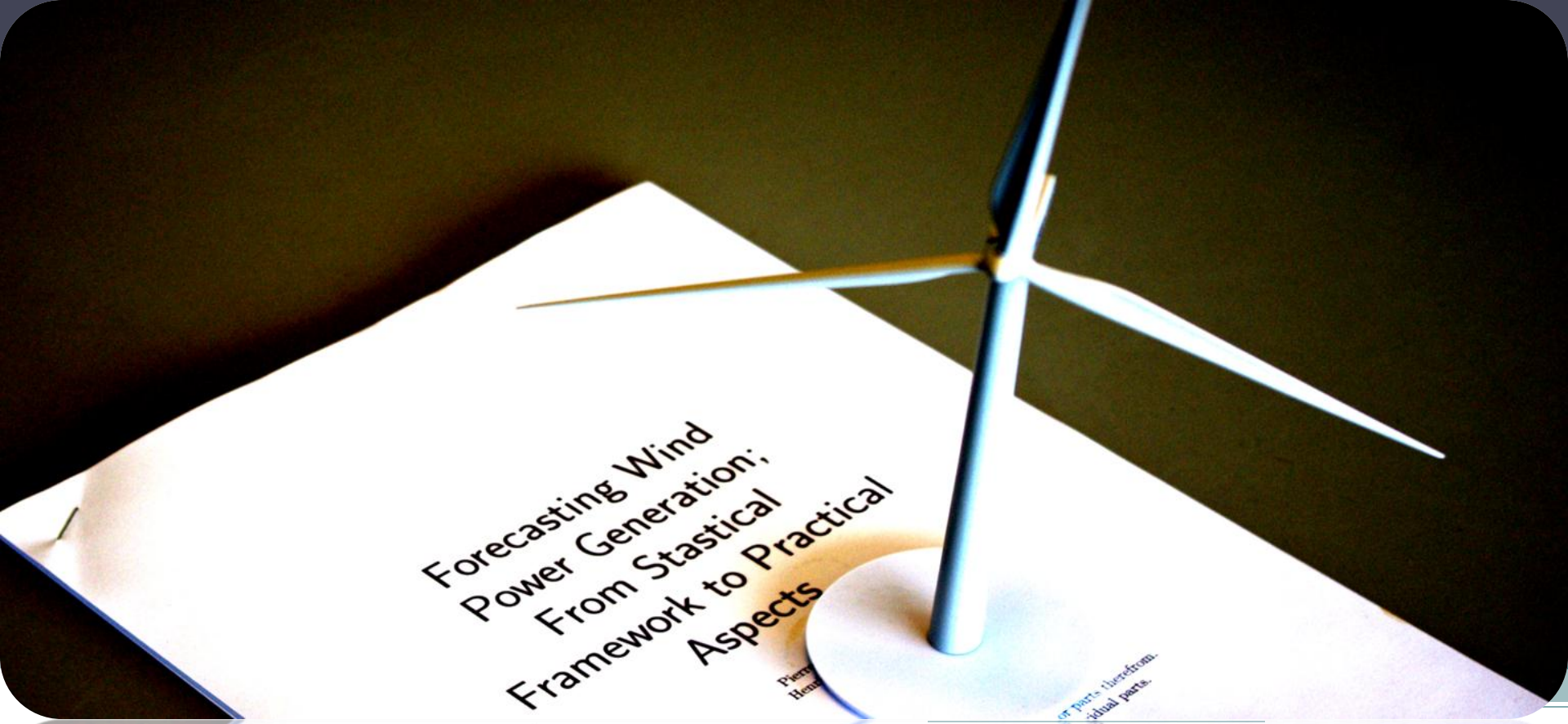


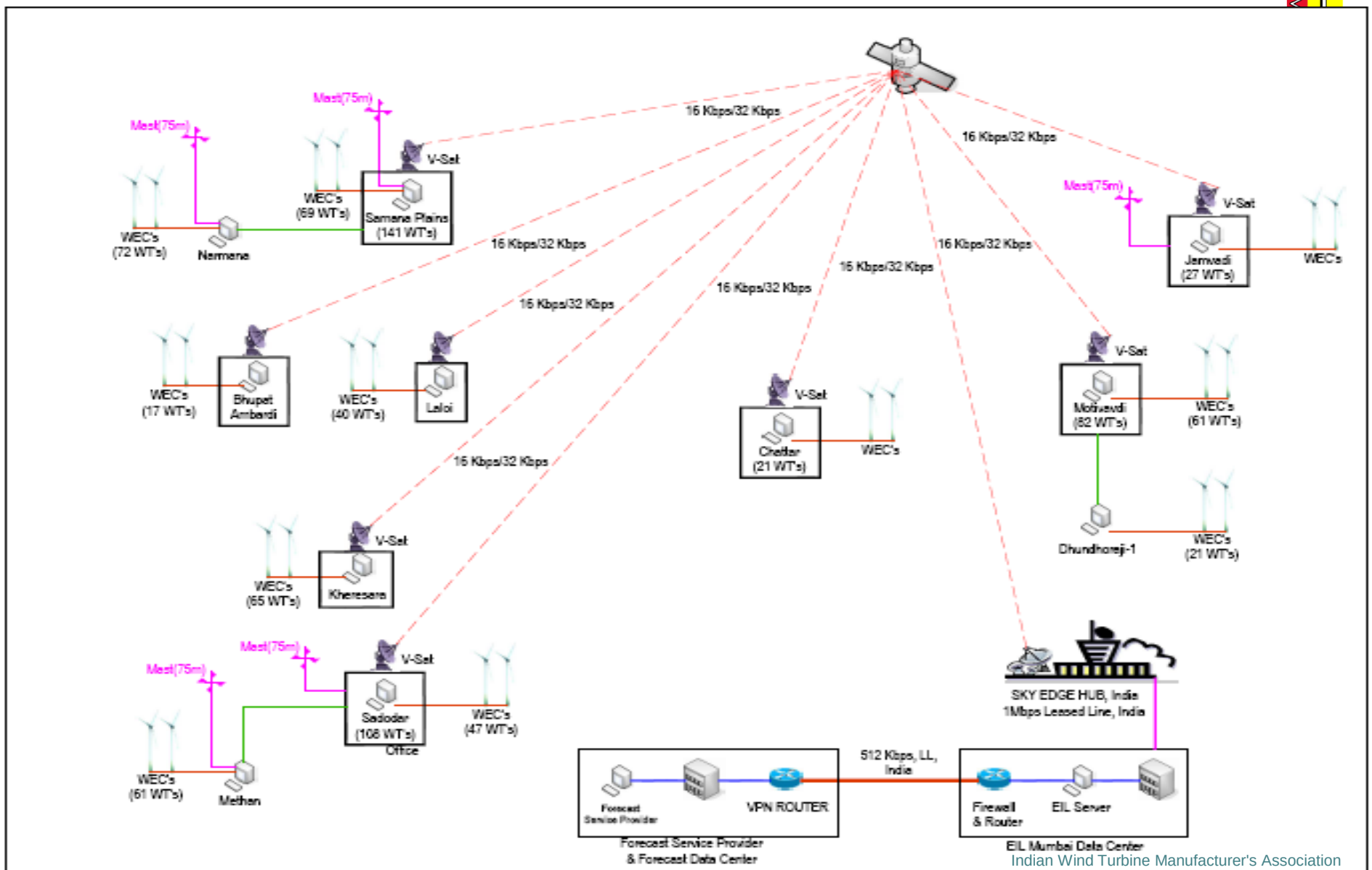
Indian Wind Turbine Manufacturer's Association

