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Integrating Renewable Energy and Energy Efficiency in the Transmission and Distribution Grids of Tamil Nadu and Karnataka

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ABSTRACT

Karnataka and Tamil Nadu are planning to increase their renewable energy generation capacity manifold in the near term. The report looks at the systemic issues related to the integration of Renewable Energy into the grid in the states of Karnataka and Tamil Nadu. It explores the technologies needed for integration in the light of solutions adopted globally. It further details out the projects underway for improving the efficiency of the grid that will lead to the strengthening of the transmission and distribution system. These initiatives have the ability to drive overall energy efficiency in the electricity system when considered and planned for in a holistic manner. Our main conclusion is that an overall systemic view of infrastructure, systems, technology, processes and organizations is required for integration of the planned increase of renewable capacity and to implement energy efficiency to the grid. In the absence of this systemic planning, generation capacity will not necessarily translate to production and consumption and the energy deficit conditions will not be met to facilitate development goals.

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I. EXECUTIVE SUMMARY

This project is in the context of the World Resources Institute (WRI) India Power Project that is aimed at reducing the electricity demand-supply gap in the states of Tamil Nadu (TN) and Karnataka (Ka) through holistic solutions. This project does so by studying the challenges of integrating RE into the TN and Ka grid to understand what changes are needed at the transmission and distribution level to accommodate more Renewable Energy (RE) and Energy Efficiency (EE). **We present the solutions that can be implemented at the State level and also the solutions which require intervention at the national level.** We will also examine ways in which smart infrastructure initiatives can be integrated with consumer level initiatives to promote EE. The partners for the broader project include the Indian Institute of Science (IISC), Consumer and civic Action Group (CAG), Consumer Rights, Education and Awareness Trust (CREAT), IFMR and the Madras School of Economics. This study focuses on the solutions to reduce demand-supply by scaling up RE generation and integration into the grid, improving the grid efficiency by reducing AT&C losses and increasing EE measures at the consumer level.

Ka and TN have very ambitious plans to scale RE. But there are infrastructure related issues that have to be resolved for integrating more RE into the grid. In general, the Indian grid suffers due to lack of adequate infrastructure for transmission and distribution. The condition is even worse for the Southern Region which has seen limited capacity addition and is connected asynchronously to the remaining grid. The states of Ka and TN which have high wind and solar potential and are considered amongst the seven RE rich states of the country, are plagued by these problems. TN and Ka further suffer from AT&C losses, thus reducing the efficiency of the network. The adoption of automation and monitoring systems in transmission and distribution systems is essential to increasing the operational efficiency of the grid (by reducing down times with improved coordination and remote control of devices) and integration of distributed generation (including RE). Thus along with looking up to RE to meet the growing deficit, the basic infrastructure and efficiency of the Ka and TN Grid have to be improved. In our report we look at the solutions for improving the infrastructure and increasing the grid efficiency. We further look at the incentive schemes for the consumers and utilities to invest in more RE and EE technologies.

Ka and TN are also installing, as a part of various schemes, smart meters and automation equipment. One smart grid pilot and a smart meter pilot are already operational. Our report focuses on how RE generation plans and smart infrastructure plans can be brought together to reduce/remove energy deficit while economic growth is maintained over the foreseeable future and the economic development aspirations of the states are met.

RE sources like wind and solar are variable by nature. Besides the variability, the distributed nature of RE generators implies renewable sources have to be connected to the grid even at the distribution levels. Thus, RE will continue to differ from conventional fuels like coal, gas, nuclear. These differences have to be considered while creating a RE roadmap by states/countries rich in RE resources and that want to exploit the potential. The issues arising out of variability and distributed nature of renewables that lead to integration problems are very much relevant to Ka and TN because of the growing penetration of RE sources. In our report, we have explored these problems and the relevant solutions, some of which have already been adopted in the RE rich countries with high levels of dependence on RE sources. Our key findings and recommendations are listed below.

Issue	State level solution	National level intervention required
Lack of T&D infrastructure to evacuate RE power	• Develop plans for T&D networks with a focus on RE evacuation and to use the existing infrastructure optimally keeping in mind the seasonal variability of RE • Focus on developing Green Power Purchase agreements with large consumers to assess the demand for new capacity and to support RE generation	• Create a body to plan out pilots for projects involving new technology
	• Align with National agencies when planning for new RE projects to have the T&D network in place for evacuating new RE power	• Align with the State agencies when planning for T&D networks to accommodate State level RE planning • Enforce Standards to develop long term evacuation plans
	• Implement standards for planning and evacuation	• Explore high voltage lines, dynamic line rating for interfacing large scale RE with the grid
Lack of robust communication systems to capture real time RE generation data	• Invest in technologies to enable data collection from old turbines and ensure data availability from new turbines equipped with communication systems • Adopt robust forecasting models and scheduling technology	
Inability to develop RE schedules due to regulatory and process issues		• Enforce IEGC standards for forecasting and scheduling for all units equipped with communication systems
	• Develop decentralized forecasting and scheduling – ensure these units work along with the SOs (can happen only when investment in tech is done) • Set up regional Renewable Energy Monitoring Centres and link them to the Regional and National Load Dispatch Centres	• Create centralized bodies for developing a repository of real time data on forecasting and to monitor deviations from planned schedules
	• Follow mechanisms for promoting forecasting and scheduling	• Use RECs along with the ABT mechanism and mandate to run at a minimum Capacity Utilization Factor

Need for assessing the potential of distributed RE generation and to incentivize distributed generators	• Include RE integration as one of the functions of the smart grid pilots with extensive coverage	• Include RE integration as one of the functions of the smart grid pilots and projects with extensive coverage • Incentivize customers through Generation Based Incentives (GBI) and similar mechanisms
		• Modify and implement Net metering technology for Indian markets
Lack of control monitoring systems for improving grid efficiency	• Invest in monitoring, automation and control technology for the overall Distribution network	
Aligning EE and smart grid initiatives	• Explore only EE functionality for specific smart grid pilots and then the projects • Plan for smart grid pilots and projects in commercial, residential and industrial areas with considerably high consumption	• Plan for smart grid pilots and projects in commercial, residential and industrial areas with considerably high consumption
	• Invest in smart meters/technology for two way communication and demand side management	• Increase availability and improve the penetration of smart appliances at the household level
	• Incentivize adoption of smart appliances at household level	
Lack of reserves/ energy storage to deal with intermittency	• Develop a holistic plan to integrate multiple RE generation sites. Develop a balancing portfolio based on conventional sources and variable generation • Maintain flexible reserves • Improve the supply chain to include more firm RE sources like biomass	• Create state and regional bodies for holistic planning of RE and conventional sources
	• Estimate grid storage requirement and work with National level agencies/organizations to develop pilots to experiment with energy storage technologies	• Explore energy storage technologies based on the economics and requirement (short term/long term) • Invest in R&D to develop technology that can work as flexible generators to balance variable generation from the RE sources • Develop pilots for energy storage technology at the grid level

Power quality concerns – current and probable in the future	• Invest in PQ technology – hardware up gradation and protection systems • Invest in microgrids that can island from the grid	• Enforce integration standards for connection of RE sources into the grid and for the regular operation
	• Implement integration standards	
	• Adopt smart grid technology to monitor and control networks evacuating and supplying RE power	

Solutions for immediate adoption

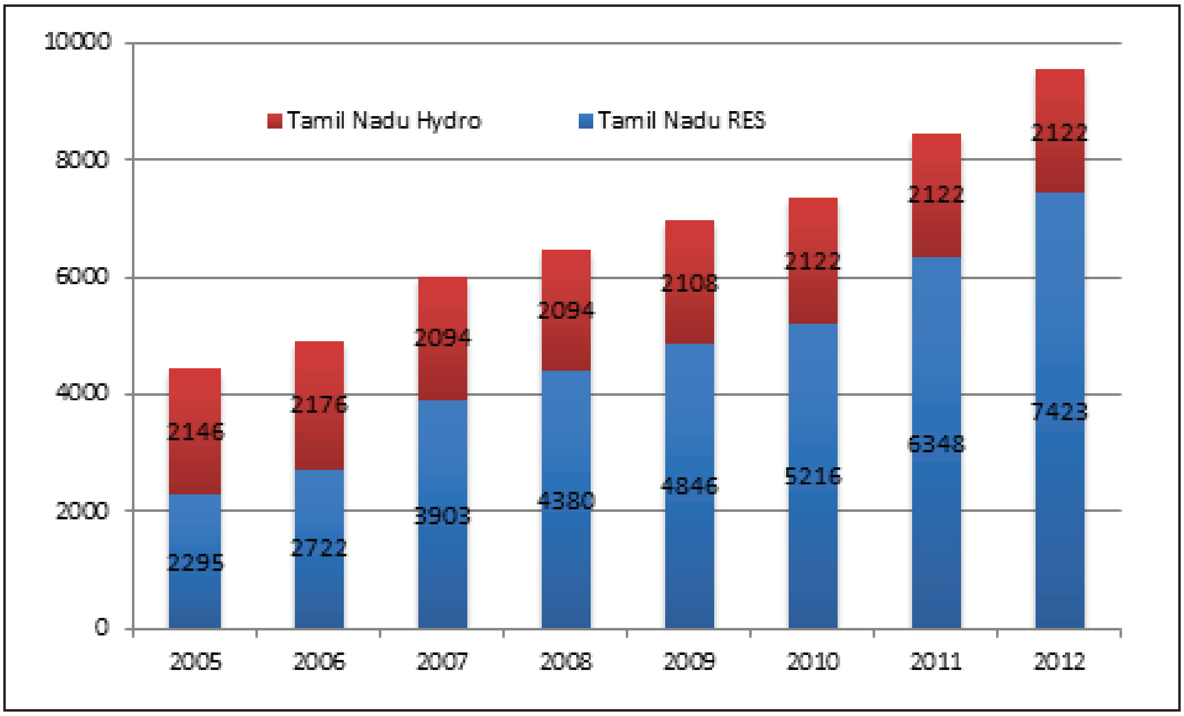
Solutions for adoption in the medium term, depends on National level decisions/ interventions

Solutions for adoption in the longer term, waiting for regulations or requires R&D and experimentation

II. TAMIL NADU (TN) RENEWABLE ENERGY (RE) CAPACITY

Total installed generation capacity in TN (conventional + un-conventional) is 13,725MW of which 5,723MW is government owned[1]. The total installed hydro+RE capacity in TN as of September 2012 was 9,545MW.

Figure 1: Installed hydro+RE capacity (MW) in TN



Source: CEA monthly reports (2012 figures are as of September, 2005-2011 figures are as of December)

Of the **7,423MW non-hydro RE sources, wind accounted for 7,134MW** as of September 2012[2]. Palghat, Shencottah, Aralvoimozhi, Kambam passes/districts are the most favourable locations for wind power generation in TN[3]. The assessed wind potential (at 80m height in waste land, non-forest scrubland) is 36.3GW[4]. A more conservative estimate of 14.2GW at 80m hub height comes from CWET[5]. With only 7.1GW installations so far, the potential is still huge. TN plans to integrate additional 6,000 MW of wind into TN grid during the 12th five-year plan[6] (2012-17).

1 From Global Investors Meet 2012
2 Wind capacity from http://www.teda.in/
3 From Wind Power evacuation TN – SLDC presentation
4 From TN Wind Power Scenario as on 31-May-2012 by Government of TN
5 From CWET - Gujarat, Andhra Pradesh, TN and Ka have a total estimated potential of 77.3GW which is 75% of the total wind potential of India. Gujarat alone accounts for 35% of the total estimated potential. - http://www.cwet.TN.nic.in/html/departments_ewpp.html
6 TN RE integration update from PRDC Grid Challenges for Renewables in TN
Best practices from Factors relevant to utility integration of intermittent renewable technologies report

The potential for grid connected PV in TN has been estimated between 4,000MW to 21,700MW[7]. The 3,000MW of solar installations planned under the TN solar policy (released in November 2012) will be met through 1,500MW of utility scale grid connected PV installations, 350MW of roof top installations and 1,150MW through REC mechanism[8]. As per the policy, the government will promote setting up of exclusive solar manufacturing parks.

Table 1: Established Grid connected Solar PV projects in TN

Location	Scheme	Capacity / technology	Interconnec-tion level	Date of commissioning and Owner
Sivaganga	Migration scheme under JNNSM	5MW / Thin film	110kV	2010, MOSERBAER Clean Energy Ltd.
Thoothukudi, Sivaganga, Nagapattinam	RPSSGP[9] under JNNSM	5MW		
Thoothukudi	NVVN[10] of JNNSM Batch I of Phase I	5MW/ Thin film	33kV	2012, CCCL (Consolidated Construction Consortium Limited)
	REC	1.055MW		Numeric Power Systems Ltd.
Total		**16.055MW**		

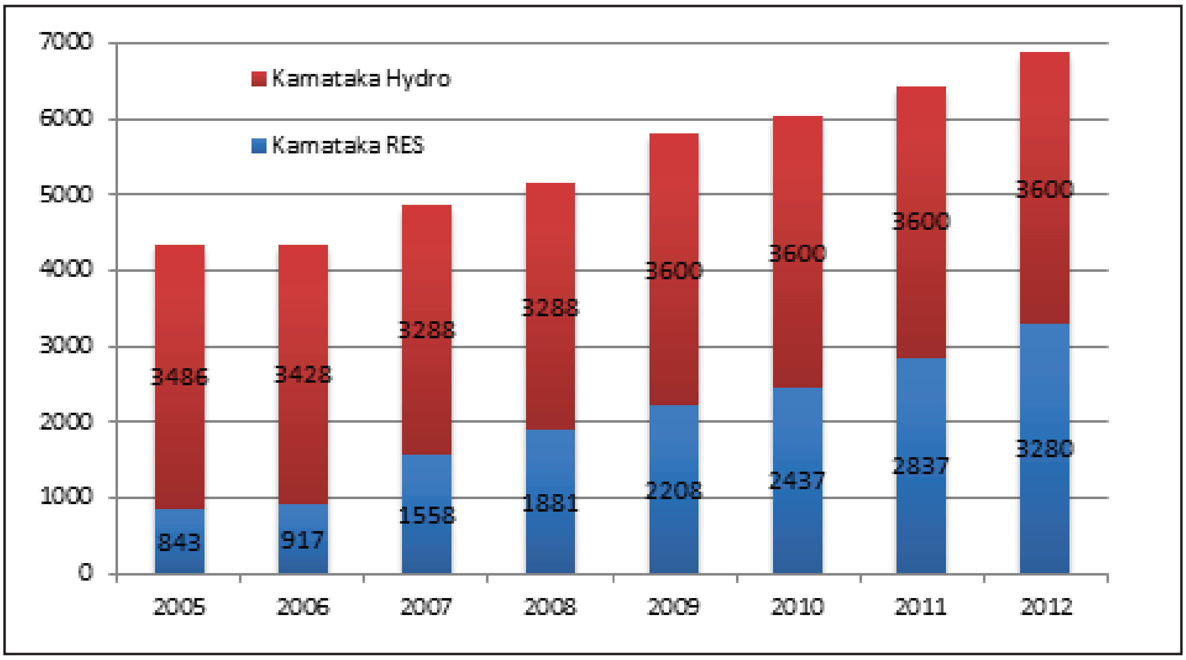
Source: "Scenario of Solar projects in TN" presentation - Global Solar EPC summit May, 2012

7 From "Scenario of Solar projects in TN" presentation - Global Solar EPC summit May, 2012. Presentation sources data from WISE
8 TN Solar policy – REConnect Energy website - http://reconnectenergy.com/blog/
9 Roof top Small Solar Grid Connected Power Plants
10 NTPC Vidyut Vyabhar Nigam Ltd. News article - http://www.statensolar.com/company/news-and-events/statensolarto build5mwpvplantintamilnaduindia

III. KARNATAKA (KA) RE CAPACITY

Total installed generation capacity (conventional + un-conventional) in Ka is 11.546GW[11]; state owns 57% of the installed capacity[12]. The RE potential of the state has been estimated to be 28GW, of which only 3.28GW (excluding hydro) has been commissioned until September - 2012. This includes grid and off-grid RE capacity. The potential for wind is 14GW[13]. Ka had 139 wind projects (grid+off grid) with cumulative capacity of 2.106GW as of 2012[14]. As per CWET[15], wind potential of Ka at 80m hub height is 13.6GW.

Figure 2: Installed RE capacity (MW) in Ka



Source: CEA monthly reports (2012 figures are as of September, 2005-2011 figures are as of December)

Coastal areas of Ka are better suited for solar power generation[16]. Four grid connected crystalline solar PV plants with cumulative capacity of 14MW have been commissioned under the "Arunodaya Program" as of July 2012[17].

11 From "Ka Energy Sector Profile" – Global Investors Meet 2012. Further as per the document, 53% is from hydro, 12% from other renewables and remaining from thermal in Ka.

12 From Global Investors Meet 2012

13 From CII Ka Conference on Power 2012 report

14 From CII Ka Conference on Power 2012 report which has sourced capacity information from KREDL

15 From CWET - Gujarat, Andhra Pradesh, TN and Ka have a total estimated potential of 77.3GW which is 75% of the total wind potential of India. Gujarat alone accounts for 35% of the total estimated potential. - http://www.cwet.TN.nic.in/html/departments_ewpp.html

16 From "Ka Energy Sector Profile" – Global Investors Meet 2012

17 From CII Ka Conference on Power 2012 report which has sourced capacity information from KREDL

Table 2: Grid connected solar PV projects[18]

Location	Capacity	Interconnection level	Date of commissioning and Owner
Yalesandra village in Bangarpet taluk, Kolar district	3MW	11kV	June 2010, KPCL
ITNal village in Chikkodi taluk, Belgaum district	3MW	11kV	Operational in June 2010, KPCL
Yapaladynni Village, Raichur district	3MW	11kV	March 2012, KPCL
Shivasamudram near Mandya	5MW	66kV	July 2012, KPCL
Total	14MW		

Source: Refer to footnore 18

The Ka government has planned for a 500 MW solar park, based on the Gujarat model, by March 2014. It will start with a small capacity of 80-100 MW and gradually scale up[19]. The other major existing sources of RE are cogeneration projects of 949MW and hydro projects of 647MW[20].

18 Kolar project – "Ka gets India's first 3MW solar plant" http://www.deccanherald.com/content/75926/indias-first-3-mw-solar.html. Belgaum and Raichur interconnection levels – Solar Magazine 2010, http://content.yudu.com/A1tpd7/solmagviii11/resources/34.htm. Operational status of Belgaum district plant - http://www.business-standard.com/india/news/biggest-solar-power-plant-commissioned/398598/. Technology of 3MW plants - http://www.asappmedia.com/News.aspx?nId=aiUzZd/YV6P03eyxah8l7g==. 3MW plant commissioned by BHEL in Raichur - http://www.business-standard.com/india/news/bhel-commissions-13mw-solar-power-plants-this-year/466795/. This plant was ready much earlier, but there were evacuation issues - http://www.eai.in/360/news/pages/2815. 5MW plant commissioned by BHEL - http://www.business-standard.com/india/news/bhel-commissions-5-mw-solar-power-plant/481753/

19 CII Ka Conference on Power 2012 report

20 From CII Ka Conference on Power 2012 report which has sourced capacity information from KREDL

IV. CONTRIBUTION OF TN AND KA TO NATIONAL RE PLANS

Seven states – TN, Ka, Andhra Pradesh, Gujarat, Maharashtra, Rajasthan and Himachal Pradesh account for 80-90% of the total installed RE capacity[21] of 24.998GW (refer to Annexure 1 for RE capacity and plans for entire country) as of September 2012[22]. The southern states (TN, Ka and Andhra Pradesh) accounted for ~ 47% of the total installed RE capacity. 70% of the installed RE capacity was wind.

