



Forecasting Wind  
Power Generation;  
Framework to Practical  
Aspects

Indian Wind Turbine  
Manufacturer's Association

# Wind Power Forecasting

14.10.2011

## OUTLINE

- ❖ Recap IEGC Stipulations
- ❖ Infrastructure to be set up for forecasting
- ❖ External issues that affect forecast accuracy
- ❖ Limitations of the mathematical models used
- ❖ Current Status of forecasting efforts by industry
- ❖ Normalization of results
- ❖ Some Definitions
- ❖ Brief Analysis
- ❖ What is expected from SLDC

# Recap IEGC Stipulations



## Proponent

- Central Electricity Regulatory Commission

## Date of Notification

- 28 April 2010

## Major Features

- Effective from 3<sup>rd</sup> May 2010
- Scheduling is a must for wind w.e.f. 01-01-2012 to help increase variable component of grid power.
- Basically is to make wind and solar generators responsible for grid discipline.
- Will also facilitate Interstate transaction of Wind and Solar through Open Access Route.
- This provision shall be applicable for new wind/solar farms with collective capacity of 10 MW and above connected at connection point of 33 KV level and above, who have yet to sign a PPA with states or others
- Revision of Schedule by wind and solar power generating stations shall be effective from 6th time-block, the first being the time -block in which notice was given. There may be maximum of 8 revisions for each 3 hour time slot starting from 00:00 hours during the day.

# Recap IEGC Stipulations

## Implications

- The wind and solar generators shall be responsible for forecasting their generation up to an accuracy of 70%.
- If the actual generation is beyond  $\pm 30\%$  of the schedule, wind/solar generators have to bear UI charges.
- Within  $\pm 30\%$ , the State which purchases power from the wind generators shall bear the UI charges for this variation.
- However, the UI charges borne by the State/s due to the wind/Solar generation, shall be shared among all the States of the country in the ratio of their peak demands on a monthly basis, in the form of a regulatory charge known as the Renewable Regulatory charge for wind/solar energy.

## Renewable Regulatory Fund (RRF)

- The RRF shall be maintained and operated by the National Load Despatch Centre on the lines of UI Pool Account at the Regional level.

**Scheduling** = 70% accuracy

**Max. Generation Allowed** = 150% of the schedule in a time block , over generation will be paid @UI corresponding to 50-50.02Hz