Wind Power Forecasting

10 / October / 2011

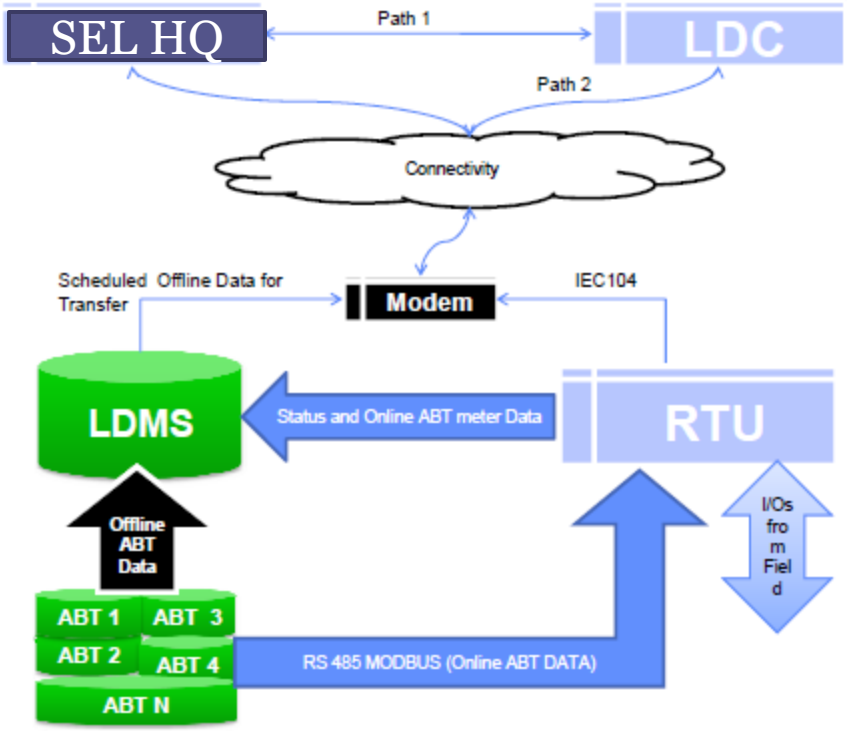
What it takes to do forecasting…

SCADA with Strong IT Infrastructure…

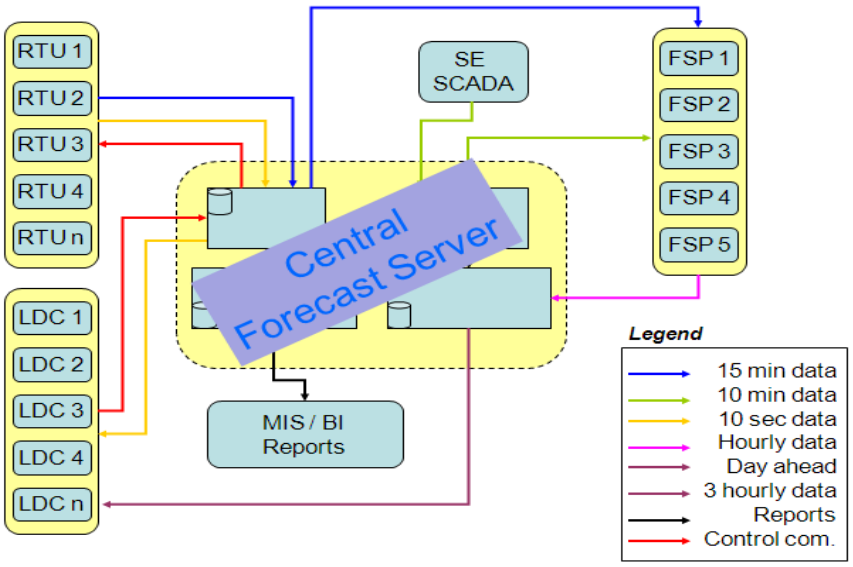


Additional setup…

At sub-station



At Central HQ



Heavy investment in infrastructure

- **All sites to have connectivity**
- **All s/s to have connectivity**
  - **Mostly V-SAT / RF**

✓Reliability
✓Security
✓High data transfer rates

- **High end Server level IT facility for hosting solution**
  - **Automatic functioning with high performance**
  - **Redundancy**
  - **Security**
  - **Data back-up**

- **At sub-station**
  - **ABT meters, RTU, LDMS systems**
  - **Hardwiring**

Challenges

- **IT Infrastructure**
  - It is essential to have dedicated connectivity for data access on a 24 x 7 basis.

- **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.

- **Frequent breaks can cause considerable confusion in model training which assumes that the input data is based on 100% availability.**

Initiatives taken…

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.

