Load and RE Forecasting –

Utilization and Impact on System Operation

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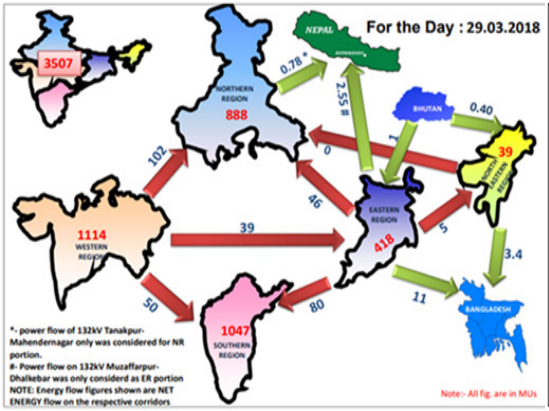
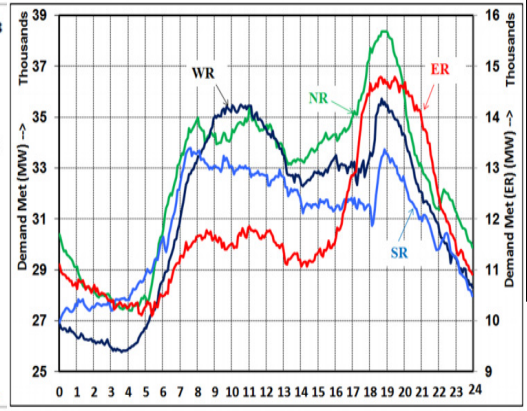
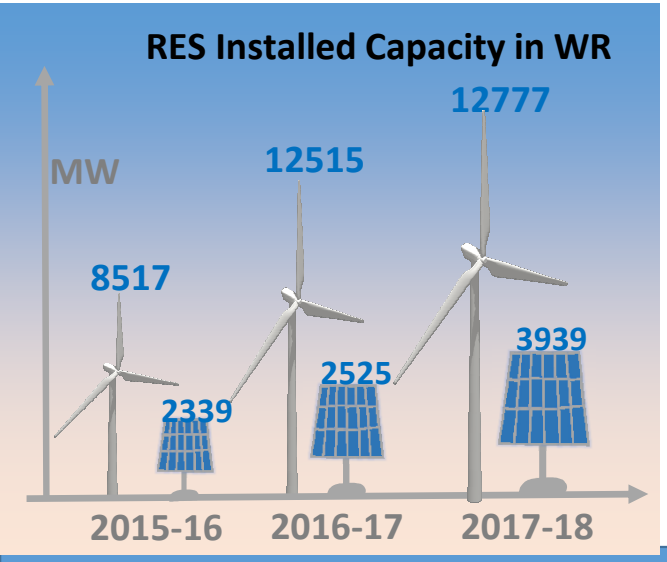
Outline

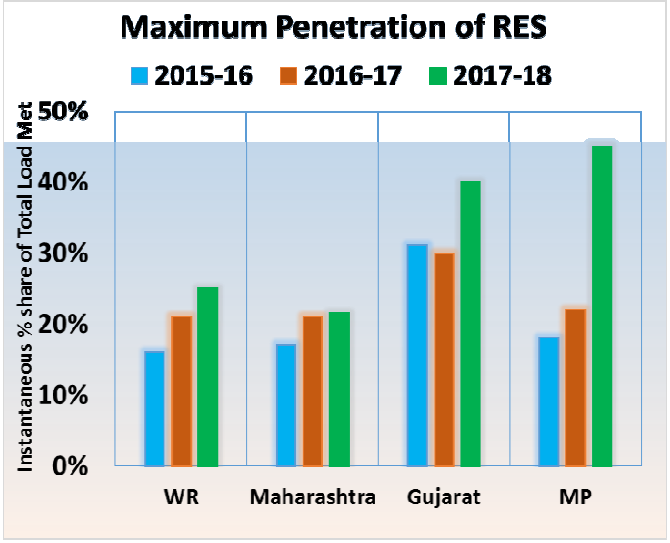
- *Introduction*
- *Characteristics of demand in Western Region(WR)*
- *Characteristics of Variable Renewable Energy(VRE) generation in WR*
- *Reserves for balancing the Grid*
- *Need for forecasting Load and VRE*
- *Regulations for Demand Estimation and RE forecasting*
- *Methodology adopted for load forecasting*
- *Case studies - load forecast error*
- *Load forecast by Forecast Service Provider(FSP)*
- *Wind forecast and experiences*
- *References*

