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

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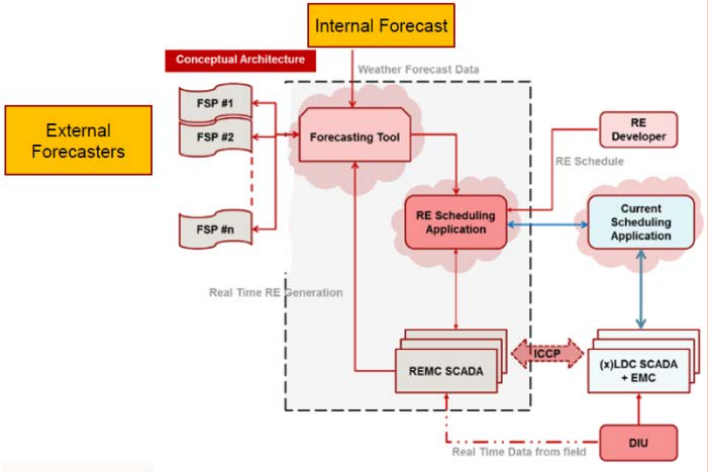
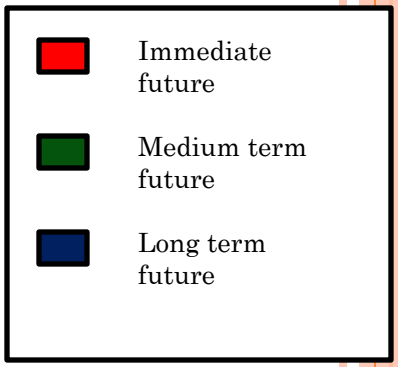
Current utilization of VRE generation forecast in Indian power system

- 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)

Entity	Usage
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
	Day ahead dimensioning and procurement of reserves
	Using DLR in day-ahead congestion forecast
DISCOM	Residual load calculation
	Reactive power potential of control area
	Scheduling and dispatch of DISCOM grid entities



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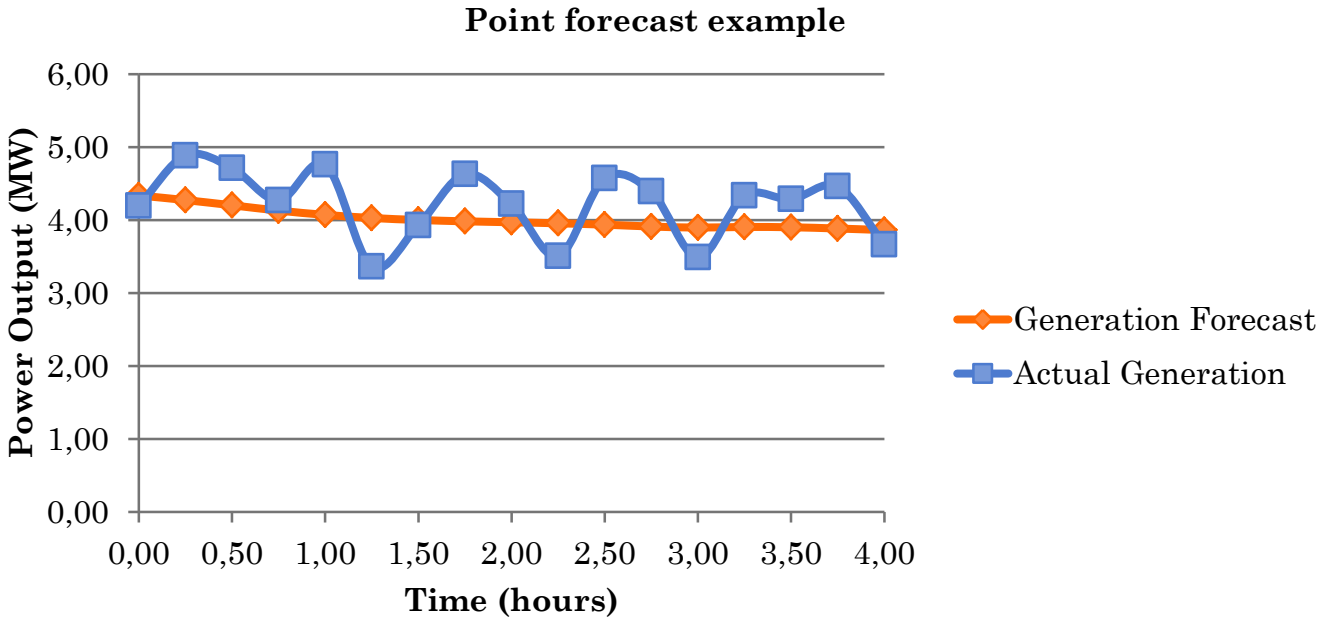
IMMEDIATE FUTURE

- Hourly or **15 minute point generation forecasts** by **VRE units and QCAs** for trading in **power exchanges**.