1 ENERCON

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

2 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

4 SUZLON

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

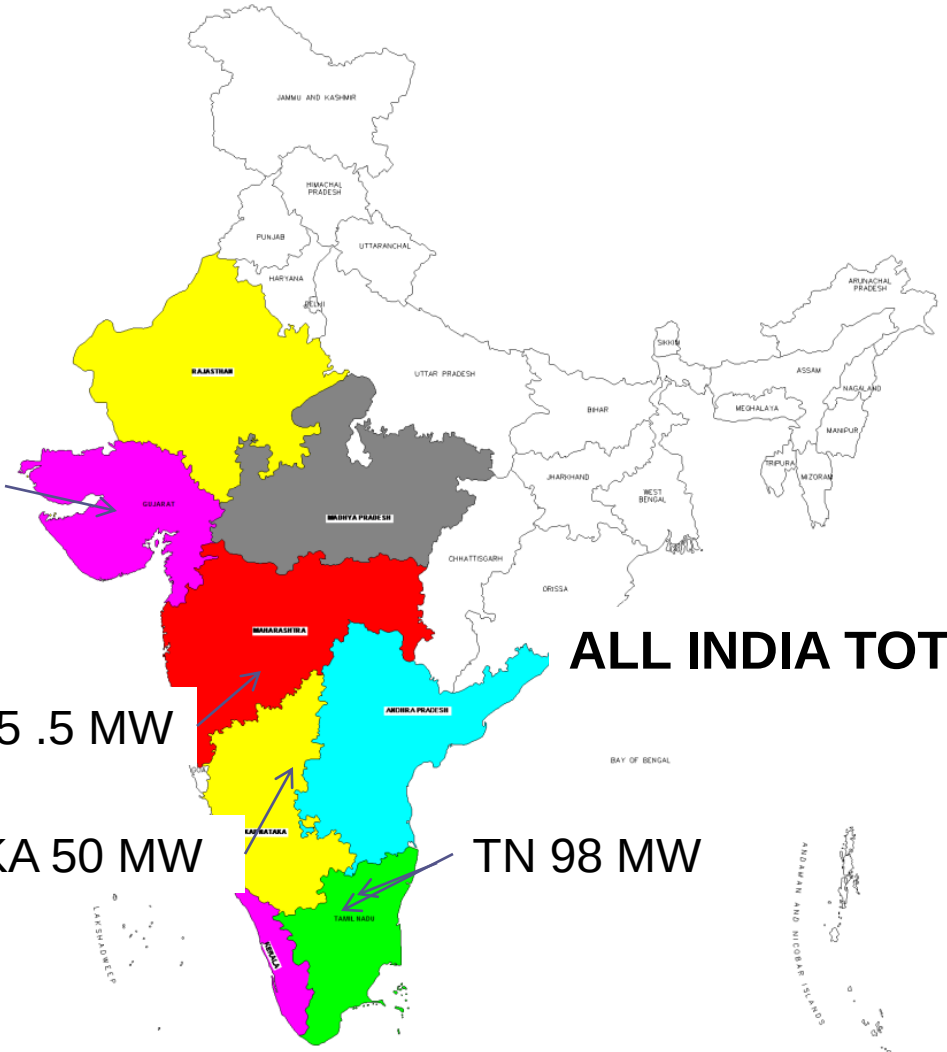
5 VESTAS

Vestas		
1.	Initiated Forecasting	Feb 2011
2.	Locations Break up	Gujarat 25 * 1.65MW = 41.25 MW
3.	Service Provider	3-TIER

