Large Scale Grid Integration of Renewable Energy Sources - Way Forward

Central Electricity Authority
November 2013

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Acronyms

AGC	Automatic Generation Control
AP	Andhra Pradesh
BU	Billion Unit
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
DISCOM	Distribution Company
HP	Himachal Pradesh
IEGC	Indian Electricity Grid Code
IPP	Independent Power Producer
ISGS	Inter State Generating Station
MU	Million Unit
MW	Mega Watt
NLDC	National Load Dispatch Center
NTPC	National Thermal Power Corporation
PPA	Power Purchase Agreement
RE	Renewable Energy
REMC	Renewable Energy Management Centres
RES	Renewable Energy Source
RLDC	Regional Load Dispatch Center
RPO	Renewable Purchase Obligation
RRF	Renewable Regulatory Fund
SERC	State Electricity Regulatory Commission
SLDC	State Load Dispatch Center
TSO	Transmission System Operator
UI	Unscheduled Interchange

Large Scale Grid integration of Renewable Energy Sources – Way Forward

1.0 Introduction

Renewable generation from wind and solar has increased substantially during past few years and forms a significance proportion of the total generation in the grid. This renewable generation is concentrated in a few states, to the extent that it cannot be called marginal generation and serious thought needs to be given to balance the variability of such generation. There is an ambitious programme for increase of such Renewable Generation and therefore, it is imperative to work out a way forward for facilitating large scale integration of such variable Renewable Energy Sources (RES), keeping in view the security of the grid. Moreover, as we move towards a tighter frequency band, it becomes even more challenging to balance this variable RES.

Generation from RE Sources depends on nature, i.e. wind velocity and sunshine. The variability of RES power can be addressed through improved forecasting techniques, which are still evolving. When the percentage of RES becomes significant, special attention needs to be paid to accurately forecast their output.

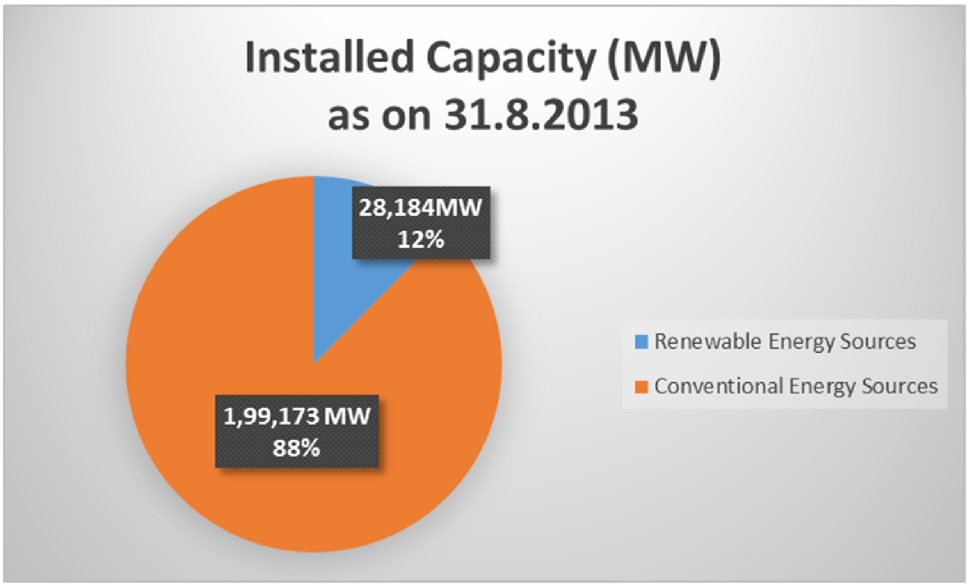
India is a country of continental size and this is helpful in balancing the variable output of renewable energy sources located in few states by integrating them into all India grid. The inter state and inter regional transmission infrastructure is already being developed and it is expected that all the five electrical regions of India would be synchronously connected in 2014. However, new transmission corridors would be required for evacuating green energy from states such as Tamil Nadu, Gujarat, Rajasthan and J & K (Ladakh). It has now been recognised by the transmission planners that in view of the short gestation period of RE plants, the transmission has to lead generation and would require upfront investment. Such transmission corridors required in the next five year time span have already been firmed up through the established process of coordinated transmission planning and their implementation is being taken up progressively.

The Report has been prepared on the basis of detailed discussions and inputs furnished by Gujarat, Rajasthan and Tamil Nadu.

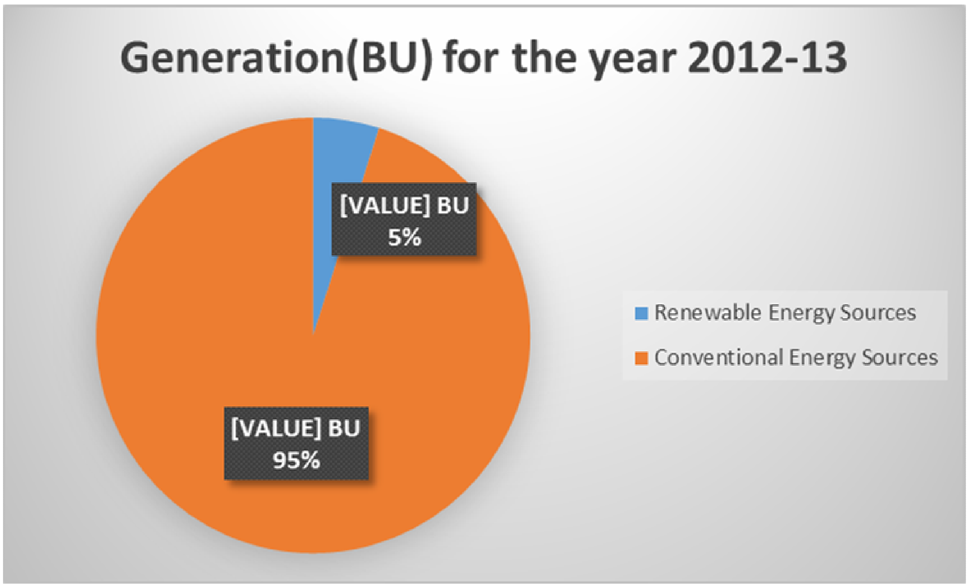
2.0 Installed Capacity of Wind and Solar Renewable Energy Sources (RES)

2.1 All India

The total All India Installed Capacity (IC) as on 31.08.2013 is 2,27,357 MW which includes 28,184 MW from Renewable Energy Sources (RES), constituting 12.4% of the total capacity. The same is shown in the form of a pi diagram below:



During 2012-13, the generation from RES sources was around 47 Billion Units (BUs), which was about 5% of the total all India generation of 959 BUs. The same is shown in the form of a pi diagram below.



2.2 Concentration of RES in certain States

The RES capacity is concentrated in five states of country, i.e. Rajasthan, Gujarat, Maharashtra, Karnataka and Tamil Nadu. The break-up of RES capacity vis-à-vis the conventional generation capacity (as on 31.7.2013) is as given below:

(Figs. In MW)

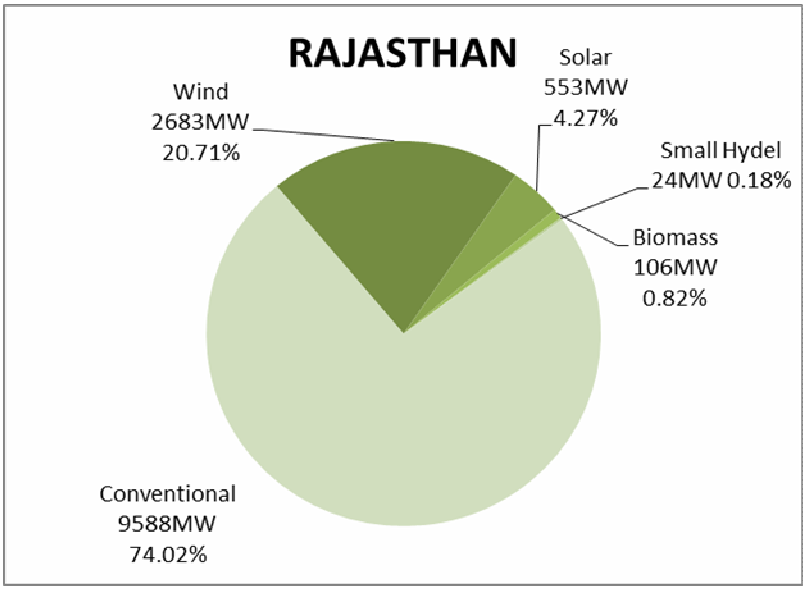
Sl. No.	State	Conventional Generation	Wind	Solar (above 1MW)	Biomass	Bagasse	Small Hydel	Total RES MW	RES capacity as % of total generating capacity
1	Rajasthan	9,588	2,683	553	106		24	3366	26%
2	Gujarat	18,479	3164	857	31		6	4058	18%
3	Maharashtra	27,137	3008	206	127	996	332	4669	14.7%
4	Karnataka	10,247	2142	14	106	1147	701	4110	28.6%
5	Tamil Nadu	11,974	7179	20	204	659		8062	40.2%
	Total	77,425	18,176	1,650	574	2802	1,063	24,265	23.86%

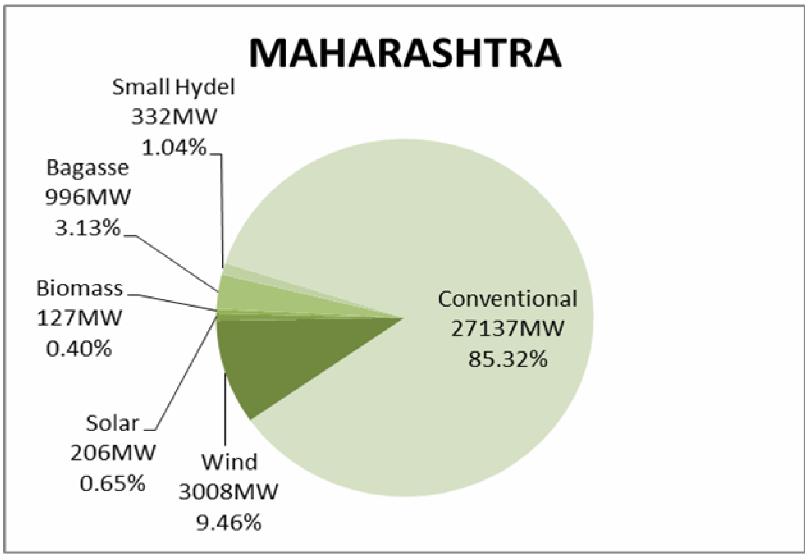
2.3 Penetration of variable RES

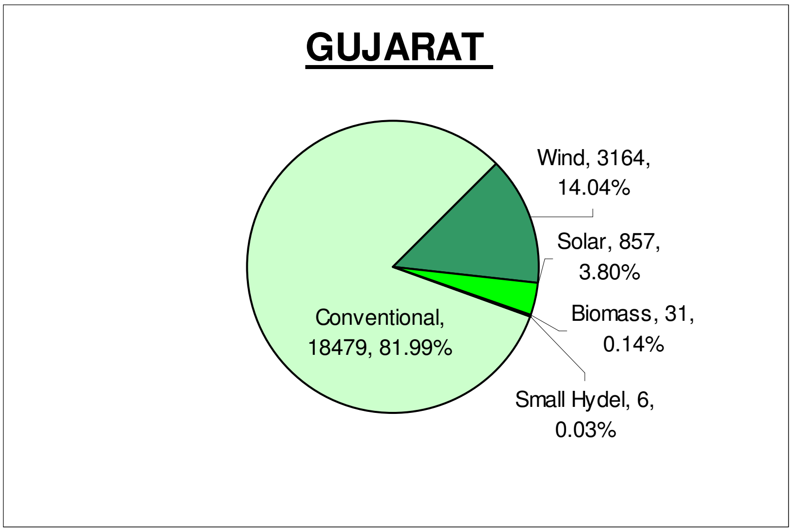
The extent of variable type of generation as compared to the total generation capacity available in the State plays an important part in determining the action required to be taken to handle the variability.

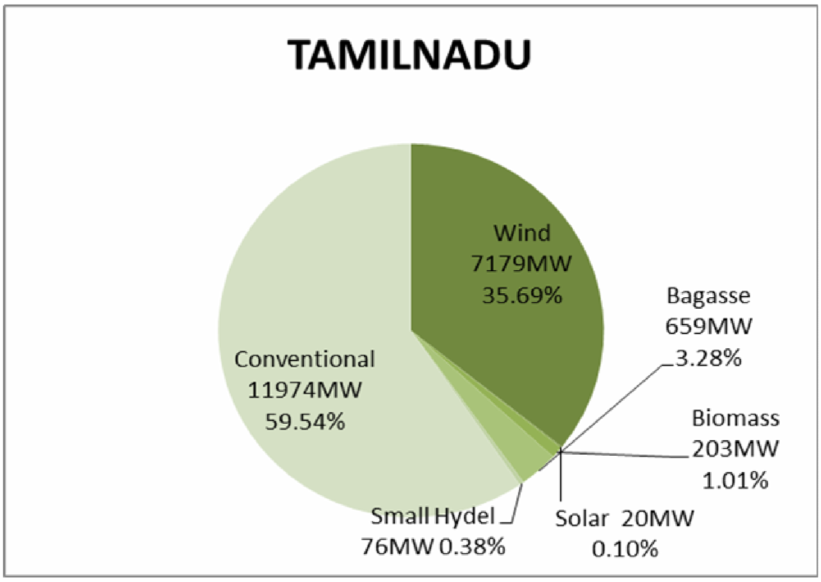
Gujarat, Tamil Nadu and Rajasthan have substantial percentages 18%, 40.5% and 26% of the RES in their total installed capacity respectively, predominant of which is wind and solar. These three States put together have 70% of the wind generation capacity and 91% of Solar generating capacity of the total all India wind (18500 MW) and Solar capacity (1500 MW) respectively. The other States with substantial RES capacity are Maharashtra and Karnataka.

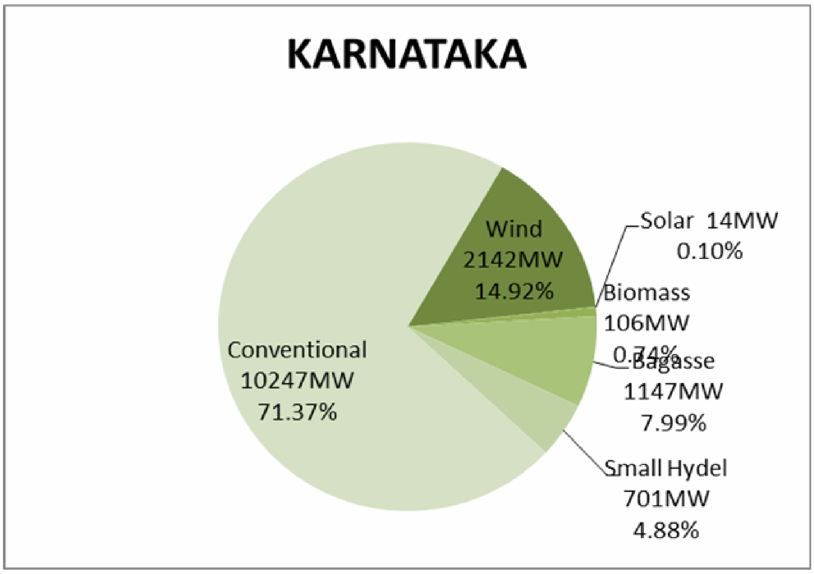
The break-up of the total installed capacity in the five States, showing the intermittent generation v/s conventional generation, is depicted below in the form of pi diagrams.