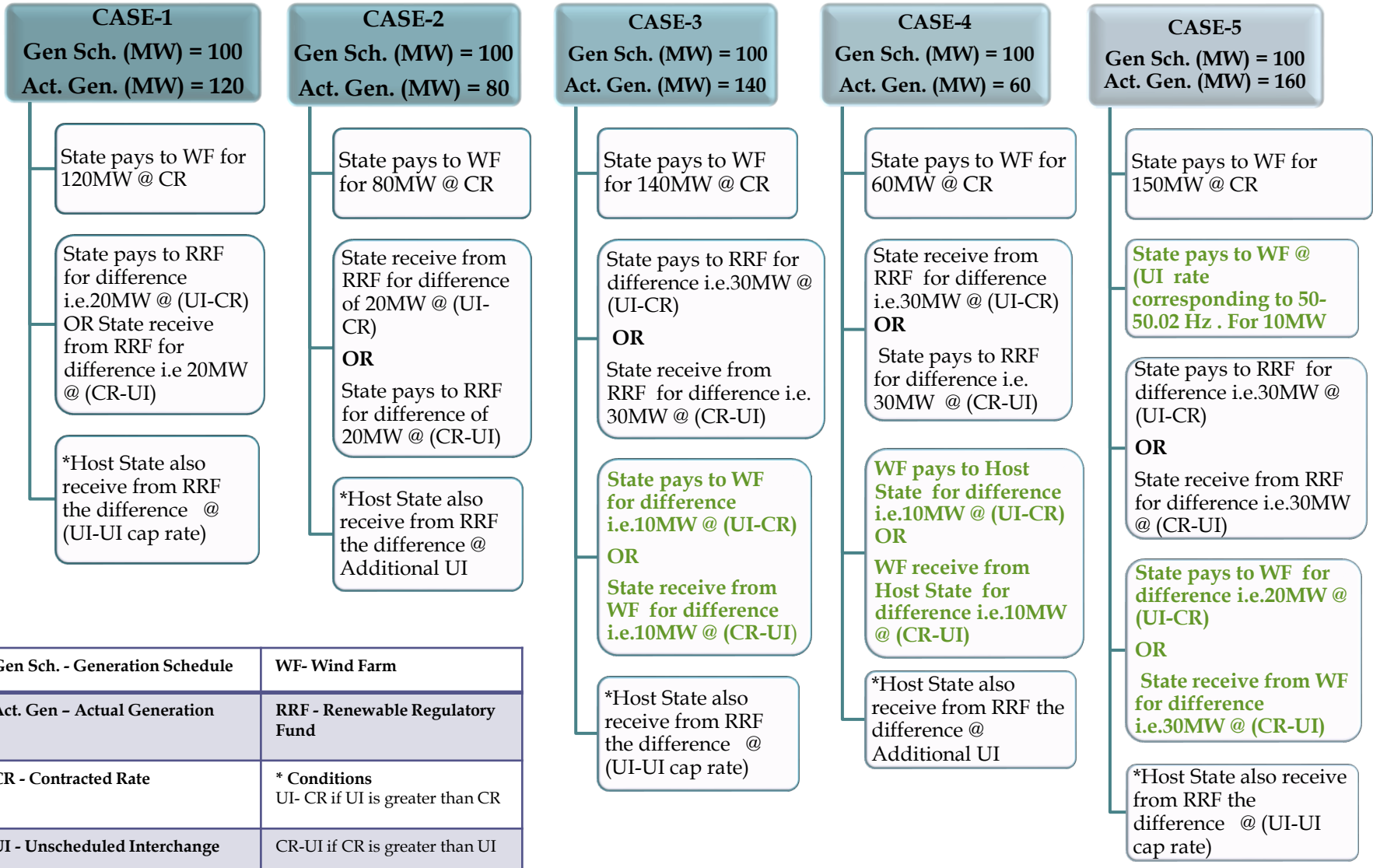
**Variation allowed** =  $\pm 30\%$

**For Intra State Transaction** = Contracted Details & Rate should be informed to -> RPC/RLDC through respective SLDC

**For Inter States Transaction** = Contracted Details & Rate should be informed to -> RLDC/NLDC through respective RPC

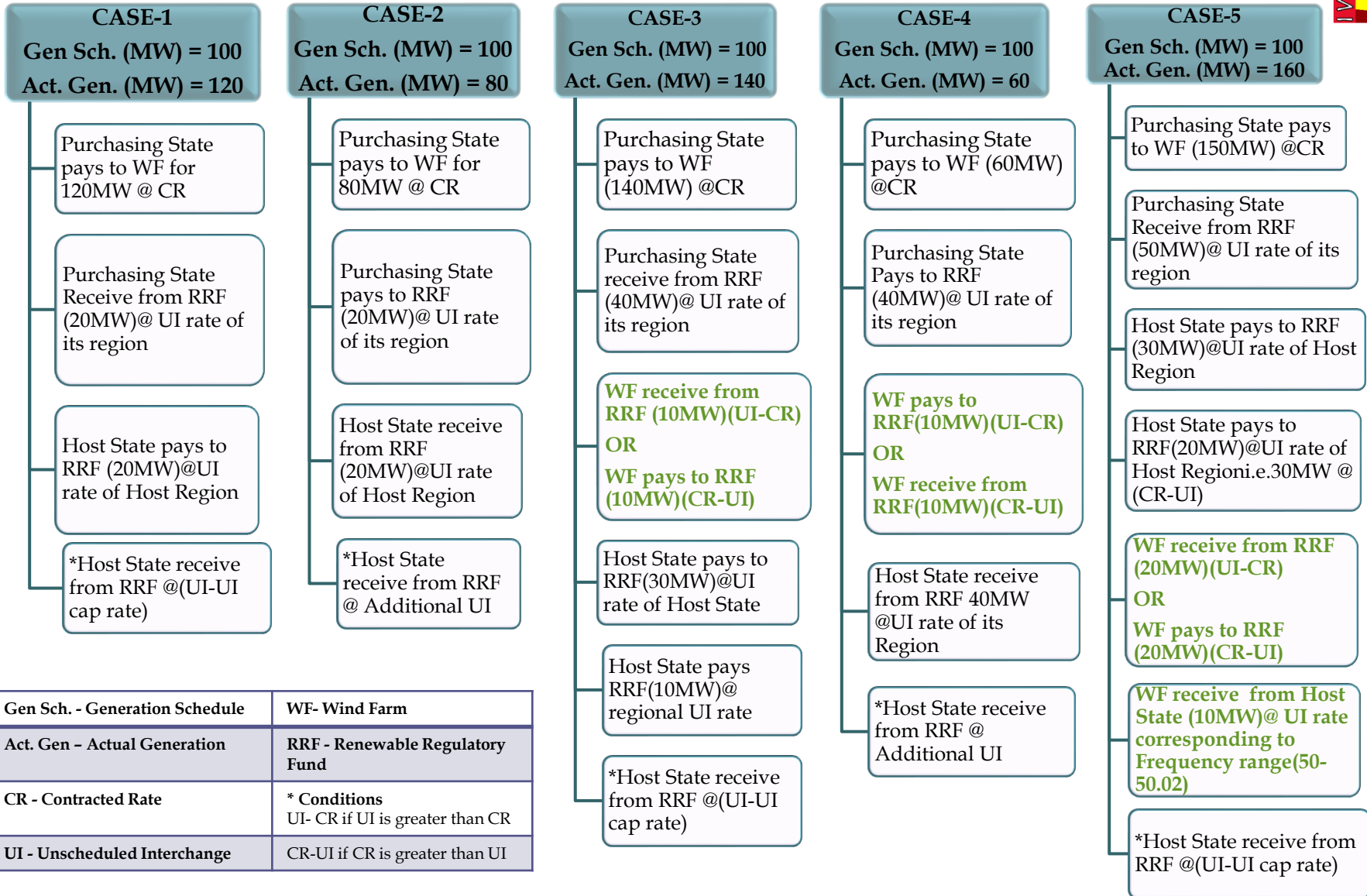


# Commercial Settlement for Wind generation – Cases (Intra State)



Gen Sch. - Generation Schedule	WF- Wind Farm
Act. Gen - Actual Generation	RRF - Renewable Regulatory Fund
CR - Contracted Rate	* Conditions UI- CR if UI is greater than CR
UI - Unscheduled Interchange	CR-UI if CR is greater than UI

# Commercial Settlement for Wind generation – Cases (Inter State)



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UI - Unscheduled Interchange	CR-UI if CR is greater than UI

# External issues that affect forecast accuracy

- **Numeric Weather Prediction (NWP) results to be used**
  - Has a huge impact on forecasting accuracy
    - A lot depends on initialisation data accuracy and the model used.
  
- **Geographical spread of wind farms**
  - Wind farm terrain topology
  - Surface roughness
  - Climatic and Weather regime
  - Wind pattern (seasonal and diurnal)
  
- **Forecast performance related to generation**
  - Time horizon (especially for short-term)
  - Quality of generation & met data from the plant
  - Sensitivity of a forecast to initialization errors
  - Turbine availability
  - Timely data transfer
  
- **Forecast Model**
  - What models (short-term and long-term) are best for forecasting wind energy
  - Different computational schemes can give rise to rather heterogeneous results and highly temporal in nature.

# Limitations of the mathematical models

- ❖ The model initialization depends on lots of weather data assimilated from a variety of sources and these inputs may have considerable uncertainties.
- ❖ The input data for the global data sets have regional issues with regard to the quality and density ( for example IMD for India)
- ❖ The GFS uses dense gridded data sets for Europe/US where as Indian data sets are sparsely distributed across the wind farming areas.
- ❖ Outputs obtained with such divergent data inputs will obviously have much uncertainty.



# Wind farm connectivity

- It is essential to have dedicated connectivity for data access on a 24 x 7 basis.
- Dedicated bandwidth can be only on leased lines or via VSATs and these are not easy to provide in remote areas.
- The availability of communication channels cannot be controlled easily.
- Frequent breaks can cause considerable confusion in model training which assumes that the input data is based on 100% availability.