Introduction



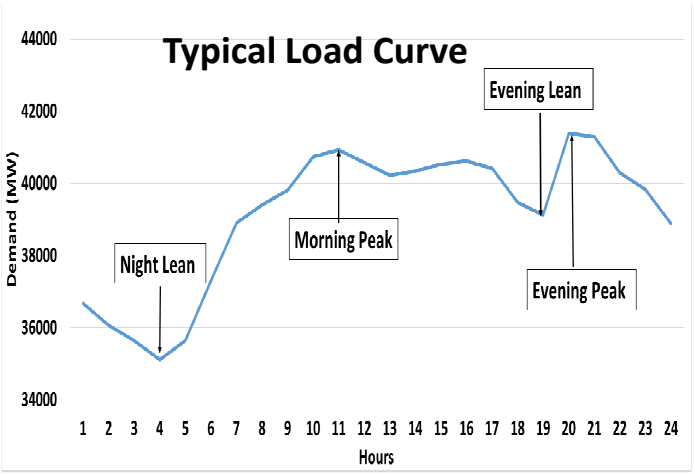


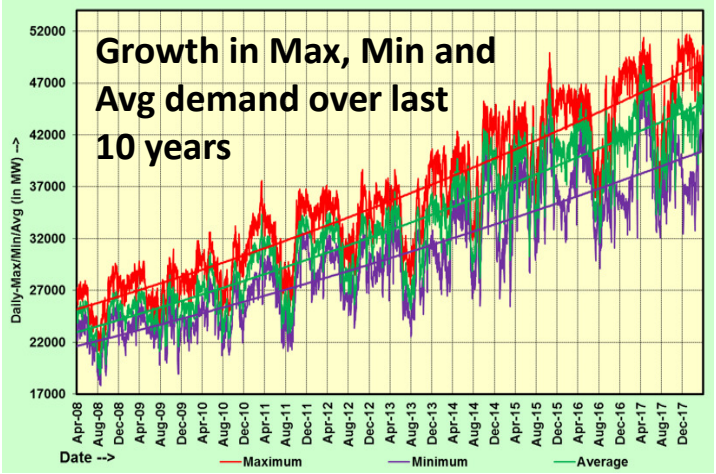


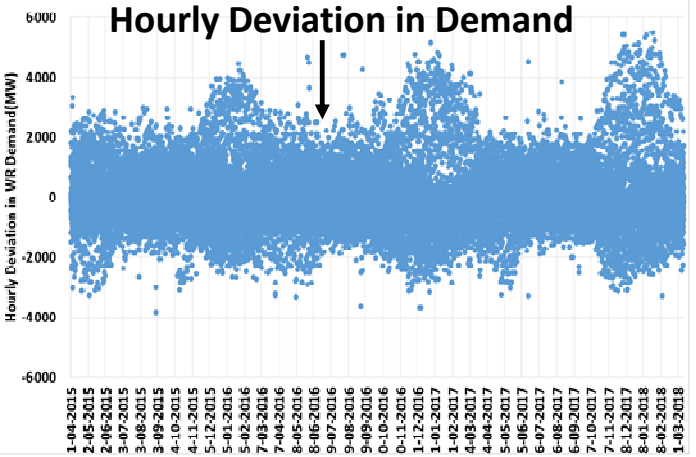


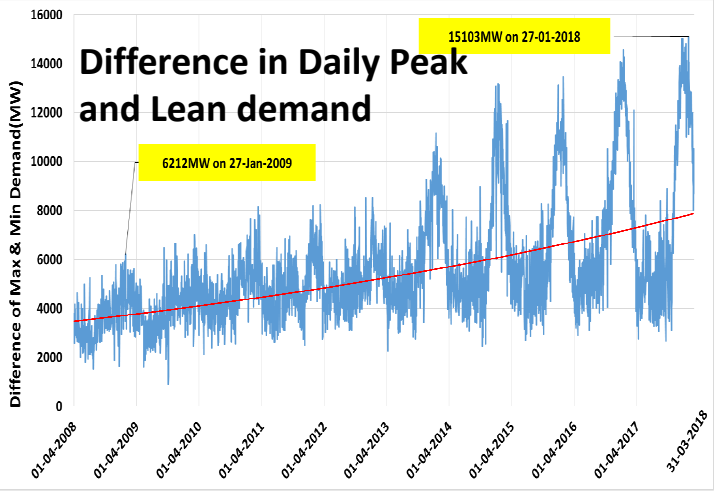
- A substantial portion of the 2022 target of 175 GW RES likely to be installed in the Western region
- Variability and uncertainty introduced by demand, wind and solar to be balanced
- Forecasting- Need of time

Characteristics of demand in WR





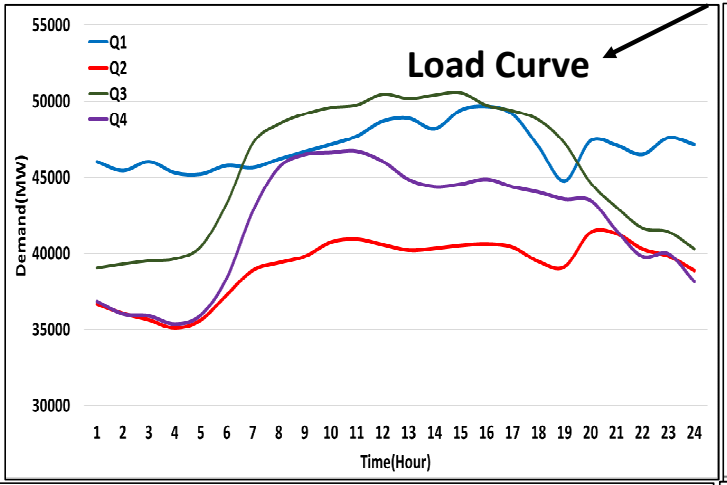


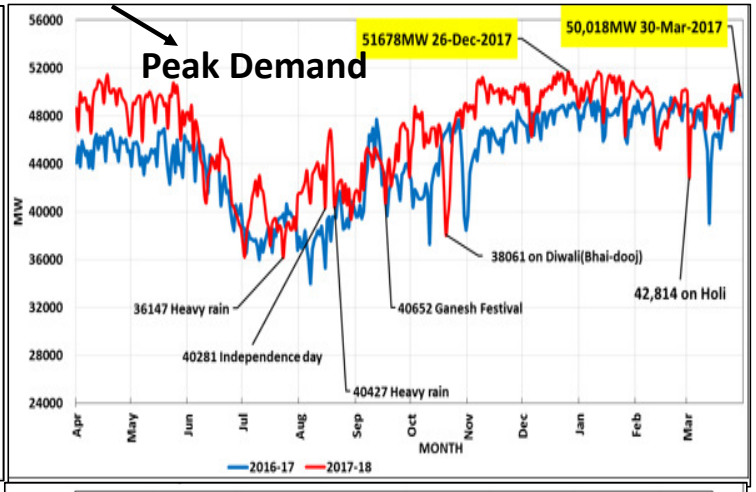


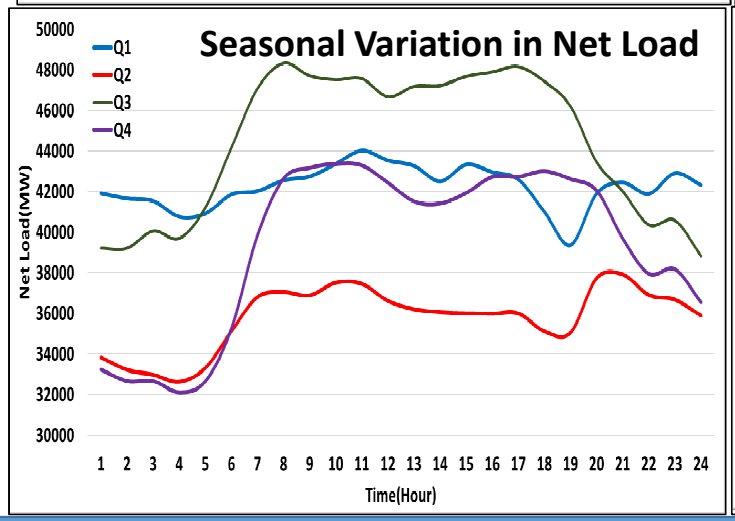
- **High variation in load curve due to weather conditions, season and due to diurnal nature of human activities.**
- **Frequent changes in schedule of generators due to large hourly variation up to 5000MW and daily variation in peak to lean up to 15000MW.**
- **Requires spinning reserves in real time handle imbalances in system.**