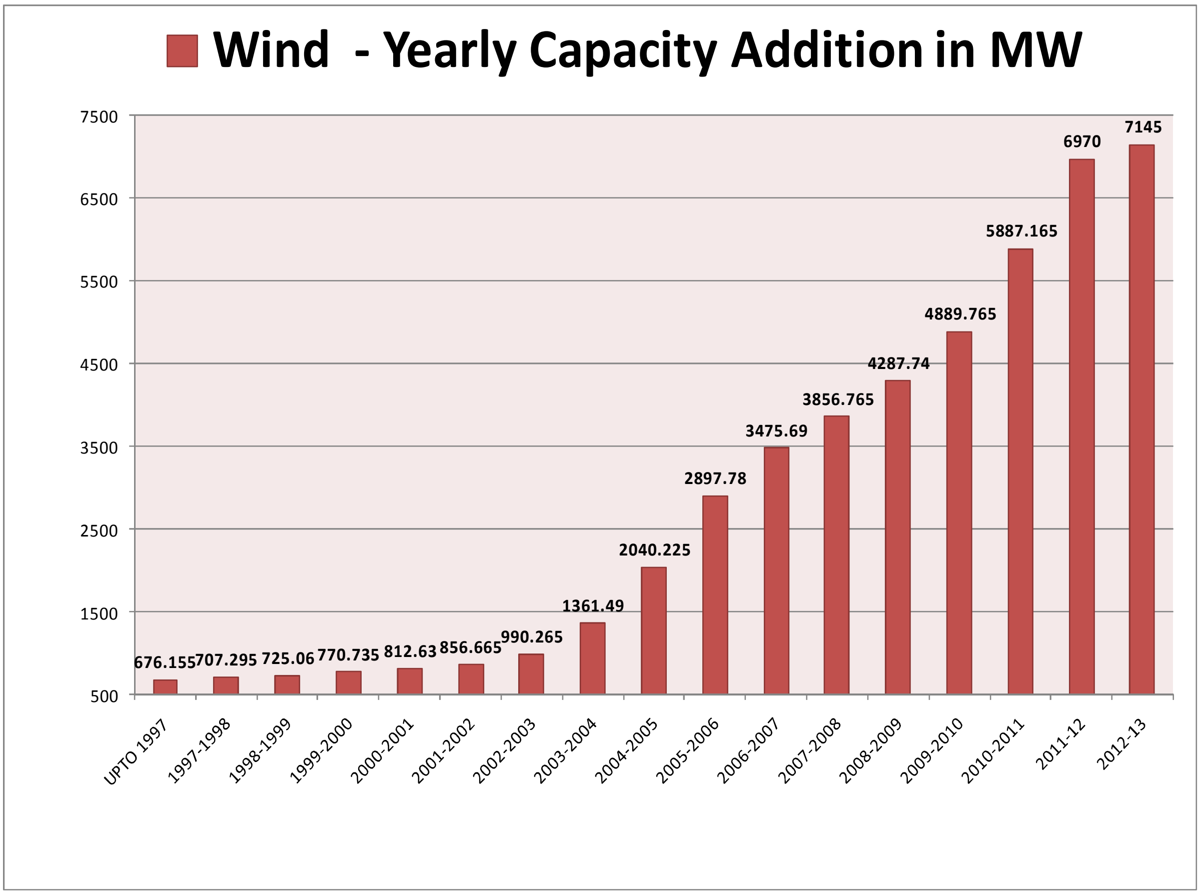

GUJARAT
Wind, 3164, 14.04%
Solar, 857, 3.80%
Biomass, 31, 0.14%
Small Hydel, 6, 0.03%
Conventional, 18479, 81.99%


TAMILNADU
Wind 7179MW 35.69%
Bagasse 659MW 3.28%
Biomass 203MW 1.01%
Solar 20MW 0.10%
Small Hydel 76MW 0.38%
Conventional 11974MW 59.54%


KARNATAKA
Wind 2142MW 14.92%
Solar 14MW 0.10%
Biomass 106MW 0.74%
Bagasse 1147MW 7.99%
Small Hydel 701MW 4.88%
Conventional 10247MW 71.37%

2.4 Growth of wind capacity in Tamil Nadu

The State of Tamil Nadu in India has the highest installed generating capacity of wind power in India, i.e. 7158 MW (as at end July, 2013) which is about 40% of Wind installed capacity in India. The growth of wind installed capacity in Tamil Nadu is shown below:



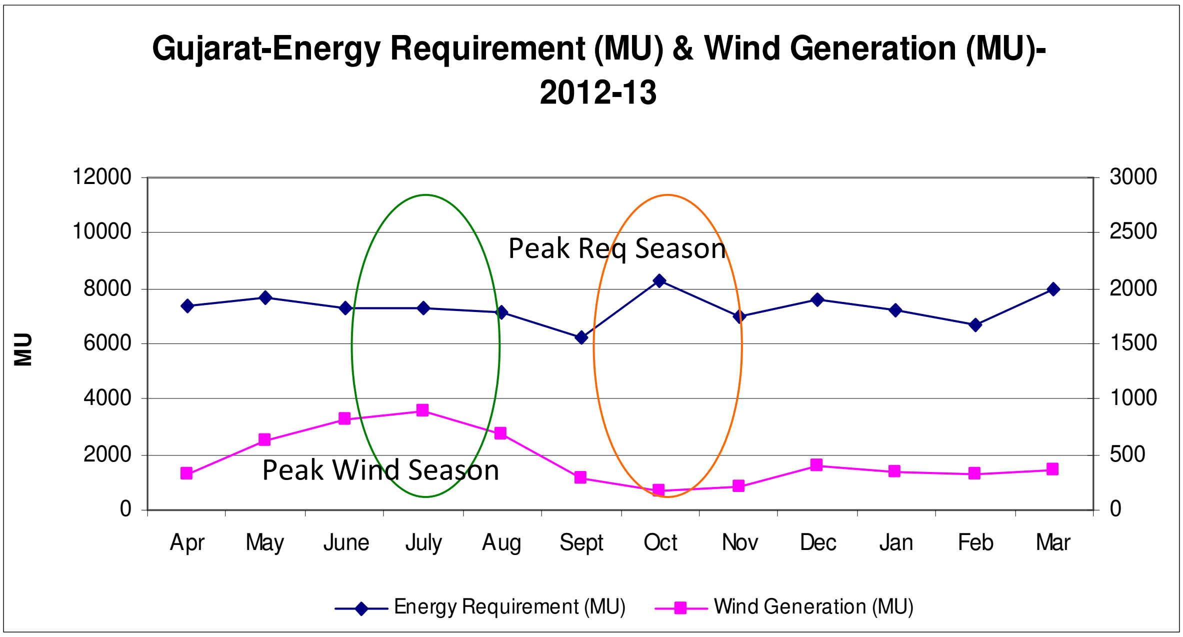
3.0 12th Plan RES additions

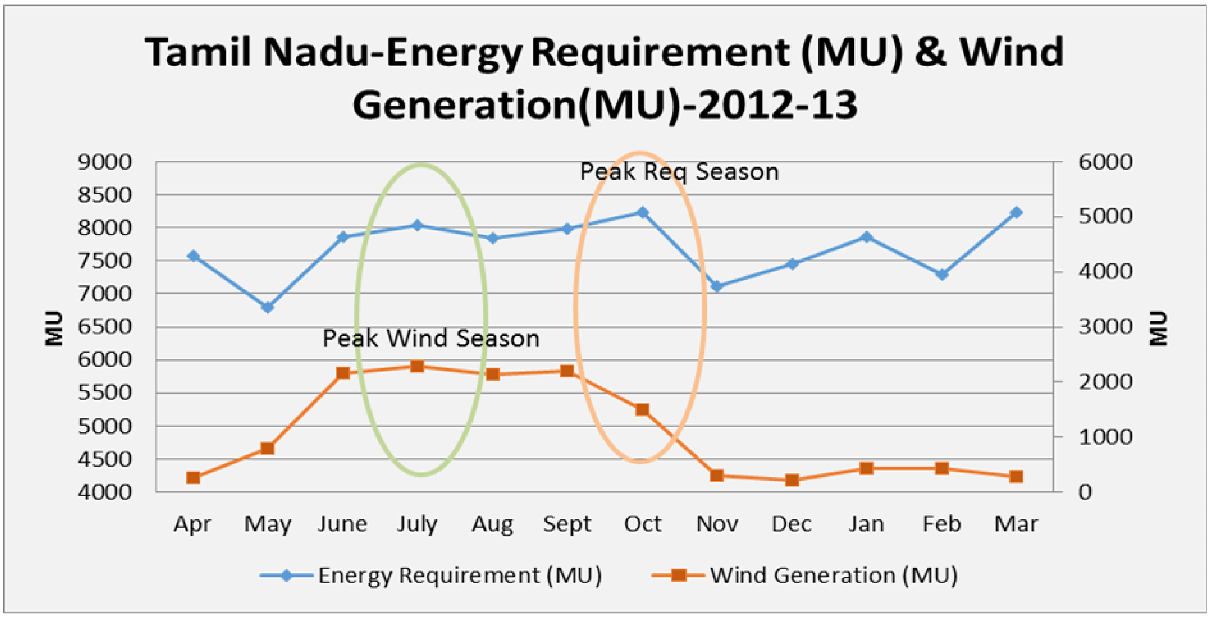
During the 12th five year plan, capacity addition programme of around 88,537 MW has been planned from conventional generation. CEA has made an assessment of capacity addition (wind/ solar/ small hydro) likely to come up during the 12th Plan and it is envisaged that about 32,000 MW is likely to come up in eight RE rich states i.e. Tamil Nadu, Karnataka, A.P., Maharashtra, Gujarat, Rajasthan, Jammu & Kashmir and H.P. The corresponding intra-state and Inter-state transmission systems have already been planned. However, a comprehensive scheme for wind and solar forecasting stations, communication system and Renewable Energy Management Centres (REMC) is yet to be planned and taken up. Out of the 32,000 MW of RES, consisting of Wind, Solar and Small Hydro, about 30,000 MW is expected to come from solar and wind energy. The break-up of such generation capacity among the various states of India is given below:

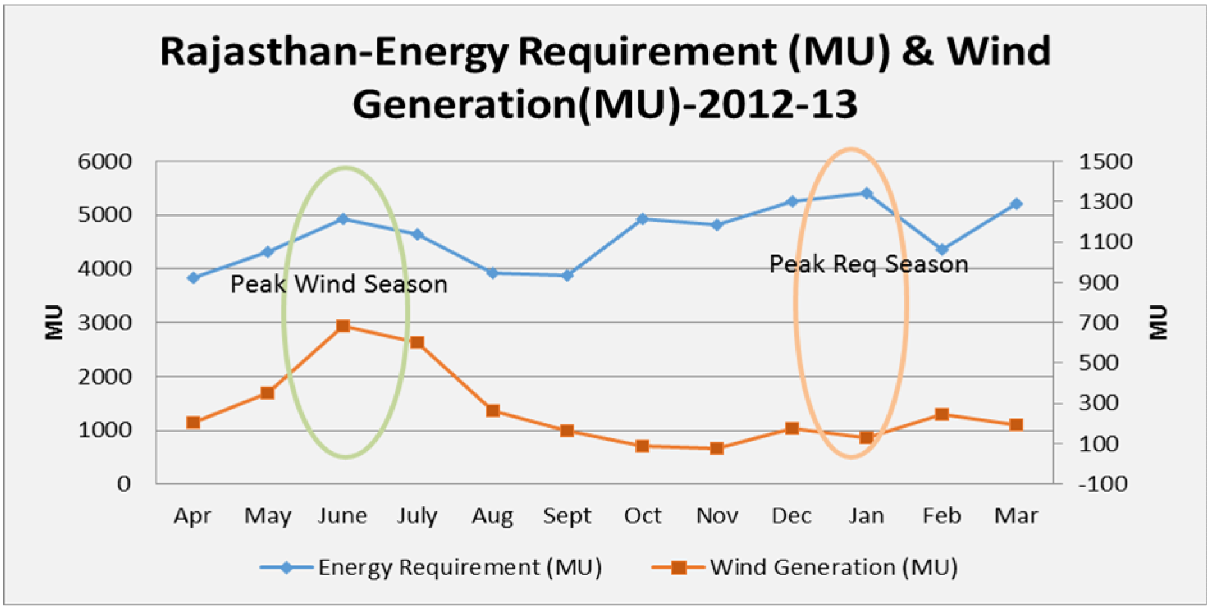
State	Wind	Solar	SHP (Small Hydro Projects)	Total, MW
Tamil Nadu	4339	3014		7353
Andhra Pradesh	3150	1677		4827
Karnataka	3619	253	418	4290
Gujarat	3368	1361		4729
Maharashtra	3763	300		4063
Rajasthan	2181	3513		5694
Himachal Pradesh			1281	1281
Jammu & Kashmir	12	102	362	476
Total	**20432**	**10220**	**2061**	**32713**

4.0 Analysis of renewable generation from Wind & Solar Energy Sources

The peak wind generation in a State occurs in a different season as compared to the months of peak requirement of the State. The variation of month-wise generation from wind and demand during the year 2012-13 for the three states of Gujarat, Tamil Nadu and Rajasthan are shown below:

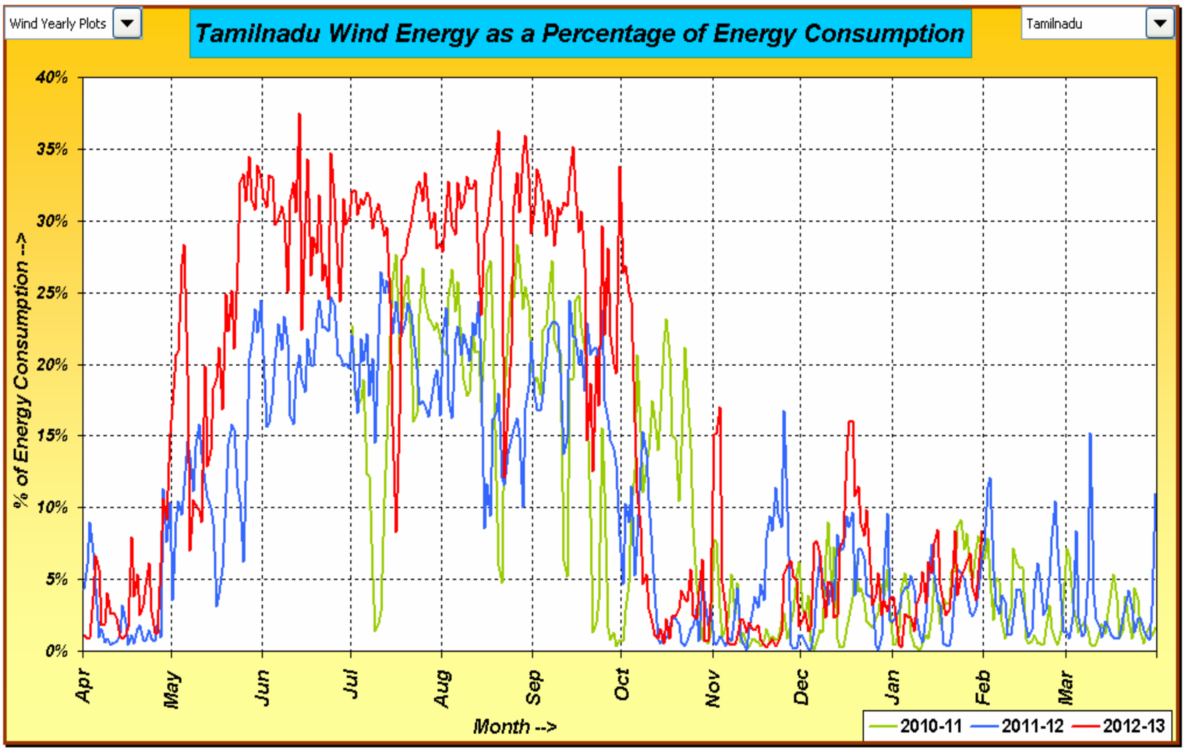

Gujarat-Energy Requirement (MU) & Wind Generation (MU)-2012-13
MU
12000
10000
8000
6000
4000
2000
0
3000
2500
2000
1500
1000
500
0
Peak Req Season
Peak Wind Season
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Energy Requirement (MU)
Wind Generation (MU)


Tamil Nadu-Energy Requirement (MU) & Wind Generation(MU)-2012-13
MU
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
6000
5000
4000
3000
2000
1000
0
MU
Peak Req Season
Peak Wind Season
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Energy Requirement (MU)
Wind Generation (MU)