Per the "Strategic plan for new and renewable energy sector for the period 2011-17", MNRE anticipates addition of 18.28GW of new RE capacity over the 12th fiver year period (2012-2017). 11GW of wind and 3.7GW of solar will account for 80% (14.7GW of 18.28GW) of the planned capacity addition (for details refer to Annexure 1). MNRE has an aspirational goal to have 82.8GW of grid connected RE power by 2022. If this were to be realized, RE would account for 18% of the generation capacity estimated at 465.5GW by 2022. This indicates a significant increase from 12% as of September 2012[23]. In TN and Ka, RE sources (inclusive of hydro, biomass) already account for 70% and 60% of the total installed generation capacity.

Versus the 14.7GW of new wind+solar capacity, the State Nodal Agencies (SNA)/ State Transmission Utilities (STU) have more ambitious plans. They have planned for 39.8GW of new wind+solar generating capacity over the same period (12th five year period) in the seven RE rich states. This is more than double the MNRE target. The SNA/STU plans are available in the Green Energy Corridor Report (refer to Annexure 1 for details of seven RE rich states).

Table 3 : Planned wind and solar capacity addition in 6 RE rich states for 12th five year plan – SNA/STU

States	Wind (MW)		Solar (MW)		Total Capacity (MW)	
	Existing	Planned	Existing	Planned	Existing	Planned
TN	6370	6000	7[24]	3000	6377	9000
Ka	1783	3223	6	160	1789	3383

Source: Green Energy Corridors report

21 The gh high voV for ion networks stations is transmitted s account for n RE capacity from 2005 until now. Closely at an all ICoal+diesel+natural gas account for majority (54%) of the total installed capacity in the South. Of the 24,998MW of installed RE capacity, 11,769MW was installed in the Southern States as of September 2012. The Western States are rapidly adding new RE capacity. As of September 2012, Western States had 8147MW of the installed capacity, followed by Northern States with 4438MW. From 2005 to September 2012, Western states added RE capacity at a CAGR of 33%, Northern states added at a CAGR of 25% and Southern States added at a CAGR of 17%.

Parameter	Ka	TN	Andhra Pradesh	Kerala	Pondicherry
% of Renewable Energy in total installed capacity - 2012	23.8	41.7	5.5	4.25	0.01

Source: CEA monthly reports compiled in the CII Ka Conference on Power Report

22 As of March 2012, off grid RE capacity was 700MW – Green Energy Corridor report

23 RE and Grid capacity plans for 2022 from Strategic plan for new and renewable energy sector for the period 2011-17, MNRE, February 2011

Transmission network issues from CII Ka Conference on Power report

24 This was the installed capacity way back in July 2011, while the Green Energy Corridors report was released in September 2012. As stated in the 29-Aug-2011 Business Line "20-grid connected solar power plants on-stream" article – Total of 20 grid connected solar power plants with capacity of 1 megawatt (MW) or more have been commissioned in the country by July 2011. Of the total capacity of 45.5 MW commissioned, Gujarat has 11 MW, Rajasthan 7.5 MW, TN 7 MW, Ka 6 MW, and Maharashtra 5 MW. Andhra Pradesh, Punjab and Delhi have 2 MW each, while Haryana and West Bengal have 1 MW respectively. These are solar photovoltaic projects.

Of the new capacity planned by the SNA/STU, TN and Ka will contribute to ~ 23% of the new RE capacity. At a national level, these two states will continue to play a pivotal role in the development of the RE landscapce.

To summarise, both TN and Ka have ambitious plans to scale up RE capacity. The focus is on increasing wind and solar for a reasonable share in the installed capacity in both states. During the 12th five year period, TN and Ka plan to add 1.4 times and 1.9 times the installed wind+solar capacity available at the end of the 11th five year period (March 2012). For solar (because the current base is small), the projected growth is about 429 times the 2012 installed capacity (March 2012) in TN and 28 times the 2012 installed capacity base (March 2012) in Ka. For wind, TN has planned to (almost) double the capacity between 2012-2017 and Ka planned to increase the capacity about 1.8 times. These are very ambitious numbers.

The ambition is well grounded in the RE capacity of these states. Both states have adequate solar and wind potential, as we have observed from published studies. In particular, the wind potential has been recalibrated upwards in both states.

V. CHALLENGES OF INTEGRATING RE AND EE INTO THE TN AND KA GRID

TN and Ka grid face problems related to infrastructure capacity, poor management of existing infrastructure, slow implementation of monitoring and automation projects, lack of incentives to invest in forecasting and scheduling and need of alignment between the smart grid pilots and EE measures. In this section of the paper, we will consider the integration issues of RE and EE into the grid in these states.

A. Evacuation Infrastructure and planning related issues

Infrastructure issues have already resulted in sub-optimal use of existing RE generation capacity, particularly in TN where wind accounts for more than 50% of the installed generation capacity.

1. Limited transmission infrastructure and planning for intra state RE evacuation

Lack of substations and transmission lines in TN have been causing concerns amongst the wind farm owners. As of 31-May-2012, the infrastructure in TN was capable of evacuating 5,000MW of wind power[25]. The maximum online capacity was 3,960MW. With 6,000MW of new capacity coming online by 2017 (12th five year plan), the existing infrastructure will not suffice. Without proper planning and new infrastructure, the performance of the grid will be affected due to overloading.

In the past, Governments have signed Power Purchase Agreements (PPA) without planning for the evacuation infrastructure[26]. This, along with the year long delays in payment from the government for power supplied to the grid, have worked against the integration of more RE into the grid[27]. In Ka, some RE sites are in rural areas without evacuation infrastructure which has affected smooth evacuation in the state, a case similar to TN[28]. Areas like North Ka and Chitradurga have great potential but evacuation has been a problem in the past[29].

2. Lack of long term planning

For intra-state transmission, infrastructure is required for wheeling away the RE power since RE sources are generally located at significant distances from the consumption centres. Pooling stations at 132kV, 220kV and 400kV and the transmission lines are required for strengthening of the intra state transmission network.

25 From TN Wind Power Scenario as on 31-May-2012 by Government of TN
26 From Interviews
27 The Hindu August 22 2012, “TN witnesses drop in installations of wind turbines” - http://www.thehindu.com/news/cities/Coimbatore/tamil-nadu-wiTNesses-drop-in-installations-of-wind-turbines/article3804359.ece
28 CII Ka conference on Power 2012
29 News article - KPTCL to set up two sub-stations to harness wind energy - http://www.deccanherald.com/content/144023/kptcl-set-up-two-sub.html

The long planning period required for T&D infrastructure does not support the installation of new wind farms since the gestation period for wind farms is much smaller. This acts as a deterrent for wind power generators.

3. Sub-optimal management of infrastructure

Wind power generation is maximum during the monsoon/off-peak seasons when total demand comes down. In case transmission infrastructure is laid down to evacuate the generated wind power during this season, the infrastructure will remain un-used when wind production falls during high demand (summer months) seasons. Underutilization with huge investment is a concern which has led to slower investment in new infrastructure. For example, the existing infrastructure in TN can evacuate only 5,000MW of the 7,000MW of installed wind capacity.

Also, to ensure grid stability, during high wind season, the wind power producers are asked to back down their production. Like the transmission and distribution networks, installed wind capacity is not used efficiently[30]. The maximum wind energy contribution in TN was 3,960MW on 4th July 2012. On an average, 12.6% of total energy fed into the grid was from wind power in 2011-12[31] though wind accounted for 40% of the total installed capacity. Total wind power generation was 8,537Million Units in TN and 2,674Million Units in Ka in 2011[32].

In Ka, 2,687Million Units[33] were generated from wind installations in 2010 and total power generation was 23,165Million Units, wind power accounted for 12% of the total power generated vs. the 19% contribution to installed capacity. The fact that TN has a lower utilization , compared to Ka (vs. contribution to installed capacity), is explained by the fact that in TN much of the capacity has been put by private developers incentivised by accelerated depreciation tax benefits as opposed to generation incentives.

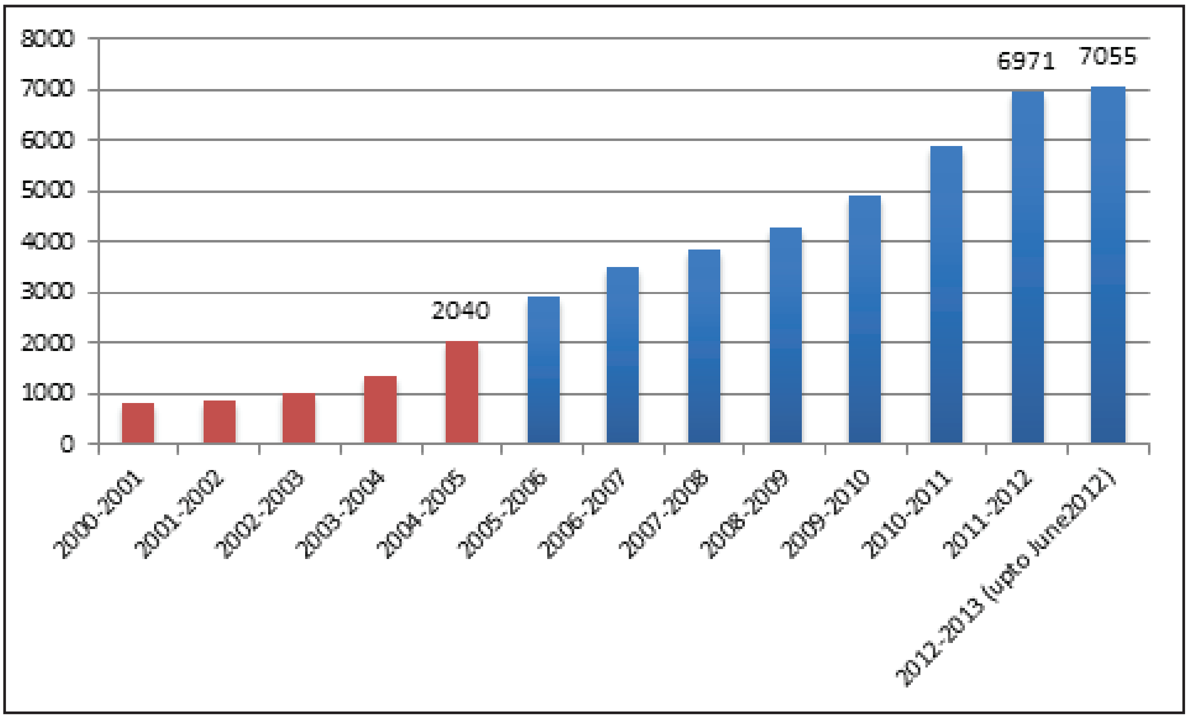
B. Lack of robust communication systems to relay real time RE generation data

Prior to 2004, individual wind turnines were installed by investors or were used for captive power generation. There was no need for generating forecasts at a regional level. Hence, the investment in communication technology for RE generators was not done. As, a result the 2-5MW installations were not connected with each other or to the Load Despatch Centres (LDC). The absence of communication systems has made it difficult for these wind energy generators to relay real time data which is used in forecasting[34] and then scheduling. Of the more than 7,000MW

30 From Wind Power Evacuation TN – SLDC presentation
31 From TN Wind Power Scenario as on 31-May-2012 by Government of TN
32 From India Wind Energy Outlook 2012 GWEC
33 Wind power generation data from India Energy Outlook 2012 – GWEC and total generation from KPCL annual plan 2010-11
34 Historical data from RE plants forms the basis of forecasting for a green field project or for installed capacity. However, the variable nature of wind and solar in the same location results in variations between historical data and actual production. This reduces the accuracy of forecasted data (short term and long term). To compensate for this, real time data has to be used in developing forecasts. Based on historical and real time data, the production pattern can be fore casted with greater accuracy. While historical data is generally available, real time data availability is still an issue in the case of old turbines

installed wind capacity in TN, 30% of the installed capacity is not equipped with communication links for transmission of real time data. This estimation is based on ratio of installed capacity before 2004-2005 vs. total installed capacity. The existence of these distributed old units makes it difficult to collect and process information from all turbines at a sub-station or regional level. Currently the CERC has mandated forecasting for any installation of 10MW or more. Without making any investments in connecting the old turbines with adequate communication links, efficient forecasting at the 10MW level will be difficult to achieve.

Figure 3: Cumulative installed wind capacity (MW) in TN



Source: TN Wind Power Scenario as on 31-May-2012 by Government of TN - http://mnre.gov.in/file-manager/UserFiles/presentation-01082012/Presentation%20on%20Wind%20Power%20Scenario%20in%20Tamil%20Nadu%20by%20Shri%20Rajeev%20Ranjan,%20Chairman,%20TNEB.pdf

It was only after 2004, that the Independent Power Producers (IPP) planned for the 100+ MW wind farms. These turbines installed after 2004 are equipped with communication systems and Supervisory Control And Data Acquisition (SCADA) systems.

The issue with the new turbines is frequent SCADA failures. Communication link failures can cause disruption in the relay of accurate real time data. In the case of wind, the major inputs from a generator to a forecaster are wind speed, output power and status of every individual turbine within a wind farm. As an example, if we consider a 100MW installation, SCADA problems may lead to data availability from a much lesser capacity (less than what is actually generating power). Real time data based on lesser capacities will produce a very different forecast from the actual production from the wind farm. The resulting forecast will not be suitable for use for scheduling purposes.

C. Inability to develop RE schedules due to regulatary and process related issues

The accuracy of forecasts (generators can develop their own forecasts or outsource to forecasting organizations) improves as one approaches the real time of operation of wind or solar generators. Thus, the schedule developed on the basis of forecasts closer to the time of real operation will have fewer deviations from actual generation patterns vs. a schedule developed a day earlier. But, the absence of accurate forecasts creates scheduling issues (System operators are responsible for scheduling) on a day ahead and more importantly on the hour ahead basis for the central and state regulating agencies/ system operators creating balancing challenges in the grid. There is a disconnect between the generators and the Load Dispatch Centers (LDC). System operators are not able to schedule dispatch of RE power in 15-minute time block due to absence of real time data.

As discussed earlier, real time data for RE generation is not available from RE sources (30% in the case of TN) that are not tele-metered/ connected through proper communication links. For the remaining 70% of wind capacity which is in TN, SLDC considers forecasts from less than 250MW (of the 5000MW of capacity equipped with communication systems) in developing its load-balancing schedule[35]. This is because units that were installed after Jaunary 2011 are providing the data to the SLDC. The remaining units are capable of, but are not incentivised to provide their generating schedules to the SLDCs.

There are no incentives for the RE generators to invest in advanced forecasting technologies and relaying real time data to the LDCs. Solar generators have been exempted from any penalties for deviation of actual production from forecasts. Wind operators were allowed to produce within +/-30% of their forecasted schedules as per the Indian Electricity Grid Code (IEGC) 2010. Any deviation would be penalized under the UI mechanism. IEGC was advocating the adoption of this law from 1st January 2011[36]. But, the standards for RE connection to the grid (refer to Solutions section for standards) developed by IEGC have not been enforced yet.

Due to lapses in scheduling, the system operators, utilities have to make arrangements for additional reserves which can be put online incase of variations from RE generation schedules. This increases the cost of integrating RE into the grid.

Another reason why it has been difficult to drive implementation of regulations and policies is the involvement of multiple small-scale stakeholders. It is practically impossible to get the buy in of every stakeholder to create a process for monitoring, forecasting and scheduling at a sub-station or regional level. There is no regional or centralized system of collecting and assessing the data and taking a decision on the allowable deviations and penalties.

Unless the regulations are passed at the National level and wind generators invest in forecasting, the lapses in forecasting and scheduling will remain.

35 From discussions
36 From Wind Power Evacuation TN – SLDC presentation

D. Limited communication, monitoring and control systems for enhancing grid efficiency

The high levels of thefts which lead to overall grid losses across India and in TN can be reduced if the monitoring and communication systems are in place. Due to absence of automation, the point of theft cannot be detected and hence these losses have increased over the past few years with rising demand.

Communication, monitoring and control systems can also help in reducing the AT&C losses by detecting thefts, faults and reducing down time. Any faults in the circuit can be easily detected and even controlled from a central control centre operated by the utilities if the grid is automated. This can help in reducing the downtime and thus maintaining grid stability.

E. Need for alignment between EE and smart grid initiatives

Two important functionalities of a smart grid project are peak load management and outage management[37]. The benefit of running a smart grid pilot or project would be maximum when the most energy intensive consumers would be able to manage their consumption to reduce their peak load. Similar to the smart grid projects, the EE projects and initiatives underway across the industrial and commercial spaces also aim to reduce the energy consumption of the highly energy intensive industries, commercial and residential spaces. These projects have to be aligned with each other in order to enable load management and thus improving the grid stability and efficiency.

F. Lack of reserves/energy storage to deal with intermittency in RE generation

Intermittency is defined as variation of electrical energy output over time due to natural fluctuations in the source. The RE production volumes vary daily as well as by season. In an overall Indian context RE penetration levels are low (about 4%). The intermittency of RE is treated by the system as an extension of natural load fluctuations. The Indian and state grids already operate at high levels of variability of demand and supply. Variability in demand arises on a daily basis. Evenings witness a high ramp up rate of load. Major ramp ups are seen during the festival seasons (200MW/minute going up to 437MW/minute during Diwali). There are also sharp changes in load due to agricultural loads. As soon as supply is switched on, all agricultural loads in a region come online simultaneously causing fluctuations of up to 1000MW in a zone. Apart from these daily variations, the country has witnessed trips on a regular basis, the most recent one being the North India Power Grid Failure. There were six trips during 2012 excluding the North India Power Grid Failure with a cumulative trip time of more than 6000 hours.

37 Other functionalities are asset management, power quality management, agricultural DSM

But, in TN and Ka, where the RE penetration level is already 12% and projected to increase, this variability may become a concern in the more immediate future.

Variability and lack of transmission capacity reduce the Plant Load Factor (PLF) of RE generators[38]. Unlike thermal power plants which normally operate at average PLFs of around 75%[39] in India, wind power plants have a PLF in the 25-30%[40] range. The static solar panel-based plants generally have PLFs of 18-18.5%[41]. The PLF of solar thermal plants ranges between 22-24%. The PLF can be improved with storage[42].

The issue of absence of grid level storage for RE generation is applicable globally. However, due to the dependency on wind power, the absence of grid level storage becomes very relevant for TN. In July 2012, power generation from wind farms in TN fell from 3,575MW to 147MW over a period of just three days. This was attributed to the unseasonal rains[43], resulting in unplanned load shedding.