# Challenges

- ❖ **IT Infrastructure**
- ❖ **Notwithstanding use of latest communication technologies our experience is:**
  - **VSAT connectivity breakdowns frequently particularly during monsoons**
  - **10 to 15 % of turbine population are off link via satellite or leased lines or RF.**
  - **Link to Forecast server also suffers from similar communication down times.**
  - **V-Sat or other means of communication cannot be done on shared bandwidths.**

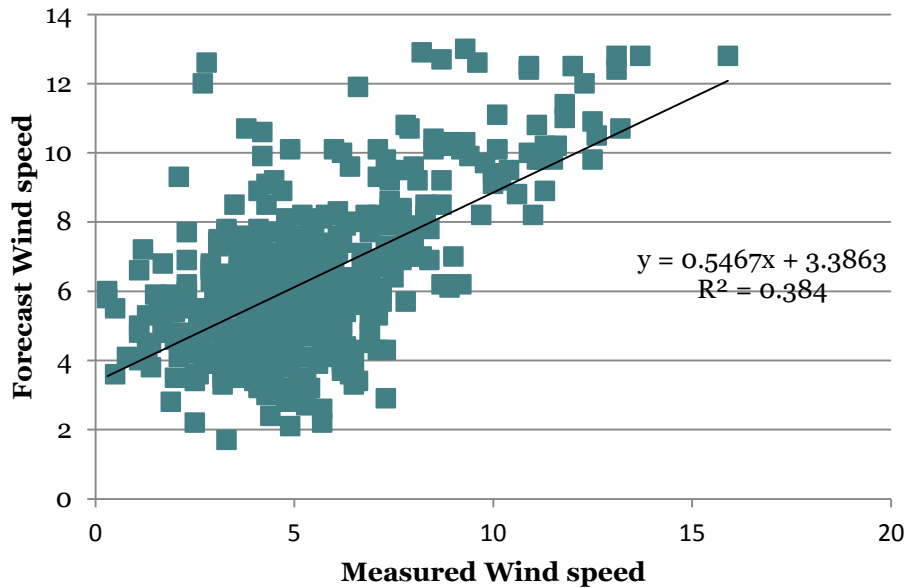
# Service providers active in India



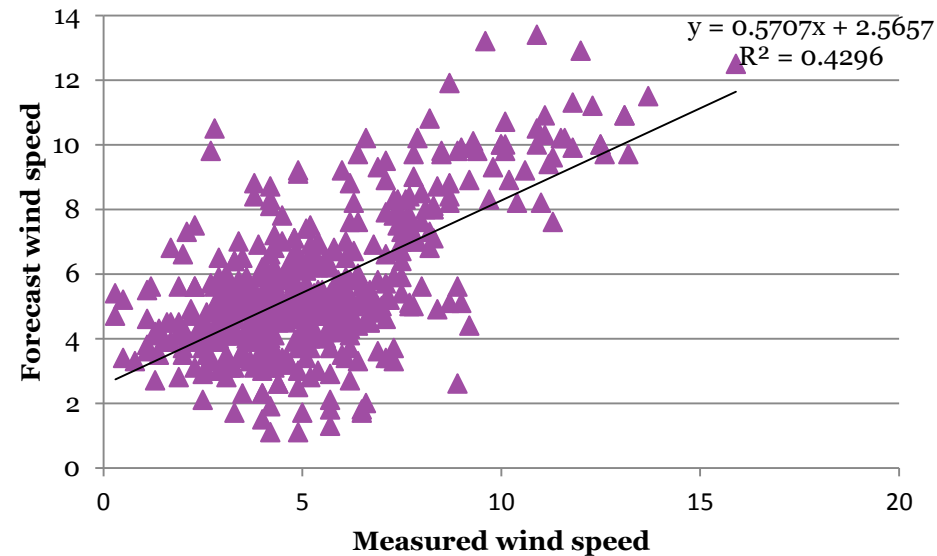
Sr.No.	Particulars	GL- GH	AWS	3_TIER	Meteologica
1	Office	India /UK	India/USA	India/USA	Spain
2	Forecast Global	33 GW	14 GW	43 GW	48 GW
3	Forecasting in India	Yes	Yes	Yes	Yes
4	Historic Data	Yes	Yes	Yes	Yes
5	Data Transfer/ Retrival	FTP	FTP	FTP	FTP
6	Day ahead forecast 24/48 hrs horizon	Yes	Yes	Yes	Yes
7	Accuracy Measurement (% AE) every 15 mins.	Yes	Yes	Yes	Yes
8	% AE	Not assured	Not Assured	Not Assured	Not Assured
9	Financial Liability	Not taken	Not taken	Not taken	Not taken

# Wind Speed forecasts

## GH Forecast Wind Speed [m/s]



## Meteologica Wind Speed [m/s]



The plot (forecast v/s actual wind speeds) shows that scatter is considerable over operational wind speed ranges. This consequently introduces considerable uncertainty in the estimate of power.

