Integration of Renewable Power in the Grid

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Renewable Integration Plan and its Impact
**Present Installed Renewable Capacity**

**Total Installed Capacity=310 GW**
*(As on 31.12.2016, source: CEA)*

- **Hydro**: 43.13 GW (14%)
- **RES**: 45.91 GW (15%)
- **Gas**: 25.28 GW (8%)
- **Diesel**: 0.91 GW
- **Nuclear**: 5.78 GW (2%)
- **Coal**: 188.96 GW (61%)

**Installed RES=45.9 GW**
*(As on 30.09.2016, source: MNRE)*

- **Wind**: 28.1 GW (61%)
- **Biomass**: 5.0 GW (11%)
- **Solar PV**: 8.5 GW (19%)
- **Small Hydro**: 4.3 GW (9%)

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**Legend**
- **RES**
- **Gas**
- **Diesel**
- **Nuclear**
- **Coal**
- **Hydro**
Impact of Non-Dispatchable Renewable power

Impact on Grid
- Difficulty in load frequency control
- Difficulty in scheduling of tertiary reserves
- Requirement of enhanced transmission network and its under utilisation
- Increase in requirement of ancillary services and increased operation cost
- Increase in transmission cost

Impact on Plant
- Lower PLF due to ducking of load curve
- High ramping requirement
- Two shifting and cycling of plants
- Increased forced outage and O&M cost
- Equipments life time reduction
- Poor heat rate and high Aux. Power
- More Carbon emissions
- Increased cost of energy
Solar PV Integration : Ducking of Net Load Curve

- **Dipping of net demand** with solar capacity penetration
- **Reduced PLF** of conventional plants.
- Dip may lead to **shut down** of some of the units if generation drops below technical minimum
- Reduction in solar generation coincides with peak demand during evening hours resulting in **sharp ramp rate** of Dispatchable Plants.
Present Net Demand Curve

- Present RE Penetration is 15% of total installed capacity
- Peak ramp rate = 222 MW/min
- Duck belly demand to peak demand ratio is approx. 80%
- Many units are running on part load resulting in lower PLF of conventional units
Scenario: Cycling, Frequent Starts / Stops

Peak demand met to installed capacity ratio has been falling rapidly over last few years and so also the Plant Load Factor – Capacity Overhang

Reasons:
- Curtailed demand due to ailing Discoms
- RE invasion, though only moderate so far

Future Scenario
- Success of UDAY Scheme might bring in some respite
- But likely to be more than offset by renewable penetration
- Capacity requirement is largely governed by peak of net demand curve irrespective of RE integration.
- Conventional plants will continue to cycle with low PLF
Peak hour ramp rate is 247 MW/min, (marginal increase from present ramp rate)

Ramping down rate with sun rise is highest (368 MW/min. with avg. ramp rate of 0.85 MW/min. with all units participating)

Duck belly demand to peak demand ratio is 61% which will lead to partial loading and frequent start stops
**Percentage Installed RE in India: Now and 2021-22**

**2015 - 16**

Total Installed Capacity: 310 GW

- Non RE Capacity: 264 GW
- RE Capacity: 45.91 GW
- Solar PV Capacity: 8.5 GW
- Peak Demand: 153.45 TWh
- Peak Demand met: 148.5 TWh

15% of total installed capacity - 2.74%

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**2021 - 22**

Total Expected Installed Capacity: 509 GW

- Non RE Capacity: 334 GW
- RE Capacity: 175 GW
- Solar PV Capacity: 100 GW
- Peak Demand: 235 TWh
- Peak Demand met: 235 TWh

- 20% of total installed capacity
- 34% of total installed capacity

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*After addition of 69 MW under construction non RE capacity (DG sets and captive power plants have not been considered in this figure)

Break-up:
- Coal: 50 GW,
- Gas: 4.34 GW,
- Hydro: 11.8 GW,
- Nuclear: 2.8 GW
Impact on Coal/gas based Plant (Flexible Operation and Damage Mitigation)
Impact of Cycling on Thermal Plants

What is Cyclic operation?

