Flexibilisation of Thermal Stations - NTPC's Approach

Anjan Kumar Sinha
NTPC Ltd
Present Installed Renewable Capacity

Total Installed Capacity=329 GW
(As on 30.06.2017, source: CEA)

Installed RES=57 GW
(As on 31.06.2017, source: MNRE)

- RES, 58, 17.7%
- Gas, 25, 8%
- Diesel, 0.91 GW
- Nuclear, 7, 2%
- Hydro, 45, 14%
- Coal, 194, 59%
- Biomass, 8, 2%
- Solar PV, 13, 22%
- Wind, 32, 56%

Copyright © 2016 NTPC Limited All Rights Reserved.
India’s Intended Nationally Determined Contribution (INDC) aims to base 40% of the total installed power generation capacity on non-fossil fuel resources by 2030 with international support on technology transfer and financing. This includes Government of India’s ambitious target of achieving 175GW of RE by the year 2022.

175 GW Renewable Integration Plan by 2022

- **Biomass**: 10GW
- **Small Hydro<25MW**: 5GW
- **Wind**: 60 GW
- **Solar PV**: 100 GW

100 GW solar PV Integration plan

- **Utility Scale solar Plant**: 40%
- **Decentralised Roof top**: 40%
- **Ultra Mega Solar Plant**: 20%
Non variable renewable energy generation refers to sources of electricity that can be generated at the request of power grid operators or of the plant owner. Since wind power and solar power cannot be controlled by operators, so these are termed as Variable Renewable Energy (VRE) sources.

- **Non Variable RE**
  - Biomass Power
  - Small Hydro <25 MW
  - Geothermal
  - Solar with storage
  - Hybrid Solar Thermal

- **Variable RE**
  - Wind Power
  - Solar Power
  - Tidal Power
Peculiarities of Variable Renewable power

- Variability
- Uncertainty
- Geographically Confined
- Low inertia

**Impact on System**
- 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 hence increased system operation cost
- Increase in transmission cost due to all above factors

**Impact on existing 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
Today’s Scenario: Cycling without Renewable Integration

- In last five years, conventional capacity was added rapidly but in same proportion electricity demand did not rise, which caused lower PLF and lower peak to installed capacity ratio.

- It is likely to fall further due to rapid addition of RE.
- Installed capacity ~ 523 GW *
- Peak hour ramp rate is 247 MW/min.
- Ramping down rate with sun rise is highest i.e. 368 MW/min.
- Duck belly demand to peak demand ratio is 61% which will lead to partial loading and two shifting i.e. cycling of fossil based power plants and hence low PLF.

Source: CEA
NTPC's present level of Flexible operation

923 MW
877 MW
Ramp-0.55 %
Group NTPC's Approach towards Flexibility

OPTION-1

- **Flexible**: 52.6 GW Capacity available for flexible operation
- **Flexible if scheduled in peak hrs**: 11 GW >25 years
- **Partly Flexible**: Must Run
- **Solar**: 10000+15000 MW
  - Operation in peak hours only in lean season
- **Hydro**: 1611 MW
  - Maximum flexibility band available: Coal-25 GW (with minimum operation 55% PLF)
  - Gas-5.5 GW
  - Hydro-1.6 GW

Copyright © 2016 Your Company All Rights Reserved.
11+ GW Capacity available for flexible operation

Flexible

Partly Flexible

Must Run

Flexible if scheduled in peak hrs

To operate as Base Load

Coal-6367 MW

To prepare for flexibility

11 GW >25 years

Gas-5984 MW

Operation in peak hours only in lean season

Hydro-1611 MW

Time of the day

Solar-10000+15000 MW

Maximum flexibility band available: Coal-25 GW (with minimum operation 55% PLF)
+ Gas-5.5 GW, Hydro-1.6 GW
Flexibilization: Need for Benchmarking

- Defining from different perspectives
- Metrics
- Quantifying
- Sources, options
- Preparedness for Coal based plants
- Regulatory framework
- Market structure and mechanisms

