC nominal power of inverter) that can be connected to the network has to be decided on a case by case basis, based on the loading of the respective DT and the feeder length, considering **over-voltage at PCC** as the deciding factor.

- If solar PV penetration capacity is **not more than the sanctioned load/contract demand**, aggregate PV power plant capacity (AC nominal power of inverter) that can be connected to a network can be up to 100% of DT capacity, even under worst case scenario(s), i.e. with 0% running load, considering feeder’s **thermal capacity** as the deciding factor.
Sites identification with High Solar Penetration

In order to assess the results of these studies, few sites identified with high solar penetration in terms of Distribution Transformer rated capacity

Total Installation
1468 nos/47.47 MWp

- Solar -182KWP
  - DT capacity-630KVA
  - % penetration -28.8%

- Solar -96KWP
  - DT capacity-400KVA
  - % penetration -24%

- Solar -200KWP
  - DT capacity-630KVA
  - % penetration -31.7%

- Solar -92KWP
  - DT capacity-400KVA
  - % penetration -23%

- Solar -40KWP
  - DT capacity-100KVA
  - % penetration -40%

- Solar -50KWP
  - DT capacity-100KVA
  - % penetration -50%
Solar -96KWp  DT capacity-400KVA; % penetration -23%;
Date of Installation -27.07.2019
Analysis of DT Peak Loading (Day Peak)

Solar - 182KWP  DT capacity - 630KVA
% Penetration - 28%
Date of Installation - 10/12/2015

Graph showing analysis of DT peak loading before and after solar installation.
Analysis of DT Peak Loading (Day Peak)

Solar -200KWP  DT capacity-630KVA
% penetration -31.7%
Date of Installation - 05.03.2019

Before Solar  After Solar
Analysis of DT Peak Loading (Day Peak)

Solar -92KWP  DT capacity-400KVA
% penetration -23%
Date of Installation - 30.12.2015
Analysis of DT Peak Loading (Day Peak)

Solar -50Kwp  DT capacity-100KVA  
% penetration -50% 
Date of Installation - 05.08.2016

Before  
After-1st year
Observations

- Rooftop solar helped in reducing the day peak loading.
- Resulted in CAPEX deferment of DTs, having peaks during sun-hours.
- No. of outages on DTs found to be reduced post-solar installations.
- No complaints of over-voltage received from consumers.
Conclusions

- No adverse impact noted in the selected sites with high penetration of solar.
- However, sympathetic tripping in case of large solar penetration on a single feeder can be avoided with more advanced protection schemes than are currently used on distribution circuits, such as
  - By use of directional over-current trip blocking
  - By implementing more advanced inverter algorithms that accomplish very fast fault-current limiting
- Solar Penetration upto 100% of DT rated capacity can be allowed with few measures such as solar plant limited to sanctioned load, active power curtailment, usage of volt-var characteristics of inverters, etc.
Go SOLAR!
A SMART STEP TOWARDS A GREENER FUTURE
FOR ALL SAVING ENVIRONMENT AND MONEY

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