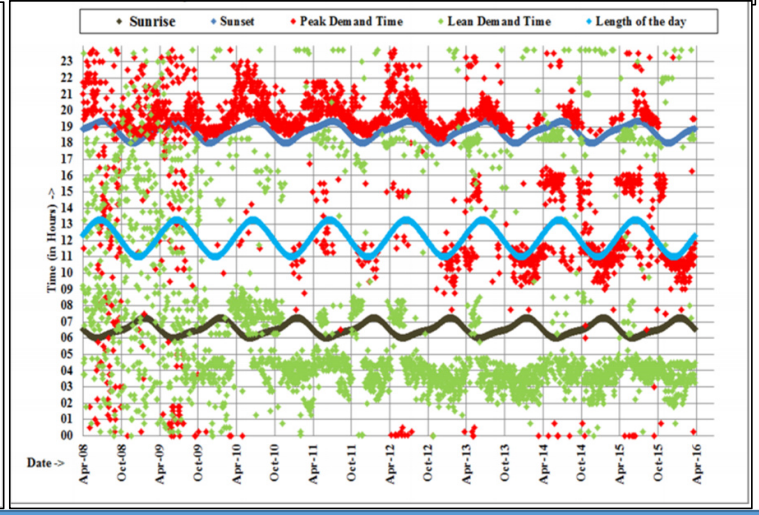
Characteristics of demand in WR contd..

Seasonal Variation



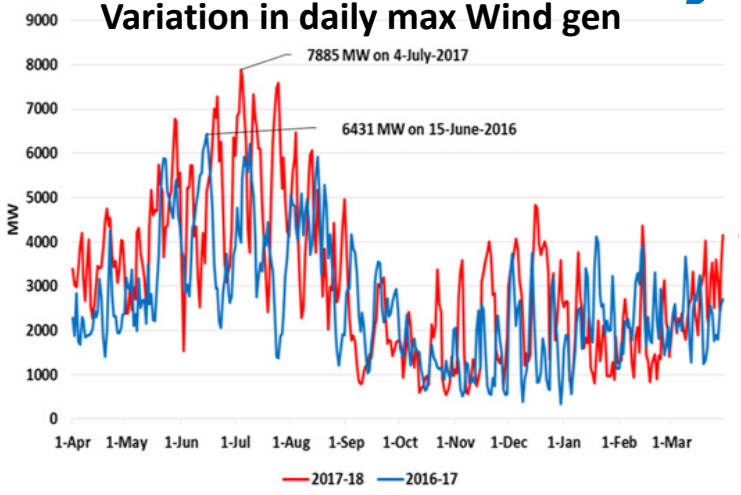


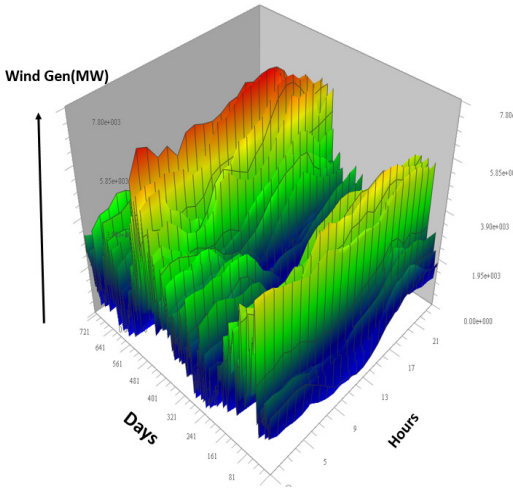




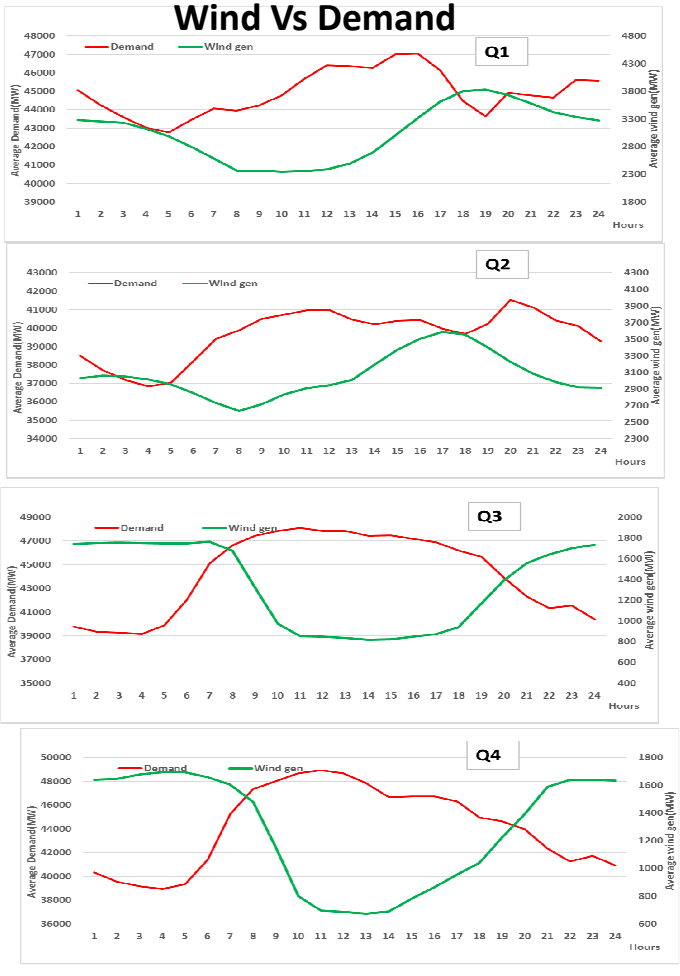
- **Demand varies with season, due to festivals, weather and different load switching in and out during the year.**
- **High Fluctuation in demand during July-September due to heavy rains in WR.**
- ***Spread of Peak and lean demand time since 2012, Peak time varying w.r.t. season.***