## Forecast Error:

$$e_{t+k|t} = P_{t+k} - \hat{P}_{t+k|t}$$

Where:

$e_{t+k|t}$  is the error corresponding to time  $t + k$  for prediction made at time  $t$

$P_{t+k}$  is the Power measured at time  $t+k$

$\hat{P}_{t+k|t}$  is the predicted power for time  $t+k$

Often, this is normalized by dividing the error by the installed capacity

$$Ne_{t+k|t} = \frac{e_{t+k|t}}{P_{inst}} = \frac{P_{t+k} - \hat{P}_{t+k|t}}{P_{inst}}$$

Where  $P_{inst}$  is the installed power.

IEGC's implied computation of % error in forecast

$$CNe_{t+k|t} = \frac{e_{t+k|t}}{\hat{P}_{t+k|t}} \cdot 100 = \frac{P_{t+k} - \hat{P}_{t+k|t}}{\hat{P}_{t+k|t}} \cdot 100 \%$$

## Current Status – EIL, Gamesa, Regen, Suzlon, Vestas

**A**

IWTMA has sponsored Forecasting for 100 MW.  
All major players are also individually exploring Implementation.

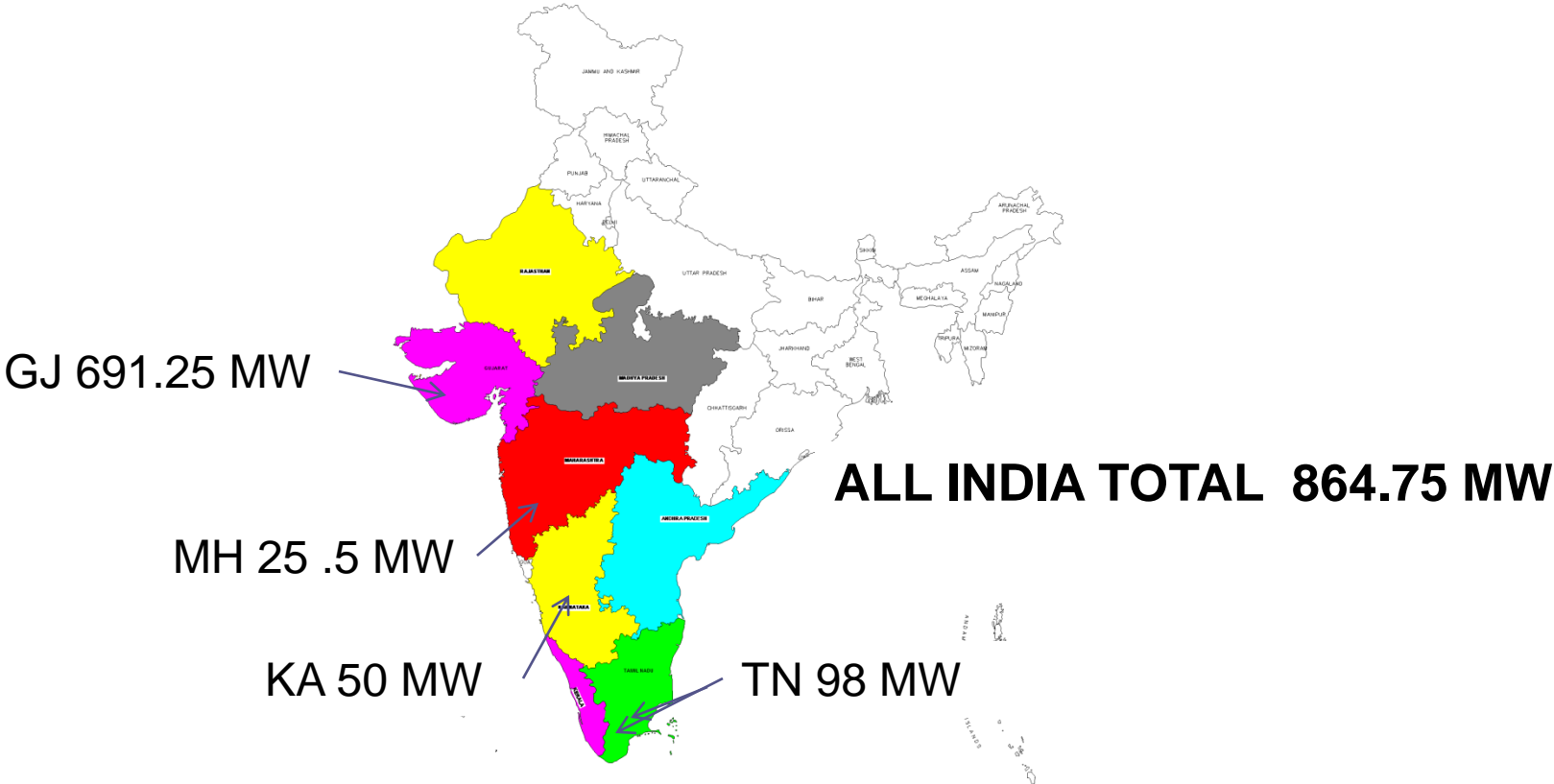
**B**

Suzlon and Enercon India have been experimenting since 2009.  
There have been issues with continuity and data feed. Practical problems about input data capture are far more serious than popular perception

**C**

Being a highly complex & scientific exercise,  
services are sought from experienced Forecast service providers.

# Pilot Forecasting in four states



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## ENERCON (INDIA) LIMITED