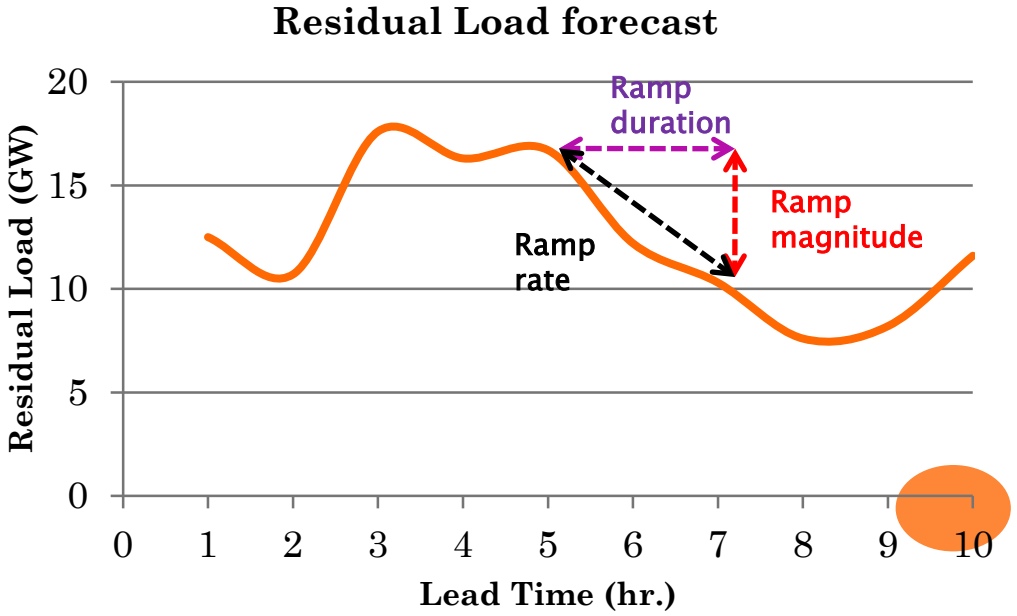


IMMEDIATE FUTURE

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

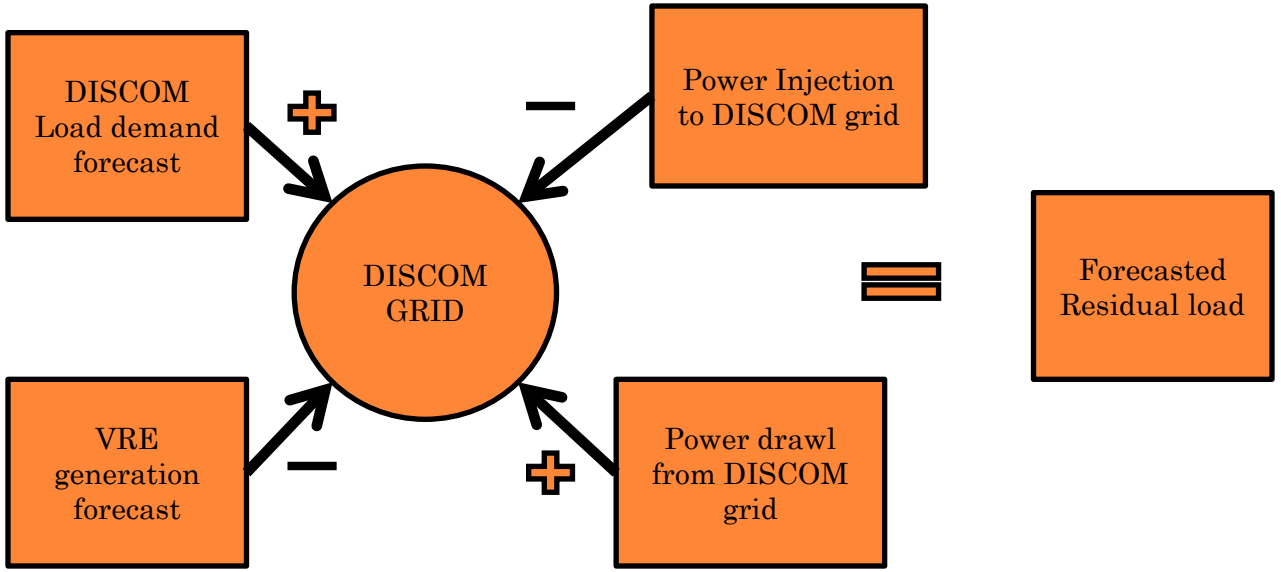
$$\left|P(t+\Delta t)-P(t)\right| \geq PR$$