6 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

Pilot Forecasting in four states



GJ 691.25 MW

MH 25 .5 MW

KA 50 MW

TN 98 MW

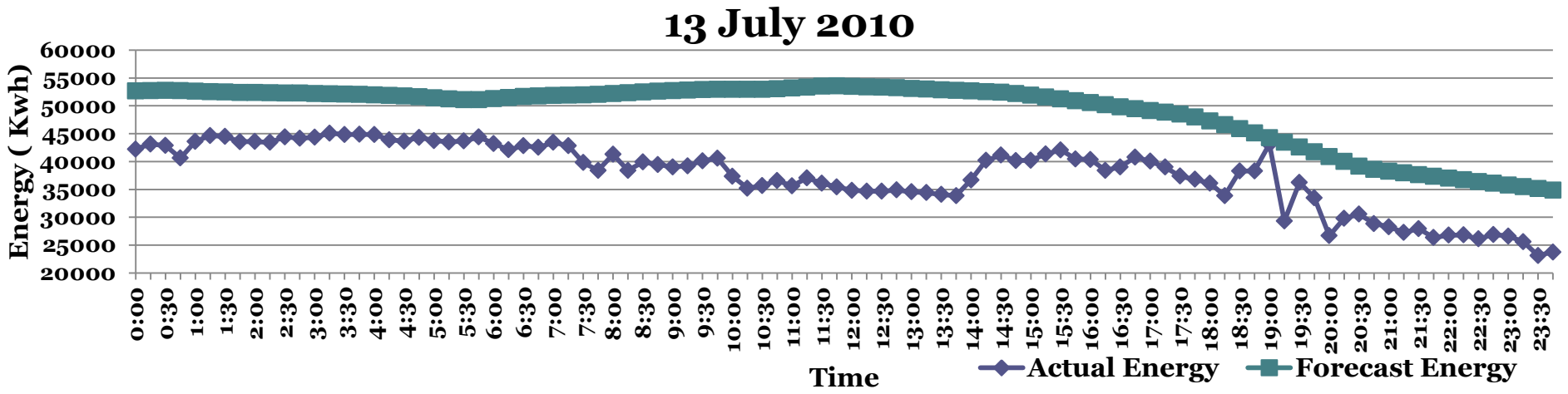
ALL INDIA TOTAL 864.75 MW

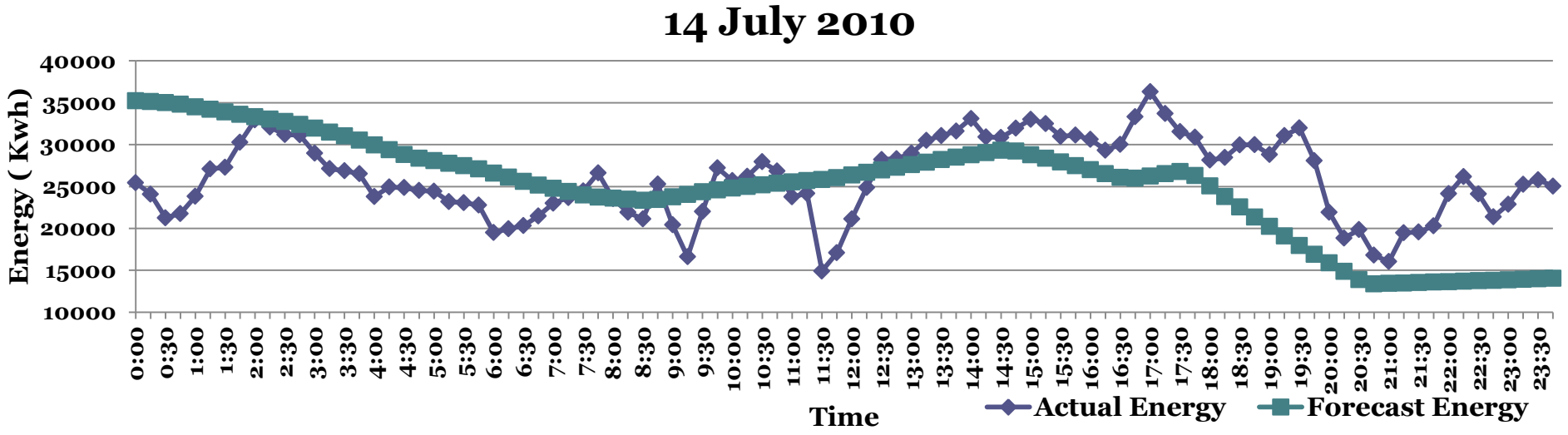
3 Service providers active in India

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

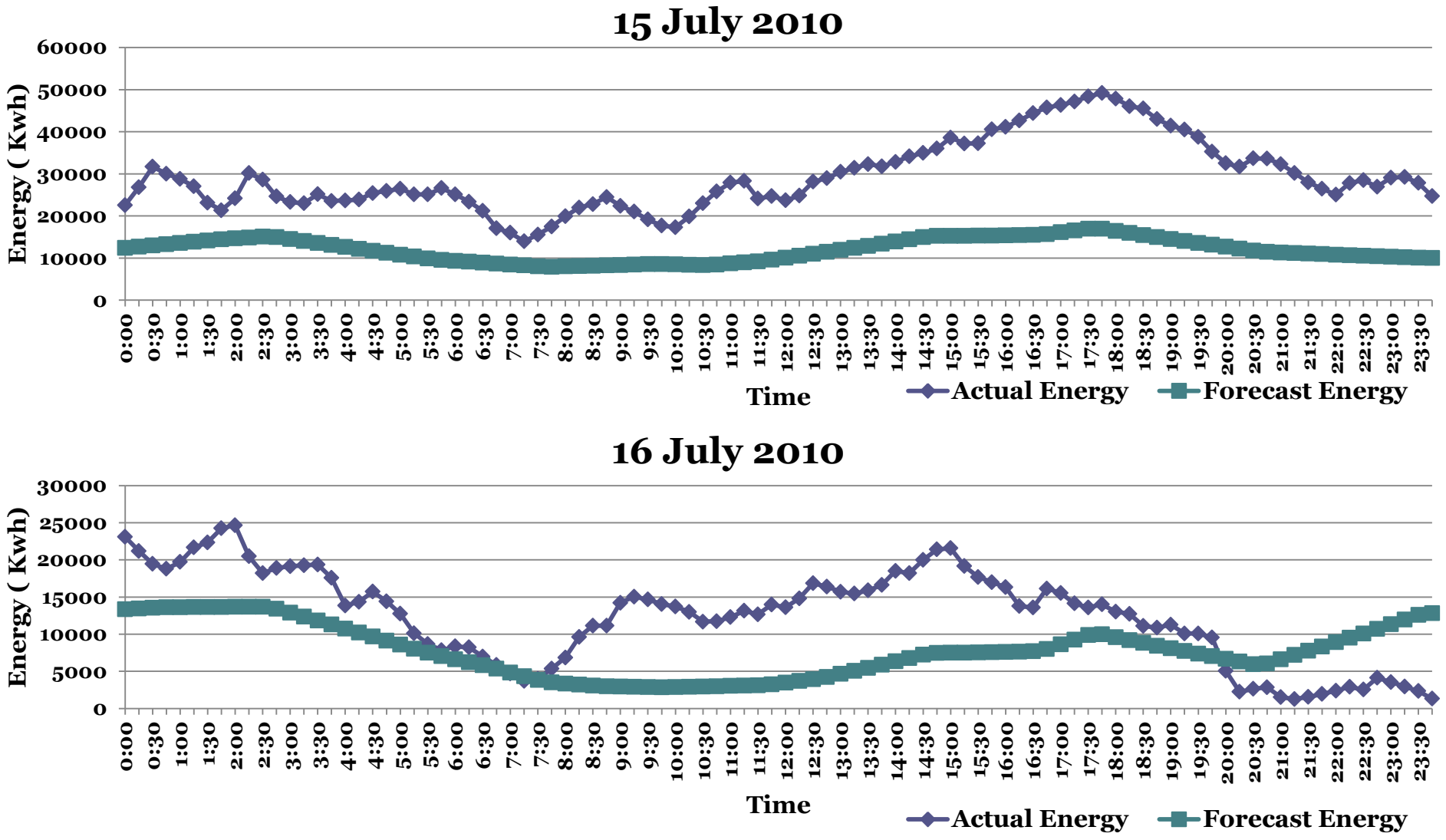