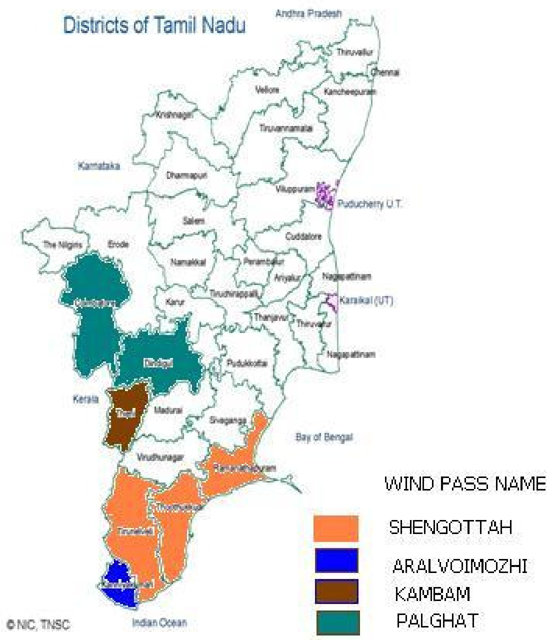


4.1 Wind Generation – Tamil Nadu

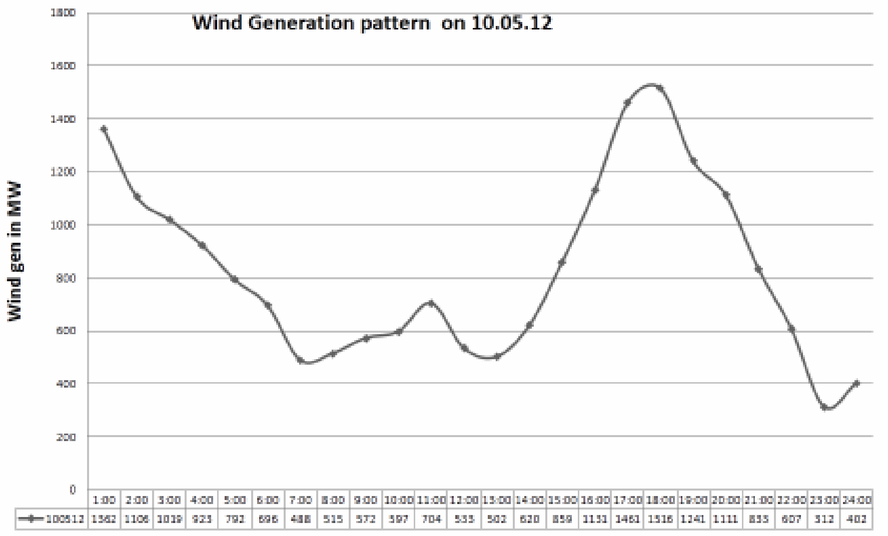
The main wind season in Tamil Nadu is from June to September. During this season, wind contributes about 30-35% of the total energy consumption in Tamil Nadu. In other wind-rich States, wind contributes about 20% in Karnataka and Rajasthan, 15% in Gujarat and 10-12% in Maharashtra. The percentage contribution of wind energy to the total energy consumption in Tamil Nadu, over various seasons for the last three years is shown in the graph given below:

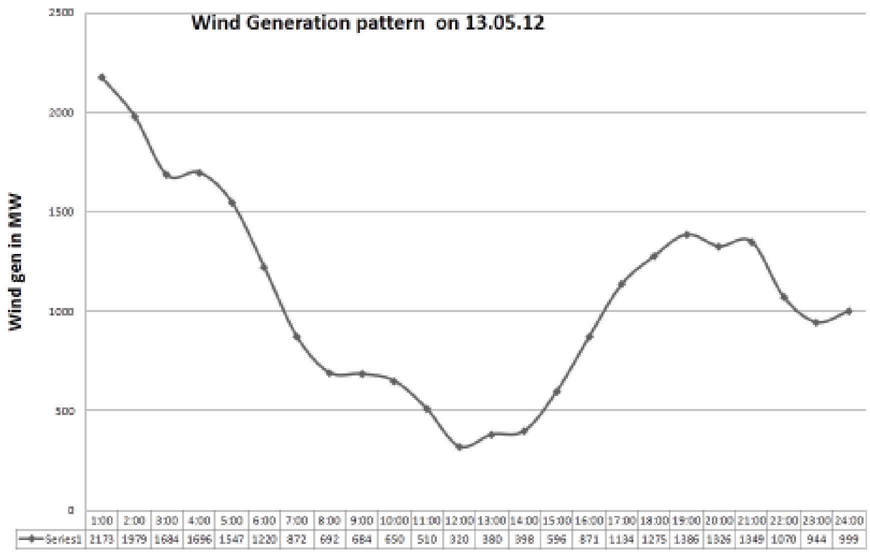


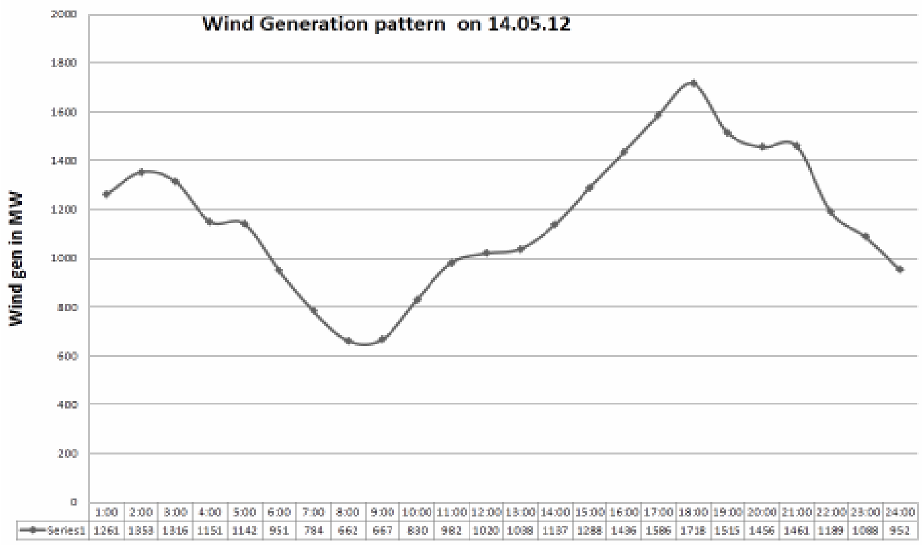
Tamil Nadu has four passes through which wind blows, viz., Palghat, Shencottah, Aralvoimozhi and Kambam. These are shown below :



Wind generators fed from these passes are connected to 15 pooling stations at 110kV and 230kV levels through which power is injected into the grid. The variation of wind generation, for all pooling stations combined, on consecutive days in Tamil Nadu in the month of May, 2012, is shown below:





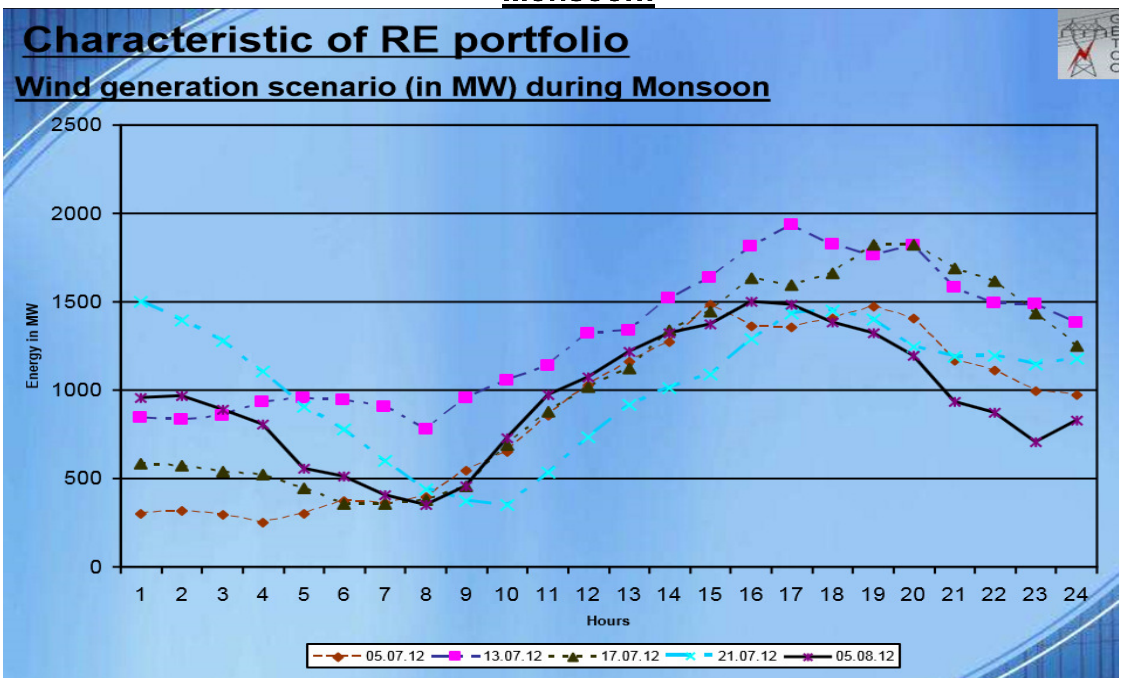


The above graphs show that even on consecutive days there is variation of wind generation. If the variation of wind generation is seen on a pooling station-wise basis, the variations would be even more, since the variations over wide geographical areas tend to counter balance each other.

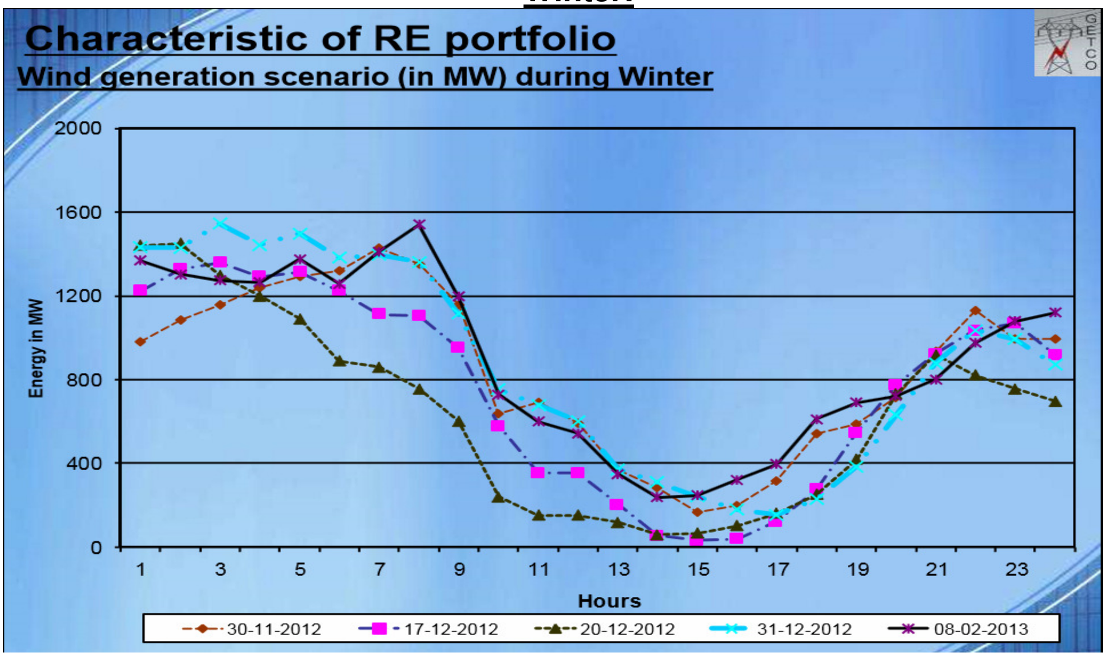
4.2 Wind Generation- Gujarat & Rajasthan

The typical seasonal variation of wind generation in **Gujarat** is given below:

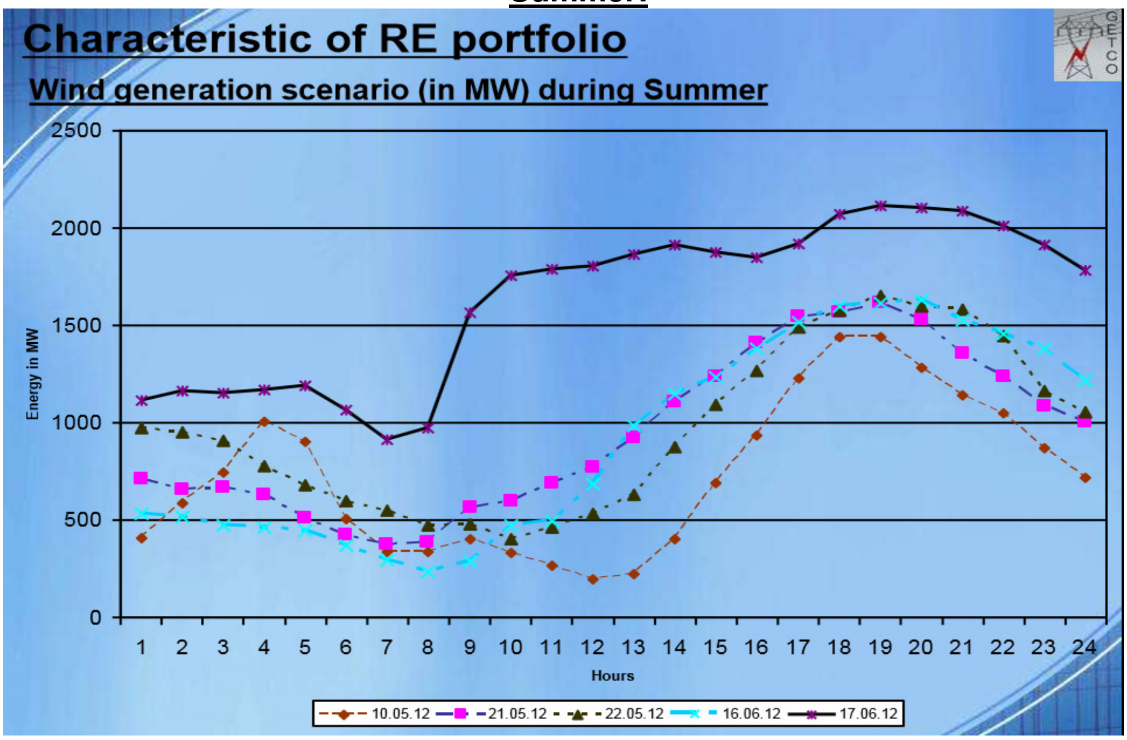
Monsoon:



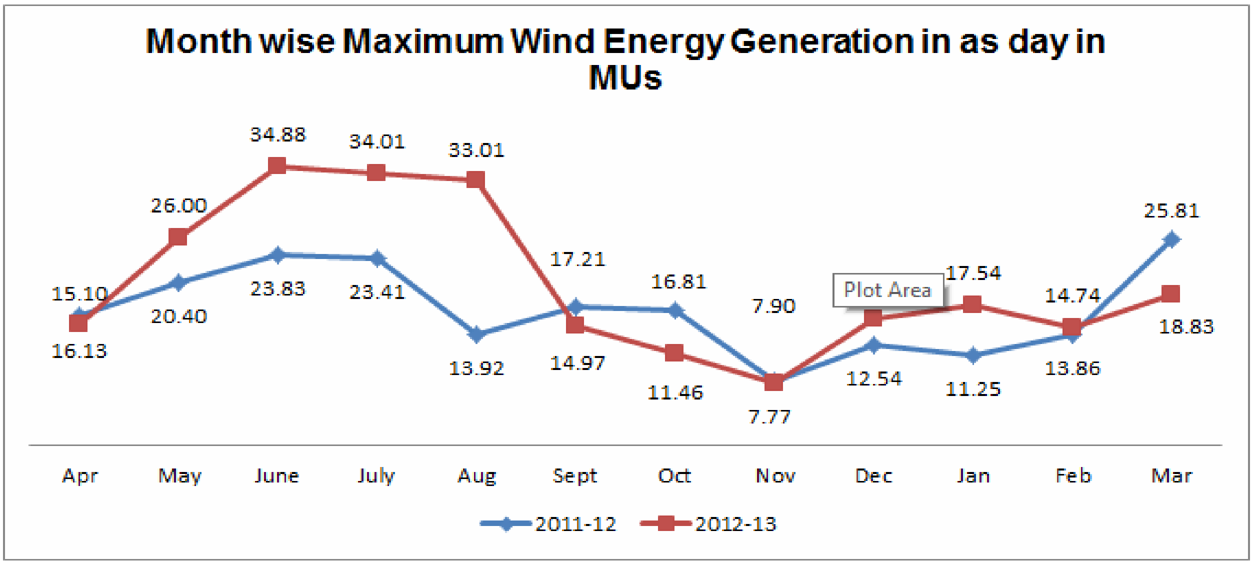
Winter:

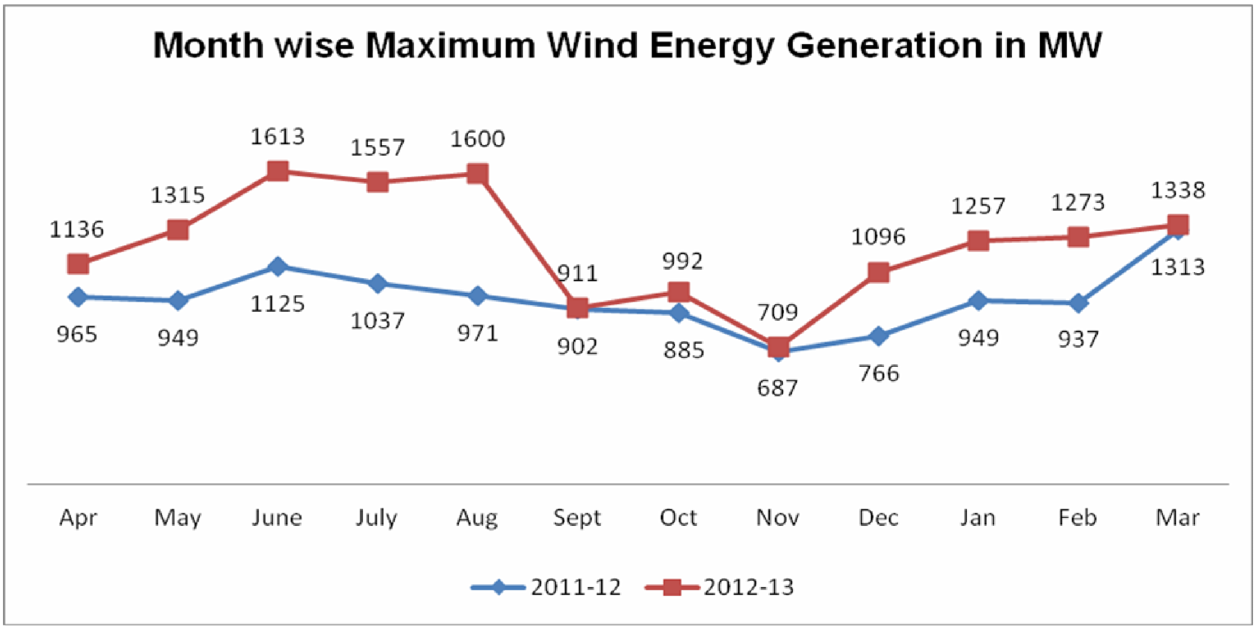


Summer:

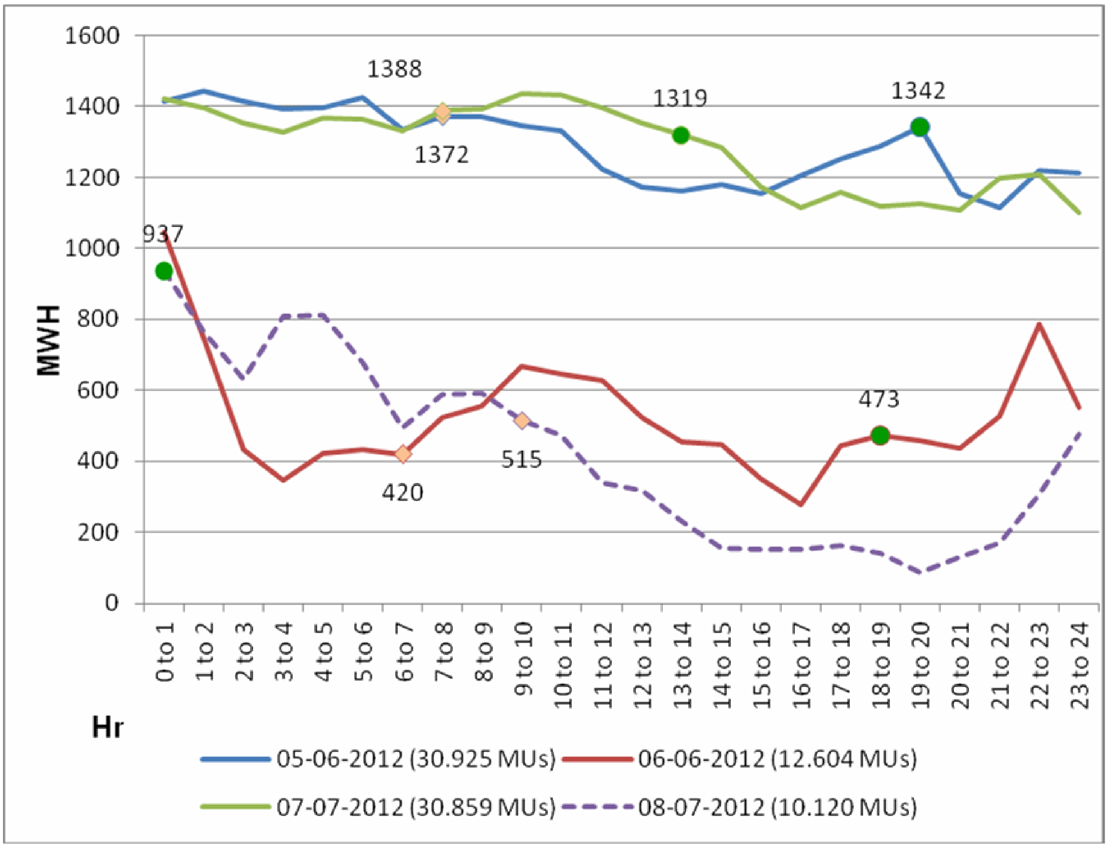


The month-wise maximum wind energy generation in million units and peak wind generation in MW for various months of the year for the last two years in **Rajasthan** is given below:





The wind variation in **Rajasthan** in MW over consecutive days in the month of June and July 2012 is given below:

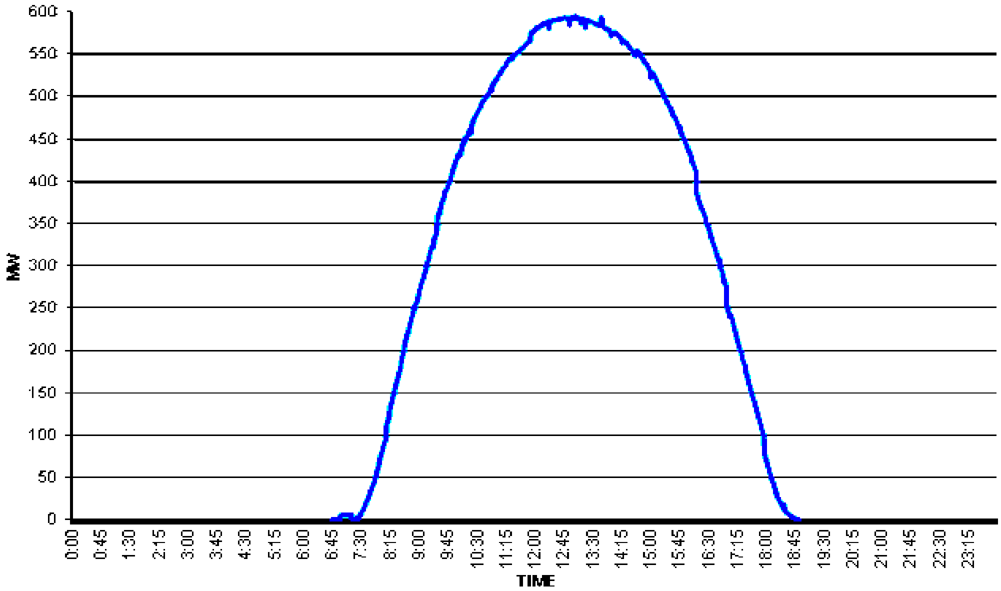


From the above, it may be concluded that the difference between maximum and minimum wind generation over a day can be quite substantial. The number of days for range of variation of wind generation over a day going beyond certain limits in the three States is given below:

States	Variation Band (MW)	Days
Gujarat	> 500 &<1000	243
	> 1000 &< 1500	55
	1547	1
Tamil Nadu	> 500 &<1500	175
	>1500 & <3000	84
	>3000	2
	3385	1
Rajasthan	>500 & <1000	154
	>1000	11
	1164	1

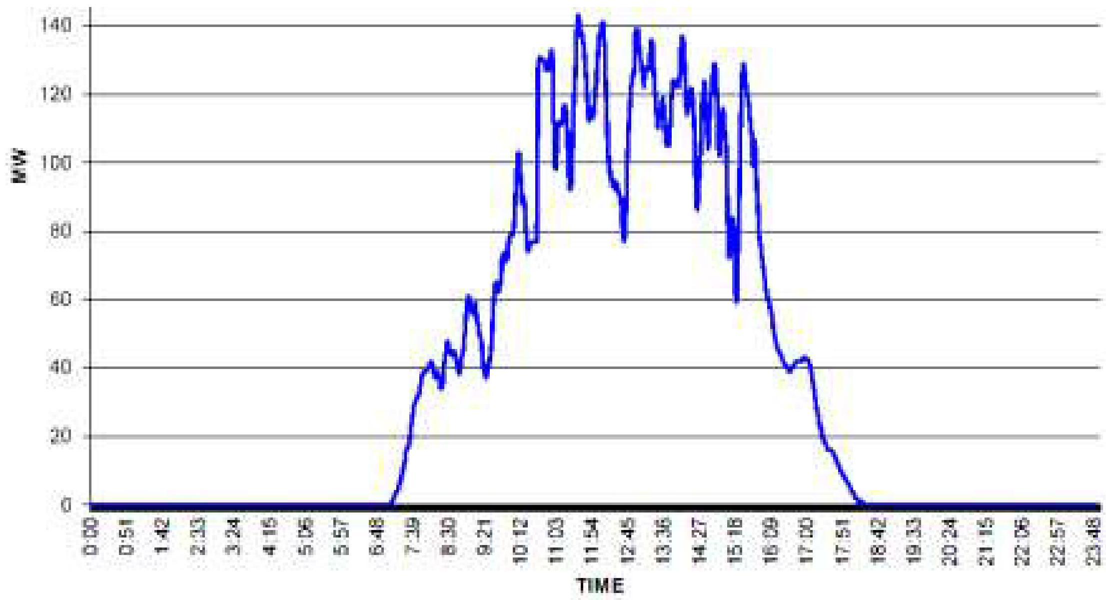
4.3 Solar Generation – Gujarat

The highest solar generating capacity in India is presently in Gujarat, i.e. 857 MW as on July 2013 against a total generating capacity of about 18,479 MW. However, solar generating capacity is in the process of coming up in a big way, due to minimum Renewable Purchase Obligations of 0.25% of the energy consumption in the State, reducing prices of Solar PV modules and the thrust given by the National Solar Mission through reducing the cost of solar power by mixing the same with coal-based power from NTPC Stations. The typical solar generation over a day in Gujarat for a non-cloudy day is given below:

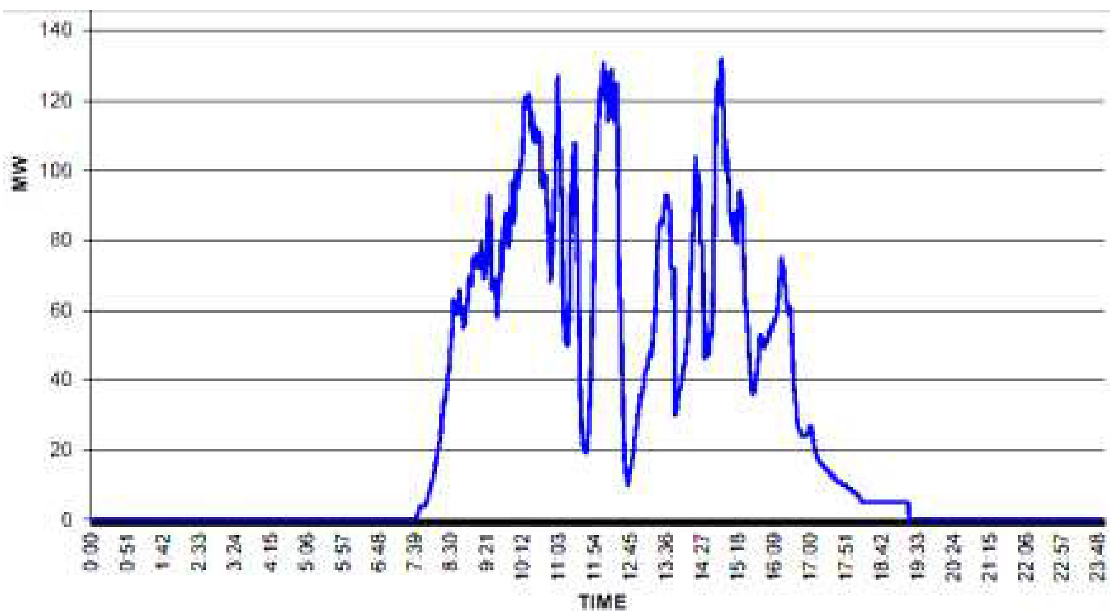


The solar generation is affected due to appearance of clouds. The solar generation on some of the cloudy days, in the **Charanka Solar Park** is given below :

(1) On 1st September, 2012



On 10th September, 2012



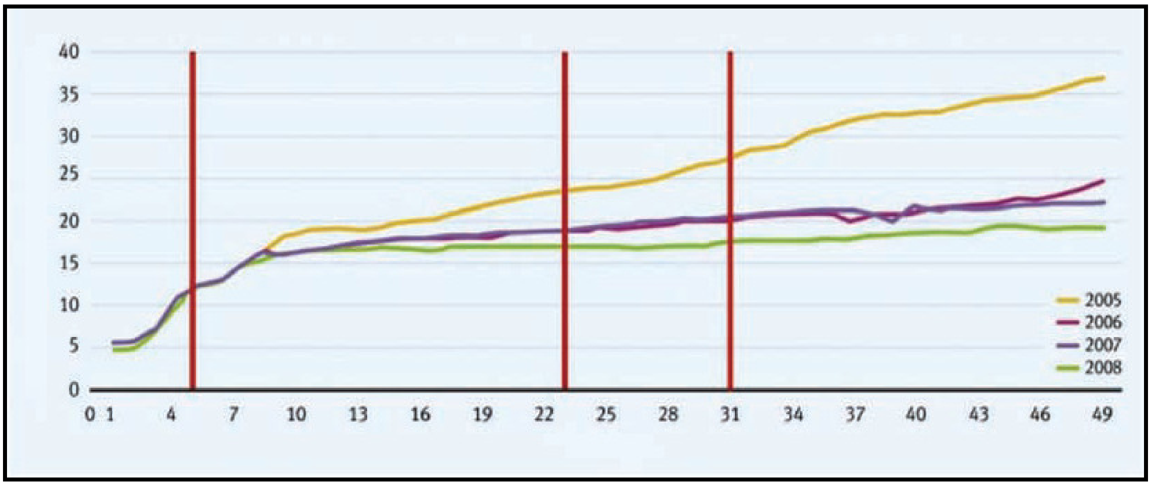
The above diagrams show how the normal shape of the daily solar generation pattern is affected by clouds coming in the way of the sun and even generation on consecutive days is different.

5.0 Forecasting of Wind and Solar Generation

In order to ensure that the grid operates safely, it is very important for the System Operator to foresee what is expected to happen a few hours ahead, in order to be able to take appropriate measures. A number of firms have entered the realm of forecasting, based on historical data, wind speed, topological features of the area, air pressure, humidity, etc. for the purpose of wind forecasting. Solar forecasting is also expected to become important in the future.