### Enercon (India) Limited

1.	Initiated Forecasting	1st Jan 2009
2.	Locations	Samana Presently -50.4 MW Pushpathur ( Presently : 50.4 MW ) : 1st August 2010:- IWTMA  Samana 400 MW forecast exercises started from July/August, 2011
3.	Service Provider	GL Garrad Hassan & Meteologica

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## GAMESA

### Gamesa

1.	Initiated Forecasting	Dec 2010
2.	Location	Theni (Tamil Nadu) - 47.6 MW Forecast now available for 3 Wind Farms
3.	Service Provider	WebMEGA

3

## RE - GEN



Re- Gen		
1.	Initiated Forecasting	1st Jan 2009
2.	Location	Bhud Project ( Maharashtra) 17 * 1.5MW = 25.5 MW
3.	Service Provider	3-TIER

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## SUZLON

Suzlon		
1.	Initiated Forecasting	May 2009
2.	Location	Suthri , Gujarat 250MW
3.	Service Provider	GL- GH

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# VESTAS



## Vestas

1.	Initiated Forecasting	Feb 2011
2.	Locations Break up	Gujarat $25 * 1.65\text{MW} = 41.25 \text{ MW}$
3.	Service Provider	3-TIER

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## IWTMA

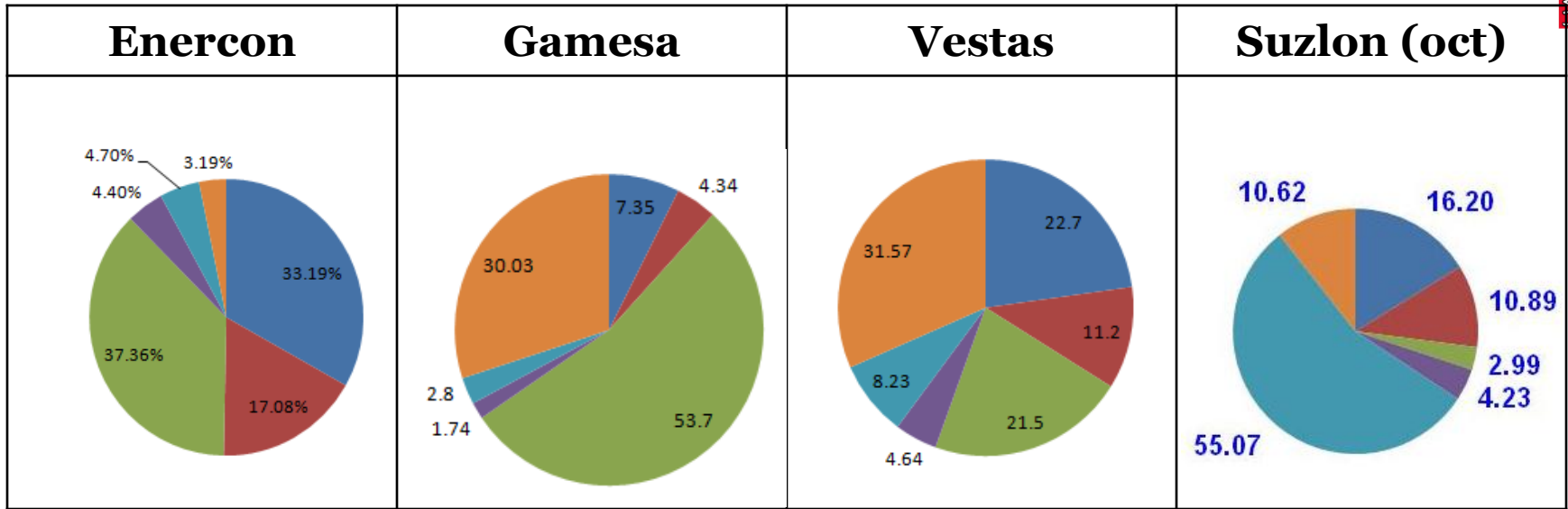
IWTMA		
1.	Initiated Forecasting	May 2009
2.	Locations	Pushpathur, Tamilnadu 50.4 MW EIL Gadag, Karnataka – 50 MW - Suzlon
3.	Service Provider	GL- GH