Amongst the various storage technologies, large scale storage systems like pumped hydro and Compressed Air Energy Storage (CAES) have not yet taken off in the RE rich states. Hydro can store any excess renewable electricity during lean periods when demand is low but generation is high. However, hydro comes with its own issues: construction can happen only in location with particular characteristics and suitable sites are very often difficult to use on account of socio-political/environmental issues. We have seen how TN and Ka have been engaged over a long discussion to share hydro resources from Cauvery river. Similarly CAES requires suitable geological formations for the compressed air storage[44]. This increases costs to utilities. Other storage mechanisms include flywheels for frequency regulation for integration of variable power sources[45]. Flywheels for large scale applications were tested for the first time in a 20MW installation facility in Stephentown/NY in 2011[46]. However, like many other large scale storage technologies, flywheels are expensive. The use of acid batteries (a means of grid level energy storage) and UPS/inverters for residential, commercial and industrial consumers market has increased significantly[47] for household applications.

38 Reasons for low PLF from Wikipedia - http://en.wikipedia.org/wiki/Capacity_factor

39 Average PLF is for 2010-11 from OPERATION PERFORMANCE OF GENERATING STATIONS IN THE COUNTRY DURING THE YEAR 2010-11 - CEA

40 PLF is the ratio of actual output of power plant over a period of time and its output if it had operated at full capacity of that time period

41 PLF for solar from News Article - http://solarknowledge.blogspot.in/2012/01/mahindra-solars-jodhpur-power-plant.html. Gives example of a 5MW PV plant commissioned in January 2012 uses trackers to enhance efficiency of the plant. This PV plant was expected to have a PLF of 22%

42 Solar Thermal PLF from Study on barriers for solar power development in India – World Bank

43 Panchabhuta article "As wind energy production dips in TN from 3575MW to 147MW, power cuts return" - http://panchabuta.com/2012/07/18/as-wind-energy-production-dips-in-tamil-nadu-from-3575mw-to-147mw-power-cuts-return/

44 Issues related to pumped hydro, CAES and flywheel from Storage needs, options and challenges today and tomorrow report

45 Flywheel information from Integrating renewable electricity on the grid report

46 Flywheel failure information from article dated 31 October 2011 – "Flywheel storage maker Beacon Power declares bankruptcy" - http://news.cnet.com/8301-11128_3-20127778-54/flywheel-storage-maker-beacon-power-declares-bankruptcy/

47 Increased use data from Advances in Energy Storage Technologies: Indian perspective, IESA – IEEE Microgrid workshop

G. Power quality concerns

RE generators are connected to the transmission as well as the distribution network unlike conventional power plants that are connected to the transmission network. The technology for RE generators has evolved over time. Some of these technologies disturb the quality of power of the distribution and transmission network. With increasing volumes of RE power being pushed into the grid and plans for roof top distributed generation in TN and Ka, power quality issues have to be resolved by these states.

1. Reactive power generated by wind farms

2,500MW capacity of wind installations in TN does not have reactive power[48] support (Wind Power Evacuation TN – SLDC).

Wind generators are synchronous or asynchronous/inductive. In a synchronous generator, reactive power flow can be controlled. Asynchronous generators act as a sink for reactive power. Even when the real power output from an induction generator is zero, it will continue to draw reactive power during operation in addition to drawing reactive power during start up (Renewable Energy in Power Systems Leon Ferris and David Infield 2008). During faults, these machines consume large amounts of power from the system which makes the recovery process from faults difficult. A big percentage of wind generators in India are induction generators.

In India, Enercon and Regen Power Tech are running the synchronous generators. Based on CWET data, as of March 2010, only 21% of the installed capacity (by MW) was from Enercon and Regen Power Tech. Hence the actual percentage of synchronous generators[49] would be even smaller.

2. PQ issues arising due to connection of wind farms to transmission network

The output from a wind turbine varies significantly due to rapidly changing wind speeds[50], which contributes to power quality issues in the grid. Voltage variation can be in the form of sag/dips, swells, short interruptions, long duration voltage variation[51]. The problem is more pronounced in the case of fixed speed wind turbines versus the variable speed turbines. In India, 79% of the installed capacity as of March 2010 was using fixed speed turbines.

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48 Alternative Current (AC) circuits have capacitive and inductive loads which give rise to reactive power. Reactive power is an inherent component of total power; the other component is the active or real power. Reactive power causes voltage and current to go out of phase and gives rise to voltage variations. The reactive power should be reduced since it does not do any real work; the active component of power does the real work. All AC circuits including wind generators will produce reactive power

49 CWET document - MANUFACTURER-WISE WIND ELECTRIC GENERATORS INSTALLED IN INDIA (As on 31.03.2010) -http://www.cwet.TN.nic.in/Docu/Manufacturers_as_on_31_03_2010.pdf

50 Reference drawn from Renewable Energy in Power Systems Leon Ferris and David Infield 2008

51 Voltage sag (swell) – momentary voltage dip (rise) for a few seconds; Over (under) voltage – steady state voltage rise (dip) lasting for several seconds; Interruptions – complete loss of voltage for few seconds to few hours; Flicker – perceptible change in output due to sudden change in voltage from Power Quality Issues in Grid Connected Wind Firms

Grid Protection Issues from Protection Issues in Micro Grid & DG – IEEE Microgrid Workshop, Factors relevant to utility integration of intermittent renewable technologies report

Also, this is a bigger issue for single turbines or small clusters. The effect of these variations is lesser in large wind farms as the power fluctuations from individual wind turbines are not correlated. In TN, 30% of the installed capacity before 2004-2005 was dominated by single units or small clusters. This makes the issue of voltage variations arising out of variable output relevant in TN with its high wind installed capacity.

Other issues like harmonics are commonly observed phenomenon across all RE installations depending on the type of generators. Harmonics or distortion of the AC sinusoidal voltage is caused by the use of static power converters (inverters) which convert DC (produced by RE generators) to AC for grid integration. The intermittent renewable generators can add to the harmonic distortions at the connection point by producing distorted 50Hz waveforms. Voltage variation irregularity is seen in the case of solar PV due to fluctuation in the solar output[52]. Hence, harmonics are common in PV output. Synchronous and DC generators in wind systems do not have significant harmonic output. However, wind systems using DC bus in conjunction with variable speed generators can contribute to harmonics.

3. Power Quality issues to watch out for in the future

The volume of roof top distributed generation which feed into the distribution grid in the two states is negligible. Currently, the roof top distributed generators are using all the produced power to meet inhouse demand. With the TN solar mission and Ka plans to set up a solar park, the PQ issues arising from Distributed Generation (DG) will become relevant in the future.

Issues arising due to connection of distributed RE to distribution network

Unlike conventional power plants which are connected to the grid at 132kV or above, RE is also connected to the distribution (below 66kV) network[53]. Power from small scale DG can feed directly into the distribution network, altering the conventional uni-directional power flow process where power flows from distribution network to the consumers. In this case, power will flow from the consumers to the distribution network as the consumer is actually generating power on the rooftops. This can give rise to power quality[54] issues in the grid. DG sources include rooftop solar and wind installations which can export surplus power to the distribution network or small captive generating units/plants (500-1000kW) that push power into the distribution network.

The point where the generator is connected to the network is called the Point of Common Coupling (PCC). The voltage can go up at the PCC when the DG source is connected which will have an adverse impact on the customers drawing power from the distribution network. The voltage rise will impose a limitation on the maximum generation that can be connected at a particular point.

52 Voltage variation in solar PV output from Electricity grid evolution in India report

53 When connected to the transmission network, generation from several sources are pooled for connection to the nearest 220kV substation. Large size/utility scale RE plants are connected directly at 132kV or 220kV. For plants more than 300-400MW pooling has been done at 400kV

54 Problems in the electric power system in the voltage, current or frequency that results in unsatisfactory operation or failure of electrical equipments are power quality issues

The allowable voltage rise will depend on how close the network is allowed to go to the maximum voltage limit[55]. Large generating stations are generally connected to the transmission network using standard equipment with protection systems available at affordable costs. Since, the DGs are connected to the distribution network; the same cannot be said for DGs.

Grid protection & personnel safety issues

When connected to the distribution network, RE sources can upset the conventional utility distribution system protection schemes. Conventional protection systems work by isolating the cause of disturbance and minimizing the area affected. However, in a two way power flow scenario, the generator may energize a line that would otherwise be dead. This creates safety issues for workers.

Distributed generation increases short circuit levels – due to fault current and overvoltage contributions from these generators. The implementation of adaptive protection is a challenging task since information is not available in distribution networks – that is needed to update the relay settings. Information systems like SCADA should be used for RE sources. Thus, apart from power quality and protection issues, distributed generators are not integrated into the utility's Automatic Generation Control (AGC)[56], a system that enables the generation of power output across various generators.

55 Voltage rise could also be considered an advantage for voltage control where voltage is low on the distribution end. This would apply in some cases in the Indian context

56 AGC enables the adjustment of power output across multiple generators in order to balance the generation and load. This balancing is based on the system frequency. Increase in frequency implies all generators are speeding up as more power is generated than being used and vice versa

VI. SUMMARIZING RE AND EE INTEGRATION CHALLENGES IN TN AND KA

Transmission infrastructure takes far longer to be put up when compared to RE generating plants and we feel that the ambitious plans on increasing RE generation capacity is not balanced by a carefully thought out plan on grid infrastructure. TN has not been able to effectively utilise its actual electricity generated from wind during the high wind period.

RE is intermittent and more difficult to forecast and schedule. In order to solve the problems arising from this inherent nature of RE power, investments need to be made into communication infrastructure that would help the better coordination between LDCs (Load Dispatch Centres) and generating stations and would also help in the collection and analysis of data that would make forecasting and scheduling of power efficient for the system, as a whole, over a period of time. Both the infrastructure and policy are required to help move towards a better forecasting and scheduling regime, we feel that adequate attention has not been given to this issue.

At the distribution level, by and large, TN and Ka (like the rest of India) have not faced any integration issues because the capacity connected at this level is too low. However, for integration of more RE, the policy around net metering needs to come into effect. The potential for roof top RE should be assessed and incentives have to be designed to promote distributed generation at the household level.

For energy efficiency measures, we are of the opinion that the monitoring, communication and control systems will help in reducing losses and improving grid stability. There is also a need for plans to align the EE initiatives with Smart Grid and Smart Metering pilots which have taken off.

The intermittent nature of RE also raises questions about the reliability of RE power. TN has already suffered due to the variable nature and dependence on wind power. Energy storage and flexible reserves will have to be considered as RE power penetration increases in the future.

RE sources can also be connected to the grid at both the transmission and the distribution levels, unlike conventional power plants which are connected to the transmission network. There are several generic technical issues involved in integration but some of the key issues relate to organizational processes and planning.

The technical issues around integrating Renewable Energy to the transmission grid are mainly in the areas of increasing grid variability, deterioration of power quality and integrated storage planning. These issues are not insurmountable and there is an effort across the globe to resolve these issues. Thus, the technical solutions to these issues are now available, what has to be verified is their applicability in the context of TN and Ka. But, the process and planning has to be robust to implement these technologies.

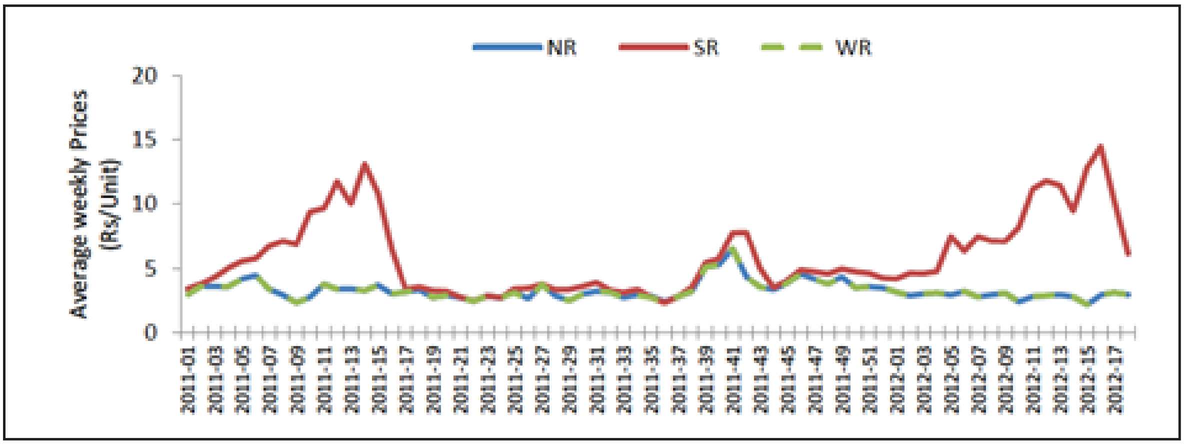
VII. OTHER ISSUES OF SOUTHERN GRID AFFECTING TN AND KA

As a whole, the Souther Region (SR) Grid which includes TN, Ka, Andhra Pradesh and Kerela suffers from limited transmission capacity which has led to congestion in the T&D network. TN and Ka along with the remaining SR states have to pay the price for the congestion.

A. Limited transmission capacity

In general, the growth in transmission and distribution capacity in the southern part of the country has been much slower than the rest of the regions. The slow growth in transmission capacity has also led to congestion in the South India grid. Congestion in the SR grid occurred almost daily between June 2010 and Aug 2011 with congestion touching 25% for most months and over 50% congestion for four months. As a result of this congestion, the South was unable to draw enough power from the exchanges. The Southern region has been paying for exchange-traded power at several multiples of the rates prevailing the rest of the country. Additional congestion charges were paid by southern consumers for purchasing power form the exchanges57. In particular, the average price paid by TNEB in 2010-11 to purchase electricity in the day ahead market in PXIL was Rs 6.73. The next highest payer was APCPDCL/APPCC (Andhra Pradesh) at Rs 5.1458. During this period, TNEB was the biggest purchase by volume (MU).

Figure 4 : Exchange Traded Power (2011-2012)



Source: Indian Energy Exchange, Average Weekly Prices, Accessed 12 May, 2012. http://www.iexindia.co m/Reports/AreaPrice.aspx from Power Shortages in India Challenges for Growth report

Apart from the price increase, congestion makes purchase of additional power from open market difficult which results in unplanned load shedding. TN has faced this problem in the recent past. As an example, immediately after conditions started deteriorating in January 2012, TN was able to get only 200-235MW power from Gujarat despite signing a contract for 500MW[59].

57 From Business Standard News Article dated Mar 12, 2010 which states that despite availability of power in the grid and on power exchanges, power demands in the southern states were not met

58 From CERC, Report on Short-term Power Market in India, 2011-12

59 From news article, Grid congestion suffocating EB - http://ibnlive.in.com/news/grid-congestion-suffocatg-eb/228510-60-120.html

B. Limited infrastructure for inter state RE evacuation from South India

Until now, power generated by RE sources has been absorbed within the producing state. Where applicable this power has been used to meet the Renewable Purchase Obligations (RPO). In the future, once RPO requirements are met, connecting RE source to the nearest substation will not be the solution for RE evacuation. In this case, a robust interstate transmission network will be required. The Southern Region (SR)[60] which includes the states of TN and Ka lags behind in the inter-regional transfer capacity.

While, the total inter-regional transfer capacity within India has gone up from 13,450MW at the end of 10th plan to 23,150MW by 30th December 2011. The inter-regional transfer capacity between the south and other regions has gone up only minimally since the end of 10th plan.

Table 4 : Inter regional transmission capacity – existing and planned

Inter-regional transmission	As of end of 10th plan (MW)31st March 2007	As of 30th Dec 2011 (MW)	Expected as of end of 11th plan (MW) 31st Mar 2012 (MW)
ER-SR	3,130	3,630	3,630
ER-NR	3,430	7,930	10,030
ER-WR	1,790	4,390	4,390
ER-NER	1,260	1,260	1,260
NR-WR	2,110	4,220	4,220
WR-SR	1,720	1,720	1,520
Total (>=200kV)	**13,450**	**23,150**	**25,250**
Total(>=110/132kV)	**14,050**	**23,750**	**23,850**

Source: CEA - Draft National Electricity Plan (Volume II) – Transmission, Feb- 2012. WR-SR reduction in Bursur-L, Sileru HVDC monopole as per Working Group on Power for 12th Plan, Jan 2012

60 India (states and union territories) is geographically divided in five transmission regions/grids – Northern (NR), Eastern (ER), Western (WR), North Eastern (NER) and Southern (SR). The first four grids operate as a single grid in a synchronous mode or single frequency. In October 1991, ER and NER grids were synchronized, in March 2003, WR grid was synchronized with the ER and NER grids. In August 2006, the NR was synchronized. Power across these regions can flow seamlessly as per the relative load generation balance. The Southern Region is interconnected with the rest of India grid through asynchronous HVDC links. Hence, quantum and direction of power flow between Southern Grid and rest of India grid is controlled manually

VIII. SUMMARIZING SR GRID CHALLENGES

These issues of the SR grid indicate the scarcity of infrastructure to support even the conventional power generation. Currently RE is consumed within the generating state. But when TN and Ka start exporting RE power, they will suffer from the limited inter-regional transmission capacity of the SR grid. The SR grid has seen the lowest addition in inter-regional transfer capacity over the years. The SR grid has lagged in key grid infrastructure improvements and this has particularly costed the state of TN.

In the next section, we first discuss the solutions for integrating RE and EE into the TN and Ka grid. Some of these solutions require intervention at the National level.

XI. SOLUTIONS FOR INTEGRATING RE AND EE INTO TN AND KA GRID

We have so far discussed the issues that would become increasingly important if the RE component to the energy mix in TN and Ka is going to increase sustainably. We have also noted that these issues are not insurmountable and that several countries have already integrated large RE capacity in their grids. In this chapter we will discuss some of the key solutions that will help in the deployment of greater RE and improvement of the grid efficiency to reduce the electricity demand supply gap without disrupting grid stability. These solutions are in the form of existing infrastructure up gradation and new technology deployment. However, even in the area of new technology deployment there is relatively little need for technology development: most technology exists in India and elsewhere.

A. Improving evacuation infrastructure

Robust infrastructure planning and pilot projects have to be run to evaluate technologies for TN and Ka. Some of these solutions will be led through the intervention at the National level that has to explore HVDC technology and Dynamic Line Rating (DLR) for integrating RE at a national level. The national and state agencies in TN, Ka will have to co-ordinate to ensure T&D infra is planned and developed in time to evacuate new RE capacity. The standards for evacuation have to be enforced at the National level for the impact to be seen at the State level.

1. Developing infrastructure strengthening plans at State level

In order to co-ordinate between the RE and conventional generation and evacuation, TN and Ka should be involved in an overall planning process instead of looking at RE as a separate piece. Before launching a RE capacity addition plan, the infrastructure/resource requirements should be identified and planned for by these states.

In Ka, a new entity responsible for transmission planning called State Transmission Utility (STU) was proposed. This entity was supposed to be operational from January 2013. The STU will be responsible for developing a long term transmission plan while Karnataka Power Transmission Corporation Limited (KPTCL) will bid for transmission projects[61]. As per the "*Ka Renewable Energy Policy*" released in 2009, KPTCL and Karnataka Renewable Energy Development Limited (KREDL) had planned to jointly undertake a survey of infrastructure necessary for RE projects. In order to finance RE projects, KREDL will set up a "Green Energy Fund" which would impose a cess of 0.05 paise per unit on electricity consumed by all commercial and industrial customers (March 2012). KREDL aims to promote the Public Private Participation (PPP) mode, distributed and decentralized RE generation[62] using the fund proceeds.