Forecasting techniques have been gradually improving over the years. The forecasting error has been coming down to 15-25 % for up to day-ahead lead time. An indicative evolution of forecasting errors is depicted below:

The Evolution of Forecasting Errors versus Lead Time, 2005–2008



In Europe, wind forecasting is done by the system operator and balancing requirements for the same are assigned to various additional system operators; in other words, the balancing requirements are socialized. However, the sizes of countries in Europe are about the size of States in India. There is a proposal to carry out market integration of the countries in Europe in order for this variability to be spread out over a wider area for balancing to be done. There is a proposal to construct transmission corridors linking the high wind generating areas in Spain, Germany etc. with the hydro reservoirs in Norway.

In India we have the advantage of a large grid integrated by high capacity transmission corridors. More such inter-state/regional inter-connections are under implementation.

6.0 Present method of balancing by the States

6.1 Tamil Nadu

Tamil Nadu has stated that it manages the variability through reduction of generation in their coal-based power plants, which are older plants of 210 MW. There are 12 such units, whose generation can be varied between 170-210 MW, below 170 MW they would need oil support, which increases the cost of thermal power. Tamil Nadu has long term PPA with IPPs totaling to 1000 MW located in the state, which are backed down, when required. They are constrained from using their hydro power plants for balancing. As against the total Hydro installed capacity of 2237 MW in Tamil Nadu, the non-irrigation based stations which could only be regulated according to the grid requirements is only 1325 MW. As June- September period has both high winds and high inflows to the reservoirs, the hydro stations have to be operated at full load and as such are not available for balancing. Further, the only available Pumped storage scheme of 400MW Kadamparai is also not operated since being the south west monsoon season, both upper and lower reservoirs i.e. Upper Aliyar & Kaddamprai are filled up to their maximum level, and hence, any restriction of generation would result in spillage of water and therefore wasting of free generation. The gas based stations in Tamil Nadu are radially connected to the gas wells and therefore gas flow cannot be varied to produce variable generation.

Tamil Nadu has suggested that the evacuation of the entire wind power needs to be facilitated by regulating the other generating sources in the Southern Region and the spinning reserve available in the Southern Region should be extended for balancing the RES of the whole region which may be extended to national level.

6.2 Gujarat

6.2.1 Gujarat presently uses both its thermal and hydro power stations for balancing. It keeps a margin in its thermal and hydro generation to balance the variations of wind and solar generation. Their thermal units of 240 MW at Sikka and Wanakbori can be varied up to 140 MW. They also get supply from NTPC units of 500 MW and NTPC has now agreed to the request of Gujarat to vary their generation from 60% to 100% of unit capacity for balancing. The increased cycling and rapid ramping up and down may result in wear and tear impacts that leads to increased capital and maintenance costs and degraded performance over a period of time. Heat rates and emissions from fossil fuel generators will be higher during cycling and ramping than during steady state operation. However, Gujarat has brought out the commercial disadvantages for managing this variability. It has stated that against a wind must-run generation with an average tariff of Rs. 3.56 per unit in June 2012, they had to back down cheaper generation of about Rs. 2.50 to Rs. 2.70 per unit. In addition they had to buy costlier power from the market.

6.2.2 Gujarat has created a renewable desk and a dedicated engineer for weather forecasting. They are in the process of installing weather sensors at places where wind generation is 50 MW and above, which would measure six parameters of weather, viz., relative humidity, temperature, wind speed, wind direction, atmospheric pressure and rainfall every 10 seconds and relay the data to the weather desk in the SLDC. These are expected to be functional within 2 months.

6.2.3 **Operational planning to cope with wind variation**

The Gujarat RE desk prepares anticipated variation for wind / solar generation as well as load for the same day, next day and for next 7 days and updates it every three hours.

Short term plan:

In case of High wind generation and high load scenario:

1. Keep adequate margin on State thermal, gas and Hydro plants to accommodate up to 50% of wind generation.

2. In absence of above margin, requisite un-requisitioned share of Gujarat in the central sector power plants and create above margin.
3. In absence of option 1 & 2, the power supply to agriculture feeders shall be arranged in groups. Curtail the feeder which has completed 50% time limit.

<u>In case of High wind – low load condition scenario:</u>

1. Back down the state generating units to technical minimum.
2. Reduce the schedule of Gujarat from the central sector units such that the units run on technical / coal minimum.
3. Reserve shut down of smaller state generating units and schedule full share from central sector units.
4. In case of less regional demand, reserve shut down of smaller central sector units.

Long term plan:

1. Keep all Hydro machines in operation.
2. A pump head storage plant may be planned.
3. Explore the possibility of use of energy storage technology to store wind energy at off peak period and use at peak period. A pilot project of such storage technology may be implemented at state level.

6.3 Rajasthan

Rajasthan has a wind generation capacity of 2539 MW as on 31.03.2013 which is expected to increase to about 3500 MW by 2016-17. Variations in wind generation up to 1140 MW have been recorded in a day. Rajasthan uses coal and lignite based generating plants to balance the wind variability in the State by reducing to the extent that they do not need oil support for steady flame in the boiler. They also use their two gas-based stations, Ramgarh (113 MW) and Dholpur (330 MW) for balancing. Since wind generators do not provide the required VAR support, over voltage causes over-fluxing in transformers resulting in tripping.

7.0 International Experience

7.1 China

According to the Renewable Energy Law and related regulations, wind power and other renewables should be given first priority in generation scheduling and dispatching under normal power system operating conditions. To meet this requirement, grid operators consider predicted wind power generation in the mid-to-long term, day-ahead and intra-day operation planning processes and fully exploit flexibility from conventional power plants, as well as the capacity of inter-grid tie-lines to accommodate the maximum wind power while maintaining system security and reliability.

The requirement is also emphasized for Wind Power Plants (WPPs) to be equipped with control and monitoring systems; these serve to enhance their controllability and provide operational information to grid operators. All grid-connected WPPs have been equipped with control and monitoring systems that can communicate with the dispatching centers in real time. Based on wind power forecasting at different time scales, a “wind power optimal dispatching decision support system” had been developed and put into operation in the dispatching centre.

7.2 Germany

50 Hertz Transmission GmbH (50 Hertz) is one of four TSOs (Transmission System Operator) in Germany. 50 Hertz operates in the northern and eastern parts of the country. At the end of 2010, the total installed generation in the 50 Hertz control area (i.e. including the share connected to related distribution grids) was about 38,000 MW, of which about 30 % was wind. The peak load in 50 Hertz control area was only about 17,600 MW. This makes 50 Hertz the only known power system in the world that has this level of wind power capacity, relative to both peak load and generation. This large constellation of RE generation has caused several operational challenges in 50Hertz control area, especially when the actual wind power in-feed exceeded the demand such as during low load conditions. During these times, the excess wind capacity in 50 Hertz has to be transported to neighboring TSOs, where the electrical demand is much higher. This transport requires a very close coordination between 50 Hertz and neighbouring TSOs in and outside of Germany.

Wind forecasting is currently being used in the 50Hertz control room. 50 Hertz uses three different forecast tools. It receives wind power forecast data from four different forecast service providers. The forecast horizon is 96 hrs and beyond that it's updated twice a day. The information is combined using a weighted sum. Dispatchers use the information to develop an operational forecast.

The German "Renewable Energy Sources Act" amendment introduced a new mechanism for wind power balancing, which requires each system operator to contribute to balancing the whole country's wind power output in proportion to the size of its regional grid. This mechanism allocates wind power and the associated fluctuation to each system operator in real time. It is more equitable in the distribution of balance services and related costs. The four system operators have developed a real-time wind power monitoring system to determine the wind power balancing capacity that every system operator should be responsible for. In fact, as concerns wind power, the regional grids have integrated into a single large grid in Germany.

7.3 Japan

Japan's power system consists of two parts, the Western 60 Hz network and the Eastern 50 Hz network, which are interconnected through frequency converter stations. The Eastern network consists of three utilities: the Hokkaido Electric Power Company (EP), Tohoku EP and Tokyo Electric Power Company (TEPCO). Hokkaido EP is interconnected with Tohoku EP through DC submarine cables, and Tohoku EP and TEPCO are connected by a 500 kV double circuit AC transmission line. The areas suitable for wind power generation are limited by geographical factors, and they are unfortunately concentrated in areas whose system capacities are comparatively small. Most wind resources are located in the smaller Hokkaido and Tohoku EP areas, where peak demand is around 5 GW and 15 GW respectively. In the area of TEPCO, which has an electricity demand of 60 GW including the Tokyo metropolitan area, there are few suitable locations for wind power. This situation poses a challenge for wind power integration, since the amount of RE that can be integrated into a grid depends on the capacity of the network where the RE is located. To enhance wind power integration, one option is to use inter-ties between utilities efficiently to balance wind power generation output with the output of the thermal power plants being reduced accordingly to absorb the incoming wind power. These collaboration schemes will improve the utilities' capability to accommodate wind power, but the capability is limited by the capacity of the inter-ties. When the capacity of the inter-ties is insufficient, excess wind power generation has to be curtailed.

7.4 Spain

Red Eléctrica de España, S.A.(REE) is dedicated to the transmission of electricity and the operation of electricity systems of Spain. Red Eléctrica, the Spanish TSO, started up a Control Centre of Renewable Energies (CECRE) in 2006, a worldwide pioneering initiative to monitor and control Renewable energy. CECRE allows the maximum amount of production from renewable energy sources, especially wind energy, to be integrated into the power system under secure conditions. CECRE is an operation unit integrated into the Power Control Centre (CECOEL). After June 30th 2007, all wind production facilities with a total installed power greater than 10 MW must be controlled by a control center that is directly connected to the CECRE. These wind generation control centers must have enough control over the plants that they can execute CECRE's orders within 15 minutes at all times.

By means of 23 control centers of the generation companies, which act as interlocutors, CECRE receives, every 12 seconds, real time information about each facility regarding the status of the grid connection, production and voltage at the connection point. This data is used by a sophisticated tool which makes it possible to verify whether the total generation obtained from renewable energies can be integrated at any moment into the electricity system without affecting the security of supply.

The control centres are able to control wind power output according to setting values issued by CECRE within 15 minutes at any time. For power system security reasons, if necessary, it has the right to reduce the wind power output. On one hand, it can determine the maximum RE which the entire system can accommodate while still guaranteeing system security. On the other hand, using an optimization method, it can calculate the maximum output of each wind farm. The resulting setting thus calculated is sent to every control centre.

Although wind farms are declaring their forecasted generation, REE is also doing wind forecasting separately. SIPREOLICO is a wind prediction tool for the

Spanish peninsular power system. It is a short-term wind power prediction tool (detailed hourly forecasts up to 48 Hrs in advance & aggregated hourly forecast up to 10 days in advance)

7.5 USA

Due to different grid composition, rules and wind power penetration, the various regional grids of the USA have developed widely varying wind power scheduling, dispatch and operational mechanisms. For example, the California Independent System Operator (CAISO), as a leader in state-of-the-art mechanisms, has developed a Participating Intermittent Resource Program (PIRP) that allows individual wind facilities to self-schedule according to shared forecasting technologies. One tool the ISO uses in managing the grid is the ancillary services market. Power suppliers offer special energy products that "stand by" and are ready to act in case of sudden loss of a power plant or transmission line. There are four types of ancillary services products: regulation up, regulation down, spinning reserve and non-spinning reserve. Regulation energy is used to control system frequency that can vary as generators access the system and must be maintained very narrowly around 60 hertz. Units and system resources providing regulation are certified by the ISO and must respond to "automatic generation control" signals to increase or decrease their operating levels depending upon the service being provided, regulation up or regulation down.

Spinning reserve is the portion of unloaded capacity from units already connected or synchronized to the grid and that can deliver their energy in 10 minutes and run for at least two hours. Non-spinning reserve is capacity that can be synchronized and ramping to a specified load within 10 minutes.

The New York Independent System Operator (NYISO) requires wind farms to behave like conventional power in order to participate in real-time electricity markets in certain circumstances, the wind farm must reduce output power or be fined if it exceeds the value specified in scheduling instructions.

8.0 Analysis in the Indian context

8.1 The basic technical challenge comes from the variability of wind and solar power which affects the load generation balance, varying demand for reactive power and impact on voltage stability. Recently 16 SVCs (+300/-200, +400/-300, +600/-

400 MVAR) / STATCOMs (± 200 MVAR – 7 nos., ± 300 MVAR- 6 nos.) have been decided to be installed at various points in the Indian grid to provide dynamic voltage compensation. However, further action is required in this direction and more simulation studies and better modelling of RE sources needs to be done with the help of international cooperation.

Most of the wind generators, being induction type are absorbing substantial reactive power during startup and some reactive power during normal operating condition. Due to intermittent characteristic of wind, generator start up takes place multiple times during a day, resulting in huge quantum of reactive power absorption from the grid and causing voltage excursions/ voltage stability.

Further, for type-1 and type-2 machines being induction generators can not participate in voltage regulation and require switched capacitor banks for reactive compensation. However, type-3 and type-4 wind turbine generators and solar inverters depend on AC-DC-AC converters which have inherent control of reactive power.

Measures must be available to mitigate the effects of the variable reactive generation of power. As a result of this, the dynamic reactive power compensation i.e. SVC/ STATCOM shall have to be provided at Renewable Energy pooling station for dynamic voltage support and avoid any undesirable reactive power flow to or from the grid.

8.2 The day ahead scheduling in India is done for all inter state schedules as per the Indian Electricity Grid Code on the basis of 15 minutes time blocks. The deviation between schedule and actual power flow is called Unscheduled Interchange for which commercial settlement is done as per the Unscheduled Interchange (UI) rates specified by the Central Electricity Regulatory Commission (CERC). The UI rates are variable depending on the frequency and the quantum of drawal and they tend to discourage over drawal and under generation. The day ahead schedules can also be revised in real time with a prior notice of 60 to 90 minutes.

8.3 Most of the electricity in India is tied up in long term PPAs. After the enactment of Electricity Act 2003, generation has been liberalised and open access in transmission has been implemented. Beginning 2004, an electricity market has evolved starting with bilateral trade between utilities and subsequently trading on the power exchange has commenced since 2008. The volume of short term market is about 40 BUs against the gross generation of about 950 BUs. About 50 MUs are traded everyday through totally automated electronic exchange based on the principle double sided bidding, uniform clearing price and market splitting in case of transmission congestion very similar to the Nord Pool Power Exchange. The price on the Indian power exchange is determined 15 minute wise. The liquidity on the Indian power exchange has lately increased with the advent of merchant power plants. The National Electricity Policy 2005 recommends 15% merchant capacity in order to create depth in the electricity market.

8.4 The transmission planning in the country is done through a coordinated process with the participation of Central Electricity Authority, Central Transmission Utility (POWERGRID) and the State Transmission Utilities. A number of “Green Corridors “ have recently been planned to take care of the expansion of wind , solar and small hydro in the states of Tamil Nadu, Gujarat, Rajasthan, Karnataka, Andhra Pradesh, Maharastra, Himachal Pradesh and Jammu & Kashmir. The transmission system costing about Rs. 32,000 crores (5 billion US $) have been planned to cater to the needs of about 32 GW RE capacity addition program for the 12th Plan (2012-17). These systems include both intra state and inter state transmission system of 132 kV, 220 kV, 400 kV and 765 kV voltage levels. Details are available at CEA website http://www.cea.nic.in/ps_wing. Major RE transmission corridors in Gujarat, Rajasthan, Tamil Nadu and Andhra Pradesh are at Annexure-III.