# Forecasts

- 1 Forecast Horizon – 24 Hours
- 2 Results and Implications



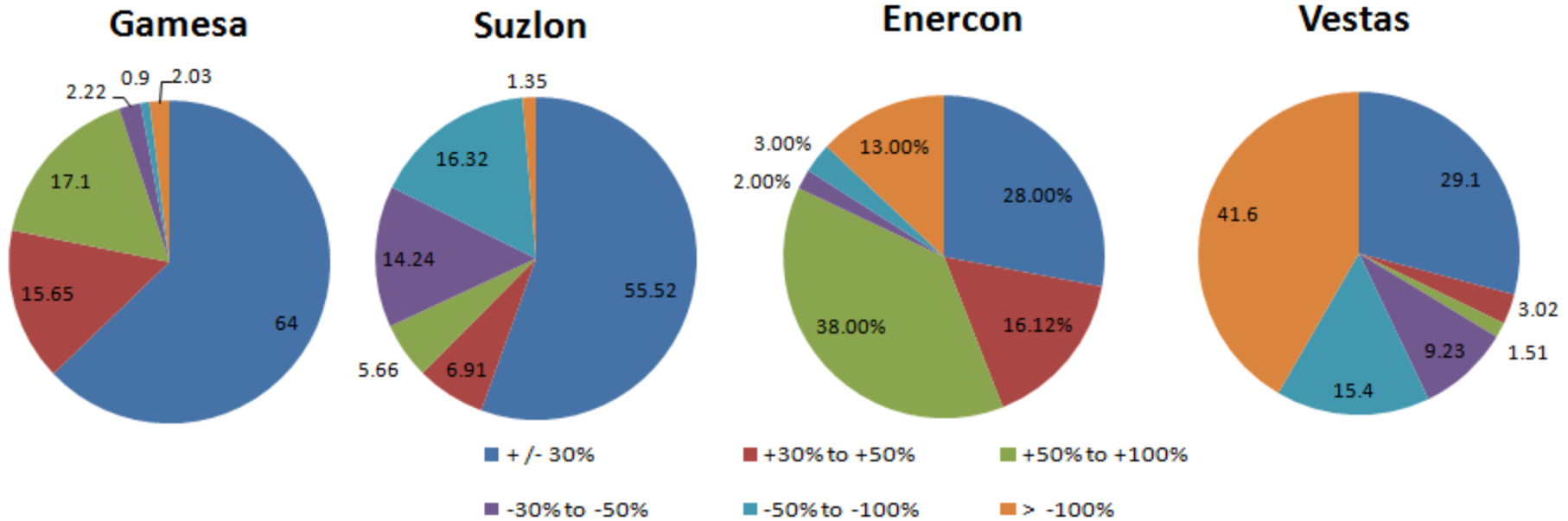
Forecast Horizon -24 hrs ahead – Low wind season – April 11



■ +/- 30%     
 ■ +30% to +50%     
 ■ +50% to +100%  
■ -30% to -50%     
 ■ -50% to -100%     
 ■ > -100%

Interval	Enercon	Gamesa	Vestas	Suzlon
+/- 30%	33.19%	7.35	22.7	16.20
+30% to +50%	17.08%	4.34	11.2	10.89
+50% to +100%	37.36%	53.7	21.5	2.99
-30% to -50%	4.40%	1.74	4.64	4.23
-50% to -100%	4.70%	2.8	8.23	55.07
> -100%	3.19%	30.03	31.57	10.62