$$PRR = \frac{\left|P(t+\Delta t)-P(t)\right|}{\Delta t}$$



IMMEDIATE FUTURE

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

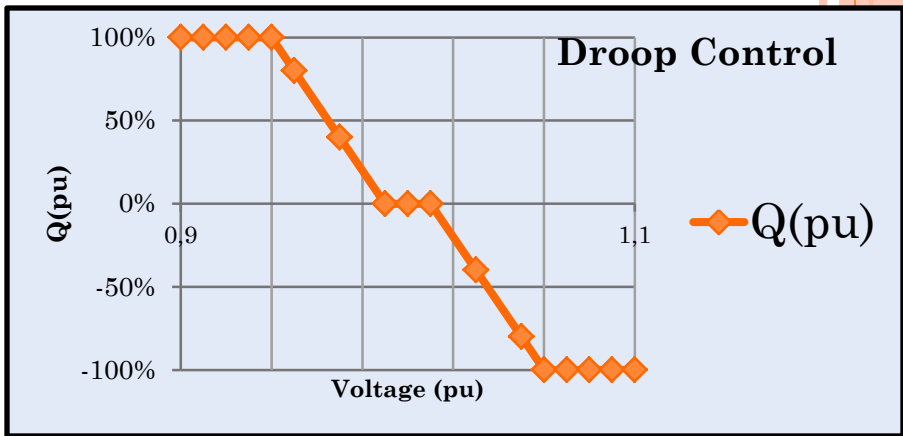


MEDIUM TERM FUTURE

- 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**.

Proportional curtailment strategy of Wind Turbine	**Constant curtailment strategy of Wind Turbine**	**Fast frequency response by Solar PV**	**Reactive power potential of VRE units**
$P_{curtailed}(t) = (1-\alpha) \times P_{available}(t)$	$P_{curtailed} = P_R$	$P_{operating} \leq P_{MPP}$ $P_{FFR} = P_{MPP} - P_{operating}$	$Q_{avail} = \sqrt{S^2_{capacity} - P^2_{available}}$

- 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

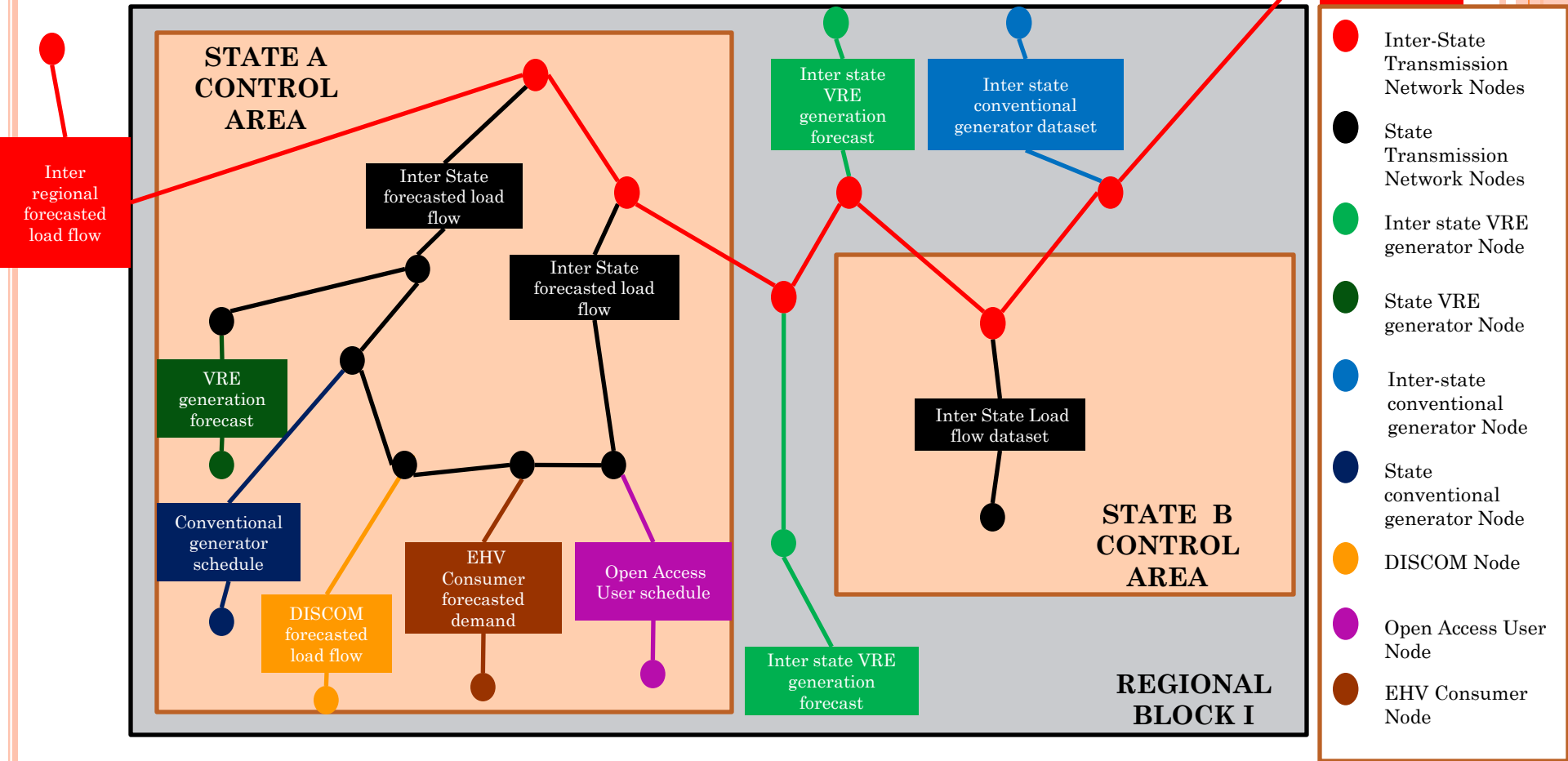
- **Day ahead congestion forecast** and **intra day congestion management with DLR**, by System Operators (load dispatch centres).
- DLR can be calculated based on maximum allowable conductor temperature T_C^{max}, ambient temperature T_A, convective cooling q_k wind speed V_S, wind direction V_D evaporative cooling q_e precipitation P, humidity H, atmospheric pressure P_a solar radiation heat gain q_s and corona heat gain q_r