Characteristics of VRE generation in WR



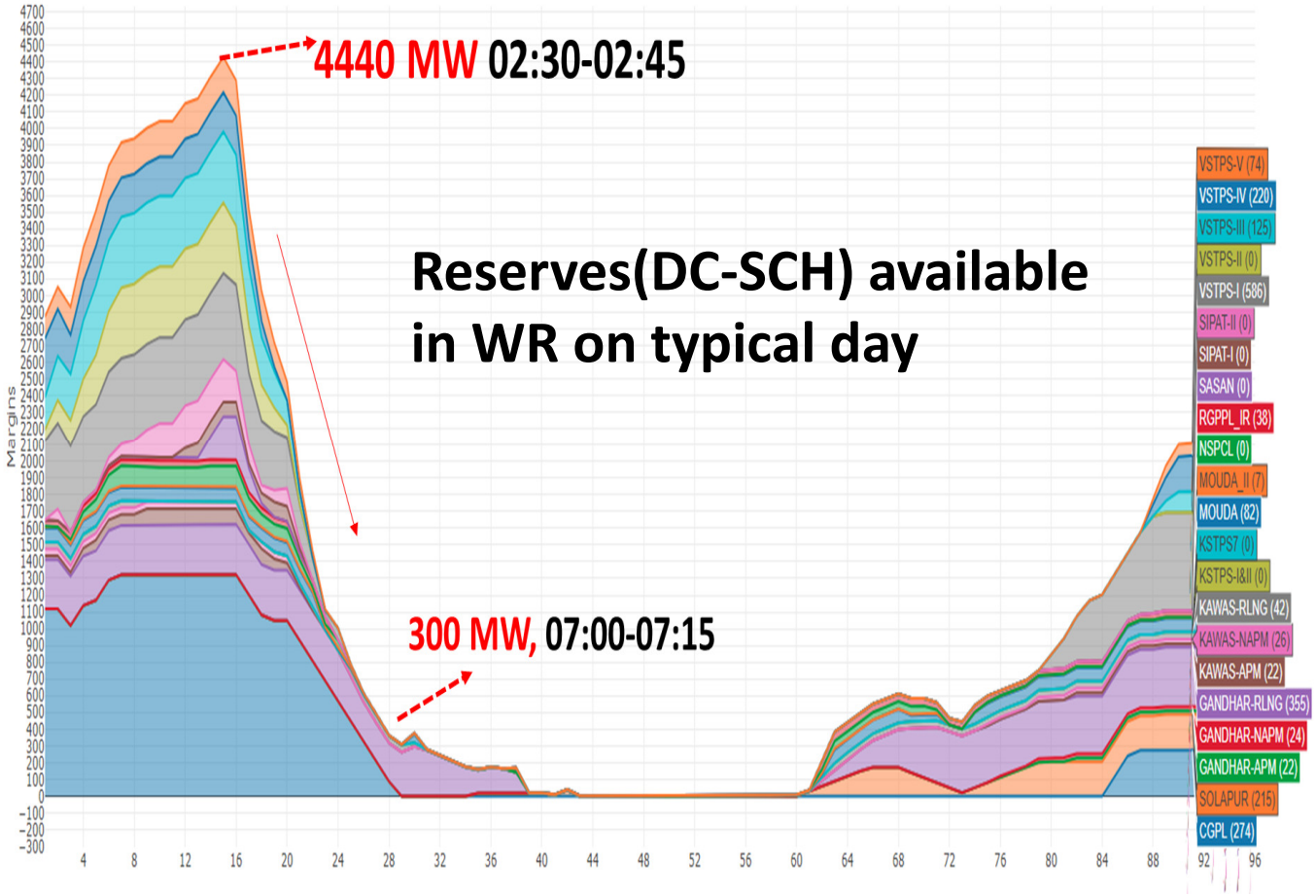


3-D Plot of Wind gen since Apr 2016



- High uncertainty in Wind generation compared to Solar generation. Solar generation supports the demand pattern.
- Wind helps in ramping down during Q1 (Apr-Jun) night time but it opposes in morning.
- Q2(July-Sept) ramps up with demand during day time and ramps down in evening.
- Wind opposes the demand in Q3(Oct-Dec) and Q4(Jan-Mar)

Reserves for balancing the Grid



- As per The National Electricity Policy(NEP) , spinning reserve of at least 5%, at national level, would need to be created to ensure grid security and quality and reliability of power supply.
- To start with, CERC mandated 800MW of Spinning reserves to be maintained in WR and approx. 4000MW in All India basis
- Reserves Regulations Ancillary Services (RRAS) being implemented by NLDC to maintain the Load-Generation balance.