TN has already invested in long term transmission plans. For wind evacuation, TN has identified the need for dedicated 765/400kV and 230KV sub stations and EHT lines in Tirunelveli and Udumalpet areas. The two phase evacuation projects for five 400kV substations and around 540kms of transmission lines proposed by the state (refer to Annexure for the evacuation phases) have been cleared by CEA. MNRE will support the state for evacuation infrastructure works, by granting the required fund of Rs.4160Cr from the Central Government's "Clean Energy Fund". CEA has recommended MNRE for release of Rs2572.397Cr under phase I and the remaining under phase II. TN is also willing to explore the PPP model for a 400 KV wind power corridor that will include three 400kV substations and 393 Kms of 400kV DC lines at an estimated capital cost of Rs.1076.72 Cr[63].

Seeing the concerns and issues faced by wind generators, TANGEDCO has reassured the solar power developers about evacuation lines coming online in time to wheel power away from the planned 1,000MW capacity under the TN solar policy[64].

With additional capacity coming online over the next five years and if TN and Ka successfully meet their internal demand, the power will be exported to nearby states and other regions. A strong SR grid will support inter-state power trading which is currently not connected synchronously with the remaining power Grids of India.

As per the 12th five year plan (2012-2017), 6,528MW (total of 38,400MW of inter-regional capacity will be added) of inter-regional transmission capacity will be added for connecting SR grid with the rest of the country. Thus Southern Region will be connected to the remaining grid post January 2014 through four links: Narendra – Kolhapur 765 kV D/c line, Raichur – Sholapur 765 kV 2xS/c line, Srikakulam – Angul 765 kV D/c line, Hyderabad – Wardha 765 kV D/c line

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61 Transmission planning status for TN and Ka from CII Ka Conference on Power 2012 report
62 Ka Renewable Energy Policy 2009-14 - http://www.eai.in/club/users/amsapna/blogs/2040
63 From TN Wind Power Scenario as on 31-May-2012 by Government of TN
64 EIA article – TN assures timely installation of evacuation infra facilities for solar producers - http://www.eai.in/360/news/pages/8127?utm_source=EAI+Daily&utm_campaign=634c276c0fEAI_Daily_28th_Dec12_28_2012&utm_medium=email

These high capacity 765kV lines are associated with the following projects:

a) ISGS Projects in Nagapattinam /Cuddalore Area of TN: Nagapattinam Pooling Station - Salem - Madhugiri – Narendra – Kolhapur

b) KrishnapaTNam IPPs in Andhra Pradesh : Nellore Pooling station – Kurnool (New) – Raichur – Sholapur

c) Vemagiri IPPs in Andhra Pradesh : Vemagiri Pooling Station – Khammam – Hyderabad – Wardha – Jabalpur

d) Srikakulam area in Andhra Pradesh : Srikakulam – Angul – Jharsuguda – Dharam Jaigarh

e) Tuticorin area in TN : Tuticorin Pooling Station – Salem – Madhugiri

It is important to note that the synchronous connection will help in power trading. But to use RE power to meet the ever increasing demand, supply gap in TN, the intra state T&D network has to be strengthened first and adequate planning is needed for the same.

Since the gestation period for new T&D infra is very high compared to the time taken for installing a RE plant, the states have to plan the new capacity addition such that the requisite infrastructure is in place to evacuate the new generation. SNA/STUs have to co-ordinate with the National agencies to plan for this new capacity addition which has to be considered while making T&D plans for the country.

2. Promoting Green Power Purchase Agreements for large consumers in the states

Green power purchase supports RE capacity planning and thus helps in development of RE sources. “Green power refers to electricity supplied in whole or in part from renewable energy sources, such as wind and solar power, geothermal, hydropower, and various forms of biomass”. In the US, electricity customers are being given electricity supply options. More than 50% of retail customers in the US now have an option of purchasing a green power product directly from their electricity supplier.

Green Power has to be purchased by any consumer that purchases power through the mode of Open Access. Captive consumers (such as steel and aluminium plants) who have captive power plants in their own premises also are obligated to buy green power (as are distribution companies too). This Green Power purchase is obligated under the RPO requirements of each State as per section 86(1) e of the Electricity Act 2003. In TN, for the year 2011-12, the RPO requirement is 9% of which the solar RPO is 0.05%. TN has, however, mandated that from Dec 2013 all H.T. consumers will have a specific Solar Purchase obligation at 6% which can be met by self-generation (roof top) or by purchasing from third parties. In Ka, the RPO requirement for Open Access customers is 5%. Green Power also has to be purchased by distribution utilities. The RPO requirements of distribution utilities vary between 7 – 10%. Customers can, buy green power in addition to the RPO requirements.

Green Power can be purchased by the consumers through open access or group captive mode. Open Access implies purchasing power directly from a renewable energy generator and not from the local distribution licensee. Open Access purchases can be through short term contracts (less than one year), medium term (anywhere between one and 5 years) and long term contracts (greater than five years). TN has one of the highest number of consumers that purchase power through open access. The CERC report on the Short Term Power market in India for 2012 shows that the number of open access consumers in TN was 482 and that in Ka was 45. Thus, green power purchase can become a potential means to create the demand and help in new RE capacity planning in TN and Ka.

3. Developing infrastructure strengthening plans at National level, supported by State Utilities

National level planning is required to develop a holistic plan to exploit the RE potential within a region. The infrastructure strengthening plans at the National level would directly impact the interstate transmission capacity in TN and Ka.

As per the mandate of MNRE and FOR (Forum Of Regulators)/CERC, PGCIL has carried out a study to assess the transmission infrastructure and CAPEX requirement for RE (wind, solar, hydro) capacity addition in the seven RE rich (or high) states during the 12th five year (2012-17) plan. The study also proposes a funding model for the capacity expansion. The study is summarized in the "Green Energy Corridor"[65] report, released in September 2012. For strengthening of the intra-state network over the next five years, Rs. 20,000Cr. and for the inter-state network and last mile connectivity, Rs22,000Cr has been proposed. The cost estimation is based on the new capacity addition targeted by the SNU/STUs over the 12th five year period.

For intra state transmission strengthening, 1440ckms of 400kV, 91ckms of 230kV and 45ckms of 110kV transmission lines has been proposed for TN during the 12th five year plan. PGCIL has also proposed one 400/230kV and one 230/110kV substation. For last mile connectivity to State Transmission Utility (STU) network, the study has proposed addition of transmission lines and sub stations. For interstate transfer, TN will benefit from the maximum number of sub stations and transmission lines amongst the seven RE rich states.

A costing plan has been developed for implementation of real time monitoring schemes, energy storage, establishment of Renewable Energy Management Centre (REMC) and dynamic reactive compensation along with the transmission lines and sub stations. The REMC and forecasting tools estimated costs are cumulated for the 6 rich RE states. Excluding this and the interstate transmission system strengthening cost, the estimated cost for TN is Rs5947Cr. and for Ka is Rs1663Cr. These programs will ensure the much needed overhauling of the South Indian grid as well.

65 Transmission investment from Green Energy Corridor Report

Such top level planning supported by bottom level information from STU/SNUs will help in accomodating new RE generation capacity.

4. Enforcing integration standards and investing in pilots across India

PRDC has created the standards and guidelines for planning evacuation for transmission systems in 2009. For defining the function/role of organization in development of wind farms, PRDC guidelines will follow the Indian Electricity Grid Code (IEGC).

- The planning code will assist in developing plans for transmission lines for evacuating wind power. The planning procedure will be as per IEGC 2003 "Electricity Act". Planning criteria will be based on study of existing systems, contingency study due to low PLF of wind farms and planning for reactive power compensation. The planning code also has guidelines for management of planning data and sharing with CTU/STU and incorporation of MNRE plans.
- For demand estimation & management, periodic reports, operational liaison, outage planning, recovery procedures, event reporting will as per the IEGC requirements.

The standards are available. Enforcment and implementation are needed at the national level in order to be adopted in the RE rich states – TN and Ka.

5. Evaluating technology at a National level

RE sources are generally located far away from the point of consumption, implying this power has to be wheeled over long distances before being consumed. 52% of the transmission network in India[66] is a 220kV AC network and 43% is a 400kV AC network. Long distance AC networks suffer from power losses due to reactive power requirements in the circuit. Hence, High Voltage Direct Current (HVDC) lines can be used to reduce power losses when power cables are more than 80kms long[67].

However, HVDC networks make better economic sense in the case of large scale installations (~ 1,000MW). In TN and Ka, RE generation is highly distributed in nature. Only since 2004, IPPs started setting up large scale wind farms. Hence, the economics of the existing projects and other similar projects in the future may not be favourable enough for investing in HVDC networks. But, the technology for the same is available and being used in RE rich countries. In Germany and Norway offshore wind projects are using HVDC underwater lines.

66 Transmission network data from CEA includes HVDC lines, 765, 400 and 220kV lines

67 Length required for DC transmission from News Article – HVDC Steals a March in Grid Technology http://www.renewableenergyworld.com/rea/news/article/2011/10/hvdc-steals-a-march-in-grid-technology

Table 5: RE transmission examples using HVDC lines (not exhaustive)

Country	Technology provider	Project Details	Project Cost
Germany	ABB	For operator – Tenne T for a 900MW project for offshore wind farm. 135kms,320kV of underwater and under-ground cable that will feed power into the onshore HVDC station in Dorpen. Scheduled to be operational in 2015	NA
Norway Denmark	ABB	For operators - StaTNett of Norway and Energinet.dk of Denmark. 240km, 500kV underwater link to intercon-nect hydro-electric based Norwegian and wind & thermal based Danish grids. Scheduled for commissioning in 2014	$180Mn
Italy	Siemens	Erecting HelWin 2, the 130km,320kV HVDC link between the North Sea offshore wind farm 300-400MW Amrum-bank West and the onshore grid for Tenne T. Scheduled to be operation in 2015	$816.4Mn
Germany	Siemens	800-MW, 300kV DC project named BorWin2, located 125km offshore (400MW BorWin 1 was completed in 2009 – first offshore HVDC project). Expected to be in operation in 2013	€400Mn
Germany	ABB	325 kV HVDC transmission link connecting three off-shore wind farms in the North Sea to the German power grid. Under construction	$700Mn

Sources: News article HVDC Steals A March in Grid Technology - http://www.renewableenergyworld.com/rea/news/article/2011/10/hvdc-steals-a-march-in-grid-technology; Siemens HVDC & FACTS Innovations and Projects presentation

For RE integration into a distribution network which operates on AC power, the DC power has to be finally converted and connected to the main AC grid since there are no transformers which can economically step down DC power to low voltages for homes and businesses. At the connection point, in case of any fault, the DC network has to be shut down immediately without affecting the main AC grid. Until now, there was a dearth of safe connecting technology or efficient and affordable circuit breakers. Mechanical switches shut off power too slowly and power electronics alone are not efficient enough and are very expensive. A hybrid HVDC circuit breaker has been developed recently (news from November 2012) which is expected to be put to use in Germany[68].

In order to explore the viability of HVDC transmission networks, pilots are needed. With the new high voltage corridors and transmission network being planned in the South, these projects can serve the purpose of testing the economics of using dedicated high voltage lines for RE transmission over long distances. Thus the technology for efficient transmission of RE power over long distances is available; the economics have to be worked out for using this technology in TN and Ka.

Another technology in discussion is the Dynamic Line Rating (DLR) for transmission circuits, already being used in the USA. It has been observed that the actual transmission line rating can be much higher than the static rating (low temperatures, windy seasons). The rating is normally based on adverse/worst weather conditions making the limits conservative. This implies, if a

68 DC circuit breaker from News article - A high-power circuit breaker makes it possible to create highly efficient DC power grids - http://www.technologyreview.com/news/507331/abb-advance-makes-renewable-energy-supergrids-practical/

120kV transmission line is built to transmit a maximum of 50MW of power at 50 Deg C, the same line will be able to carry more power when temperature falls. Currently, Indian grid system has not been able to exploit this feature. As a result power generation from wind farms during windy days has to be curtailed.

DLR allows to measure the real time variability in the weather condition across tranmsission circuit and quantify the power that can be carried by the circuits without exceeding the safety limits. DLR can capture the factors affecting the line rating like temperature, wind speed and direction, solar radiation. A DLR system comprises of the transmission network instrumentation and communication link to control centre/ SO.

DLR can be used for wind farms since wind production is highest when the sun is going down or during the night (temperature is lower). Solar power generation is highest when the sun is out and temperatures are high, so DLR is not suitable for lines carrying solar power. Using DLR, existing infrastructure can be used to carry more power instead of investing in new infrastructure. Efficient use of existing transmission capacity can reduce congestion problem that SR grid faces. The technology is available and already in use, the product has to be tested in the transmission networks carrying wind power in TN and Ka.

6. Summarising solutions for dealing with T&D infrastructure issues

The important infrastructure up-gradation required is the increase in transmission and evacuation infrastructure. The technology of improving T&D network is not an issue, processes and organizational challenges exist. Establishing new standards and creating bodies to run pilots and monitor RE at a National level will help in overcoming these challenges.

We emphasize long term planning in particular because transmission infrastructure takes longer to implement than RE generating infrastructure. Ka seems to have taken the initial planning steps but the implementation of the plans is yet to be seen. TN and Ka can ensure availability of evacuation infrastructure to the new projects coming up in the two states through long term planning. The study undertaken by PGCIL and published in the Green Corridor Report identifies specific projects and the investment amounts required to improve inter-state transmission network. At the same time, both TN and Ka are developing the state level transmission infrastructure.

At the state level, TN and Ka should focus on developing a consortium of green power purchasers to assess the demand for RE in the future. These measures will help in optimizing the use of existing T&D network and new infrastructure.

National agencies have to enforce standards and follow standards while evaluating the need for new T&D infrastructure for conventional and RE power stations. National agencies have to lead initiatives for exploring HVDC technology – particularly relevant if very large wind installations in TN and Ka have to transmit power over long distances. Globally, HVDC lines have helped in long distance RE transmission. Its cost effectiveness in TN and Ka needs to be examined carefully as it seems to work best when there is a significant concentration of RE production at the source and the areas of consumption are geographically far. Investments in Dynamic Line Rating systems should be planned as a part of the long term smart grid project plan for India. Early stage pilots for the new corridors (discussed earlier) should be considered to test out the practical issues of installation and operation of DLR in Indian transmission network.

B. Improving technology for collecting real time data and scheduling of RE power

The error in the RE forecast drives the need for operating reserves in the event the RE sources do not generate at scheduled levels. Hence, better forecasting can reduce integration costs by reducing the requirement to hold large reserves. Accurate forecasts will help in creating schedules for optimal use of RE resources. Forecasting and scheduling technologies are available, some investments at the state level are needed.

1. Investing in forecasting technology for old turbines

Old wind turbines are not equipped with SCADA systems or communication links. In order to gather information from clusters of old turbines, meteorological stations can be installed after every 20-30kms. These stations can provide real time data on the weather condition at the wind site to the forecaster. Using the location co-ordinates (latitude and longitude information) of the turbines, the forecaster can estimate the wind speed/direction data for the exact position of each turbine. Using historical data of the old turbines, real time data on the wind speed, the wind power curves can be developed for each turbine. Currently, the fund for setting up of Met stations is not available. These investments have to be considered by the states like TN and Ka where RE penetration is gaining significant proportions (already 12%).

2. Setting up processes for relaying accurate data from new turbines

New wind turbines are equipped with latest SCADA systems. SCADA can capture all events that occur during the lifetime of the turbine and relay this information in blocks of 10 – 15minutes. The wind speed, output power and turbine status information can be filtered from the events log for the forecaster and transmitted through FTP protocol – a standard process. Some of the bigger generators like ReGen, Suzlon, Enercon, and Kenersys are already capturing this information individually to assess the performance of the turbines. Hence, the data is available for site specific or client specific operations. In order to develop regional forecasts, generators will have to relay information to the third party forecasting companies/regional Renewable Energy Monitoring Centre (REMC). To do so, generators/project operators should have a team of trained personnel to monitor the collected data from the turbines and ensure all communication links, SCADA systems are up and running at all times.

Using SCADA, the same data can be shared with the SLDCs/RLDCs also. A two way communication link can be established between the SLDCs/RLDCs and the generators using smart grid technology. The SCADA technology for RE generators is the same as that used for conventional power plants.

3. Investing in technology for improving forecasting accuracy

At the load dispatch centre, the load generation balance schedules have to be created for blocks of every 15 minutes. Hence, high level of accuracy in hour ahead forecasts of RE power will help in integrating RE into the dispatch schedule. The necessary tools/software for forecasting RE power generation with these accuracy levels are already available.

The fundamental forecasting technology involves conversion of raw weather data (data input) into power curves (data output). In order to improve the accuracy levels, some tools use multiple data sources for the input data. The tools explained below helps in reducing errors due to lack of data or changing weather conditions

a. Global weather data, regional weather data and surface data are fed into standard statistical models to generate forecasts on wind speed and weather

b. This weather and wind data from the statistical model is converted into a power forecast curve. These curves can be created on a day ahead or a week ahead basis – which is a standard forecasting procedure

c. To improve the accuracy of hourly forecasts this day ahead forecast along with real time SCADA data on wind speed, power output, turbine status and off-site observations are used to develop the hourly forecasts. Accuracy levels are improved since lack of data from one source can be compensated by the other source. The best fit model is used for the hourly forecasting

4. Investing in Technology to help in Scheduling

The process of scheduling RE power is the same as that used for scheduling conventional power. Lack of accurate, reliable forecasting data and absence of communication links for relaying this data to the Load Dispatch Centres in the case of distributed generation make it difficult for the SLDC or RLDC to integrate RE into dispatch schedules. Thus the technology is available, implementation is an issue. When regulations are enforced, the scheduling models can be modified to include regulatory guidelines based on maximum or minimum RE to be integrated into a dispatch schedule. The fundamental components of the system used for scheduling are:

a. An engineering component to develop the model for creating the schedules based on information from the generators and the loads. Key Performance Indicators can be defined and integrated into the model. For example, the KPIs could be around the number of hours of outage and maintenance

b. A server which enables seamless connections for data transfer between the generator and load dispatch centre which develops the schedule.

c. A portal to monitor the performance of the scheduling model – comparing results against KPIs

The models allow creation of optimal generation schedules for Transmission Utility operating several generating stations. This is very relevant for RE power due to its smaller scale and distributed nature. On the demand side, the load condition or demand can be predicted/forecasted in advance. Based on the generation schedule and load forecast, power dispatch schedules can be developed. The distribution companies can also plan out a demand response. These models can help in forecasting the Unscheduled Interchange (UI) or expected deviations from planned dispatch schedules. In other words, it optimizes transmission and distribution operations.

Besides, technology to aid in scheduling RE power, there is a need for softwares/models which will help in the real time scheduling from multiple sources including conventional generation.

5. Summarizing the solutions to develop robust forecasting & scheduling systems

Indian companies and multinational companies operating in India already have the necessary expertise to provide software tools for integrating weather data, real time communication tools, control systems such as SCADA to achieve the necessary sophistication in forecasting and scheduling. Further research should be done in developing softwares to integrate scheduling from multiple sources.

Globally, RE rich countries are already using these tools to reduce deviations between schedules and actual production patterns. The states authorities or the SLDCs have to step in to ensure the large RE producers ensure transmission of accurate data. The generators have to support the forecasting bodies working at the sub-station level. While the forecasting bodies should use the latest forecasting tools. SLDCs should use the latest scheduling models which are capable of incorporating the standards for incentivizing or penalizing RE genertors based on their generation and deviation from schedules.