The existing and the planned transmission facilities are summed up in the tables below:

Growth of transmission sector

Transmission System Type	Voltage (KV) level	Unit	Ach. as on 31.03.2007 (End of 10th Plan)	Ach. as on 31.03.2012 (End of 11th Plan)	Ach. as on 30.09.2013	Target 31.03.2017 (End of 12th Plan)
AC Transmission lines	765	ckm	1704	5250	7910	32250
	400	ckm	69174	106819	120693	144819
	220	ckm	110805	135980	142536	170980
	Total	ckm	**181683**	**248049**	**271139**	**348049**
HVDC		ckm	5872	9432	9432	16872
Total (AC+HVDC)		**ckm**	**187555**	**257481**	**280571**	**364921**
AC Substations Transformation Capacity	765	MVA	0	25,000	56500	174000
	400	MVA	92942	151,027	170397	196027
	220	MVA	156497	223,774	247194	299774
	Total AC	**MVA**	**249439**	**399801**	**474091**	**669801**
HVDC		MW	**8000**	**9750**	**13500**	**22500**
AC+HVDC			**257439**	**409551**	**487591**	**692301**
Inter-regional Capacity		MW	**14050**	**27750**	**31850**	**65550**

8.5 Given that the penetration of electricity in India is of the order of 70%, there is tremendous scope for supplementing the resources with RE generation including distributed micro grids and roof top solar plants. However, due to limited paying capacity of the people at large and poor financial health of the DISCOMs, the demand of electricity is sensitive to price. The price of solar energy has come down by 50% in the last five years due to introduction of competitive bidding for tariff. However, wind energy continues to be paid preferential or feed in tariff and as such the price of wind energy has not come down in the last ten years. History of regulation worldwide bears out that cost plus tariff in generation does not normally result in reduction in tariff. Further technological breakthroughs and pressure of competition is required to make RE affordable in India.

8.6 India has a federal setup in respect of electricity wherein each state is responsible for maintaining its load-generation balance and complying with inter state grid code (IEGC). There is a provision in the Electricity Act that SERC can specify the RPO (Renewable Purchase Obligation) on the state distribution utilities. However, it has to be kept in view that in order to meet any RPO obligation the state should have requisite renewable balancing capability and renewable purchase capacity. The all India grid is divided into 28 control areas interconnected with each other through inter state transmission links and high capacity corridors. Each state has its own generation sources in addition to the shared generation resources called inter state generating stations (ISGS). The induction of RES does not reduce the requirement of conventional sources of generation which are required to provide backup when the RE power is not available. Further the introduction of variable RE resources puts pressure on grid security. State of the art forecasting tools are required to be provided in the RE rich states in order to improve the quality of forecast for the purpose of maintaining load-generation balance. Regulatory support is required to incentivise flexibility of conventional generation sources. The regulations should compensate the conventional generator for partial operation and start up and stop costs so that it can perform the balancing function without incurring financial loss.

8.7 Indian Electricity Grid Code (IEGC) 2010 states that wind energy being of variable nature, needs to be predicted with reasonable accuracy for proper scheduling and dispatching of power from these sources in the interconnected system. Wind generation forecasting can be done on an individual developer basis or joint basis for an aggregated generation capacity of 10 MW and above connected at a connection point of 33 kV and above. IEGC specifies the wind energy forecasting on day ahead basis with 70 % accuracy. If the variation in actual generation is beyond +/- 30% of the schedule, wind generator would have to bear the UI charges. For actual generation within +/- 30% of the schedule, no UI would be payable/receivable by the wind generator. For variation of actual generation within +/- 30% of the schedule, the host state shall bear the UI charges which shall be shared among all the States of the country in the ratio of their peak demands in the previous month based on the data published by CEA, in the form of a regulatory charge known as the Renewable Regulatory Charge operated through the Renewable Regulatory Fund (RRF). This provision shall be applicable with effect from 1.1.2011, for new wind farms with collective capacity of 10 MW and above connected at connection point of 33 KV level and above , and where pooling station was commissioned on or after 3.5.2010 and total connected generating capacity is 10 MW or above.

The above provision of flexibility in scheduling only provides commercial compensation to the host states for deviating from the schedule on account of RES but does not absolve the state SLDC of the responsibility to comply with the IEGC. Therefore, it is imperative to minimise the deviation by RE generators by accurate forecasting techniques and revising their schedules at least one to two hours ahead. If the forecasts are accurate and RE schedules are revised in time then responsibility of balancing of the host state shall be limited to its own RE schedule and for the remaining power being exported by the RE rich states the responsibility of balancing will be passed on to the respective RE buying state.

8.8 CEA Connectivity Standards (2013) for wind and solar generating stations stipulate that harmonic current injections and flicker introduced shall not be beyond the limits specified in IEEE Standard 519 and IEC 61000 respectively. The DC current injection shall not be greater than 0.5% of the full rated output. The wind generating station shall be capable of supplying dynamically varying reactive power support so as to maintain power factor within the limits of 0.95 lagging to 0.95 leading. The generating units shall be capable of operating in the frequency range of 47.5 Hz to 52 Hz and shall be able to deliver rated output in the frequency range of 49.5 Hz to 50.5 Hz. The wind generating stations connected to the grid at 66 kV voltage level and above shall have the fault ride through capability. During the fault/voltage dip, the individual wind generating units in the generating station shall generate active power in proportion to the retained voltage and shall maximise supply of reactive current till the time voltage starts recovering or for 300 ms, which ever time is lower. Please refer Annexure-II.

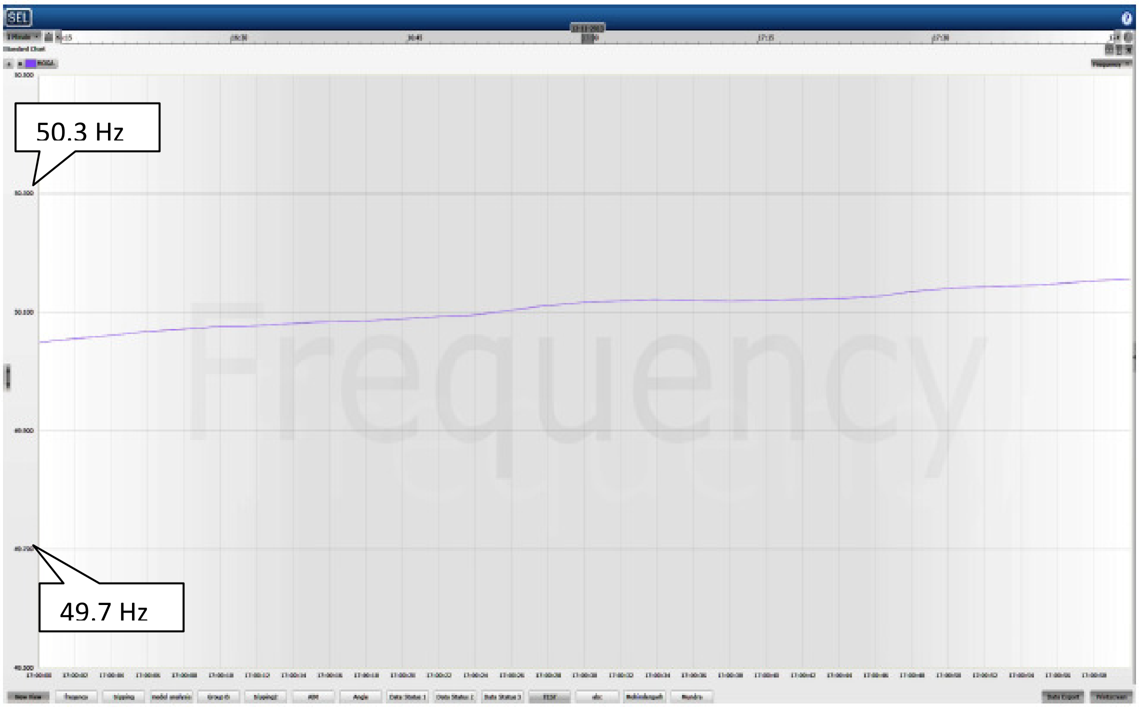
8.9 The excursions of grid frequency in India have been brought down progressively since 2003 after the introduction of penal mechanism of deviation from schedule known as the UI mechanism. However, this is only a commercial mechanism and depends on voluntary response by the load and the generators. The permitted frequency band has been brought down from 49.0-50.5 Hz to 49.7-50.2 Hz. Nevertheless the grid frequency is not steady and keeps on fluctuating even though the range of fluctuation has been narrowed The typical excursions of frequency in a day, in an hour, in 10 minutes and in a minute are depicted below:

Typical frequency excursions in a day

Typical frequency excursions in an hour

Typical frequency excursions in 10 minutes

Typical frequency excursions in a minute



The frequency excursions are due to the absence of Automatic Generation Control (AGC). A very large grid of the size of India ought to have steady frequency with turbine speed governors giving primary response followed by secondary response from spinning reserves, back up reserves and fast acting load shedding contracts. This would require the introduction of AGC, extensive preparation and a well designed plan for which international consultant could be roped in. Basically, in the event of introduction of AGC each control area/state would become a tight control area and area control error would have to be determined by applying frequency correction to unscheduled interchange.

8.10 India has huge hydro power potential and storage type hydro plants are suitable for providing balancing service. The hydro turbine design should be of the Pelton wheel type, wherever possible, since the generation from this type of hydro generator can vary easily from zero to full capacity. Pumped storage power plants should be encouraged as they provide effective tool for grid balancing. Presently, out of nine (9) plants of 4,785 MW capacity, only five (5) plants of 2,600 MW total capacity are working as pumped storage. Two plants i.e. Tehri-II (100 MW) and Koyna LB (80 MW) are under construction. Survey and Investigation of three plants is in progress these are – Malshej Ghat (Maharashtra 700 MW), Humbarli (Maharashtra, 400 MW) and Turga (West Bengal, 1000 MW). Further, a potential of about 92,000 MW of pumped storage plants was assessed in 90s. Please refer Annexure-I.

8.11 India has a gas based combined cycle capacity of the order of 20,000 MW and another 8000 MW capacity is ready for commissioning. However, due to shortage of gas the new capacity has been stranded and the existing plants are running at very lower plant load factor of less than 30%. The option of running these plants with imported LNG does not appear to be economically viable. In such a scenario one cannot conceive gas based capacity contributing towards balancing the grid even though gas based plants have a high ramping rate and are suitable for such purpose.

8.12 In view of above India has to use its coal based generating capacity of the order of 135,000 MW for balancing the variation of RE generations as already been practised by Tamil Nadu, Rajasthan and Gujarat. The variability (without oil support) of older 200 MW thermal plants can be restored to 70-100 % from the present by improving their control systems. The new plants such as supercritical units can be varied from 50 -100% without oil support.

9.0 Way Forward

9.1 In order to deal with variability of renewable generation forecasts are crucial for resource adequacy during operation and grid security.

9.2 Each state should assess its balancing capacity and enter into RE purchase obligation accordingly. Based on the status of measures available with the state, they should assess their present capacity to balance the combined variability of load & RE generation,

9.3 The respective buyer State of RE power shall be responsible for maintaining its load-generation balance taking into account the revised forecasts of their RE portfolios. In order to save time in revision of schedules, the SLDCs/RLDC/NLDC, as the case may be, would *suo-motu* revise the RE schedule of a state based on inputs from the host REMC/SLDC. In this manner the responsibility of RE balancing would be shared by all the RE purchasing states.

9.4 The present power exchange provides only one opportunity for buying and selling on day ahead basis. Real time markets (i.e the opportunity to buy and sell power about two hours ahead) should be started to provide a platform for selling surplus power or buying power when in deficit. 10 -15 % merchant capacity in generating plants as per the National Electricity Policy may be useful for providing liquidity in the electricity market.

9.5 Technical and regulatory measures to enhance the flexibility of conventional generation to increase the balancing capacity of the grid.

9.6 Establishment of Renewable Energy Management centers (REMC) equipped with advanced forecasting tools, smart dispatching solutions, real time monitoring of RE generation, closely coordinating with SLDC/RLDC should be provided.

9.7 Wind farms may also be set up through competitive bidding in order to reduce tariff.

9.8 It is necessary that healthiness of grid protection schemes through regular monitoring and updating is ensured.

9.9 International cooperation for developing REMCs in the RE rich states, balancing capabilities using indigenous sources of conventional power, optimum development of enabling transmission infrastructure and capacity building of grid operators has become necessary at this stage of RE development.

10.0 Renewable Energy Management Centers (REMCs)

10.1 Renewable Energy Management Centers (REMCs) at State, Regional and National level should be co-located with respective Load dispatch centers (LDC) and integrated with real time measurement and information flow. There should be a hierarchical connection between the state Load Dispatch Centre, Regional Load Dispatch Centre and National Load Dispatch Centre.

10.2 The REMC may have following functions:

i. Forecasting of RE generation in jurisdiction area on day-ahead, hour-ahead, week-ahead, month-ahead basis.
ii. Real time tracking of generation from RE sources
iii. Geo-spatial visualization of RE generation
iv. Close coordination with respective LDC for RE generation and control for smooth grid operation.
v. Single source information repository and coordination point for RE penetration.

10.3 Forecasting should be done by the REMC:

(i) cluster-wise for determination of power flows on intra-State network,
(ii) the state as a whole to predict power flow at the inter-state boundary
(iii) forecasting its own RE portfolio for maintaining the load-generation balance of the host state
(iv) forecasting the RE portfolio of other states who have contracted RE power from the host state.

10.4 Forecasting by the state REMC would be passed on to the state SLDC, which would be used for scheduling. In case RE power is being sold by RE generators located in a wind-rich state to another state, the revision of schedule, based on forecast, as mentioned above, would have to be done for the host and purchasing state at their respective state boundaries. The SLDC of the host state would pass the schedule to the concerned RLDC for scheduling of wind generation at the states boundaries. In case the host state and purchasing state lie in different regions, the RLDC of the host region will inform the NLDC, who will schedule power at the regional boundaries of the two states. This would lead to allocation of balancing responsibility among the States to the extent of their shares in the RE power. Since the forecast is being done by the host State, the cost of forecasting would be shared by the purchasing States.

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Annexure – I

Note on Development of Pumped Storage Plants (PSP) in India

1. Background:

Pumped Storage Plants are playing an increasingly important role in providing peaking power and maintaining system stability in the power system of many of the developed countries. The base load requirements are generally met by thermal and / or nuclear generating plants whereas peaking loads are often met from conventional hydro projects along with pumped storage plants. The decline of available sites in a conventional hydro-electric generation makes the development of pumped storage plants relevant. Pumped storage plants are also relevant when the availability of water decreases in the river system due to upstream consumptive uses.

The original concept behind the development of pumped storage plants was the conversion of relatively low cost off peak energy generated in thermal plants into high value peak power. Pumped storage plants improve overall economy of power system operation, increase capacity utilization of thermal stations and reduce operational problem of thermal stations during light load period. The other advantages of pumped storage development are availability of large reactive capacity for regulation, availability of spinning reserve at almost no cost to the system regulating frequency to meet sudden load changes in the network. The fact that energy gained from the pumped storage development is always less than energy input should not obscure the fact that this loss to the system is small when compared with substantial savings in the fuel which are made when these stations are operated in an integrated manner.

2. Development of Pumped Storage Plants in India:

2.1 Potential Assessed:

Reassessment studies carried out by CEA during 1978-87 identified 63 sites for pumped storage plants (PSP) with total installation of about 96,500 MW with individual capacities varying from 600 MW to 2800 MW. Out of these, 7 Pumped Storage Plants with an installation of 2604 MW were under operation / construction at the time of re-assessment study.

Region wise / state wise distribution of potential sites identified for installation of pumped storage schemes is given below:

Sl. No.	Region / State	Probable Installed Capacity (MW)
	Northern	
1	Jammu & Kashmir	1650
2	Himachal Pradesh	3600
3	Uttar Pradesh	4035
4	Rajasthan	3780
	Sub-Total	**13065**
	Western	
1	Madhya Pradesh	11150
2	Maharashtra	27094
3	Gujarat	1440
	Sub-Total	**39684**
	Southern	
1	Andhra Pradesh	2350
2	Karnataka	7900
3	Kerala	4400
4	Tamil Nadu	3100
	Sub-Total	**17750**
	Eastern Region	
1	Bihar	2800
2	Orissa	2500
3	West Bengal	3825
	Sub-Total	**9125**
	N. Eastern Region	
1	Manipur	4350
2	Assam	2100
3	Mizoram	10450
	Sub-Total	**16900**
	Total	**96524**

Western region has the largest potential (about 41% of the total) for development of pumped storage plants. This is mainly due to the topographical features with steep gradients of the rivers originating from the Western Ghats.