# Forecast Horizon 24 hrs – High wind season – June /July 11



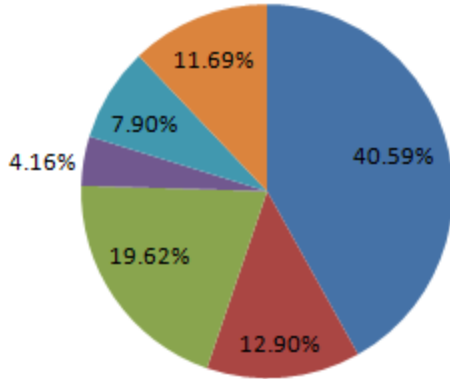
June 2011		
Interval	Gamesa	Suzlon
+/- 30%	64%	55.52
+30% to +50%	15.65%	6.91
+50% to +100%	17.1%	5.66
-30% to -50%	2.22%	14.24
-50% to -100%	0.9%	16.32
> -100%	2.03%	1.35

July 2011		
Interval	Enercon	Vestas
+/- 30%	28.0%	29.1%
+30% to +50%	16.1%	3.02%
+50% to +100%	38.0%	1.51%
-30% to -50%	2.0%	9.23%
-50% to -100%	3.0%	15.4%
> -100%	13.0%	41.6%

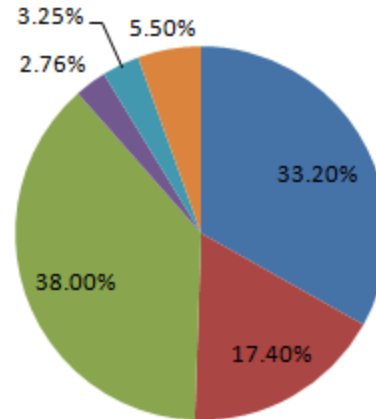


# Forecast – EIL – August / Sept 11 – Meteologica & GL-GH - 400MW

## Meteologica



## GL-GH



- +/- 30%
- +30% to +50%
- +50% to +100%
- -30% to -50%
- -50% to -100%
- > -100%

August 2011	
Interval	Meteologica
+/- 30%	40.59%
+30% to +50%	12.90%
+50% to +100%	19.62%
-30% to -50%	4.16%
-50% to -100%	7.90%
> -100%	11.69%

August- September 2011	
Interval	GL-GH
+/- 30%	33.20%
+30% to +50%	17.40%
+50% to +100%	38.00%
-30% to -50%	2.76%
-50% to -100%	3.25%
> -100%	5.50%

## ▶ Results and Implications

### Observations

- The instances of forecast being within  $\pm 30\%$  was high from May to August.
- The instances of forecast being within  $\pm 30\%$  was very poor during October to March
- Larger wind farms geographically spread out gives a good averaging
- ‘Model training’ takes much longer
- Unexpected grid outages reduces the forecast accuracy

# Forecast quality – external and internal influences

- **Forecast quality depends on many external and internal factors many of which are changing over time.**
- **External factors**
  - **Chosen NWP outputs – strong influence on uncertainty**
  - **Breaks in IT service**
- **Internal factors**
  - **Wind farm modeling**
  - **Unscheduled outages of grid and WT**
  - **Model training based on breaks in input data**
  - **Influence of monsoon on the model training**

## ISSUES & CONCERNS

### Customers / Financing Institutions wants more clarification on

- How do we model the UI implications in cash flow of investors today?
- Customers and financing institutions are demanding more clarity on potential UI risk
- How is the UI implication at the inter-connection point going to be apportioned to individual customers within the same wind farm?
- If one (or more) customer opts to give forecast separately for his group of turbines, how will LDC receive and act on this information?
- It is absolutely important that we are able to represent the financial implications of scheduling with supporting data to prospective customers and their financing institutions  
Else, investors will shy away from wind sector

# Operational issues to be tackled



**The industry is gearing up to providing forecasts from January 1<sup>st</sup>, 2012 at fully operational wind farms that come on stream as per IEGC.**

**The following operational issues need to be addressed:**

- Establishing the continuous data communication from site to SLDC server.
- Clarity needed on data transfer to SLDC - preferred means FTP
- Establish ground rules for dispute resolution arising out of set procedures.
- Though wind and solar energy plants have a 'must run' status, they are asked to back down to maintain grid stability. Commercial implications to be addressed.



**THANK YOU !!**

Indian Wind Turbine Manufacturer's Association