C. Process and organizational solutions to improve forecasting and scheduling

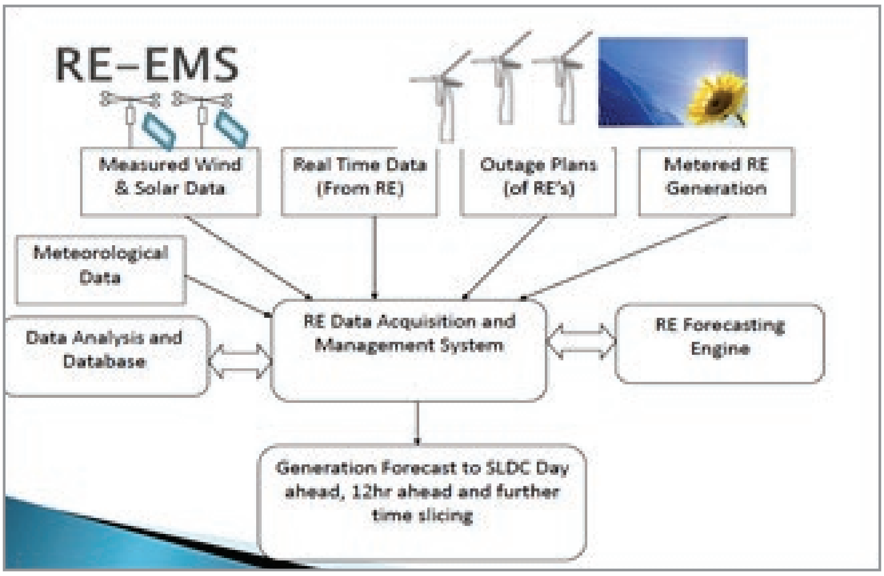
Accurate forecasting helps in resource and infrastructure management. The technology and software used for developing forecasts are already available. However, adoption has been delayed due to absence of regulations and incentives for generators of RE power. These policies will have to be enforced at the National level for the individual states to mandate these regulations for their RE generators. The states can set up the organizations needed for data acquisition and monitoring at the decentralized level.

1. Setting up Organizations for decentralized forecasting in the states

For forecasting, as suggested by the Green Energy Corridor report, it should be done at a decentralized level and then at a central level (NLDC). Currently the limited forecasting which is made available to the dispatch centres is done only at the site level.

One way to achieve this is to set up regional RE Management Centres (REMC) across the country and with immediate affect in the RE rich states. They will help in RE data acquisition system, scheduling, increasing the accuracy of forecasting. The REMC will collect data on physical site, meteorology and production from wind farms along with the information on grid frequency, voltage, faults and other events on interconnection of RE generators to the grid. This data is used in forecasting. The REMCs will be co-located with the RLDC for real time management and information sharing. These centres will have to be integrated with the SCADA/EMS systems. The regional REMC will be able to leverage the variation in RE generation across geographies within a region.

Figure 5 : Planned structure for RE management system



Source: PRDC Guidelines for Renewables in TN

Thus the main functions of REMC (as in the Green Energy Corridor report) within their respective jurisdictions will be

- Forecasting on day-ahead, hour-ahead, week-ahead, month-ahead basis
- Nowcasting - real time tracking of generation from RE sources and forecasting for a period of 0-6 hours ahead
- Close coordination with respective RLDC for RE generation and control for smooth grid operation – these center's will co-ordinate with the operators at regional level

- Act as a single source information repository and coordination point for RE penetration, evaluate the performance of individual RE generators
- Use on-line Dynamic Security Assessment (DSA) for assessing system stability in real time

TN government has proposed setting up of Wind Energy Management Systems (WEMS) for monitoring wind farms integrated with Wind forecasting / remote management capability to administer data effectively to SLDC. As per the Government of TN, MNRE will provide exclusive fund for setting up of WEMS. The state has also proposed a RLDC exclusively for wind generation. The government is considering the repowering of old farms/turbines with low PLF. Repowering will help in forecasting. To promote repowering which is being considered as mandatory, TN Renewable Energy Park (TREP) has been proposed by the State Government. In the first phase 100 MW in the Kayathar Wind farm area will be repowered. The possibility of installing hybrid solar – wind system is under study[69].

Ka has faced issues in repowering old sites[70]. The state has identified the need to invest in assessment stations for reviewing performance of the wind turbines[71]. However, any further information on forecasting and scheduling plans is not available. We suggest the creation of the regional level REMCs for the Southern Region which will help in holistic planning for the entire southern RE portfolio.

2. Setting up Organizations for making settlements

A Balancing Authority (BA) or Balancing Responsible Parties (BRP) for the wind farms at a state/ regional level who will in turn co-ordinate with the SLDC, RLDC and NLDC is needed. They can also undertake the responsibility of settlement of charges for not meeting the minimum Capacity Utilization Factor (CUF)[72]. Such parties have to work in conjunction with the System Operators at the SLDCs and RLDCs rather than working independently. This is required for seamless integration and data sharing between the two bodies.

The centralized process will help in accumulating data at the country level which will help in improving system security. The cost of any imbalance/ deviation from schedule should be passed to the wind farm developer/operator through decentralized process.

3. Enforcing Guidelines for forecasting & scheduling at the national level

To improve scheduling, it can be done on a Day-ahead Scheduling (DAS) and Intra Day Scheduling (IDS) basis.

69 From TN Wind Power Scenario as on 31-May-2012 by Government of TN
70 Wind Power Programme in India – MNRE presentation from August 2012
71 CII Ka Conference on Power, 2012
72 BA/BRP concept from RE Forecasting and Scheduling presentation by Dr.K.Balaraman, PRDC, Bangalore – IEEE Microgrid workshop

The 2009, Indian Wind Grid Code Draft Report by PRDC has guidelines on forecasting and scheduling for wind farms. For defining the function/role of organization in the development of wind farms, it will follow the Indian Electricity Grid Code (IEGC).

- The operating code lays emphasis on the need for wind energy forecasting and scheduling. Guidelines for forecasting at centralized level for 200MW and above capacity, forecasting periods are available. The spinning reserve/back up generation requirement will be decided by SSLDC, SLDC and RLDC.

IEGC, 2010 provides the guidelines on how SLDC will consider wind forecasts for load generation balance, management of daily reports covering wind power generation and injection, outage planning of RE. For **scheduling and despatch**, the code provides guidelines for scheduling and rescheduling of wind and solar. Scheduling of wind and solar power generation plants would have to be done where the sum of generation capacity of such plants connected at the connection point to the transmission or distribution system is greater than 10MW and connection point is 33 KV and above, where PPA has not yet been signed. For capacity and voltage level below this and for old wind farms, the decision would be made by the Wind Generator and the transmission/ distribution utility. Forecasting requirements are for aggregate generation capacity of 10MW at connection point of 33kV and above.

These standards for scheduling have to be enforced at the National level before TN and Ka can adopt these standards. In the absence of these mandates, the SLDCs can continue to consider the data from the new plants and TN and Ka should continue to connect more turbines to the SLDC to help in scheduling.

Global application of control and forecast practices

[73]Centralized forecasting has proven to be the best practice for wind integration in Spain which draws 60% of its power from wind energy. Other countries like Germany and Belgium also have forecasting systems. In Germany, 42% of the total installed capacity of TSO 50 Hertz Transmission GMBH utility is wind. In Belgium, 1 GW of the total 16GW of installed capacity is wind. The Belgian grid is also connected to other European countries – France, Netherlands and Luxembourg.

73 Best practice for wind integration from Green Energy Corridor report

Table 6 : International best practices for forecasting, RE management and reserves maintenance

Country, Utility	RE Control Centre	RT information collection	Forecasting	Reserves[74]
Spain, Red Electrical De Espana S.A. (REE) – TSO	CECRE monitors and controls RE generation through 23 Generation Control Centres to which the RE generators are assigned	CECRE receives RT information every 12 seconds to decide whether RE can be integrated into the system	Done by individual wind farms and the transmission utility Forecasting based on real time and past wind data Wind forecasts updated for every hour with a horizon of 2.8days, 6.5days and 10days	Spinning reserves – combined cycle power plants
Germany, 50 Hertz Transmission GmBH – TSO	None	CORESO[75] monitors RT data – a regional technical centre for European TSOs	Four forecast providers give forecast data to develop forecast with a horizon of 96 hours and twice a day	Data not available
Belgium, Elia – TSO	TSO Control Centre (no separate centre for RE)	CORESO monitors RT data	CORESO does forecasting for D-2 day ahead and intraday	Data not available
USA, California ISO	None	ISO collects RT information from the weather stations	ISO does hourly load forecasting	Spinning reserves - Hydro and gas

Source: Green Energy Corridor report

80% of Denmark's energy needs are met by RE sources. In order to optimize the use of infrastructure and natural resources, Denmark has also built transmission and distribution lines that can carry excess RE power, not consumed in the country to the other European nations. The CORESO model which monitors RE data at a regional level for European SOs can serve as a reference during the creation of REMCs in South India.

4. Setting up ABT mechanism and imposing minimum CUF along with RECs at the national level

There is a hope that ABT will incentivise investments in forecasting and will promote market driven pricing which will promote Renewables in the future. Under the ABT mechanism, buyers of wind power have to pay a fixed charge for the generation, operation of the plant. For any kind of under-generation, the generator will have to compensate the buyer. Similiarly, the wind

74 For the conventional grid, pumped hydro storage has been in use in the US since 70's
As of August 2012, UK had 2,800 MW of pumped hydroelectricity storage, which can store 27,000MWh or 2.5% of the daily electricity production. The storage requirement is expected to go up to 8000MW by 2025. Pumped storage meets most of the storage requirements in the UK - News article on UK – Why we need more energy storage to balance generation with efficiency
Europe has the highest volumes of pumped hydro storage, Switzerland and Norway to lead investment in PHS – Storage needs, options and challenges today and tomorrow – Renewables Grid Initiative

75 CORESO is the Co-Ordination of Electricity System Operator for co-ordination between all the Transmission System Operators (TSO) in Europe

generators should be compensated for over-generation. But there is a possibility that in case of over-generation, the UI payable to the generator is zero or negligible if the grid frequency is already high. So the RE generator does not gain from the UI mechanism[76]. In that case, there should be different means of compensating the generator. Renewable Energy Certficates (REC) can be used to compensate/incentivise the generators. RECs can be sold by the generator on the exchange. Similarly, the generator can compensate the buyer by purchasing corresponding number of RECs for the buyer even though the RE generator is not eligible for UI charges. ABT mechanism along with RECs can act as an incentive for the RE generators.

The wind farms should also be incentivised to operate at a minimum Capacity Utilization Factor (CUF). Higher the CUF is favorible since it leads to higher generation and more attractive ROI for wind farms. Where this requires over generation, RECs can again be used to compensate the generator.

Before introducing ABT for RE, ABT for conventional power plants has to be operational. Ka released an action plan for introduction of intra-state ABT in December 2005. However, as of April 2012, intra-state ABT had not been implemented[77]. In TN, TNERC published a draft consultative paper on introduction of intra-state ABT in 2006. However, since TNEB was not unbundled in 2006, suggestion was made to consider ABT post un-bundling. Post the re-organisation in November 2010, TNERC re-initiated the process of introducing intra-state ABT in TN[78]. A staff consultative paper for the same was released; comments/suggestions on the same were invited before 17 August 2012.

5. Summarizing process and organizational solutions to improve forecasting and scheduling

The Centre has a strong role to play. PRDC and IEGC have created the standards for forecasting and scheduling. These standards have to enforced at a National level. In the absence of any mandates, the generators will not have any incentives to invest in accurate forecasting which helps in developing schedules with few deviations. The bigger wind installations are monitoring data for their individual sites. This data has to be shared with the SOs. A strong regulatory environment is required to ensure this. To incentivise generators, a few pilots on the ABT mechanism and minimum CUF coupled with the REC scheme are needed. We would advocate investments in these models and do centralized as well as decentralized/regional level forecasting instead of dispersed site level data analysis with limited visibility at the SLDC and RLDC levels.

76 For wind, farms forecasting with +/-30% of their forecasted schedule would be exempted from any UI charges under the ABT scheme. Instead the host state bears these charges for deviations. The fund created from it is called the Renewable Regulatory Fund (RRF). Collective capacity of wind farms of 10MW or solar farms of 5MW connected at 33kV and who have not signed PPAs are considered for RRF. This fund is yet to be activated due to the delays in decisions related to UI charges for wind farms because of the variable nature of generation.

77 From the Hindu, article KPTCL's average employee cost is Rs. 49,000 a month

78 From Staff Consultative Paper on Implementation of Intra-State ABT in TN

Smart grid as defined by Kalkitech - "A grid with remote and secure communication capability between various devices in the grid, two way data exchange between utility and meters, ability to understand load patters for better planning, detection of techno commercial losses"

The Southern Region can develop the REMC, TN has already initiated the process of creating a state level REMC. These bodies will work in association with the RLDCs. The database for all the states should be maintained by a Central body. States should also consider one Balancing Authority for all the RE sites which will have to generate as per submitted schedule (allowing for deviations as allowed per the standards).

D. Assessing the potential of distributed RE generation and incentivising the generators

Disributed RE generation technology is widely available and in use in TN and Ka. However, the possibility of connecting such generating units to the distribution grid to supply power is not yet known. Hence, the potential of distributed RE generation has to be explored. The plan to install distributed RE generators should be supported by the capability of the grid to consume additional power without disturbing the grid Power Quality. Integrated planning from feeder to roof tops is required.

Also, the State and the National agencies have to frame incentives to promote grid tied roof-top RE.

1. Exploring Smart grid pilots and long term projects for RE in the states

Smart grids will help in the RE integration process by allowing two way data flow between the utilities, generators and consumers. For example, using the information from the smart grid, a RE consumer can chose to select his/her energy source. On supply side, it will constantly communicate with the RE generator to instruct how much power should be pushed into the grid without affecting the grid stability. Thus the smart grid will promote the integration of renewables into the grid.

In order to understand the impact of distributed roof top generators on the grid power quality and protection issues, TN and Ka need smart grid pilots to focus on the functionality of RE integration. Currently only three of the fourteen pilots have this functionality along with other functionalities. In Gujarat, Renewable energy integration has been proposed to be carried out at Patan Solar Park and few roof top installations at some of the universities. The Patan Solar Park has 702MW of installed solar capacity over a space of 2000 hectares with capacities of 1MW to 40MW being developed by 84 developers[79]. A pilot for RE integration at this scale is expected to yield results which can serve as guidelines for other smart grids. The other two states to include integration of distributed generation (solar and available back-up DG set) are Assam and Ka (Mysore project). Where possible, Ka and TN should develop smart grid pilots similar to the Gujarat RE project to evaluate the practical issues related to the integration of roof top RE to the grid. Pilots should lead to long term smart grid RE projects in TN and Ka.

79 Details from http://en.wikipedia.org/wiki/Gujarat_Solar_Park

The Ministry of Power has sanctioned 14 smart grid pilots so far. At the National level, projects with focus on RE should be planned. Information about the technologies, installation and after service operational & maintenance issues should be shared across the states.

2. Setting up Generation Based Incentives for roof top generators

As per the new Solar Policy of TN released in 2012, domestic consumers will be incentivized through a Generation Based Incentive (GBI) of Rs2/unit for the first two years, Rs1/unit for the next two years, Rs0.5/unit for the next two years. This will be applicable for all roof-top solar or roof-top solar-wind hybrid systems installed before March 2014. These customers will have to install separate meters to measure generation. Net meters would be allowed at multiple voltages for individual homes and extended to commercial establishments. Solar PV systems less than 10kWp will be connected to the grid at 240V. Systems less than 15kWp will be connected at 240V/415V. Systems less than 100kWp will be connected at 415V and bigger systems will be connected at 11kV.

Only recently, under the TN Solar Policy 2012, TN has planned to give GBI to domestic roof-top solar installers and monitor the production using an additional meter. This incentive in addition to the depreciation on investment should help in distributed RE integration. However, currently there are concerns about the long paybacks of these schemes[80]. In the first rooftop solar PV pilot project in TN, TANGEDCO has provided an additional meter to record the energy which is exported to the grid from the 2kW and 1.7kW rooftop PV installations in Auroville.

3. Installing net meters in TN and Ka

[81]The bi-directional metering system is applicable when there is a two way flow in the grid. Net metering enables monitoring and billing for this two way metering process. It records the import and export of electricity at a consumer level. Net metering enables customers to use their own generation from on-site renewable energy systems to offset their consumption over a billing period by allowing their electric meters to turn backwards when they generate electricity in excess of their demand, enabling customers to receive retail prices for the excess electricity they generate. In absence of a net meter, a second meter is installed to measure the amount of electricity that flows back to the utility. In this case, the utility purchases the power at a rate much lower than the retail rate. Thus net metering serves as an incentive for the consumer to install RE power.

Application of net metering to distributed generation

Net metering is widely prevalent in the US – 43 states; DC and 4 territories follow the net metering policy. New Jersey and Colorado are said to have the best net metering policies in the US[82].

80 As an example, the payback is only RS 10,000 over a 3 yr period for a 1.7 lakh investment(after 30% subsidy by TEDA) for a 1kw roof top

81 Net metering working from Net metering article - US DoE Green Power Markets

82 From Best practices and model rules, IREC and Wikipedia

However, there is a difference in the state laws. Some states do not impose a limit on the number of consumers using net metering. New Jersey and Colorado have no subscriber limit. Other state laws have a limit based on the percentage of the load.

Based on the experience of implementing net metering, US agencies have suggested some ***Best Practices[83] in Net Metering:***

- *Allow net metering system size limits to cover large commercial and industrial customers' loads; systems at the 2 MW level are no longer uncommon.*
- *Do not arbitrarily limit net metering as a present of a utility's peak demand.*
- *Allow monthly carryover of excess electricity at the utility's full retail rate*
- *Specify that customer-sited generators retain all renewable energy credits for energy they produce.*
- *Allow all renewable technologies to net meter.*
- *Allow all customer classes to net meter.*
- *Protect customer-sited generators from unnecessary and burdensome red tape and special fees.*
- *Apply net metering standards to all utilities in the state, so customers and installers fully understand the policy, regardless of service territory.*

Some parts of Canada have adopted net metering. Ontario has a limit of 500kW. British Columbia allows 50kW and New Brunswick allows 100kW. In the European Union, Denmark, Italy and Spain offer net metering. France has recently introduced net metering.

Indeed, TN and Ka can also follow the pilots that are being executed in Gujarat[84] and Kerala The project in Kerala is off-grid. However, the entire 5MW of rooftop installations in Gandhinagar in Gujarat will be grid connected. This program will be extended to five other cities – Vadodara, Mehsana, Rajkot, Bhavnagar and Surat, adding another 25MW to the grid connected rooftop PV project. 80% of the installations will be on the government buildings and remaining 20% on the residential buildings. Instead of owing the infrastructure and operating it, the building owners have leased out the rooftops to a third party project developer. In this case Azure Power and Sun Edison will be handling 2.5MW each. These developers will operate the projects and the roof owners will be benefited from a monthly income of Rs3/kWh or unit of electricity produced from their rooftops. The electricity generated will be monitored by a normal uni-directional meter to be installed by the project developer. The project developers will sign PPAs with the Distribution

83 Freeing the grid 2009 Edition

84 News article - Rooftop solar PV in India – Gujarat and Kerala show the way - http://www.re-solve.in/perspectives-and-insights/rooftop-solar-pv-in-india-gujarat-and-kerala-show-the-way/ and Gandhinagar Solar Rooftop Program Details-http://www.rooftopsolargujarat.com/gpcl_rsg/gandhinagar_solar_rooftop.html

Company will benefit from the feed in tariffs. However, the power produced from the rooftops will not directly offset the power consumed by the building owners from the grid. Hence, there will be no adjustments in the Electricity bill unlike the case when an owner benefits directly from the power produced from his/her rooftop.