Need for forecasting Load and VRE

- Complexity of the Grid
- High Variability in Demand
- Doubled uncertainty due to integrated VRE generation
- Frequent scheduling of conventional generators due to uncertainty in VRE generation.
- Optimum utilization of available generation
- Advance planning to maintain the reserves
- Proper Sale/Purchase of Power
- Mandated Regulations

Regulations for Load and RE forecasting

As per IEGC Regulation on Demand Estimation-

- **The demand estimation is to be done on daily/weekly/monthly /yearly basis for current year for load - generation balance planning.**

For implementation of RRAS to schedule the spinning reserves, As per CERC approved Detailed Procedure for Ancillary Services Operation-

- **The Nodal Agency shall forecast the daily region-wise and All India demand on day-ahead basis generally by aggregating demand forecast by the State Load Despatch Centre (SLDC) and BBMB, DVC, SSP, etc. If required, the aggregated demand forecast may be moderated by the Nodal Agency.**

RE forecasting, as per clause 6.5.23(ii) of IEGC

- **Forecasting shall be done by wind and solar generators which are regional entities as well as the concerned RLDC. The concerned RLDC may engage forecasting agency(ies) and prepare a schedule for such generating stations. The forecast by the concerned RLDC shall be with the objective of ensuring secure grid operation.**

Methodology adopted for load forecasting

$$D_{F_{n+1}i} = (1 + \mathcal{E}) * D_{A_{n-1}i}$$

$$\mathcal{E} = \frac{\sum_{x=1}^{3} \mathcal{E}_x}{3}$$

$$\mathcal{E}_1 = \frac{D_{A_{n-6}i} - D_{A_{n-1}i}}{D_{A_{n-1}i}}$$

$$\mathcal{E}_2 = \frac{D_{A_{n-6}i} - D_{A_{n-8}i}}{D_{A_{n-8}i}}$$

$$\mathcal{E}_3 = \frac{D_{A_{n-13}i} - D_{A_{n-8}i}}{D_{A_{n-8}i}}$$

Where,

n = day of preparation of day ahead forecast

i = Time Block starting from 1 to n

D_{Fi}= Forecasted Demand in i^{th} time block

D_{Ai}= Actual Demand in i^{th} time block

$\mathcal{E}$= variation in demand w.r.t. day of week

Day wise form of Forecast methodology-

$$D_{Forecast\ for\ wed} = (1 + \mathcal{E}) * D_{actual\ on\ last\ mon}$$

$$\mathcal{E} = \frac{\sum_{x=1}^{3} \mathcal{E}_x}{3}$$

$$\mathcal{E}_1 = \frac{D_{actual\ on\ last\ Wed} - D_{actual\ on\ last\ mon}}{D_{actual\ on\ last\ mon}}$$

$$\mathcal{E}_2 = \frac{D_{actual\ on\ last\ Wed} - D_{actual\ on\ last\ to\ last\ mon}}{D_{actual\ on\ last\ to\ last\ mon}}$$

$$\mathcal{E}_3 = \frac{D_{actual\ on\ last\ to\ last\ Wed} - D_{actual\ on\ last\ to\ last\ mon}}{D_{actual\ on\ last\ to\ last\ mon}}$$

Case studies - load forecast error

$$\text{Root Mean Square Error, RMSE(MW)} = \sqrt{\frac{\sum_{i=1}^{y}(D_{Fi}-D_{Ai})^2}{y}}$$

$$\text{RMSE(\%)} = \boldsymbol{RMSE(MW)} * \frac{y*100}{\sum_{i=1}^{y} D_{Ai}}$$

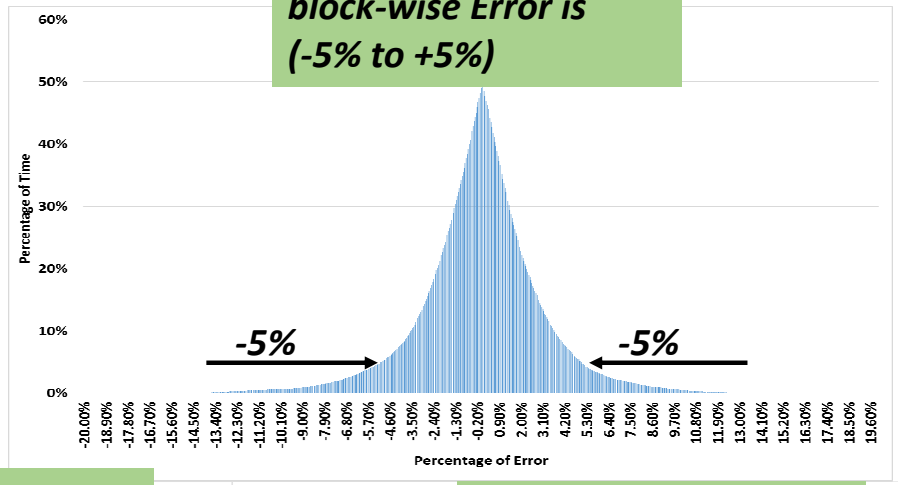
$$\text{Mean Absolute Error, MAE(MW)} = \frac{\sum_{i=1}^{y} Abs(D_{Fi}-D_{Ai})}{y}$$

$$\text{MAE(\%)} = \frac{100*\sum_{i=1}^{y} Abs(\frac{D_{Fi}-D_{Ai}}{D_{Ai}})}{y}$$

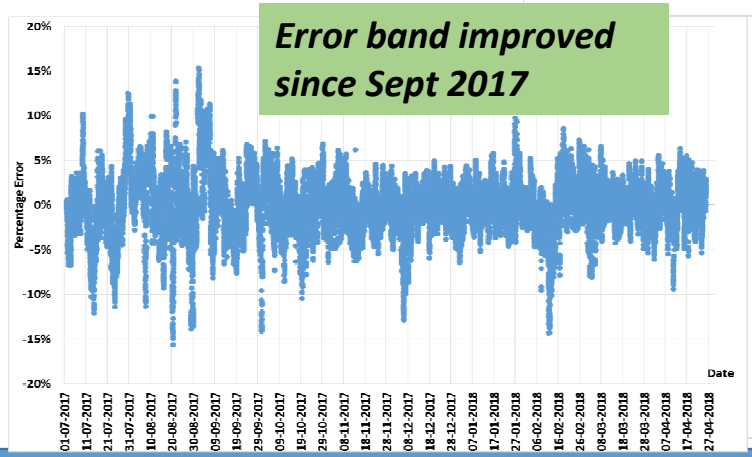
Where,

y = No of Time Block in a day(96)
i = Time Block starting from 1 to y
D_{Fi}= Forecasted Demand in i^{th} time block
D_{Ai}= Actual Demand in i^{th} time block