- Start up/Shut down (Hot/Warm/Cold)
- On load cycling (LL1, LL2, LL3)
- High frequency load variations (RGMO/AGC)

• Thermal fatigue combined with creep is the main cause of damage.
• Cyclic load variations within SH/RH temp. control range may be tolerable
• Start/stops are the severest in terms of life consumption
Cost to Cycle a Unit

TYPICAL CYCLING COST FOR A 500MW COAL FIRED POWER PLANT (USA) (COST ARE SHOWN IN 2008 DOLLARS) ,SOURCE:- INTERTEK APTECH

Warm and cold starts are the most damaging for units.

Load following up to technical minimum is the least damaging.

<table>
<thead>
<tr>
<th></th>
<th>Load follow down to 180MW</th>
<th>Hot Start</th>
<th>Warm Start</th>
<th>Cold Start</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water chemistry and manpower support</td>
<td>0</td>
<td>0.6</td>
<td>2.3</td>
<td>6.9</td>
</tr>
<tr>
<td>HR</td>
<td>0.5</td>
<td>2.1</td>
<td>2.3</td>
<td>2.6</td>
</tr>
<tr>
<td>APC</td>
<td>0.5</td>
<td>4.4</td>
<td>9.4</td>
<td>12</td>
</tr>
<tr>
<td>Start up fuel</td>
<td>0</td>
<td>8.5</td>
<td>17.8</td>
<td>26.8</td>
</tr>
<tr>
<td>Forced outage</td>
<td>3.9</td>
<td>25.1</td>
<td>26.9</td>
<td>40.2</td>
</tr>
<tr>
<td>Maintenance and capital</td>
<td>8.9</td>
<td>53.2</td>
<td>57</td>
<td>85.4</td>
</tr>
</tbody>
</table>
## Components Vulnerable to Cycling

| Thick wall components                              | Casting such as turbine valves and casings  
|                                                    | Turbine Rotor  
|                                                    | Thick walled vessels  
|                                                    | MS, CRH, HRH headers (especially Y-piece section)  
| High temperature component                        | Superheater, Reheater  
|                                                    | Ties used to support SH, RH tubing  
|                                                    | Tube to header joints etc.  
|                                                    | Gas duct work  
| Corrosion and scaling prone component              | Water wall tubing at attachments (wind box, corner tubes, wall box opening, buck stay)  
|                                                    | Heater tube  
|                                                    | Condenser tube  
|                                                    | Welded joints  
| Degeneration of insulation due to thermal transients| Generator insulation  
|                                                    | Transformer insulation  
|                                                    | Insulation of HV drives (FD, ID, PA fans, mills motor)  

## Strategies for Mitigating Flexible Operation Damage

| Operation Philosophy | ☑ Sliding pressure operation  
| | ☑ VFD for main cycle and Aux. equipment  
| | ☑ Stringent water chemistry control  
| Two shift operating practice | ☑ Regular check up of oil guns for light up without delay  
| | ☑ Reduce start up time by advance preparation  
| Avoid wide thermal transients | ☑ Avoid any such operation which can lead to thermal shock or fatigue like sending cold water in hot economiser  
| | ☑ Standby equipments maintained in warm up condition  
| Modification for cycling | ☑ Natural circulation boilers can be fitted with off load circulating system to eliminate tube to tube temperature difference  

**Flexibilisation : New Design / Modification**

**Boiler**
- Steam flow redistribution and metallurgy improvement in SH/RH
- Improvement in selected critical and degraded expansion joints
- Improved material for APH basket making it capable of operating in wet flue gas region
- Automatic pressure control on roll and race to adjust grinding pressure of mill
- Smart soot blowing
- Advanced tilt mechanism
- Improved automated boiler drains
- Introducing ball and tube mills

**Turbine**
- Turbine heating and electric blankets
- Modification to sliding pressure mode
- Using Shrink ring on HP inner casing in place of joint flange bolt Design of HPT
- Converting Throttle governing to Nozzle governing
- Welded rotor design for faster ramp rate and improved startup time
Impact of Variable Renewables on Grid and its Mitigation
Germany: The Green Energy Leader