Results…

High wind month

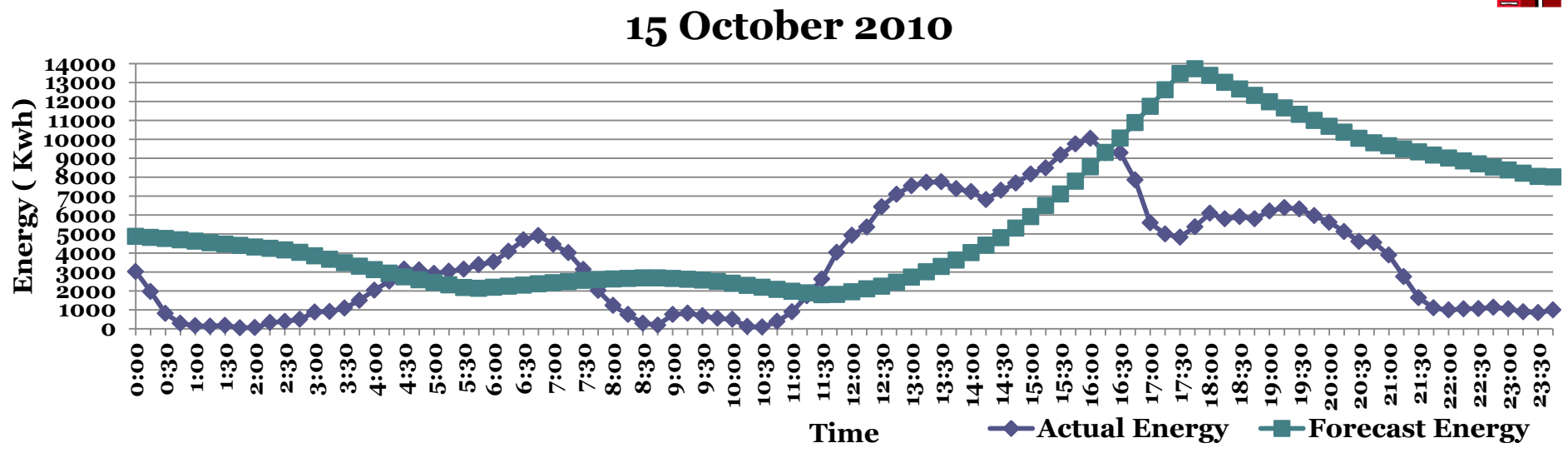


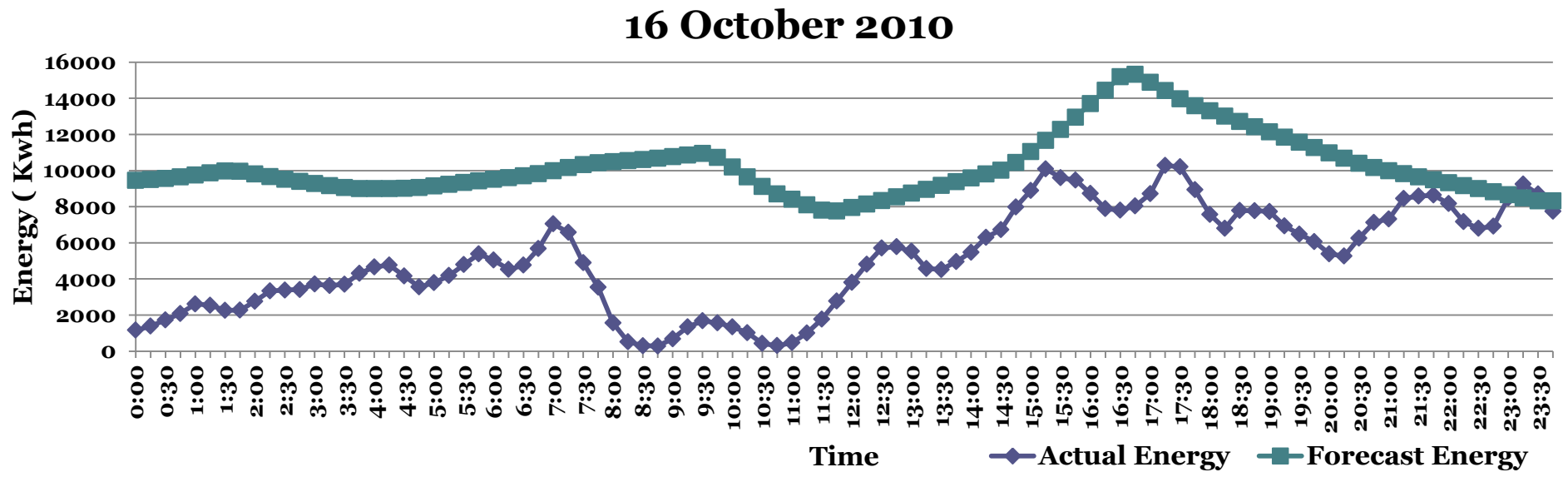


High wind month

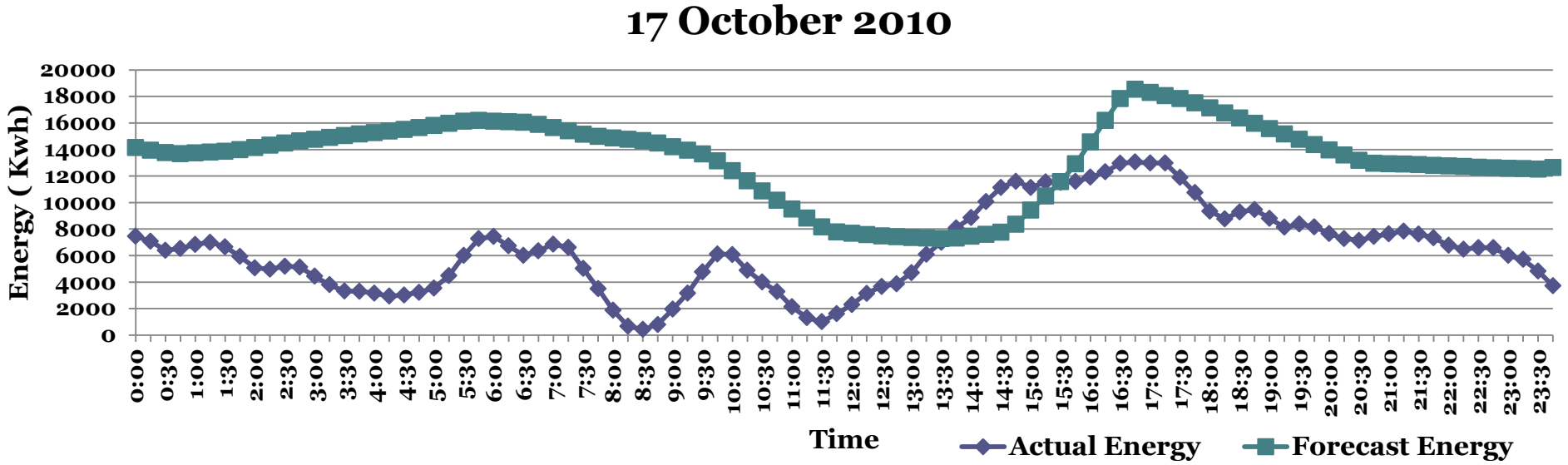


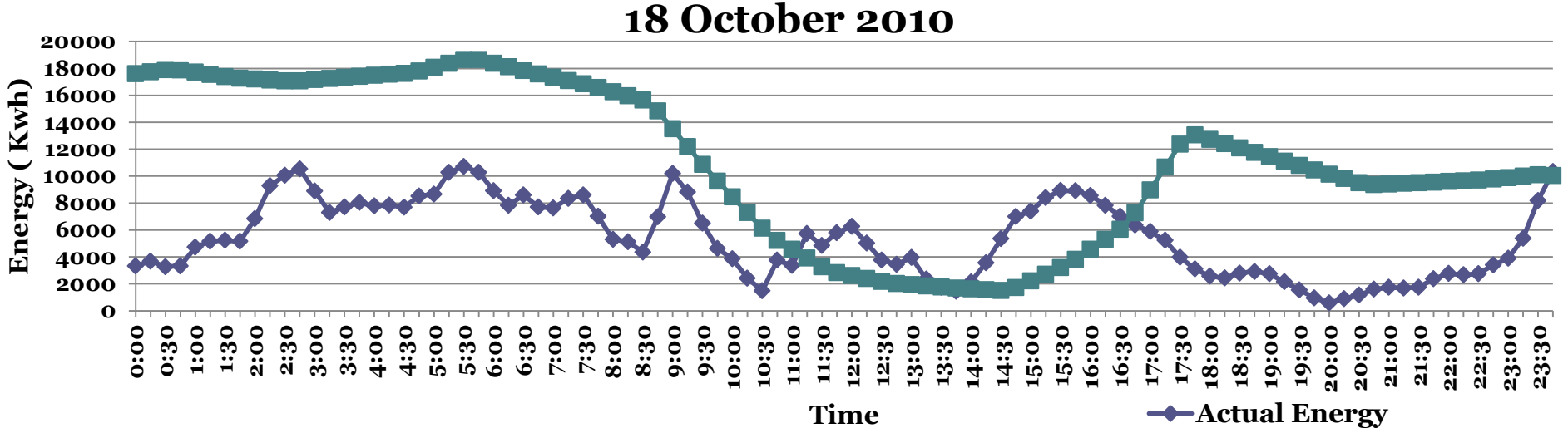
Low wind month





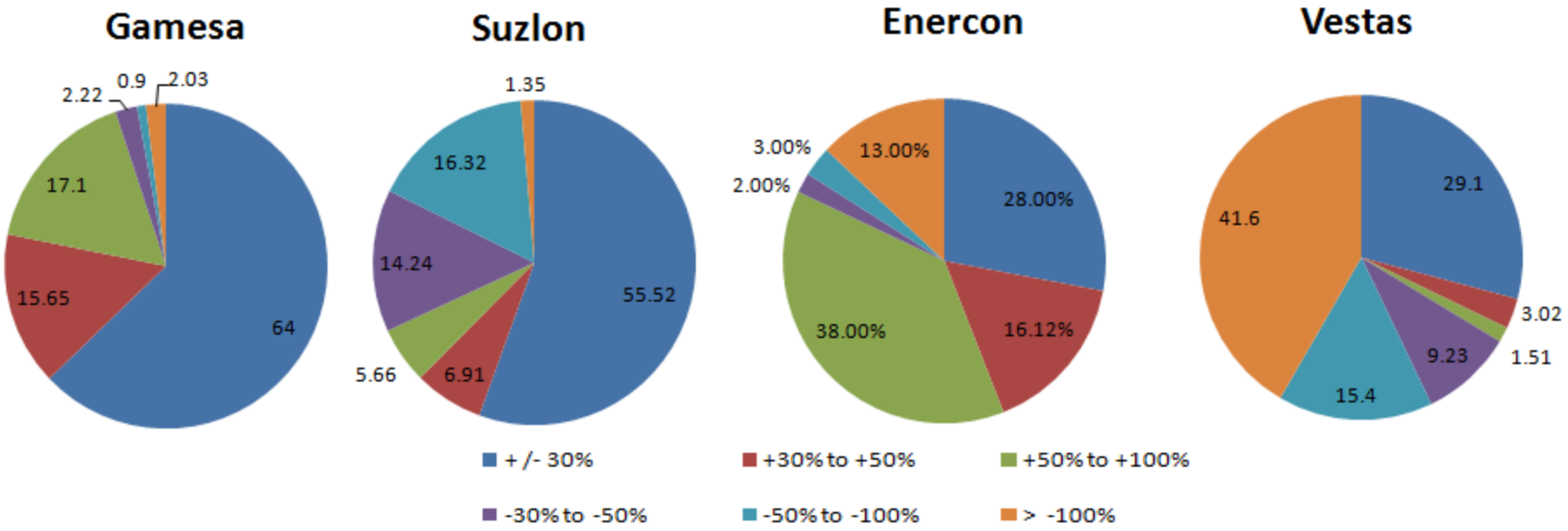
Low wind month





Probability of hitting ± 30%

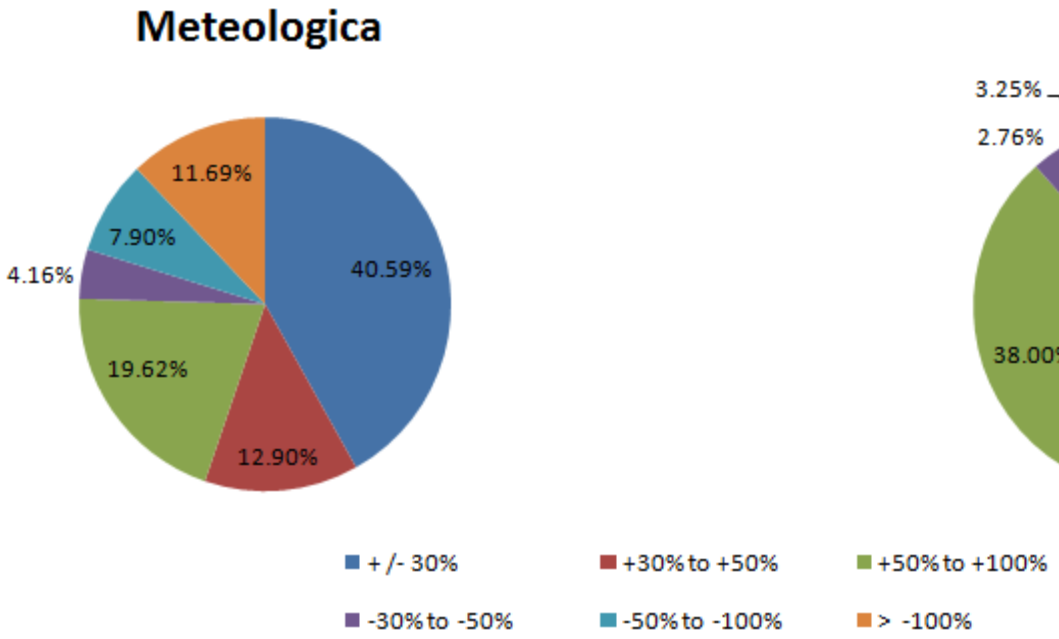