4. Summarizing solutions for assessing potential of and incentivizing distributed generation

The Smart grid pilots underway in India and in Mysore (more about it in the EE section) have distributed generation as one of the functionalities. Instead, states should take up large scale integration of small distributed generators as a separate smart grid pilots and develop them into full scale projects. This would help in assessing the possibility of drawing power from distributed generation. The proper deployment of smart grid technologies can help TN and Ka to leapfrog and help integrate RE.

Integrated planning is required to check whether the distribution network is capable of supporting new generation capacity on the roof tops. This will be a determining factor while trying to assess the potential for distributed generation.

Similarly, the net metering concept to incentivise the generator for producing RE has to be adopted at the state level. The technology is available. The Centre has to evaluate the incentives for distributed generators including GBI.

E. Investing in Technology for Monitoring & Automation to improve grid efficiency

The single most important feature of a T&D network is its ability to transmit information on the status of the assets, power quality and to develop systems which can reduce the downtime to improve the grid stability. The technology for automating the grid has been deployed across the globe. The DAS and SCADA projects of BESCOM have been a significant development in the automation area in Ka. For technology deployment the smart grid pilots are best placed since they are already underway in Mysore. BESCOM has been working on the smart metering project. On a long term basis, central organizations should be set up to collect data on performance of RE generators and state level units which work in conjunction with the SOs should be set up for day to day monitoring and forecasting.

For grid automation and subsequently making every T&D grid smart, the technologies are already available and in use across the globe. Automation technologies are aimed at improving the grid efficiency to strengthen the basic grid infrastructure. However, in the future, automation will be an important requirement for integrating distributed RE into the distribution grid. From monitoring assets and their activities to gathering information from meters, robust communication applications have been developed.

1. Monitoring systems

Real time monitoring of the distribution assets enable immediate detection of faults and thefts in the distribution network which can reduce losses and improve the efficiency of the grid. Distribution assets like the auto-reclosers, RTUs (Remote Terminal Unit), FPIs (Fault Phase Indicator), capacitor banks, transformers can be remotely monitored using advanced monitoring solutions specifically developed for field conditions. Available monitoring technology comes with a large protocol base and can capture both analog and digital signals. The status of these assets is relayed to a central supervisory centre using a secure communication network.

The monitoring technology in use is not monitoring the harmonics levels or power quality issues since there is no requirement yet for such level of monitoring. The focus will be on asset monitoring unless the standards for interconnection of RE are enforced (primary research).

2. Substation automation systems

Automated substations can rapidly react to real time events, take rapid actions and ensure un-interrupted power supply. Substation automation products include:

- Protocol gateways support one to one and many to one conversion of protocols and support many protocols at the same time. It enables interoperability of different devices in the substation by converting standard protocol of one device to protocol suitable for other device[85]
- Substation Data Concentrator Unit is equipped with multiple protocols support. DCUs acquire data from Meter Interface Units and in-built GSM/GPRS and transmit the same to data acquisition servers. The DCUs have internal memory
- Phasor Data Concentrator Units are used for Wide Area Monitoring (WAM) applications. They can collect data from several Phasor Measurement Units (PMU which measures the electrical waves on an electricity grid) simultaneously, validate data, align time, and send the results to multiple clients
- Upgrade cards are used to enable the latest protocols. Any new protocol can be upgraded using the upgrade cards.
- Intelligent compact Remote Telemetry Units (RTU) collect data from the sensors

3. Communication for advanced metering

Using advanced communication products, the challenges of incompatible protocols, limited communication functionalities, and integration issues with other IT systems related to advanced

85 Protocol converter information from Wikipedia - http://en.wikipedia.org/wiki/Protocol_converter

metering solutions have been resolved. Based on the application, different communication solutions are available:

- Meter Data Acquisition System for Grid Meters, LT consumer Metering and Demand side Management and Network Management
- Device Language Messaging Specification (DLMS) application to communicate with the DLMS-COSEM[86] (Companion Specification for Energy Metering) compliant meters and convert the data to a format which can be easily opened by unzipping
- An upgrading application for Meter OEMs so that they can implement DLMS-COSEM protocol in their existing and new meters
- Upgrading applications that can be plugged into existing meters so that the meters can have the latest wireless and protocol technologies

Advanced metering or Automated metering is a functionality in the smart grid pilots. Thus updated communication systems are relevant for the smart grid pilot in Mysore that aims to install AMIs.

4. On-going automation projects

Utilities in Ka have already launched or are part of national schemes for improving the grid efficiency.

BESCOM DAS project

In 2008, BESCOM launched the BESCOM DAS (Distribution Automation System) project, a first of its kind of automation project in the country. This project was conceptualized before 2005 to develop a platform for integration of global information system (GIS), interactive voice response system (IVRS), work management system, energy auditing system and management information system that could be monitored from the distribution automation master station[87].

The automation of the distribution infrastructure of Bangalore City aimed to improve the reliability and quality of power and the revenue realization for BESCOM. The automation would allow quick restoration and reduction in break down time. The project was to be implemented from 2008-09 to 2011-12. The reliability of power supply at 11kV feeder was 99% prior to the DAS project which translated into interruption of 86.22hours a year per consumer[88].

86 The DLMS/COSEM standard suite (IEC 62056 / EN 13757-1) is the most widely accepted international standard for utility meter data exchange - http://www.dlms.com/news/09-3-dlms-cosem-for-smart-metering.html

87 News Clipping – Economic Times - http://articles.economictimes.indiatimes.com/2005-08-06/news/27510279_1_distribution-system-power-distribution-automation

88 News clipping – BESCOM takes up Distribution Automation - http://www.hindu.com/2008/07/11/stories/2008071160150400.htm

Bangalore Distribution Up-gradation Project (DAS):

"BESCOM has embarked upon a project to automate the Distribution network for monitoring, control and operation of the 11 kV network in the Bangalore City. The implementation of Distribution Automation in the Bangalore City will enhance the reliability and quality of power supply.

The cost of the Project is estimated to Rs. 563 Cr. The JICA (Japan International Cooperation Agency) is extending financial assistance to an extent of Rs. 417 Cr for this project. The project is schedule to be completed on FY 2013-14. The Project Management Consultancy has been awarded to M/S KEMA, USA and M/S CPRI, Bangalore."

Source: BESCOM - http://bescom.org/en/das/

Currently, Bangalore is the only city in the country with a 400kV, 220kV, 66kV GIS sub-station in the country[89].

BESCOM SCADA project

In 2009, ABB delivered a network management system that integrated SCADA technology with Energy Management Services (EMS) technology and Distribution Management Systems (DMS). 867 main transmission and distribution substations spread across Ka including that in Bangalore are controlled through 16 control centres. Another 450 substations have been integrated ever since. There are Remote Telemetry Units in each of these substations for data collection and relay. For communication, VSAT and leased lines are used. KPTCL wanted an integrated solution for energy auditing, billing and ABT. The project was aimed to collect real time data of renewable energy generation from the Remote Terminal Units (RTU) in the substations.

By January 2011 the Ka Power Transmission Corporation Ltd, had already implemented the Integrated Extended SCADA covering more than 1000 substations networked with VSATs to a MCC (Master Control Centre) running SCADA/EMS and DMS (Date Management System) software packages[90].

Participation in All India RAPDRP project

98 towns in Ka and 110 towns in TN are eligible under Part A of the All India RAPDRP project. TN has 7 SCADA eligible towns. 86 towns in Ka and 87 towns in TN are eligible under Part B. The baseline AT&C losses in 2009-10 were above 30% for GESCOM. Thus GESCOM had a target reduction of 3% per year as per RAPDRP guidelines. Over the same period, MESCOM and BESCOM had the lowest losses in Ka (15.37% and 16.35% respectively). HESCOM and CESCOM had higher losses (26.91% and 29.73% respectively). The only DISCOM in TN – TANGEDCO had losses of 16.19% in 2009-10.

89 KPTCL 2010-11 annual report
90 Reference from ABB

The latest update from APDRP site indicated that IT Consultant and the IT implementation agency, SCADA consultant and the SCADA implementation agency where applicable[91] have been appointed (2009,2010). 30% of the loans sanctioned under Part A and 15% under Part B have been disbursed in the states of TN and Ka. Under Part A, 66% of the funds have been sanctioned for BESCOM alone in Ka.

The overall progress of RAPDRP has fallen behind schedule due to highly ambitious time frames. The time frame to complete the work – 18 months from award of contract was very ambitious. Activities like GIS mapping are resource intensive requiring lot of field verification. Ideally there should have been lesser number of modules initially and the aim should have been to build up on it. Of the multiple modules, IT implementation under Part A has commenced in the small towns and the metering project in Ka has made good progress. On a positive side, the disbursement status of loans in these two states was better off than that in the rest of the country.

5. Summarizing solutions for grid automation

In terms of technology deployment, the key technology that requires to be deployed is in better automation tools for monitoring, communication and control of the distribution network. Indian companies and multinational companies operating in India already have the necessary expertise to provide software tools for monitoring, automation and control systems.

TN and Ka have to consider incorporating these solutions into their distribution networks. Ka has already taken the initiative. BESCOM has started work on its automation projects. The two states are also participating in the All India RAPDRP projects. Regular updates on the progress of these projects and the reduction in AT&C losses will help in assessing the success of these projects. This will aid the decision making process for the other DISCOMs in Ka and in TN when trying to develop automation plans and allocate funds to such projects.

F. Aligning EE and smart grid initiatives

Smart grids help in making Energy Efficient choices by consumers. For example, using the information from the smart grid, a RE consumer can chose to select his/her energy source and shift his/her consumption to off-peak hours. Smart grid data and technology would help consumers to monitor and control their energy consumption data.

Smart grid pilots and full scale projects should work in tandem with EE initiatives in energy intensive industrial, commercial and residential areas. Large consumers should be identified within each sector. Customers who have already been assigned targets for reducing energy consumption and which have already adopted various EE measures can become the early adopters of smart grid pilots. To start with, the installation of metering technology in such areas can help customers to

91 For details on consultants please refer to APDRP site – www.apdrp.gov.in

exert control on their energy consumption and utilities to reduce meter reading costs. Groups of large customers can help in shifting the load during peak hours. Similarly installation of sensing and measurement devices in distribution networks, substations catering to industries and other HT consumers can help in immediate detection of faults, reduction of outages and recovery time. Smart grid pilots should also consider Time of Use metering concept that will help in shaving off peak load. These measures will help in Demand Side Management and Demand Response in the future.

At the household level, smart appliances which can interact with the smart meters should find more acceptance. Currently, the smart appliances like the washing machines, pumpsets are very expensive and most of it is still in the concept stage. High cost is an important barrier for these appliances. These products should find their way into the average household which are all electrified households (with consumption of 3000 units per annum). The number of these households is rapidly increasing in the cities like Bangalore and Chennai. Smart projects should be developed in a holistic manner including these appliances.

As with the case of RE, EE is not the primary focus of any of the Smart Grid Pilots underway. KPIs should be developed to measure the improvement in energy performance of the buildings, industries or municipality covered by the smart grid pilots focussing on EE. The states will have to set aside funds for investments in such projects.

BESCOM has been working on the smart meters pilot and had started a smart grid pilot. The India Smart Grid Forum has created a roadmap for smart grid implementation in India. Mysore's smart grid pilot is one of the fourteen pilots undertaken at the national level.

1. BESCOM Smart Meters Pilot

BESCOM had initiated the process of incorporating smart meters in LT segment in a phased manner in 2009[92]. A Rs36Cr pilot project was proposed for installation of these smart meters in Electronics City. With a delay of a year, as per June 2010, the target was to complete implementation over the next 36 months[93].

The pilot finally kicked off with BESCOM workshop on remote prepaid metering using smart meters on 2nd December 2011, BESCOM had connected a smart meter to a transformer in Girinagar[94]. For the pilot at consumer level, BESCOM chose 80 consumers from apartments, commercial establishments, individual establishments, individual houses and small industries. As of 25th February 2012, BESCOM had installed 60 smart meters in Bank Colony and Hanumanth Nagar. As stated by BESCOM, "*Each meter will have the maximum limit automatically and when the load exceeds, the meter will shut down. When the consumer reduces the load, the meter starts running automatically*"[95].

92 BESCOM - http://bescom.org/en/smart-meter/?pid=32
93 News Article - http://www.dnaindia.com/bangalore/report_smart-electricity-meter-project-moving-in-the-dark-in-bangalore_1399656
94 News Article - http://newindianexpress.com/cities/bangalore/article1327401.ece
95 News Article - http://flashnewstoday.com/bangalore/?p=3570

In the latest update, as of 5th November 2012, BESCOM had decided to connect ~ 50 transformers in Malleswaram with smart meters and was planning to call for a global tender. The third party who would win the contract would be allowed to scale it once the installation was commissioned and evaluated. The smart meters would cost between Rs 4300 to Rs 6000[96] per unit.

2. BESCOM Smart Grid Pilot

BESCOM aims to integrate the smart meters into the smart grid – the plans for a pilot project were being developed. The ground work for distribution automation and SCADA by BESCOM would support its smart grid project. In January 2011, CPRI had released a Detailed Project Report for a Design and Development of an 18 months Smart Grid Pilot Project for BESCOM with the support of USAID. Thereafter, International Consultants, KEMA[97] of USA were supposed to study the entire system requirements and submit the final recommendations. The results of BESCOM's smart grid pilot were meant to help in the development of a national smart grid road map. Of the five potential sites studied for the smart grid project, Electronics City was chosen based on assessment of consumer participation. The project included the installation of AMI, smart distribution, facilitation of DSM, renewables integration[98] among other things. The project covered 17,500 domestic and business users[99]. As per the project plan, starting with stakeholder consultation in January 2010, the smart grid implementation was scheduled for completion by April 2011[100].

Subsequently, BESCOM's smart grid project does not figure in the list of the 14 pilot projects that have taken off under Ministry of Power (MoP) to promote smart grid work in India. This smart grid project has not yet taken off in Electronics City.

3. Participation in Pilots initiated by Ministry of Power (MoP)

In 2011, Ministry of Power (MOP) decided to launch pilot projects for smart grid implementation. It invited utilities for participation. In first quarter 2012, 17 utilities expressed interest and finally 14 utilities were selected for the smart grid pilots. ISGTF issued model specifications and guidelines to utilities for choosing the pilots and technology parTNers. The South Indian pilots are:

- MSEB, Ka for 21,824 customers across all segments
- KSEB, Kerala for 25,078 LT industrial customers
- Electricity Department, Government of Pondicherry (PUD) for 87,031 customers (79% domestic)
- APCPDCL, Andhra Pradesh for 11,904 customers

96 News Article - http://newindianexpress.com/cities/bangalore/article1327401.ece
97 News Article - http://www.deccanherald.com/content/288701/bescom-ropes-us-firm-smart.html
98 BESCOM project details from desismartgrid.com A Compact Review on India's First Smart Grid Pilot
99 Users information from Micro-Grid Integration with Renewable Energy in Indian Perspective
100 From State Utility Perspective of Smart Grid by BESCOM

The functionalities proposed in the pilots are residential Automated Metering Infrastructure (AMI), Industrial AMI, outage management, peak load management, power quality management, micro grid, distributed generation. The proposed project area for the pilots in Haryanam Tripura, Pondicherry, Andhra Pradesh, Punjab and Rajasthan are also covered under the RAPDRP scheme. 50% of the investment in Smart Grid Pilots will be supported by the Government.

Mysore Smart Grid Pilot project for the distribution sector

Location: Additional City Area Division (ACAD)

Project involves 21,824 residential, commercial, industrial and agricultural consumers including 512 irrigation pump sets covering over 14 feeders and 473 distribution transformers and accounting for input energy of 151.89 MU. The functionalities of Peak load management, Outage Management are proposed by implementing Automated Metering Infrastructure (AMI) for Residential Consumers and Industrial Consumers and Integration to Distributed Generation / Micro Grid Integration.

Some additional functionality like Agriculture DSM with community Portal, Consumer Portal to Support DSM/DR, Employee portal for Knowledge Sharing and Benefit realization, KPI based MIS and Data Analytics for decision Support are also proposed

Expected Benefits:

- *Reduction in AT&C losses*
- *Shifting of load in industrial and domestic consumer during peak hours*
- *Reduction in number of transformer failure*
- *Reduction in Meter Reading cost*
- *Reduction in unforeseen outages and also recovery time for unforeseen outages*

There are some concerns around the achievable targets of these smart grid pilots given that utilities lack in resources. Focussing on one area instead of looking across different types of consumers and all technologies at the same time (for one project) may help in making these pilots successful. The current targets to deploy multiple measures simultaneously within the given time frames may be over ambitious.

At an All India level, an Indian Smart Grid Forum (ISGF) was set up for accelerated development and deployment of smart grid technologies in India. It is a public private partnership initiative of Ministry of Power. ISGF was launched along with Indian Smart Grid Task Force, an inter-ministerial government task force. The main objective of developing a smart grid in India as stated by the India Smart Grid Forum are to eliminate power cuts, to reduce T&D losses, improve quality of supply and revenue cycle optimization, to manage peak power, demand response and to integrate renewables/ distributed generation efficiently. The final aim is to create smart customers, utilities, generation & transmission and policies over a period of 25 years from 2012 to 2027. The efficiency of the grid will be improved by investing in monitoring, controlling, auditing, automation, metering. RE integration will be facilitated using microgrids, energy storage and better load and generation forecasting measures. (Refer to Annexure for detailed road map from ISGF).

4. Summarizing solutions for aligning EE with smart grids

While smart grid technology development and deployment can have a long and sophisticated roadmap, the deployment of smart meters, GIS mapping (as part of the ongoing RAPDRP program), ongoing sub-station automation and SCADA systems should be the foundation of a smart grid system. These initiatives should be coordinated with common objectives of improving the grid efficiency.

TN and Ka should invest in smart grid projects that can improve the grid efficiency by promoting smart appliances at the household level and covering energy intensive areas in the states. To better integrate the EE measures, we would recommend smart grid pilots that can align with the EE initiatives already underway in the areas that have high levels of energy consumption. The states also have to incentivize adoption of smart appliances. Currently, the cost of such technology makes their adoption difficult across the society. Energy efficient yet economically favorible technologies should be introduced in the market. Intervention at the national level to support such technology manufacturers is needed.

BESCOM has already started the smart meter pilot in Bangalore. The other DISCOMs in Ka and in TN should invest in smart meters which will finally help in two way communication to improve demand side management and to support full fledged smart grid projects. As in the case of automation projects, regular updates from smart meter and smart grid pilots will help in creating awareness and generating support amongst the consumers. The smart grid pilot in Mysore (as in other cities in other states) should also yield important information but a more coordinated programmatic approach would help.

G. Dealing with lack of reserves and energy strorage to reducing the impact of intermittency

RE will remain variable by nature. The solutions for dealing with intermittency will help in increasing the confidence in RE and improving the grid stability where power quality becomes an issue.

