POTENTIAL APPLICATIONS OF SHORT-TERM SOLAR, WIND GENERATION FORECASTS & DYNAMIC LINE RATING IN INDIAN POWER SYSTEM

Arindam Roy
National Institute of Wind Energy
Chennai, India

Indradip Mitra
GIZ GmbH
New Delhi, India
CURRENT UTILIZATION OF VRE GENERATION FORECAST IN INDIAN POWER SYSTEM

- Broadly, two distinct entities have been mandated/required to perform Variable Renewable Energy (VRE) generation forecast in the power system – System Operators and VRE units or QCAs.
- VRE units or QCA can perform generation forecasting with the primary objective of scheduling and accounting of their generation. Deviations can be settled based on forecasted schedule.
- System operators can perform aggregate VRE generation forecast of its control area, through dedicated Renewable Energy Management Centers (REMCs), for maintaining grid security.
### Proposed Additional Applications of Forecasting & Dynamic Line Rating (DLR)

<table>
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<th>Entity</th>
<th>Usage</th>
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| Inter-State/ Intra-State VRE Units, Ultra Mega Power Parks, Qualified Co-ordinating Agencies | Trading in power exchange  
Primary ancillary reserve providing capability  
Reactive power ancillary service potential  
Secondary ancillary service providing capability  
Optimization of power and reserves trading, for profit maximization |
| Regional Load Dispatch Centre, State Load Dispatch Centre              | Ramp event forecasting  
Reactive power potential from VRE units in control area  
Day ahead congestion forecast & intra-day congestion management with DLR |
| DISCOM                                                                | Residual load calculation  
Reactive power potential of control area  
Scheduling and dispatch of DISCOM grid entities |

### Immediate future
- Trading in power exchange
- Primary ancillary reserve providing capability
- Reactive power ancillary service potential
- Secondary ancillary service providing capability
- Optimization of power and reserves trading, for profit maximization

### Medium term future
- Ramp event forecasting
- Reactive power potential from VRE units in control area
- Day ahead congestion forecast & intra-day congestion management with DLR
- Day ahead dimensioning and procurement of reserves
- Using DLR in day-ahead congestion forecast

### Long term future
- Residual load calculation
- Reactive power potential of control area
- Scheduling and dispatch of DISCOM grid entities
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- Immediate Future
- Medium term future
- Long term future
Hourly or 15 minute point generation forecasts by VRE units and QCAs for trading in power exchanges.
IMMEDIATE FUTURE

- Residual load ramp detection & quantification using aggregate VRE generation forecast, load forecast and flexibility metrics, by System Operators (LDCs).

\[ |P(t + \Delta t) - P(t)| \geq PR \]

\[ PRR = \frac{|P(t + \Delta t) - P(t)|}{\Delta t} \]

Graph showing Residual Load forecast parameters: Ramp duration, Ramp magnitude, Ramp rate.
**IMMEDIATE FUTURE**

- **Forecasted Residual load** calculation of DISCOM grid by utilizing aggregate VRE generation forecast.

![Diagram](image_url)
Wind turbine & solar PV based VRE units & QCAs can provide primary frequency reserve and reactive power ancillary services.

“Firm” active power reserve & reactive power potential availability needs to be calculated from generation forecasts for participating in ancillary services market.

Reactive power service can be provided by different strategies – Droop control based on local voltage, centralized set-point control, etc.

Aggregate VRE active power generation forecast and converter capacity estimate can be used by LDCs and DISCOM control centres for estimating the reactive power potentially available from VRE units & QCAs.
MEDIUM TERM FUTURE

- Day ahead congestion forecast and intra day congestion management with DLR, by System Operators (load dispatch centres).

- DLR can be calculated based on maximum allowable conductor temperature $T_c^{\text{max}}$, ambient temperature $T_a$, convective cooling $q_k$, wind speed $V_s$, wind direction $V_D$, evaporative cooling $q_e$, precipitation $P$, humidity $H$, atmospheric pressure $P_a$, solar radiation heat gain $q_s$ and corona heat gain $q_c$.

$$I_{\text{max}} = \sqrt{q_c(T_c^{\text{max}} - T_a \cdot V_s \cdot V_D) + q_k(T_c^{\text{max}} - q_e(P,H,P_a) - q_s - q_k)}$$

- Congestion situations can be predicted both on day-ahead & intra-day basis. $F_{l-k}$ active power flow, $GGDF$ generalized generation distribution factor, $F_{l-k}^{\text{max}}$ maximum active power flow.

$$F_{l-k} = \sum_{\text{gen}} GGDF_{l-k,\text{gen}} P_{\text{gen}} + \sum_{g \in \text{Conv.}} GGDF_{l-k,\text{g}} P_{g,\text{g}} + \sum_{w \in \text{VRE}} GGDF_{l-k,\text{w}} P_{w,\text{w}} \leq F_{l-k}^{\text{max}}$$
At high VRE penetration into the grid, it may become necessary for VRE units & QCAs to start providing secondary ancillary services too.

The ‘firm’ secondary & primary reserve potential can be calculated based on lower interval of VRE generation forecast at specified confidence level. Reserve availability offer can be declared to the System Operator based on this lower interval value.

QCAs and VRE units can utilize different optimization strategies for maximizing their revenue from power trading and ancillary services market.

VRE forecast error show dependency on VRE generation level, and is dynamic in nature. Dynamic day ahead reserve procurement can be done by LDCs (System Operators) to improve the reliability.

Reserves can be procured by LDCs through (a) explicit dynamic day ahead dimensioning or (b) implicit reserve procurement through stochastic unit commitment.
LONG TERM FUTURE

- For explicit dimensioning of reserve, current day ahead generation forecast, historical day ahead generation forecasts and their corresponding forecast errors can be used to estimate the forecast error distribution for the next day.

- Day ahead forecast error distribution can be used to estimate the dynamic reserve requirement as a result of the volatility of VRE units.

\[
\text{prob}_{\text{imbalance}} = \text{prob}_{\text{loadForecastError}} \times \text{prob}_{\text{loadFluctuation}} \times \text{prob}_{\text{VREForecastError}} \times \text{prob}_{\text{VREFluctuation}} \times \text{prob}_{\text{generatorOutage}}
\]

- Reserve requirement can be quantified in order to meet the imbalance for specified confidence levels.

- For implicit reserve procurement through stochastic unit commitment, different VRE generation forecast scenarios can be considered.

- Optimal reserve level, which is able to secure generation-load balance under every or most of the scenarios in a cost efficient manner, can be obtained through different optimization techniques.
LONG TERM FUTURE

- Active scheduling of distribution grid entities and injection to/drawl from the transmission grid.

- Objective of scheduling tool is to minimize the total operational cost while maintaining power balance and voltage regulation in the DISCOM grid.
THANK YOU