1 Forecast Horizon 24 hrs – High wind season – June /July 11

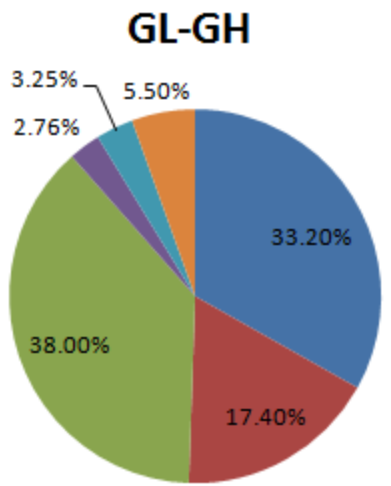


June 2011		
Interval	Gamesa	Suzlon
+/- 30%	64%	55.52
+30% to +50%	15.65%	6.91
+50% to +100%	17.1%	5.66
-30% to -50%	2.22%	14.24
-50% to -100%	0.9%	16.32
> -100%	2.03%	1.35

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%

1 Forecast – EIL – August / Sept 11 – Metelogica & GL-GH - 400MW



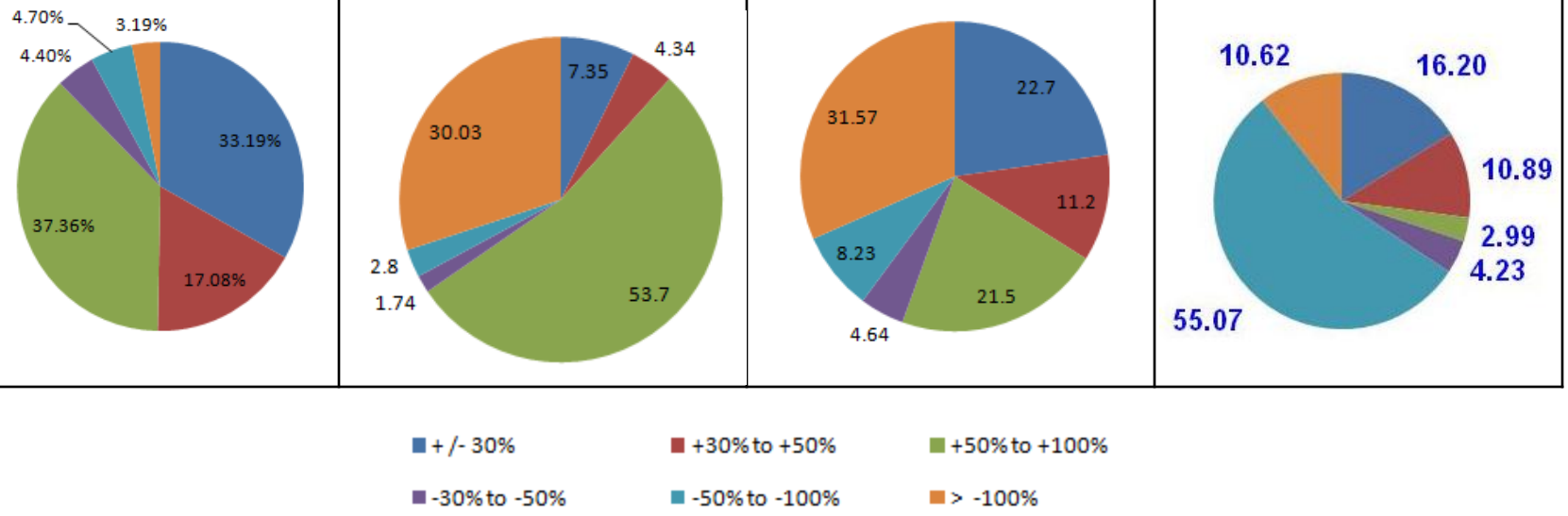


August 2011	
Interval	Meteologica
+/- 30%	40.59%
+30% to +50%	12.90%
+50% to +100%	19.62%
-30% to -50%	4.16%
-50% to -100%	7.90%
> -100%	11.69%

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%

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

Enercon	Gamesa	Vestas	Suzlon (oct)