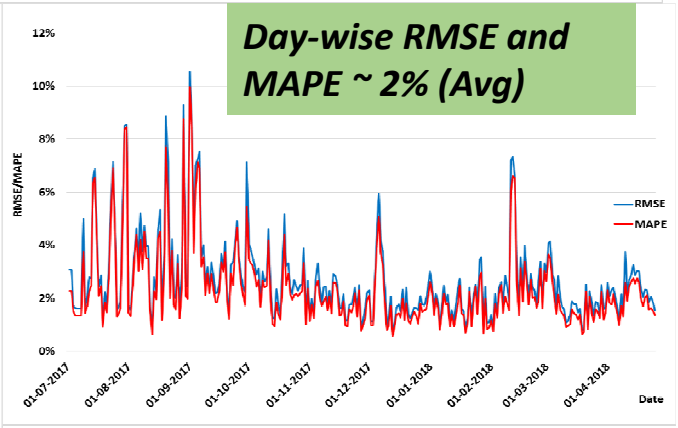
~90% of time 15 mins block-wise Error is (-5% to +5%)



Error band improved since Sept 2017

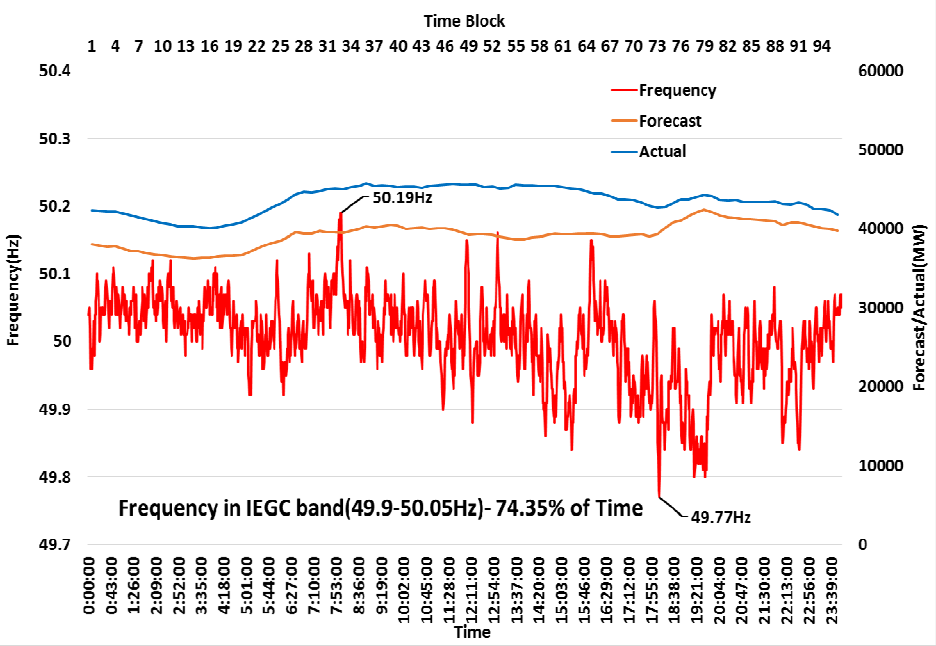


Day-wise RMSE and MAPE ~ 2% (Avg)

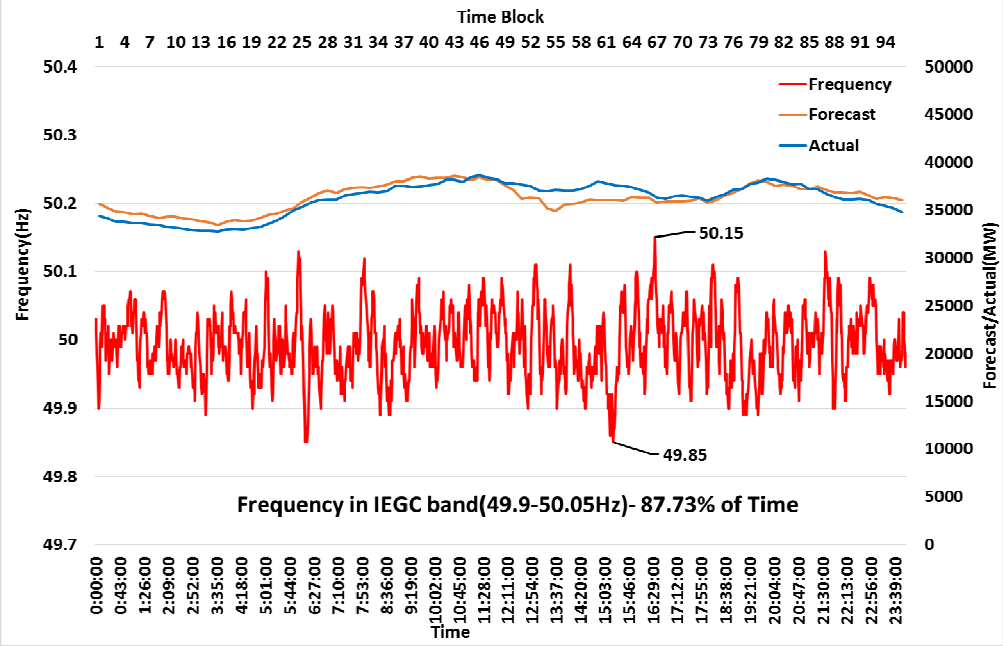


Case studies - load forecast error contd....