- Quantity (MW) which is required to be kept in reserves
- Turndown - Minimum boiler load:
- Cycling capability (start-up to full load best achieved time taken)
  - Very hot start-up: <1h
  - Hot start-up: 1.5–2.5 h
  - Warm start-up: 3-5 h
  - Cold start-up: 6-7 h
- Ramp rate
  - 30-50% load: %/min
  - 50-90% load: %/min
  - 90-100% load: %/min

We can assign a flexibility index for each unit based on the above parameters
Operationalisation of flexibility

- **Frequency Droop**
  - (RGMO/FGMO)
- **Spinning reserves**
  - DSM
- **Tertiary reserve**
  - Ancillary Service
- **Operating reserves**
  - Operation till Tech. Min.
- **Capacity reserves**
  - RSD

**Demand Response**

- **0-10 seconds**
- **5 min to 30 min**
- **15 min to hrs**

- **Studies carried out at NTPC Dadri (490 MW)** for: Flexible control Retrofitting
  - Condenser Throttling
  - The ramp rates achieved: 3.6% at lower load ramp size of 10%, and 5% at higher loads
- **Pilot successfully completed at NTPC Dadri (490 MW)** for on AGC for operationalisation of Spinning Reserves
  - Another Pilot to be carried out at NTPC Simhadri
- **Ancillary Service Regulation**
  - Technical Minimum at 55%
  - Part Load compensation based on Heat Rate, APC & Sp. Oil
  - Forecasting
- **Fleet wide monitoring**
  - Reducing stresses during start-up
  - Reducing the level of minimum loads
  - Part Load optimization
  - Structured APC Reduction Programme
  - Tuning of auto-control loops
  - Sliding Pressure Operation

**Capacity Building**
Design and Incentivize cost effective power system based on economic evaluation

Cost Drivers

- Profile costs – because of variability
  - There is a requirement of back-up capacity
  - Decrease in full load hours of capital intensive dispatchable power plants
  - Frequent Ramp up/down
  - VRE supply may exceed demand and thus over produce
- Balancing Costs- because of uncertainty.
  - Day ahead forecast errors cause unplanned intra day adjustments of dispatchable power plants and require operating reserves to respond within minutes to seconds
- Grid related costs
  - VRE located far off from load centres- requiring investments in transmission
  - Cost of congestion management

Economic Evaluation of Cycling Costs of Thermal Units:

- Modification cost required for making units cyclic ready
- Loss of useful life
- Increased O&M expenses
- Start up fuel cost
- Loss of availability due to Forced Outages
- Poorer heat rate
- Increased Aux. Power Consumption
System Levelised Cost of Electricity: German Experience

Effect of increasing share of wind on System LCOE

Effect of increasing share of solar on Profile Cost

Typical costs (approx.), depending on grid penetration of VRE:
Grid Costs - 3 to 15 Euro /MWh
Balancing Costs - 3 to 6 Euro /MWh

<table>
<thead>
<tr>
<th></th>
<th>Solar</th>
<th>Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>3.6%</td>
<td>9.7%</td>
</tr>
<tr>
<td>2022</td>
<td>19.1%</td>
<td>11.4%</td>
</tr>
</tbody>
</table>

Source Weblinks:
(2) http://www.internationalenergyworkshop.org/docs/IEW%202013_4E1Ueckerdt.pdf
### System Levelised Cost of Electricity: Inference