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

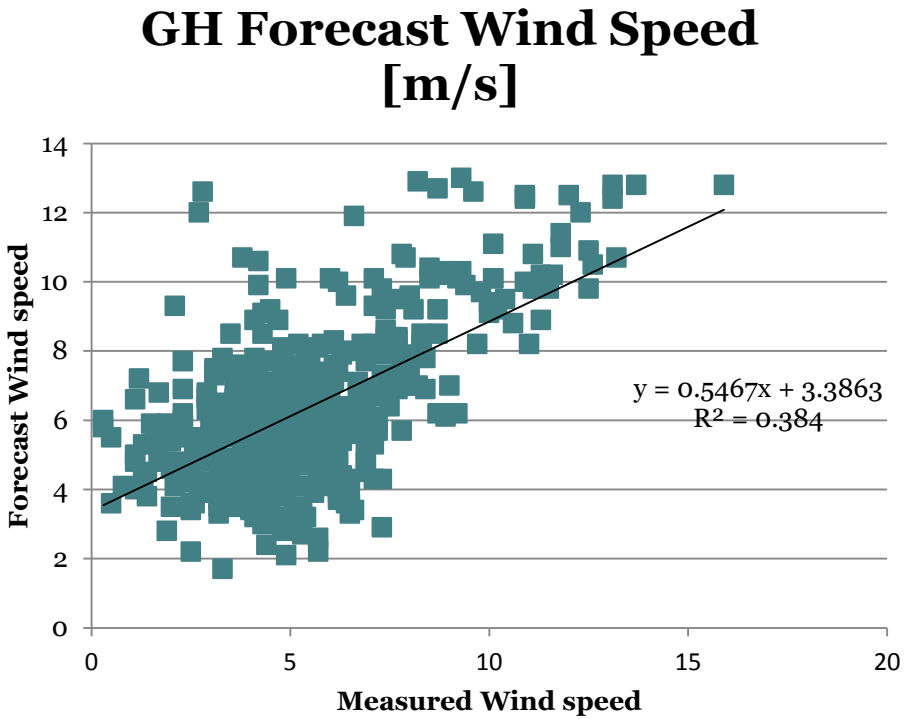
Findings…

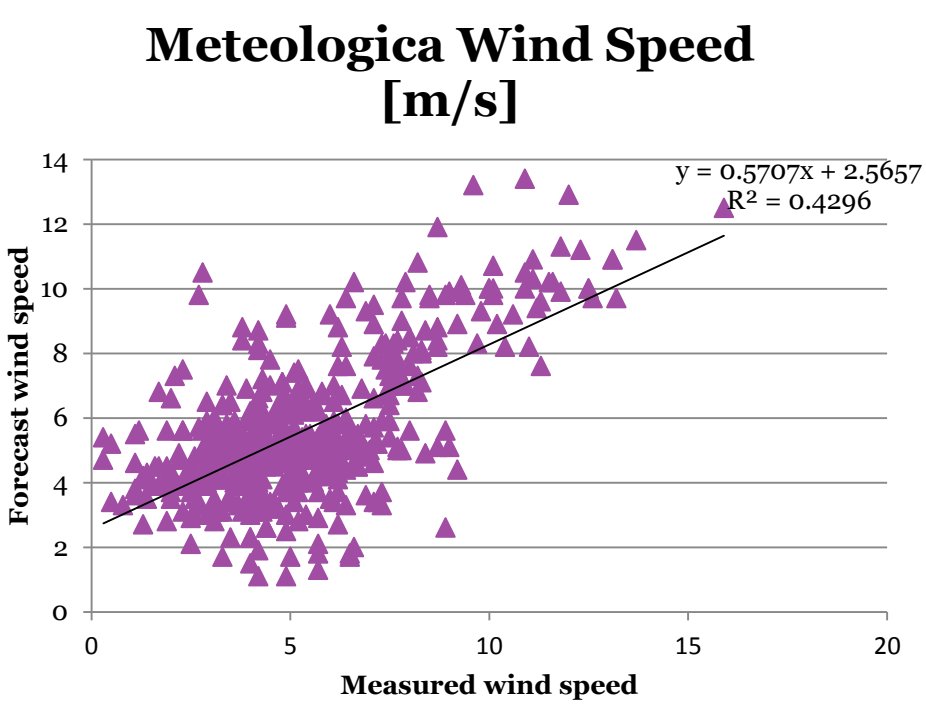
- The instances of forecast being within ±30% was better during high wind months (May to August)
  - However, the probability of hitting this target in a month was at best 65%
  - Typically it hovered around 30% to 50%
- The same was very poor during low wind months (October to March)
  - The probability of hitting this target in a month hovered around a poor 10% to15%
- Forecasting for larger wind farms gave better results – effect of averaging
- ‘Model training’ takes much longer
- Unexpected grid outages reduces the forecast accuracy

Limitations of the mathematical models

- Global Circulation Models are basically complex differential equations that are numerically solved.
- A number of linearization's, boundary conditions are to be assumed and these assumptions are region specific, climatic condition specific and requires considerable fine tuning to obtain reasonable results.
- 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 Speed forecasts





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.

External issues that affect forecast accuracy

- **NWP –** Essentially NWP outputs have a time step of 3 to 9 hours
  - Values in between are determined by a set of algorithms that need to be trained over a period of time.
  - 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, and Surface roughness
  – Climatic and Weather regime
  – Wind pattern (seasonal and diurnal)

- **Site data**
  –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.

Other issues that has adverse impact…

- Breaks in IT service
- Unscheduled outages of grid and WT
- Model training based on breaks in input data
- Wind farm modeling
  - Eg. TN – the most dynamic and hence most challenging
- Monsoon – getting it right in the model training
  - The single atmospheric phenomenon that drives wind in India…

Our concern…

Calculation of 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

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

Customers / Financing Institutions seeking clarity…

- How do we model the UI implications in cash flow of investors today?
- Customers and financing institutions are demanding more clarity on potential project 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 for us 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

Our representation…

Submissions to CERC

- We are committed to start scheduling as of 1st January 2012

- However, in view of various issues as detailed above, we herewith represent for the kind consideration of CERC that the commercial implication (UI) be exempted for wind power for a period one year…ie.: UI to start from 1st Jan, 2013
  - One year of scheduling across India will give the necessary information / data in establishing a base for financial modeling of impact of scheduling to give confidence to investors…

Our operational requirements…

- **First and foremost - Permission to install necessary ABT meters and RTUs at all sub-stations**
  - **Delay in this could delay start of scheduling…**
- **SLDC to accept schedules via FTP / email attachments**

THANK YOU !!

Indian Wind Turbine Manufacturer's Association