Case 1. When MAPE = 10% on 01-09-2017



Case 2. When MAPE=2% on 17-07-2017 (Average error day)-

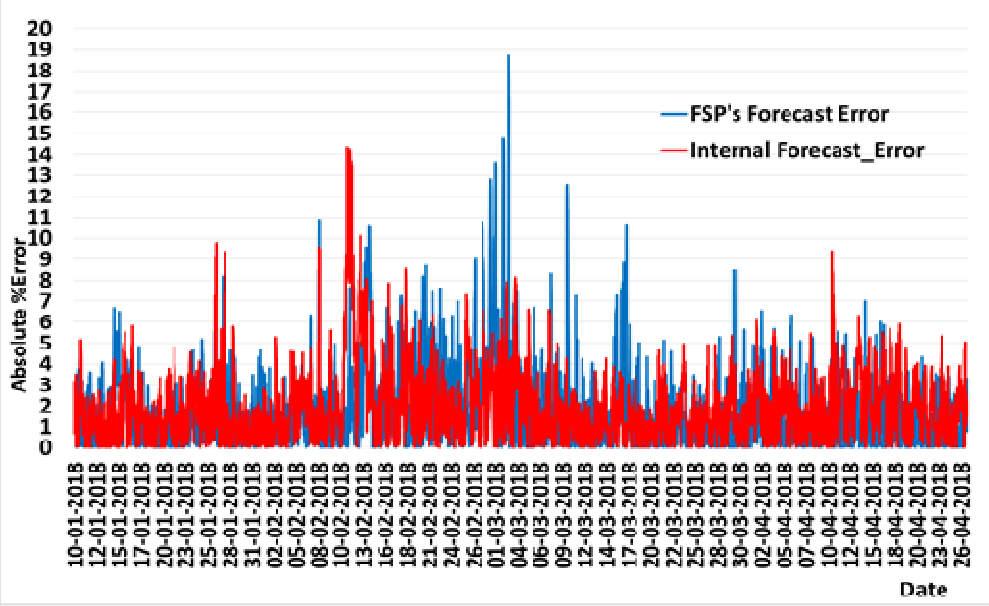


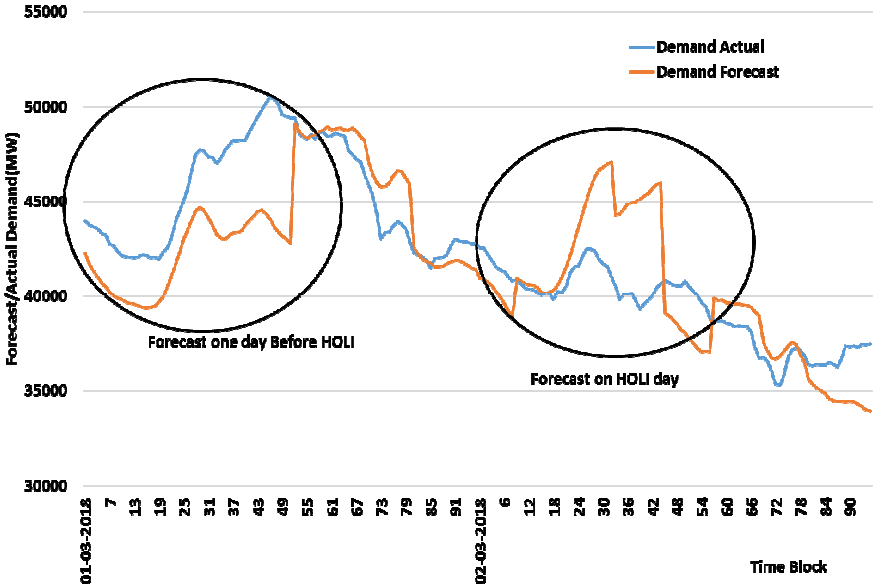
- High deviation in forecast results in frequent changes in generator schedule
- Increased non compliance in grid
- Causes deterioration of frequency

- Good forecast causes smooth operation and less changes in generator schedule
- Secure grid
- Improved system frequency

Load forecast by Forecast Service Provider(FSP)

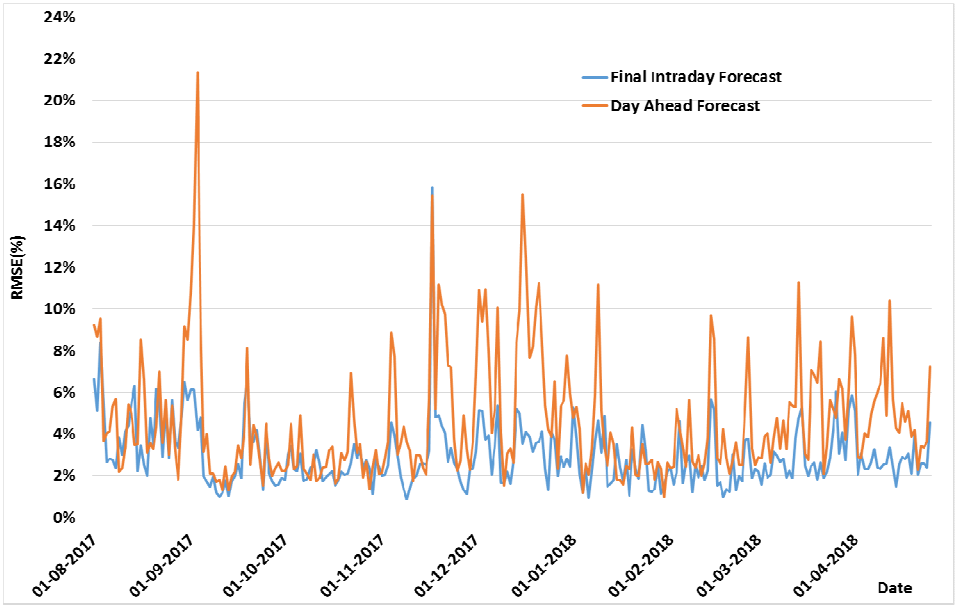
- FSP issuing the forecast of WR as a pilot project
- Considering the weather parameters for forecasting
- Multiple algorithms being used for selection of the best during the day
- Time to Time feedback given by WRLDC on errors in forecast to FSP for modification