1. Integrating multiple RE sites

The variation in output from a single turbine can be as huge as 20% of capacity usage to 100% of capacity usage within the same day[101]. The variability aspect of the output from a wind farm can be reduced to a large extent by combining the output from several wind farms across different wind sites.

101 Variation in capacity usage form RenewableEnergyWorld.com article – Solving winds variability with more wind power - http://www.renewableenergyworld.com/rea/blog/post/2011/08/solving-wind-powers-variability-with-more-wind-power

In an example from Texas, United States, the variation was reduced from 20%-100% to 15%-50% of capacity by combining the output from five wind sites. This is over the period of one day, the impact was even more pronounced over the year, with periods of zero output from the five sites together being reduced to a few hours per year only. In another research, the output from 2007, the level of guaranteed output had gone up by 4 times when the output from 19 dispersed wind sites was combined. Thus the reliability increases with dispersed generation.

Solar power is available during the day when the sun is up. From SLDC data, solar has seen to peak during the day time, around 1pm-3pm. While, in the case of wind, the peak has been observed between 12pm to 5pm (data from SLDCs). Output from solar during the evening hours is zero, while wind continues to produce even after 5pm, though with a reduced availability factor. Hence, a solar wind hybrid system for small scale as well as utility scale generation can be considered for smoothening the output from the combined generation. The shadow effects from wind turbines have to be assessed before investing in large scale wind,solar hybrids.

2. Managing generation from conventional power plants to support RE generation

For generation management, conventional power plants should be designed to meet the challenge of balancing supply from RE sources. Instead of looking at RE specific planning only, the plan should be made such that it accommodates RE and conventional sources. For example, in India, hydro is used to balance the varying output from wind.

Power from conventional generators (thermal, hydro, gas) is generally dispatched in the “merit order”, such that the cheapest power is used to meet base load. In order to promote RE power generation, as per the TN solar policy, 1,000MW of solar power plants will operate on “must run” basis and the power generated will not be dispatched in “merit order”. Hence, the distribution companies will be obliged to buy the power from solar producers even if cheaper power is available. However the power producers would not be paid for loss of generation revenues for lack of transmission infrastructure, commonly known as “deemed generation” provision[102]. In Southern states, base load thermal generators are backed down to allow dispatch from wind generation during other than peak period. The management of generation portfolio of thermal, hydro and wind becomes complicated when there is surplus RE generation during low demand period[103].

3. Maintaining adequate reserve volumes

Due to the intermittent nature of RE, additional measures have to be taken to achieve a reliability level that is acceptable under the Grid code. Hence, to ensure reliability from RE sources, in particular wind, flexible generation reserves are required. Reserves can be of three types[104]

102 EIA article – TN assures timely installation of evacuation infra facilities for solar producers - http://www.eai.in/360/news/pages/8127?utm_source=EAI+Daily&utm_campaign=634c276c0fEAI_Daily_28th_Dec12_28_2012&utm_medium=email

103 Reference from Green Energy Corridor report

104 Reserve types from Green Energy Corridor report

- Primary or frequency response reserves are already connected to the grid and can be ramped up or down with a few seconds
- Secondary or spinning & non spinning reserves which may or may not be online but can be ramped up or down within 10-15 minutes
- Tertiary reserves which are not online, they require a few hours to days for ramping up/down

To run spinning reserve, generating stations run offline until demand increases require additional generating capacity to be brought online. Spinning reserve is expensive and inefficient, since the utility has to use fuel to run a generating station that is idling for long periods[105]. TN palns to promote Mega Wind farms with spinning reserves of equivalent capacity[106]. Accurate forecasting can help in maintaining adequate volumes of spinning reserves to reduce the integration costs.

Countries with high RE penetration maintain spinning reserves with low ramp up/down time. Hydro, gas turbine, thermal plants provide this flexibility. In India hydro power with reservoir can be used to store the water and release it when needed to generate electricity. Along with hydro, pumped storage plants where water has to be pumped up to an upper reservoir using a pump and energy can lend reliability to the RE source[107]. Other options like combined cycle power plants are more expensive. While, thermal plants have high response times. They can be used as reserve plants only when they are running near their Technical Minimum however this reduces the efficiency of the plant and the operators are not given any incentive to do so. Supercritical units with high efficiency and higher flexibility can be used in the future (42% of new thermal capacity in 12th plan period will be supercritical). The Green Energy Corridor report has proposal for investment in the transmission network to exploit hydro potential.

Re-evaluating the RE portfolio – working on supply chain issues

Unlike wind and solar, biomass, bagasse are more firm sources of RE power. Despite the potential, these resources have not been tapped completely yet due to supply chain issues. India's total biomass potential capacity with existing technology is around 22GW that includes on grid and off grid installations. India produces 500 million tonnes of biomass per year, of which 120-150 million tonnes is surplus. The bulk of India's potential capacity is in the form of agricultural residue, which could supply 17GW of power, compared to only 900MW which is currently installed.

Table 7: Biomass/Bagasse Potential vs Actual in MW

State	Potential (MW) TEDA/KREDL	Potential (MW) WISE
TN	1185 (revised TEDA est. - 828 MW) All Biomass	1185
Ka	87 (KREDL) 561.5 (IISC)(Biomass) 694(Bagasse Cogen)	1000 (Biomass) 1500 (Cogen) 135 (WTE)

Source: TEDA/KREDL/WISE/IISC as on 29-2-2012

105 Definition from Energy storage solving power quality problems article
106 From Tamil Nadu Wind Power Scenario as on 31-May-2012 by Government of TN
107 India options from Green Energy Corridor report

State level data on the potential of biomass based energy is pegged at 1185 MW for TN and 781 MW for Ka.

IISC Bangalore estimated the potential of biomass at 1,122.9 MW from the surplus biomass of forestry, agricultural and wastelands in KA of which at least 50% can be tapped. Out of 1122.9 MW of power generation potential from surplus biomass only 88 MW of power projects have been commissioned. The assessed Bagasse cogeneration potential by MNRE for KA was 450MW which has been exceeded by the installed capacity of 678.5 MW of which 510.23 is exportable.

The WTE potential in KA primarily come from solid waste (71.79MW) municipal/urban liquid waste (26.8MW) and industrial waste (62.14MW). The total power generation potential is 160.73MW of which nothing has been realized.

Thus, the existing potential has not yet been realized. There are several reasons for the same. On the ground availability is a challenge. Supply contracts on the ground matter a lot to source the biomass. There is competition for biomass resource for domestic and industrial consumption which have driven costs up and the distribution system is lacking. Bagasse cogeneration potential holds more promise as the cooperative plants get converted to full capacity cogeneration plants.

The possibility to exploit the existing potential by re-instating the interest in biomass and bagasse should be explored. What is required is a deep dive into viability and potential of biomass supply linkages to provide a secure, captive biomass resource and research into delineating off grid biomass potential.

5. Assessing the need for grid storage

The volume of energy storage required has to be estimated. In TN and Ka, wind energy dominates the renewable energy scenario. Storage promotes the use of RE by helping in power quality improvement, providing contingency reserves when the renewable energy sources cannot generate as per schedule. Short term energy storage can be used for peak shaving. During high demands, storage devices can provide output which reduces the system peak, thus deferring the need for capacity additions. Any excess renewable energy sources produced during the peak wind or solar output hours can feed these devices. This also reduces the need of additional transmission lines to meet demand during peak periods. Long term energy storage can be used for load shifting which moves demand from peak hours to off-peak hours. The energy produced from RE sources can be stored in the storage devices to meet the off-peak demand.

The TN Solar Policy targets 3,000MW of solar PV and 1,500MW of utility scale installations, planning for grid level energy storage technologies will help in optimal usage of the new capacity. Also, with the addition of distributed generators like grid tied roof top PV projects in the future, energy storage will be required to manage power quality issues. A holistic plan for the large scale generators and distributed generators including roof top generators will help in meeting peak loads and reducing load shedding. However, the planning process will have to consider the huge investments required and the risks involved since the technology is still evolving.

Countries like Germany which are betting big on renewable energy to replace nuclear are focussing on energy storage. Even in these countries, energy storage projects built specifically for RE integration into the grid are still limited. Some examples of successful storage practices have been compiled here:

Table 7 : International examples on storage technologies used for integrating RE into the grid[108]

Type	Purpose	Technology
Thermal	To provide power during peak hours after the sun is down and reduce cost of the project by using storage to supplement the solar installations	Bright Source Energy has planned to add molten salt storage to its three solar projects that will supply power to the utility - Southern California Edison
Chemical	Battery system used for load levelling, storing low cost off-peak power. Smart grid helps in monitoring real time power output, operating status of each turbine and charge status of battery units. Smart grid develops generation operation plan	A 51MW Rokkasho-Futamata wind farm in Japan has a 34MW Sodium Sulphur (NaS) Battery System which is charged at night. Stored electricity is supplied to the grid along with power from wind farms directly during peak hours. A smart grid system has also been installed
Chemical	Lithium ion batteries store energy generated by wind farms when generation exceeds demand, helping in peak load management. This combined technology also has dynamic voltage control capabilities	Static Var Compensatory (SVC) Light Technology combined with Lithium Ion Battery storage solution installed by ABB in NorFolk, England for a 11kV distribution grid that has a considerable supply from wind power generators

The Indian Energy Storage Alliance (IESA) has estimated the potential for wind and solar energy storage at 1,680MW and 350MW[109] for the period from 2013 to 2017.

6. Setting up Regional Organizations and pilots

The holistic planning for RE and energy storage has to be done at the central and regional level instead of focussing on one site. To achieve this, regional planning bodies have to be created which can also be associated with the balancing authority at the regional level. The South India Region which is rich in RE can benefit from one regional authority which develops reserves management, energy storage and generation management plans for the dispersed sites and multiple stakeholders/ owners/investors. While each state is rich in wind, the fluctuations are different across the sites. For optimal planning and resource management, the regional body can step in and take a holistic view of the generation scenario to reduce the overall variability of the combined output.

108 USA case – Molten Salt keeps solar flowing - news.cnet.com/8301-11128_3-57333789-54/molten-salt-keeps-solar-power-flowing/
Japan case study - Rokkasho-Futamata Wind Farm | Case Study; Wind Power + Sodium-Sulphur (NaS) Battery Energy Storage: 85 MW - http://www.cleanenergyactionproject.com/CleanEnergyActionProject/CS.Rokkasho-Futamata_Wind_Farm___Energy_Storage_Case_Study.html
UK case study - Energy storage in the UK - Flexible AC Transmission Systems (Power T&D Solutions) – http://www.abb.com/industries/ap/db0003db004333/8C1F3603E2C36BEBC1257892003252AA.aspx

109 IESA Status & Trends in Energy Storage – presented at India Smart Grid Day, 2013

To understand the viability of storage technology in the Indian context since technologies for energy storage are still in the development stage, investments should be made in pilot projects. Chemical batteries are already in use in off-grid solar PV systems. Similar battery banks should be tested for utility scale solar projects planned under the TN Solar policy, 2012.

7. Investing in Energy storage technology at national level

Storage technologies vary by response time and storage capacity. In order to meet the changes arising out of variations which occur over a period of minutes, a low capacity but fast response storage system is required. To respond to changes that extend over days, high capacity but slow response storage systems are needed[110]. In case of RE, both the technologies are required. Energy storage will enhance the reliability of the grid, improve power quality and reduce the need of maintaining conventional reserves[111].

Storage technologies are of four[112] types. However, none of these technologies are specifically designed for RE only.

- Mechanical - Flywheels, large batteries, Compressed Air Energy Storage (CAES), Pumped Hydroelectric
- Thermal storage – Molten salt
- Electrical – Super capacitors, Superconducting Magnetic Energy Storage (SMES)
- Chemical – Batteries, Hydrogen

Table 7 : Details of energy storage technologies

Technology	Power	Energy density	Back-up time	Response time	Efficiency	Lifetime (years)
Pumped hydro	100MW-2GW	400MWh – 20GWh	Hours	12minutes	70-80%	50
CAES	110MW-290MW	1.16GWh - 3 GWh	Hours	12minutes	99%	<50
Batteries	100W-100MW	1kWh - 200MWh	Hours	Seconds	60-80%	<10
Flywheels	5kW-90MW	5kWh – 200kWh	Minutes	12minutes	80-95%	20
SMES	170kW-100MW	110Wh – 27kWh	Seconds	Milliseconds	95%	30
Super capacitor	<1MW	1Wh- 1kWh	Seconds	Milliseconds	>95%	>10

Source: Super capacitors: Alternative Energy Storage Systems

110 Storage systems information from Integrating renewable energy on the grid report
111 Storing low-cost wind Energy generated during low demand and pumped back when energy demand and the cost (UI rate) is high
112 Storage needs, options and challenges today and tomorrow – Renewables Grid Initiative

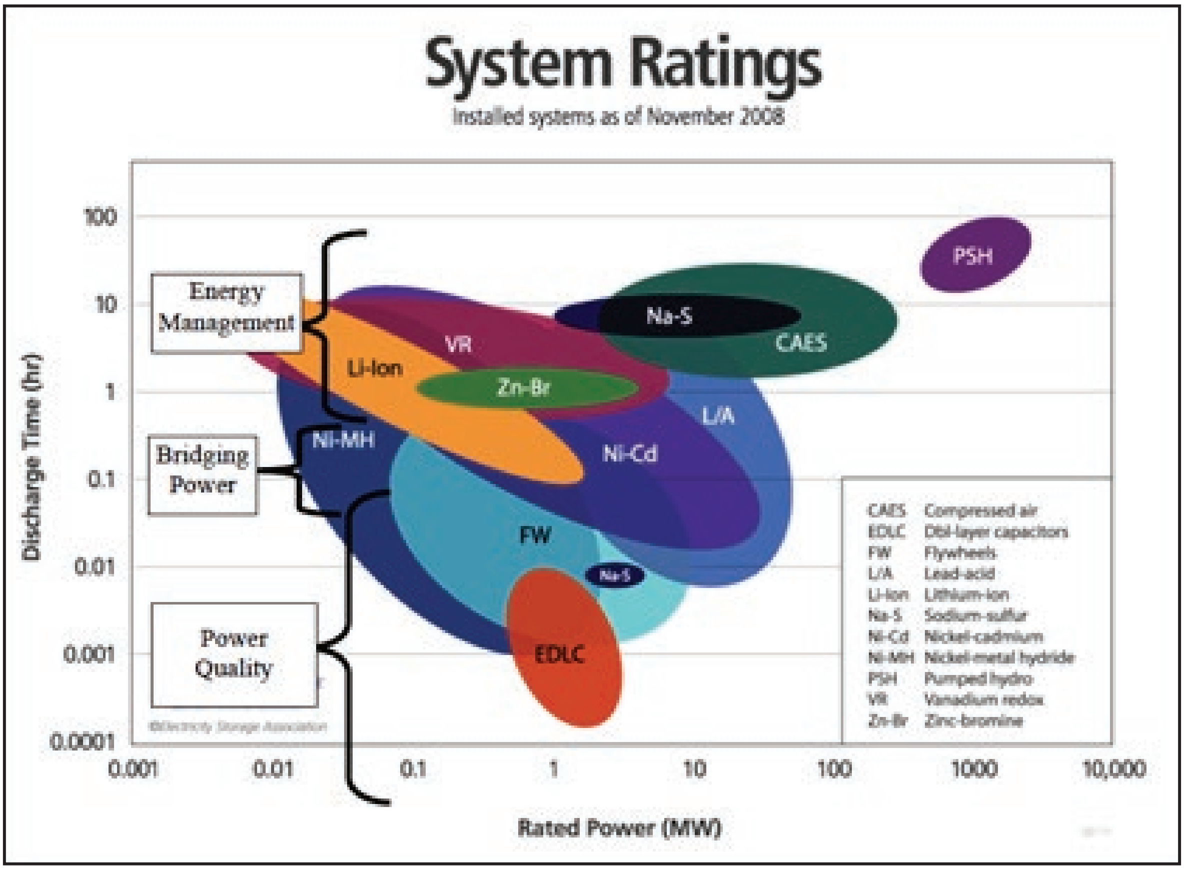
Based on the discharge time and type of power output, all these energy storage technologies can have different applications.

Table 8 : Energy storage types - applications and discharge times

Type	Applications	Discharge time required
Power quality	Transient stability, frequency regulation	Seconds – minutes
Bridging power	Contingency reserves, ramping	Minutes – 1 hr
Energy Management	Load levelling, firm capacity, T&D deferral	Hours

Source: The role of energy storage in renewable electricity generation, NREL

Figure 6 : Storage types, discharge times and ratings



Source: The role of energy storage in renewable electricity generation, NREL – Technologies deployed or proposed as of Nov 2008

Countries like Germany which are betting big on renewable energy to replace nuclear are focussing on energy storage. However, at this point of time Energy storage projects built specifically for RE integration into the grid are limited. We have listed out some of the existing RE projects with storage capacity.

Table 9 : International examples on storage technologies used for integrating RE into the grid[113]

Type	Purpose	Technology
Thermal	To provide power during peak hours after the sun is down and reduce cost of the project by using storage to supplement the solar installations	BrightSource Energy has planned to add molten salt storage to its three solar projects that will supply power to the utility - Southern California Edision
Chemical	Battery system used for load levelling, storing low cost off-peak power. Smart grid helps in monitoring real time power output, operating status of each turbine and charge status of battery units. Smart grid develops generation operation plan	A 51MW Rokkasho-Futamata wind farm in Japan has a 34MW Sodium Sulphur (NaS) Battery System which is charged at night. Stored electricity is supplied to the grid along with power from wind farms directly during peak hours. A smart grid system has also been installed
Chemical	Lithium ion batteries store energy generated by wind farms when generation exceeds demand, helping in peak load management . This combined technology also has dynamic voltage control capabilities	Static Var Compensatory (SVC) Light Technology combined with Lithium Ion Battery storage solution installed by ABB in NorFolk, England for a 11kV distribution grid that has a considerable supply from wind power generators

Besides these, to balance intermittent renewable energy sources using smart grid technology, Iberdola was developing a 150 MW salt-based CAES project in New York[114]. As a form of electrical storage, supercacitors are used in electric vehicles, however, not their usage in renewable energy storage is being considered.

IESA is developing partnerships with global organizations and generating awereness about technologies and the need for energy storage regulations. India has to look into International best practices to identify the storage technologies that make economic sense for the country.

8. Investing in creation of flexible generation technology – driven by R&D at global level

In order to make variable generation from RE sources more reliable, firm sources like thermal power should be able to act as the flexible generators when needed. Energy storage has different response times as observed above. Similarly the thermal generators have longer start-up times. Hydroelectric and gas based power plants have high ramp up rate (time taken to reach power output of 1MW from 0MW, lesser the time taken, higher the ramp up rate). Hence, they are used in peak load management. But they have high variable cost. On the other hand, coal plants have low variable cost but cannot be put on and off instantly, hence they run as base load plant and cannot meet the fluctuations in RE output. Thus, the technology to balance variability in RE portfolio is limited due to slow ramp up rates or high variable cost. Investments are needed to

113 USA case – Molten Salt keeps solar flowing - news.cnet.com/8301-11128_3-57333789-54/molten-salt-keeps-solar-power-flowing/
Japan case study - Rokkasho-Futamata Wind Farm | Case Study; Wind Power + Sodium-Sulfur (NaS) Battery Energy Storage: 85 MW - http://www.cleanenergyactionproject.com/CleanEnergyActionProject/CS.Rokkasho-Futamata_Wind_Farm___Energy_Storage_Case_Study.html
UK case study - Energy storage in the UK - Flexible AC Transmission Systems (Power T&D Solutions) – http://www.abb.com/industries/ap/db0003db004333/8C1F3603E2C36BEBC1257892003252AA.aspx

114 Wikipedia

build the portfolio of RE and such conventional sources along with the transmission infrastructure and control systems.