- At high level of solar integration, for example at 25%, even if the solar tariff offered is ZERO, the cost at system level to the consumer is expected to be of the order of 10 Euro Cent per kWh (Rs. 7-8 per kWh).
- Similarly for wind penetration level of 40%, if the wind tariff offered is ZERO, the cost at system level to the consumer is expected to be of the order of 7 Euro Cent per kWh (Rs. 4 - 5 per kWh).
- Non variable renewable energy such as hydro, hydro with pumped storage, biomass, solar thermal, solar with storage, geothermal, waste to energy do not have such hidden system costs.
- The cost of electricity from common non variable renewable sources are as below:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Non Variable Renewable energy</th>
<th>Typical tariff (Rs./kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Biomass</td>
<td>7 -8</td>
</tr>
<tr>
<td>2.</td>
<td>Hydro/Small Hydro</td>
<td>4 – 6</td>
</tr>
<tr>
<td>3.</td>
<td>Geothermal</td>
<td>8-10</td>
</tr>
<tr>
<td>4.</td>
<td>Solar Thermal</td>
<td>12</td>
</tr>
<tr>
<td>5.</td>
<td>Solar with storage</td>
<td>12 - 14</td>
</tr>
<tr>
<td>6.</td>
<td>Pumped storage</td>
<td>7 - 9</td>
</tr>
</tbody>
</table>

- The cost to consumer from non variable RE is much less than the cost of solar and wind even with sharp fall in their prices. Therefore, they may be expedited to achieve full potential, in the benefit of consumers and existing infrastructure.
It is Time For Flexible Generation Management

Actual Cost of Generation (Cyclic Load) = Cost of generation (Base load) + Integration Cost

Time to learn how to minimise equipment damage and assess the true cost of cycling to find out actual cost of generation.

True cost of operation arrives often years later. So, if cost of cycling is unknown making profits becomes a matter of luck rather than good management.

Find out what, in terms of fuel cost and cycling cost, is the least expensive combination of units to meet system load?

Knowing cycling cost would help in deciding either shut down unit (and incur cyclic damage) or to operate at minimum load.

High fuel cost units (poor merit order) may require to cycle more than low fuel cost units, so they should be designed accordingly for heavy cycling duty. Old units with suitable cyclic modification, if required, can also be allocated for cyclic duty.
Preparation for for Flexibilisation

- Flexibilisation Study carried out at two of NTPC stations (Dadri and Simhadri) under IGEF
  (A) Demonstration of technical and economic feasibility
  (B) Analysis of legal framework conditions
  (C) Capacity building of coal fired power plants operators
- Study at Two stations (Unchahar and Farakka) for the cost and impact of cyclic loading is scheduled to start in Sept'2017.
- Study of two NTPC Stations under USAID for flexibilisation is planned.
- Study at a few stations by OEMs.

- Test runs carried out at different units to determine the existing flexibilisation capability and potential limitations
  Each start-up is monitored in Antariksh by a team of experts and feedback for improvements is provided to the station.
  Analysis of operating data for full and partial load situations
  Determining the static and dynamic stability of the components
  Determining the stability for all downstream heating components
- All new units with increased flexibilisation capability, with advanced alloys, thinner materials capable of faster temperature rise and lower stresses.
Way Forward....

The integration of a significant share of variable renewables into power grids requires a substantial transformation of the existing networks in order to:

a) Policy orientation towards minimising **levelised system cost of electricity** rather than looking at **RE tariff in isolation**. This requires a **market redesign**.

b) Promote and **prioritise non Variable RE** such as Hydro, Biomass, Geothermal, Solar with storage, Solar Hybrid

c) Participation of maximum number of units for **AGC**, so that effective ramp rate requirement on individual units can be minimised and better load frequency control can be obtained.

d) Introduce energy storage capacity to store electricity from variable renewable sources when power supply exceeds demand and aimed at increasing system flexibility and security of supply.

e) Centralized RE forecasting mechanisms need to be tightly integrated with system operations. Advanced decision-making and control systems need to be implemented that enable system operators to respond significantly faster to changed grid conditions.
Integration of variable renewable energy (VRE) impacts both grid stability as well as other generating units connected to grid, thus increases cost of transmission and generation and finally cost to consumer.

However, these cost can be reduced by adopting suitable operation practices, mitigation technologies, a better policy in picture, though it can not be eliminated totally. After all, we have to pay for better environment.