$$I_{max} = \sqrt{\frac{q_r\left(T_C^{max}, T_A\right) + q_k\left(T_C^{max}, T_A, V_S, V_D\right) + q_e\left(P, H, P_a\right) - q_s - q_k}{R\left(T_C^{max}\right)}}$$

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

$$F_{l-k} = \sum_{gen} GGDF_{l-k,gen} P_{gen} \qquad \left| \sum_{g \in Conv.} GGDF_{l-k,g} P_{g,t} + \sum_{w \in VRE} GGDF_{l-k,w} P_{w,t} \right| \le F_{l-k}^{max}$$

MEDIUM TERM FUTURE



LONG TERM FUTURE

- 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

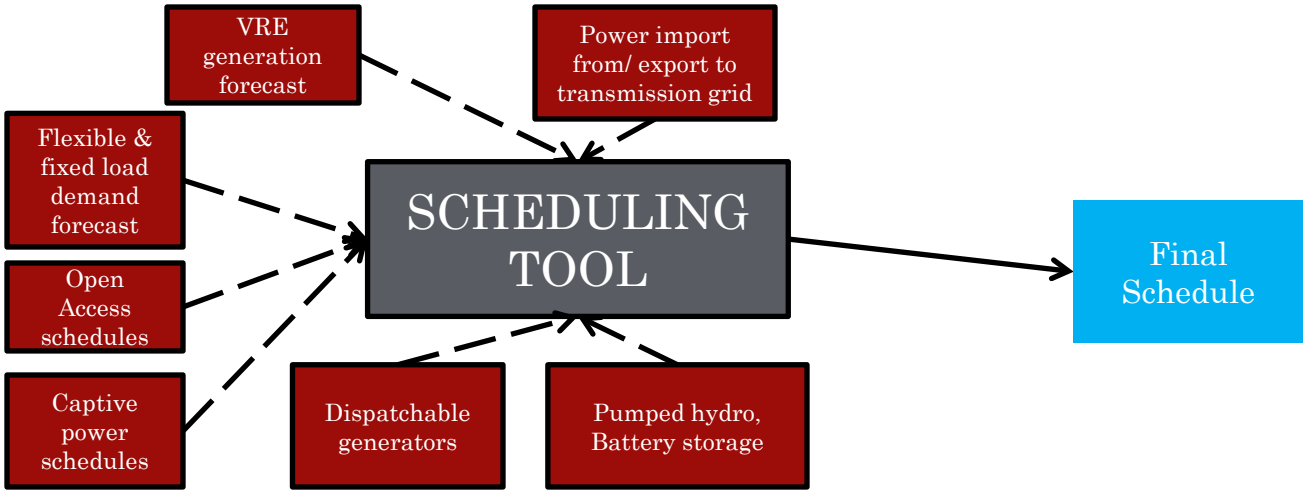
- **For explicit dimensioning of reserve**, current day ahead **generation forecast**, **historical** day ahead **generation forecasts** and **their corresponding forecast errors** can be used to **estimate** the **forecast error distribution** for the next day.
- Day ahead **forecast error distribution** can be used **to estimate** the **dynamic reserve requirement** as a result of the volatility of VRE units.

$$prob_{imbalance} = prob_{loadForecastError} \times prob_{loadFluctuation} \times prob_{VREForecastError} \times prob_{VREFluctuation} \times prob_{generatorOutage}$$

- 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