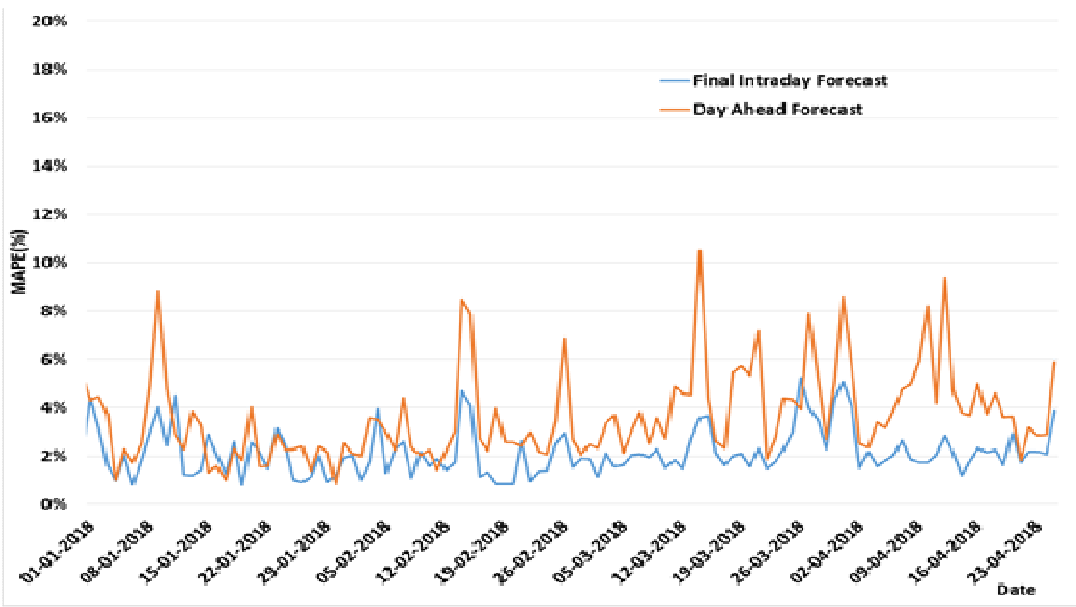




- FSP Forecast has higher error than internal forecast due to wrong input of information i.e. Holi day
- Forecast improved over the time
- Absolute Error ~ 2% (Avg)

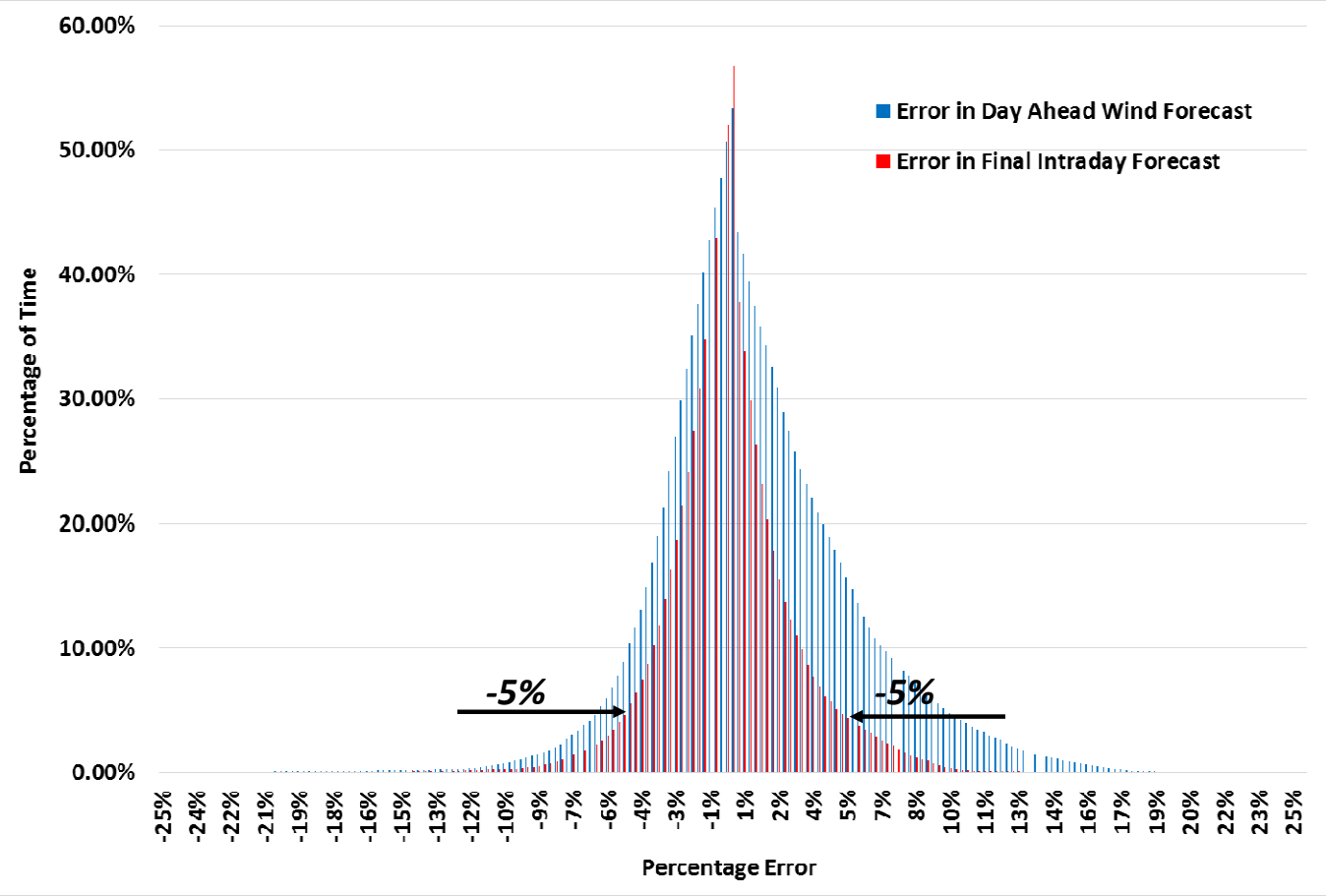
Wind forecast and experiences





- Different FSPs provide forecast of wind power for different constituents of WR as a pilot project
- The accuracy of day ahead and intraday forecast has been evaluated on basis of RMSE and MAPE
- RMSE and MAPE in final intraday forecast issued in real time is up to max 5%
- Error in day ahead forecast ~ 10% i.e. 800-1000MW reserves required in WR

Wind forecast and experiences contd…



- Block-wise percentage error in intraday wind forecast is concentrated between -5% to +5% for more than 90% of time
- Error in day ahead forecast is on higher side

References

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- Chang, W.-Y. (2014) A Literature Review of Wind Forecasting Methods. Journal of Power and Energy Engineering, 2, 161-168. http://dx.doi.org/10.4236/jpee.2014.24023