2.2 Pumped storage plants in operation:

At present 9 pumped storage schemes with aggregate installed capacity of 4785.6 MW are in operation in the country. Out of these, only 5 No. of plants with aggregate installed capacity of 2600 MW are being operated in pumping mode. The details of these schemes along with the reasons for the remaining plants not being able to operate in pumping mode are given below:

S. No.	Name of Project / State	Installed Capacity		Pumping Mode Operation	Reasons for not working in Pumping mode
		No. of units x MW	Total (MW)		
1	Kadana St. I&II Gujarat	2x60+2x60	240	Not working	Due to vibration problem
2	Nagarjuna Sagar Andhra Pradesh	7x100.80	705.60	Not working	Tail pool dam under construction
3	Kadamparai Tamil Nadu	4x100	400	Working	-
4	Panchet Hill - DVC	1x40	40	Not working	Tail pool dam not constructed
5	Bhira Maharashtra	1x150	150	Working	-
6	Srisailam LBPH Andhra Pradsesh	6x150	900	Working	-
7	Sardar Sarovar Gujarat	6x200	1200	Not working	Tail pool dam not constructed
8	Purlia PSS West Bengal	4x225	900	Working	-
9	Ghatgar Maharashtra	2x125	250	Working	-
		Total	**4785.60**		

2.3 Pumped storage plants under construction:

At present, 2 Pumped Storage Plants with aggregate installed capacity of 1080 MW are under construction in the country as given below:

S. No.	Name of Project / State	Installed Capacity	
		No. of units x MW	Total I.C. (MW)
1	Tehri St.-II - Uttarakhand	4x250	1000
2	Koyna Left Bank – Maharashtra	2x40	80
		Total	**1080**

These Plants are likely to give benefits in 13th Plan.

2.4 Pumped Storage Plants being taken up for development in India:

Detailed Project Report of one no. pumped storage scheme with installed capacity of 500 MW has been returned to the state authorities for re-submission after taking into account the comments of CEA and CWC as given below:

Sl. No.	Name of the Scheme	State	Installed Capacity (MW)	Remarks
1.	Kundah	Tamil Nadu	500	DPR returned due to non-resolution of inter-state aspects.

Further, 3 pumped storage plants with aggregate installed capacity of 2100 MW are under Survey & Investigation in the country. Details of these schemes are given below:

Sl. No.	Name of the Scheme	State	Installed Capacity (MW)	Remarks
1.	Malshej Ghat	Maharashtra	700	DPR prepared by THDC. Implementation

Sl. No.	Name of the Scheme	State	Installed Capacity (MW)	Remarks
				agreement to be signed.
2.	Humbarli	Maharashtra	400	Under Survey & Investigation by THDC for preparation of DPR.
3.	Turga	West Bengal	1000	Under Survey & Investigation by WAPCOS for preparation of DPR
	TOTAL		**2100**	

In addition, two PSP namely Mara (1100 MW) and Binauda (2250 MW) were earlier considered by Madhya Pradesh for development.

3. Issues / Action Points:

- Since the energy gained from Pumped Storage Plants (PSP) is less than the energy input, it is necessary that off-Peak power to be used as input may be available at reasonable tariff for making the Pumped Storage Plant commercially viable.
- As brought out in para 2.2 above, the tail pool dam for Panchet Hill (40 MW) and Sardar Sarovar (1200 MW) need to be constructed at the earliest. The vibration problem in Kadana PSP (240 MW) also needs to be resolved.
- The resolution of Inter-State aspects in case of Kundah PSP in Tamil Nadu needs to be taken up.
- Implementation Agreement needs to be signed for development of Malshej Ghat PSP (700 MW) in Maharashtra.
- The Survey & Investigation on Humbarli PSP (400 MW) in Maharashtra and Turga PSP (1000 MW) in West Bengal needs to be completed at the earliest for taking up these projects for development.
- Survey & Investigation and preparation of DPR needs to be taken up for Mara PSP (1100 MW) and Binauda PSP (2250 MW) in Madhya Pradesh expeditiously.

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Annexure-II

(Published in the Extraordinary Gazette of India, Part III section 4)

Government of India
Ministry of Power

(Central Electricity Authority)

Notification

New Delhi, dated the 15th October, 2013

No.12/X/STD(CONN)/GM/CEA. – Whereas the draft of the Central Electricity Authority (Technical Standard for Connectivity to the Grid) (Amendment) Regulations, 2012 were published, under sub-section (3) of section 177 of the Electricity Act, 2003 (36 of 2003) and rule 3 of the Electricity (Procedure for previous Publication) Rules, 2005 on 16th march, 2012;

Now, therefore, in exercise of powers conferred by section 7 and clause (b) of section 73 read with sub-section (2) of section 177 of the Electricity Act, 2003, the Central Electricity Authority hereby makes the following regulations to amend the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 , namely:--

1. **Short title and commencement. - (1)**These regulations may be called the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Amendment Regulations, 2013.

(2) These Regulations shall come into force on the date of their publication in the Official Gazette .

2. In the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 (hereinafter referred to as the said regulations), in regulation 2, -

(a) for clause (10) the following clause shall be substituted, namely :-

"Earthing" means electrical connection between non-energized conducting parts and the general mass of earth by an earthing device";

(b) in clause (14) the following paragraph shall be added at the end, namely:-

"In case of Solar Photo voltaic generating station, each inverter along with associated modules will be reckoned as a separate generating unit";

(c) for clause (17) the following clause shall be substituted, namely:-

"Interconnection point" means a point on the grid, including a sub-station or a switchyard, where the interconnection is established between the facility of the requester and the grid and where electricity injected into or drawn from the grid can be measured unambiguously for the requester";

(d) after clause (17), the following clause shall be inserted, namely:-

"(17A) "Inverter" means a device that changes direct current power into alternating current power";

(e) for clause (19) the following clause shall be substituted, namely:-

"Maximum Continuous Rating" (MCR) will carry same meaning as defined in the Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010";

(f) clause 20 shall be omitted;

(g) after clause (28) the following clause shall be inserted, namely:-

"(28A) "Standard Protection" means electrical protection functions specified in Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010".

3. in the said regulations, for the words "Central Electricity Authority (Grid Standards for Operation and Maintenance of Transmission Lines) as and when they come into force" the words "Central Electricity Authority (Grid Standards) Regulations, 2010", shall be substituted.

4. In regulation 6 of the said regulations, -

(a) in clause (6) the following proviso shall be Inserted at the end, namely:-

" Provided that in order to carry out the said study, the requester shall present the mathematical model of the equipment in accordance with the requirements as stipulated by the Appropriate Transmission Utility or distribution licensee, as the case may be."

(b) after clause (7) following clause shall be inserted, namely:-

"(8) The State Transmission Utility shall inform the Central Transmission Utility and the Authority, within thirty days of acceptance of application for connectivity of a generating station to electricity system operating at 110 kV and above."

5. In regulation 7 of the said regulations, in clause (1) for the words "owner of the sub-station where" the words " generating company or licensee operating the electricity system to which" shall be substituted.

6. In the Schedule of the said regulations, -

(a) for Part II the following shall be substituted, namely:-

“Part II

Connectivity Standard applicable to the generating stations

A. Connectivity Standards applicable to the Generating Stations other than wind and generating stations using inverters

These generating stations shall comply with the following requirements besides the general connectivity conditions given in the said regulations and Part I of the schedule:-

A1. For Generating stations which are connected on or after the date on which Central Electricity Authority (Technical Standards for Connectivity of the Grid) Regulation, 2007 became effective

(1) The excitation system for every generating unit:--

(a) Shall have state of the art excitation system;

(b) Shall have Automatic Voltage Regulator (AVR). Generators of 100 MW rating and above shall have Automatic Voltage Regulator with digital control and two separate channels having independent inputs and automatic changeover; and

(c) The Automatic Voltage Regulator of generator of 100 MW and above shall include Power System Stabilizer (PSS).

(2) The Short-Circuit Ratio (SCR) for generators shall be as per IEC-34.

(3) The generator transformer windings shall have delta connection on low voltage side and star connection on high voltage side. Star point of high voltage side shall be effectively (solidly) earthed so as to achieve the Earth Fault Factor of 1.4 or less.

(4) All generating machines irrespective of capacity shall have electronically controlled governing system with appropriate speed/load characteristics to regulate frequency. The governors of thermal generating units shall have a droop of 3 to 6% and those of hydro generating units 0 to 10%.

(5) Generating Units located near load centre, shall be capable of operating at rated output for power factor varying between 0.85 lagging (over-excited) to 0.95 leading (under-excited) and Generating Units located far from load centres shall be capable of operating at rated output for power factor varying between 0.9 lagging (over-excited) to 0.95 leading (under- excited).

Provided that all generating units commissioned on or after 01.01.2014, shall be capable of operating at rated output for power factor varying between 0.85 lagging (over-excited) to 0.95 leading (under-excited).

Provided further that the above performance shall also be achieved with voltage variation of ± 5% of nominal, frequency variation of +3% and -5% and combined voltage and frequency variation of ±5%. However, for gas turbines, the above performance shall be achieved for voltage variation of ±5%.

(6) The coal and lignite based thermal generating units shall be capable of generating up to 105% of Maximum Continuous Rating (subject to maximum load capability under Valve Wide Open Condition) for short duration to provide the frequency response.

(7) The hydro generating units shall be capable of generating up to 110% of rated capacity (subject to rated head being available) on continuous basis.

(8) Every generating unit shall have standard protections to protect the units not only from faults within the units and within the station but also from faults in transmission lines. For generating units having rated capacity greater than 100 MW, two independent sets of protections acting on two independent sets of trip coils fed from independent Direct Current (DC) supplies shall be provided. The protections shall include but not be limited to the Local Breaker Back-up (LBB) protection.

(9) Hydro generating units having rated capacity of 50 MW and above shall be capable of operation in synchronous condenser mode, wherever feasible.

Provided that hydro generating units commissioned on or after 01.01.2014 and having rated capacity of 50 MW and above shall be equipped with facility to operate in synchronous condenser mode, if necessity for the same is established by the interconnection studies.

(10) Bus bar protection shall be provided at the switchyard of all generating station.

(11) Automatic synchronisation facilities shall be provided in the requester's Project.

(12) The station auxiliary power requirement, including voltage and reactive requirements, shall not impose operating restrictions on the grid beyond those specified in the Grid Code or state Grid Code as the case may be.

(13) In case of hydro generating units, self-starting facility may be provided. The hydro generating station may also have a small diesel generator for meeting the station auxiliary requirements for black start.

Provided that hydro generating units shall have black start facilities in accordance with provisions of Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010 from the date of publication of these Regulations.

(14) The standards in respect of the switchyard associated with the generating stations shall be in accordance with the provisions specified in respect of 'Sub-stations' under Part III of these Standards.

A2. Generating stations which were already connected to the grid on the date on which Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 became effective

For thermal generating units having rated capacity of 200 MW and above and hydro units having rated capacity of 100 MW and above, the following facilities would be provided at the time of renovation and modernization.

(1) Every generating unit shall have Automatic Voltage Regulator. Generators having rated capacity of 100 MW and above shall have Automatic Voltage Regulator with two separate channels having independent inputs and automatic changeover.

(2) Every generating unit of capacity having rated capacity higher than 100MW shall have Power System Stabilizer.

(3) All generating units shall have standard protections to protect the units not only from faults within the units and within the station but also from faults in transmission lines. The protections shall include but not limited to the Local Breaker Back-up (LBB) protection.

B. Connectivity Standards applicable to the Wind generating stations and generating stations using inverters

These generating stations shall comply with the following requirements besides the general connectivity conditions given in the said regulations and Part I of the Schedule:-

B1. Requirements with respect to Harmonics, Direct Current (DC) Injection and Flicker

(1) Harmonic current injections from a generating station shall not exceed the limits specified in Institute of Electrical and Electronics Engineers (IEEE) Standard 519.

(2) The Generating station shall not inject DC current greater than 0.5 % of the full rated output at the interconnection point.

(3) The generating station shall not introduce flicker beyond the limits specified in IEC 61000.

Provided that the standards for flicker will come into effect from 1st April 2014.

(4) Measurement of harmonic content, DC injection and flicker shall be done at least once in a year in presence of the parties concerned and the indicative date for the same shall be mentioned in the connection agreement;

Provided that in addition to annual measurement, if distribution licensee or transmission licensee or the generating company, as the case may be, desires to measure harmonic content or DC injection or flicker, it shall inform the other party in writing and the measurement shall be carried out within 5 working days";

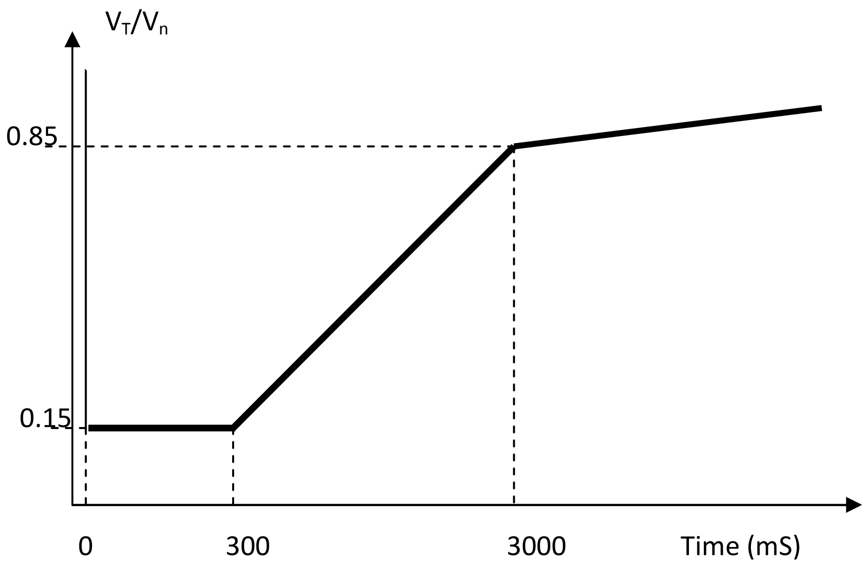
B2. For generating station getting connected on or after completion of 6 months from date of publication of these Regulations in the Official Gazette.

(1) The generating station shall be capable of supplying dynamically varying reactive power support so as to maintain power factor within the limits of 0.95 lagging to 0.95 leading.

(2) The generating units shall be capable of operating in the frequency range of 47.5 Hz to 52 Hz and shall be able to deliver rated output in the frequency range of 49.5 Hz to 50.5 Hz.

Provided that above performance shall be achieved with voltage variation of up to ± 5% subject to availability of commensurate wind speed in case of wind generating stations and solar insolation in case of solar generating stations.

(3) Wind generating stations connected at voltage level of 66 kV and above shall remain connected to the grid when voltage at the interconnection point on any or all phases dips up to the levels depicted by the thick lines in the following curve:



Where

V_T/V_n is the ratio of the actual voltage to the nominal system voltage at the interconnection point

Provided that during the voltage dip, the individual wind generating units in the generating station shall generate active power in proportion to the retained voltage;

Provided further that during the voltage dip, the generating station shall maximise supply of reactive current till the time voltage starts recovering or for 300 ms, which ever time is lower.

(4) Wind generating station connected at voltage level of 66 kV and above shall have facility to control active power injection in accordance with a set point, which shall be capable of being revised based on the directions of the appropriate Load Despatch Centre.

Provided that as far as possible, reduction in active power shall be done without shutting down an operational generating unit and with reduction being shared by all the operational generating units pro-rata to their capacity.

(5) The standards in respect of the switchyard associated with the generating stations shall be in accordance with the provisions specified in respect of 'Sub-stations' under Part III of these Standards.