Germany: Electricity sector

<table>
<thead>
<tr>
<th>Data</th>
</tr>
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<tbody>
<tr>
<td><strong>Continuity of supply</strong></td>
</tr>
<tr>
<td>0.2815 hrs (16.89 min) interruption per subscriber per year</td>
</tr>
<tr>
<td><strong>Installed capacity</strong></td>
</tr>
<tr>
<td>171.566 GW[1]</td>
</tr>
<tr>
<td><strong>Share of fossil energy</strong></td>
</tr>
<tr>
<td>69.5% (2015)[2]</td>
</tr>
<tr>
<td><strong>Share of renewable energy</strong></td>
</tr>
<tr>
<td>31.5% (2015)[2]</td>
</tr>
<tr>
<td><strong>GHG emissions from electricity generation (2013)</strong></td>
</tr>
<tr>
<td>363.7 Mt CO₂ [631.4 TWh × 576 g/kWh]</td>
</tr>
<tr>
<td><strong>Average industrial tariff (US$/kW·h, 2013)</strong></td>
</tr>
<tr>
<td>medium: 20.60[3]</td>
</tr>
</tbody>
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Electricity by source in 2014

- Nuclear: 91.8 TWh (17.2%)
- Brown coal: 140.7 TWh (20.4%)
- Hard coal: 110.1 TWh (20.4%)
- Natural gas: 33.9 TWh (6.4%)
- Wind: 51.4 TWh (9.7%)
- Solar: 32.8 TWh (6.2%)
- Biomass: 53 TWh (10.0%)
- Hydro: 18.5 TWh (3.5%)
Even as Germany adds lots of wind and solar power to the electric grid, the country’s carbon emission is rising. Will the rest of the world learn from its lesson?

In wake of grid stability, variability of renewables forces Germany to keep other power plants running and produce more electricity than its need.

**Total Installed Capacity : 171 GW (2015)**

- **Non RE Capacity**: 88
- **RE Capacity**: 83
- **Solar PV Capacity**: 38

48% of total installed capacity
Lessons to learn from Germany

With 48% of its installed capacity as RE, Germany has successfully demonstrated the way to integrate RE into its grid.

Although, of late, it has been, experiencing the heat of excessive RE integration, Success of Germany has been mainly due to:

- Robust power grids
- Flexible operation of coal and nuclear plants (and to a lesser extent gas and pumped hydro)
- Better design of the balancing (ancillary) power markets, to make them more effective, faster, and open
- Better system control software and day-ahead weather forecasting
- Modest technical improvements to local-level distribution systems
- Exports of power to neighboring countries
**Strategy to Improve overall Grid Operation Efficiency**

**Upgradation of Grid Technology**
Centralized RE forecasting mechanisms need to be tightly integrated with system operations. Advanced decision-making and control systems need to be implemented to enable system operators to respond significantly faster to changed grid conditions.

**Upgradation of Grid Protocols**
Scheduling occurs on a day-ahead basis while dispatch occurs on a 15-minute basis. System operations technologies and protocols need to be updated to enable five-minute scheduling with automated incorporation of RE forecasts. This will also lower ancillary service requirements and hence the overall cost to consumer.

**Promote Flexible Demand & Supply Resource**
Power systems, especially those with a high share of RE, require access to sufficient flexible resources (e.g. gas turbines, hydroelectricity, flexible coal units with AGC etc.) India has 22% of total installed capacity of these flexible resources (gas and hydro power).

**Expand Balancing Areas**
More and more units should be brought under AGC, so that effective ramp rate requirement on individual units can be minimised and better load frequency control can be obtained.
The Imperatives

As the all India PLF for dispatchable generation is bound to reduce with renewable integration, the threshold PLF for fixed cost recovery may accordingly be reduced.

Units catering to variable load requirement may be sufficiently compensated through special tariffs.

Cost of VRE is not a true indicator of the cost of electricity to consumer because it imposes additional cost on dispatchable generation.

There should be a farsighted policy in picture to ensure the grid stability and reduction of over all system operation cost (grid as well as generating units) in long run by reducing the extent of cycling on coal based generating stations as far as possible.
Conclusion

- Large-scale RE has been successfully integrated into grids world over
- No reported issues due to often talked about PV variability, harmonics, DC current injection, anti-islanding failure or protection coordination
- Bulk energy storage has not been necessary for variable generation integration in many countries with significant RE penetration
- Falling prices of PV electricity should not be seen in isolation, it is adding to the cost of conventional electricity (cycling costs, under utilization) and the cost of transmission network
- Regulation will have to play a major role in integration of RE for the sake of promoting Green Energy

Thank You