B3. For generating units which are connected before and upto 6 months after the date of publication of these Regulations in the Official Gazette

The generating company and the licensee of the electricity system to which the generating station is connected shall mutually discuss and agree on the measures which can be taken to meet the standards specified in (B1) and (B2) subject to technical feasibility";

(b) in Part IV for clause 6, the following clause shall be substituted, namely:-

"6. Back-energization

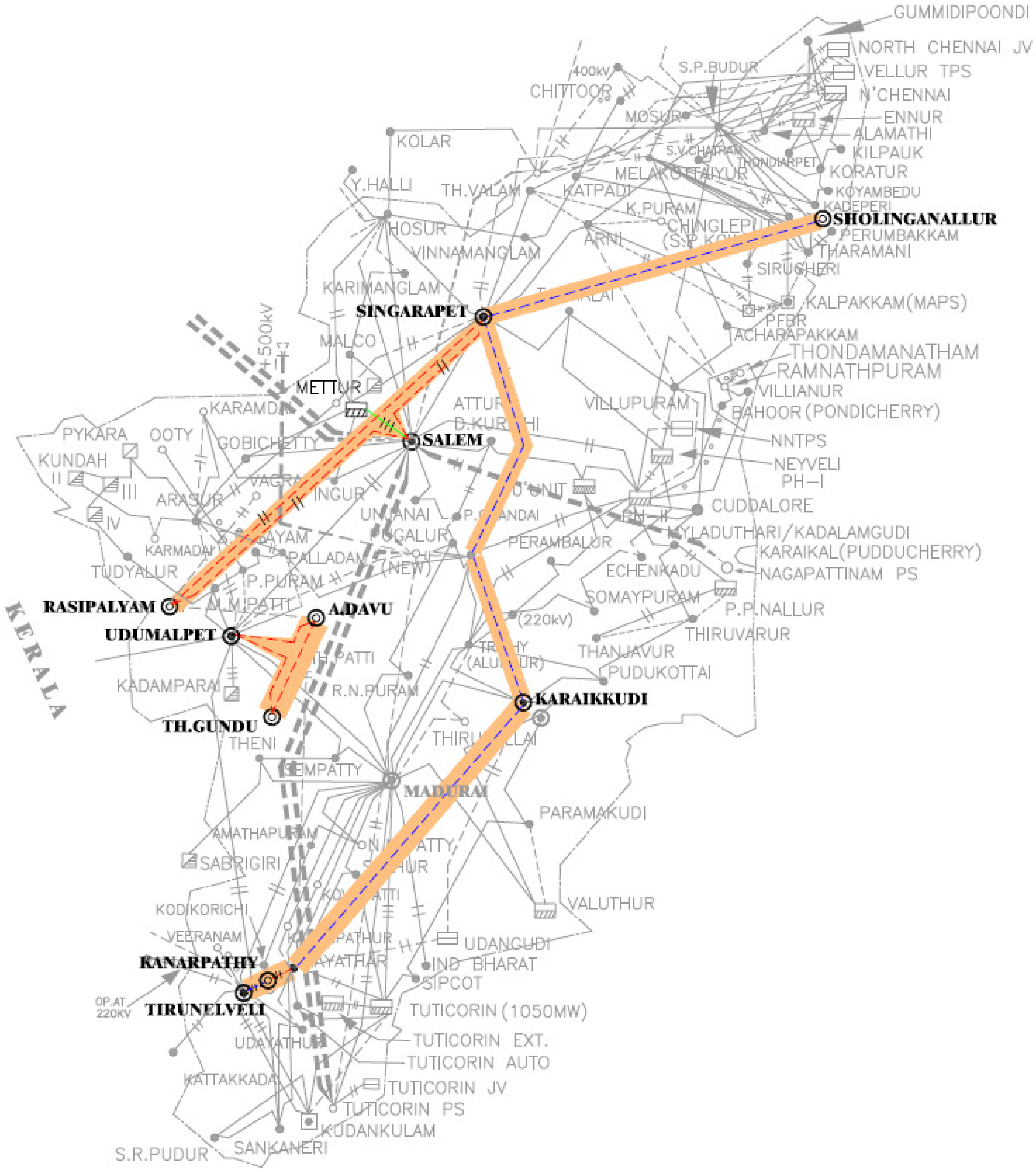
The bulk consumer shall not energize transmission or distribution system by injecting supply from his generators or any other source either by automatic controls or manually unless specifically provided for in the connection agreement with the Transmission or Distribution Licensee".

M. S. Puri,

(Secretary)

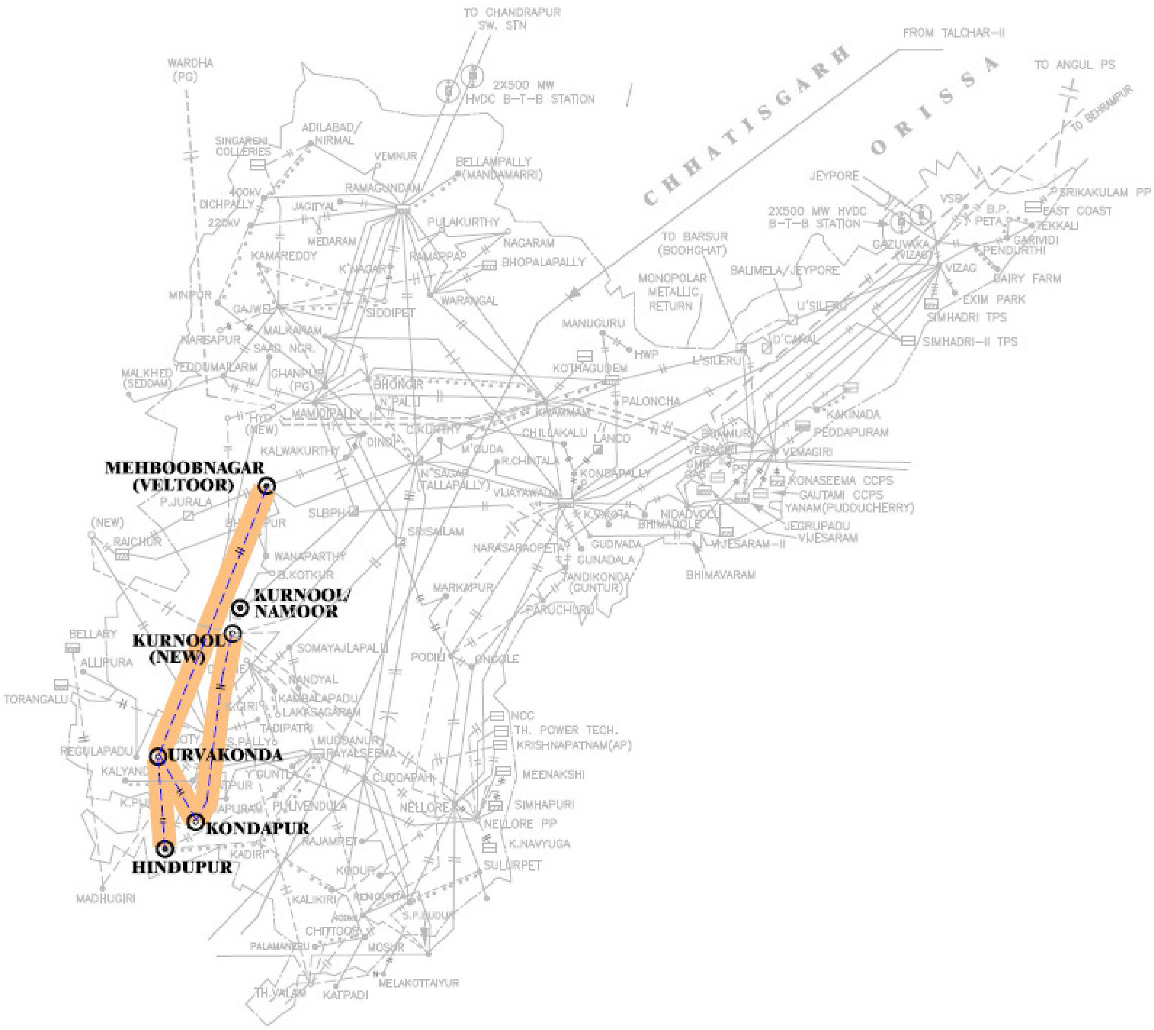
Foot note- The principle regulations were published in the Gazette of India vide number 12/X/STD(CONN)/GM/CEA dated the 21st February 2007.

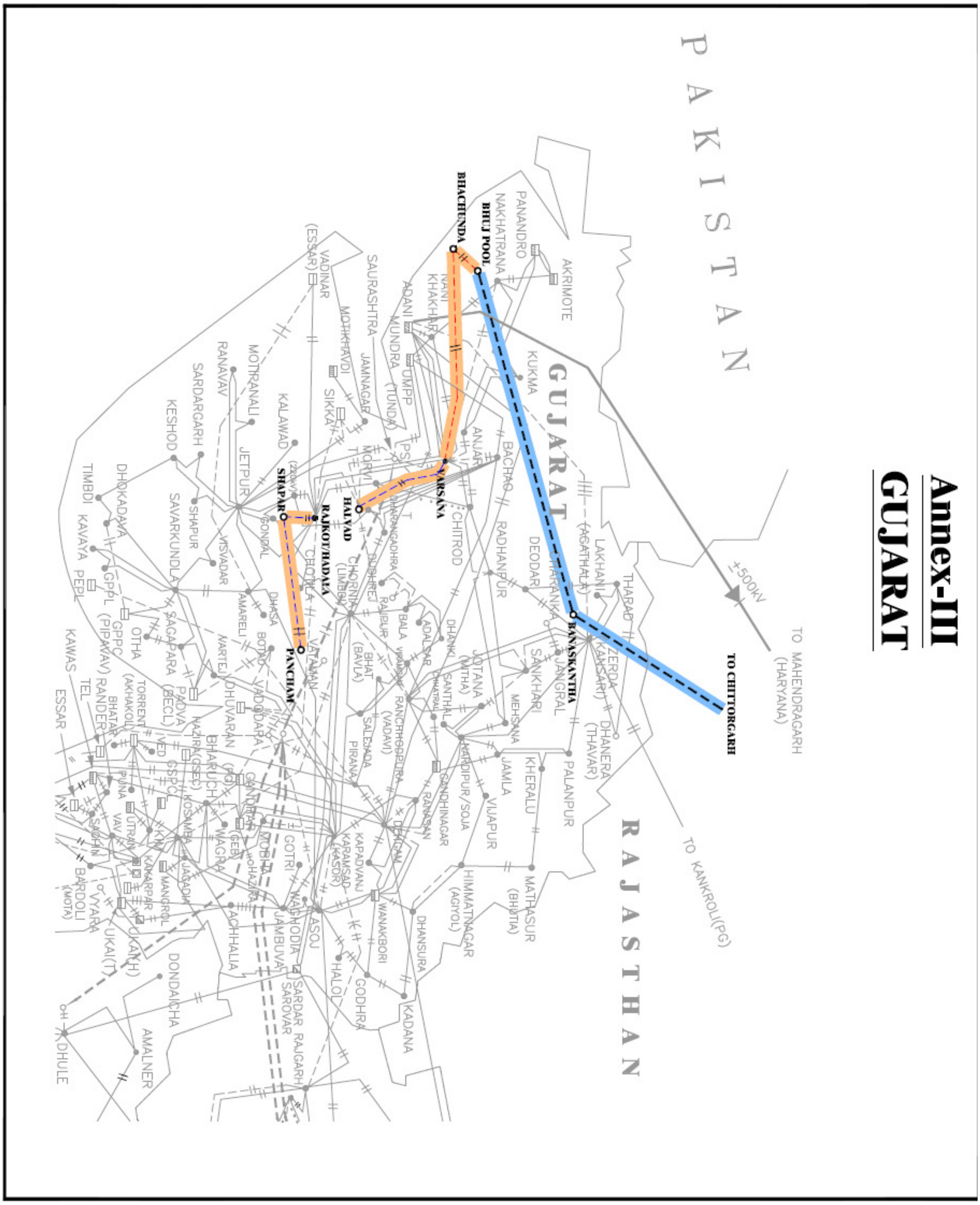
Annex-III
TAMILNADU



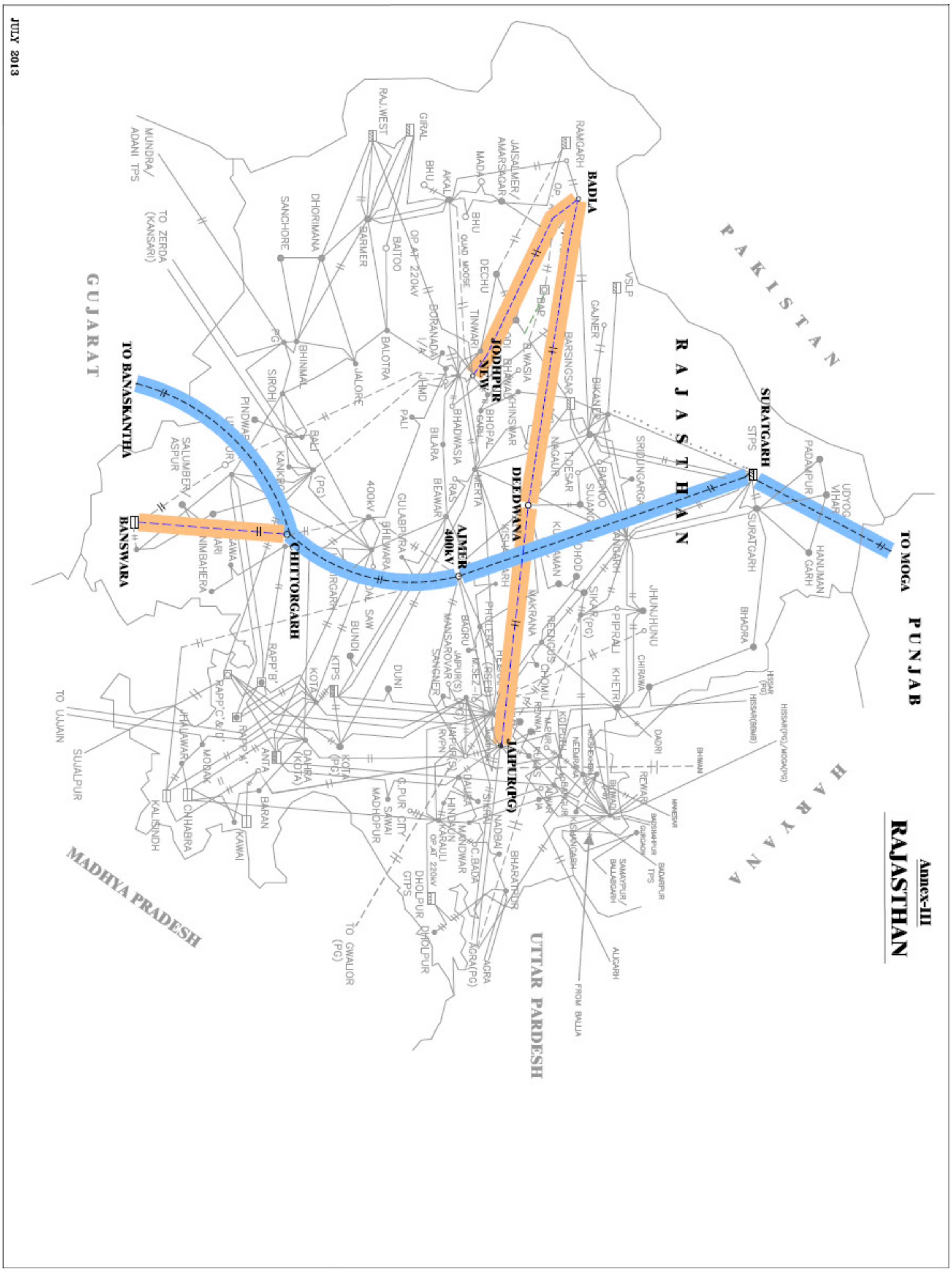
Annex-III

ANDHRA PRADESH





Annex-III
GUJARAT
PAKISTAN
GUJARAT
RAJASTHAN
BHACHUNDA
BHUJ POOL
VARSANA
HALVAD
RAJKOT/HADALA
SHAPAR
PANCHAM
BANASKANTHA
TO CHITTORGARH
±500kV
TO MAHENDRAGARH (HARYANA)
TO KANKROLI(PG)


Annex-III
RAJASTHAN
JULY 2013
PAKISTAN
PUNJAB
HARYANA
GUJARAT
MADHYA PRADESH
UTTAR PARDESH
BADLA
SURATGARH
TO MOGA
TO BANASKANTHA
BANSWARA
CHITTORGARH
AJMER 400kV
DEEDWANA
JODHPUR NEW
JAIPUR(PG)