Intensive R&D work is required to support variable power sources with firmer flexible sources like thermal or hydro at economical rates for India. Flexible generation technology which can be ramped up within minutes will reduce the variability from the combined portfolio of RE + conventional sources, promoting more RE.

GE is test piloting (as of May 2011) a gas-fired combined cycle power plant to start up rapidly enough to be able to help the grid to adapt to the variability of RE. The power plant can ramp up at a rate of more than 50MW per minute and the plant can start up from scratch within less than 30 minutes. The plant is not expected to come into operation before 2015[115]. More of these pilots are needed at a global level.

9. Summarizing solutions for dealing with variability

With the deployment of large RE capacity both at the utility level and at the distributed level, storage issues would become critical. While several technologies exist for storage, planning for specific state level conditions will need to be assessed. Along with storage technology, to smoothen the output from RE sources, the portfolio re-balancing with an assessment of supply chain issues for firm sources like biomass should be done. Within the wind and solar sector, hybrid models should be assessed to take advantage of the different production profiles from wind and solar.

At a national and global level, R&D into large scale storage technologies to make them economically attractive will lead to adoption of these technologies in India. The country should also look out for any developments in the area of flexible generation technologies.

H. Dealing with existing and expected Power Quality issues

The technology for power quality improvement is available. With smart grids and microgrids the means to reduce the impact on the grid stability are many. All these solutions have to be considered in the view of a relatively old network that TN and Ka have. Also, the states have to plan before hand on how to deal with possible PQ issues that may arise when distributed RE generators are connected to the distribution network.

1. Investing in Technology for Power Quality improvement

[116]The utilities can install load conditioning systems (which take in power and modify based on requirements of the load) to suppress or counteract the power system disturbances. Energy

115 From the MIT Technology Review article dated May 2011, A gas power plant to make renewables more practical - http://www.technologyreview.com/article/424118/a-gas-power-plant-to-make-renewables-more-practical/

116 PQ improvement from Power quality in grid connected renewable energy systems report

storage devices along with constant voltage transformers, noise filters, isolation transformers, transient voltage surge suppressors, harmonic filters can be used for this purpose. The UPS is a common example of an energy storage device used for PQ[117]. Custom Power Devices (CPD) like DSTATCOM, DVR, and UPQC[118] are used for mitigating these PQ problems. DSTATCOM enables power factor correction, current harmonics filtering and load balancing and voltage regulation at distribution bus.DVR protects sensitive loads from supply side disturbances (excluding outages). It can also isolate the source from harmonics generated by loads. UPQC mitigates supply side disturbances – voltage sags, swells, flickers, unbalances and harmonics. Reactive power can be managed using dynamic voltage control devices like SVCs (Static VAR compensator).

Hardware up gradation

To prevent overvoltage, overvoltage relays and arrestors should be installed. In case of fault current, protection must be individually examined for each case. On the generators end, there is protection equipment to detect abnormal power conditions. Also, to prevent direct current injection from generators into the utility lines, transformer-less power conditioning units are available. Hardware for all generator types and capacities are commercially available for synchronizing a distributed generator with the utility waveform.

Islanding

[119]For improvement of protection systems, hardware solutions are available, though at high costs. The solutions for increasing safety include islanding. During islanding, a generator continues to supply the local load after being disconnected from the main network.

Distributed generation sources like RE should be isolated during any faults in the main grid and when main supply is not available. This can be achieved by installing internal destabilizing circuits, internal trip mechanisms. Also islanding detection schemes can be incorporated in the distribution system. One such means could be to monitor the harmonics levels at power conditioning unit terminals. When utility power is disconnected, the level of harmonics would change dramatically.

The PQ improvement devices for RE specific usage are expensive in the Indian context, this area is lacking in investments.

2. Exploring Microgrids

A microgrid is a smaller power grid that can operate either by itself as an island or can be connected to a larger grid. Thus, a microgrid can improve the reliability of power supply. When a distributed generator like a roof top installation is connected to the grid, the concerns are around the power

117 Information on UPS from Integrating renewable electricity on the grid report
118 DSTATCOM – Distribution Static Compensator; DVR – Dynamic Voltage Restorer; UPQC – Unified Power Quality Conditioner
119 Protection and safety systems from Factors relevant to utility integration of intermittent renewable technologies

quality due to intermittent power from the generator and protection systems. Also, the main grid must be operational for the distributed generator to be able to export power into the grid. Hence, the distributed generator is dependent on the grid for voltage and frequency regulation.

In case of microgrids, when there is an outage, a grid-connected microgrid can disconnect itself from the grid at a moment's notice and continue to supply power to the community. When the main grid is running smoothly the microgrid can export power to the grid[120]. The microgrid would comprise of several clustered loads on a Medium Voltage or Low Voltage distribution system. The energy source can be one or multiple. The microgrid may be connected to the remaining distribution grid using a Point of Common Connection (PCC) like a RE generator. The microgrid can seamlessly transfer between two states of the grid connected mode and an Isolated Grid (IG) mode. In the grid connected mode, the microgrid can shift between the Grid Dependent (GD) mode or Grid Independent (GI) or autonomous mode. Similar to a smart grid, microgrid includes metering infrastructure, communications systems, grid controls and energy management systems.

3. Adopting Smart Grid Technology

A smart grid will enable utilities to monitor real time and controlling its assets. Communication, sensing and measurement and control technologies can help utilities to detect fluctuations caused by connection of RE generators to the grid, take immediate action to turn of relays/ circuit breakers and reduce the negative impact on the grid stability. The communication and monitoring technologies have been available for some time now, what is required is a more rigorous adoption of the same.

Advanced sensors installed at various points in the grid will help in continuously monitoring the asset status. These sensors, measurement technologies are already available.

- Wide Area Monitoring System (WAMS) involves setting up of GPS based PMUs to measure current and voltage across the grid. This can be combined with SCADA data for accurately estimating the status of the assets
- Dynamic Line Rating sensors measure the current carrying capability of lines
- Conductor/compressor sensors measure conductor temperature and line sag
- Insulation contamination leakage current sensors monitor leakage

Digital relays have replaced electro-mechanical relays which have better fault isolation, detection and self-checking diagnostics. In the future, advanced meters will enable fault location detection, provide information on power factor, power quality, equipment health & capacity, and meter tampering, vegetation intrusion, transformer & line loading. The available communication technology can relay the information from advanced sensors.

120 Microgrid information from Microgrids: So much more than backup energy article, NREL and Microgrids & Hybrid systems – IEEEE Microgrid conference

Advanced Control Methods are devices and algorithms which predict the condition of the grid by analysing the current state of the grid and take automatic corrective actions to eliminate outage and power quality issues. With ACM, the grid software will be equipped to take corrective action autonomously. This will reduce the time taken to react. ACM is still in the R&D stage. The scope of ACM is limited with limited communication infrastructure. However, the advances in software based control algorithms have been significant.

Going forward advanced communication networks will be needed to realize the potential benefits of ACM technologies. Instead of controlling locally, ACM will be used to control centralized systems. ACMs will collect data, analyse data, diagnose and solve problems, take autonomous actions, provide information and options for human operators and integrate these methods with other automation technologies, softwares.

Power electronics that help in voltage control and power quality control will be integral to AC and High Voltage Direct Current transmission (for long distance transmission). Universal power flow controllers, Dynamic Variable Response (VAR), MV VAR, and Static Variable Compensator (SVC) are some of the devices already in the grid using power electronics. Though the solutions are available, at this point of time, HVDC transmission lines and Flexible AC Transmission System Devices (FACT) like SVC may not make economic sense yet.

4. Forumulating and implementing integration standards for connection and operation

In order to resolve the power quality concerns and protection issues, the guidelines for connecting RE generators to the grid have to be enforced. The standards were created in 2009 by Power Research and Development Consultants Pvt. Ltd. (PRDC) and the Indian Electricity Grid Code (IEGC) included some of these guidelines (as discussed below) in the Electricity Act of 2010. The 2009, Indian Wind Grid Code Draft Report by PRDC has guidelines on technical standards for the connection point and operating code for wind farms.

- The connection code for wind farms will be applicable for all farms seeking connection to ISTS/STS/STUs at any voltage level. It specifies minimum technical and design criteria for voltage levels, reactive power management systems, frequency tolerance range, active power control ability, disconnection equipment, explains situations for remaining connected, ability to withstand repetitive faults, protection systems, signal and data communication requirements, system recording instruments and other equipment like earthing, lighTNing protection, auxiliary supply, revenue metering, procedures for site access, O&M and operational safety.
- Operating code lists out the operating conditions that wind farms should comply to ensure they operate as integrated systems with the grid. It is applicable to wind farms connected to the grid, SEB, STU, SSLDC, SLDC, and RLDC. Operating margins have been defined for voltage limits, frequency limits, active power and power factor. Reactive power and voltage control measures (VAR compensation and drawal) and ramp rate limits for 50MW or more installed

capacity are given. Power quality maintenance guidelines at connection point for voltage flicker, harmonics, start up and stop criteria, operating procedures during transmission congestion, emergency condition are also detailed. Demand estimation & management, periodic reports, operational liaison, outage planning, recovery procedures, event reporting will as per the IEGC requirements.

The draft Indian Electricity Grid Code, for implementation from 1st April 2010 covered some of the **technical standards** for connection of wind and solar generating facilities to the State Power System or ISTS. The standards have been mandated for connectivity of wind turbines at a connection point of 33 kV and above, if the collective capacity of the wind generator at the connection point exceeds 10 MW and where PPA has not yet been tied up.

Under the same Code, the grid operating code which includes a set of detailed operating procedures for the national grid, regional grids and state grid for integrated grid operation includes special requirements for wind generators. It lists out the guidelines for drawing/injecting VAr, managing reactive power, reacting to grid congestion. It has guidelines on how SLDC will consider wind forecasts for load generation balance, management of daily reports covering wind power generation and injection, outage planning of RE.

For protection of connections at 11kV, generators with more than 100kW installed capacity should be mandated to install requisite protection and communication systems. With upcoming projects for distributed generation of solar in TN and Ka, protection standards for small scale generators will be equally important.

5. Summarizing solutions for dealing with PQ issues

To address power quality and grid and personnel safety issues that we have identified a combination of planning to control PQ issues, integration standards and hardware is called for. We believe that adequate capacity is available in India in both areas. Some of the power quality devices are still expensive, in that context the smart grid pilots will be important. While some components like ACM have relatively lesser scope due to the need for strong communication links, the other components of smart grids are already being considered for the pilots across the country. The smart grid pilots with their monitoring and communication and control systems can help in immediate detection of faults and their resolution. Also, the interconnection issues of RE should be monitored using these smart grid pilots wherever the pilot involves integration of distributed generation. While microgrid concept can be explored in a country like India which has tremendous potential for distributed generation and where the grid is already overburdened making it unstable and weak.

X. CONCLUSION

Our main conclusion is that an overall systemic view of infrastructure, systems, technology, processes and organizations is required for integration of the planned increase of renewable capacity to the grid. In the absence of this systemic planning, generation capacity will not necessarily translate to production and consumption. The resolution of these issues is important since TN and Ka have seen an increase in RE penetration over the last 5-6 years. While at a national level, the penetration is less than 5%, Ka and TN already have penetration levels of more than 10%.

Ka and TN have embarked on the path of infrastructure planning and capacity addition to strengthen the overall transmission and distribution grid. The technology for generation management, loss reduction, forecasting and scheduling already exists. The question about how smoothly these technologies can be adopted has to be dealt with through pilots and planning at state and regional level rather than customer level. Integration standards for connecting RE to the grid have to be enforced at the National level and processes have to developed to incentivise generators (large scale and distributed) to invest in latest technologies. We advocate integrated planning that considers new RE capacity addition plans, infrastructure upgradation requirements and PQ control measures instead of developing individual plans for each area.

Deployment of technologies to improve the efficiency of the grid will further support RE integration. Ka has undertaken projects around GIS mapping, DAS, SCADA implementation and smart meter implementation. Both Ka and TN also part of national programs like the RAPDRP scheme to improve grid efficiency. Ka also has an on-going smart grid pilot in the city of Mysore, one of the fourteen pilots running across India. The long term roadmap for smart grids has been developed and proposed by independent bodies.

These initiatives have the ability to drive overall energy efficiency in the electricity system when considered and planned for in a holistic manner. We also urge that these smart initiatives on the grid be considered in tandem with other energy efficiency measures at the consumer end as well as the overall issue of strengthening the transmission and distribution systems.

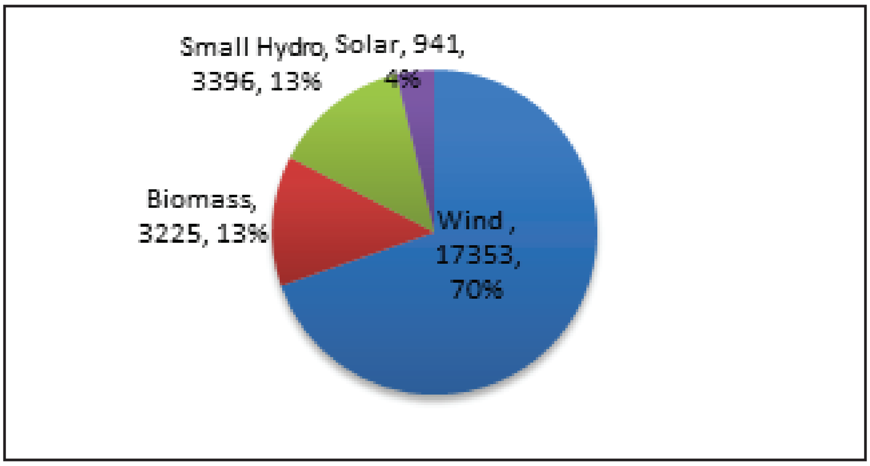
A systemic and holistic planning would help the two states in reducing energy deficits, maximizing their energy potential and most importantly, provide a sustainable mechanism for providing energy, accelerate economic growth and raise standards of living.

XI. ANNEXURE:

1. India RE capacity and plans

In 2005, the installed Renewable Energy (RE) capacity in India was 6,158MW. That number grew by about 4 times in the next 7 years.

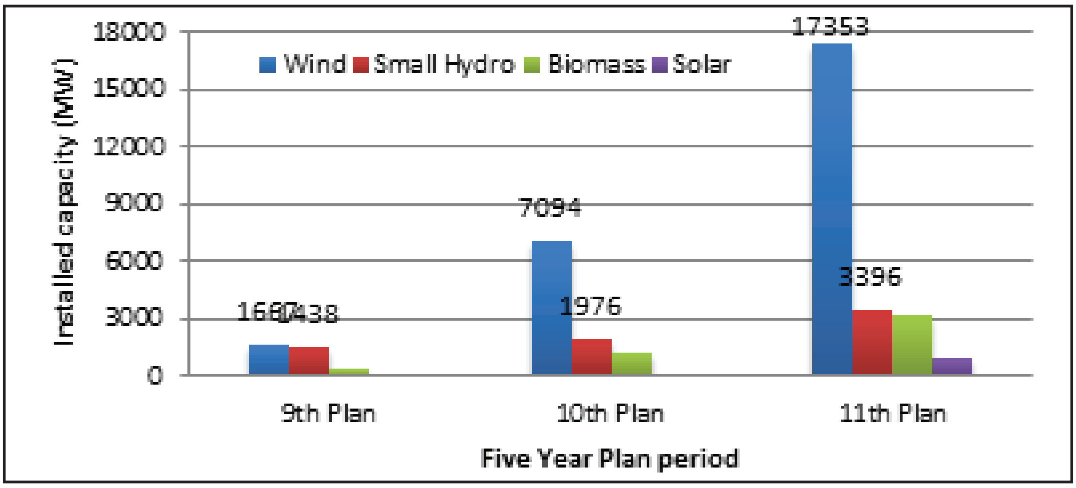
Figure 7 : Installed RE capacity (MW) as of 30-March-2012



Source: Green Energy Corridor report

From 2005 to September 2012, Western states added RE capacity at a CAGR of 33%, Northern states added capacity at a CAGR of 25% and Southern States added capacity at a CAGR of 17%.

Figure 8 : Growth in installed RE capacity by type



Source: Green Energy Corridor report

As per CWET, total wind potential of India is 103GW at 80m hub height. The solar potential of India is 20-30MW/sq. km which is equivalent to more than 100GW of solar power.

MNRE has set targets for addition of new RE capacity, wind followed by small hydro and solar will account for the major capacity additions.

Table 10 : All India year wise target for grid interactive RE power (MW) for 12th five year plan (2012-17 MNRE)

Technologies/year	Biomass/ Agro-waste	Bagasse Cogen	Urban & Industrial waste power energy	Small Hydro Power	Solar	Wind	Total
Cum. antcpt. to 31.03.2011	1025	1616	84	3040	35	13900	**19683**
2011-12	100	250	20	350	300	2400	**3420**
2012-13	80	300	25	300	800	2200	**3705**
2013-14	80	300	35	300	400	2200	**3315**
2014-15	80	250	45	300	400	2200	**3275**
2015-16	80	250	55	350	1000	2200	**3935**
2016-17	80	250	60	360	1100	2200	**4050**
Total	**500**	**1600**	**240**	**1960**	**4000**	**13400**	**21700**
Cumulative total	**1525**	**3216**	**324**	**5000**	**4035**	**27300**	**41383**

Source: Strategic plan for new and renewable energy sector for the period 2011-17, MNRE, February 2011

Versus the the State Nodal Agencies (SNA)/ State Transmission Utilities (STU)[121] have even more ambitious RE plans over the same period (12th five year plan period). The estimated potential of small/micro/mini hydro projects is about 15GW and that of biomass is 22GW. Small hydro projects in Himachal Pradesh and Ka will add another 1715MW taking total installed hydro capacity to 2700MW by 2016-17.

Table 11 : Planned wind and solar capacity addition in 6 RE rich states for 12th five year plan – SNA/STU

States	**Wind (MW)**		**Solar (MW)**		**Total Capacity (MW)**	
	Existing	Planned	Existing	Planned	Existing	Planned
TN	6370	6000	7[122]	3000	6377	9000
Ka	1783	3223	6	160	1789	3383
Andhra Pradesh	392	5048	92	285	484	5333
Gujarat	2600	5083	600	1400	3200	6483
Maharashtra	2460	9016	17	905	2477	9921
Rajasthan	2100	2000	200	3700	2300	5700
Total	**15705**	**30370**	**922**	**9450**	**16627**	**39820**

Source: Green Energy Corridors report

2. Central, State regulatory bodies for grid management

PGCIL (Power Grid Corporation of India Limited), the Central Transmission Utility (CTU) wheels power from central generating utilities (as listed in the Generation section) and interstate Mega IPPs. PGCIL carries 50% of the country's electric power. The CTU is responsible for interstate

121 From the Green Energy Corridor report

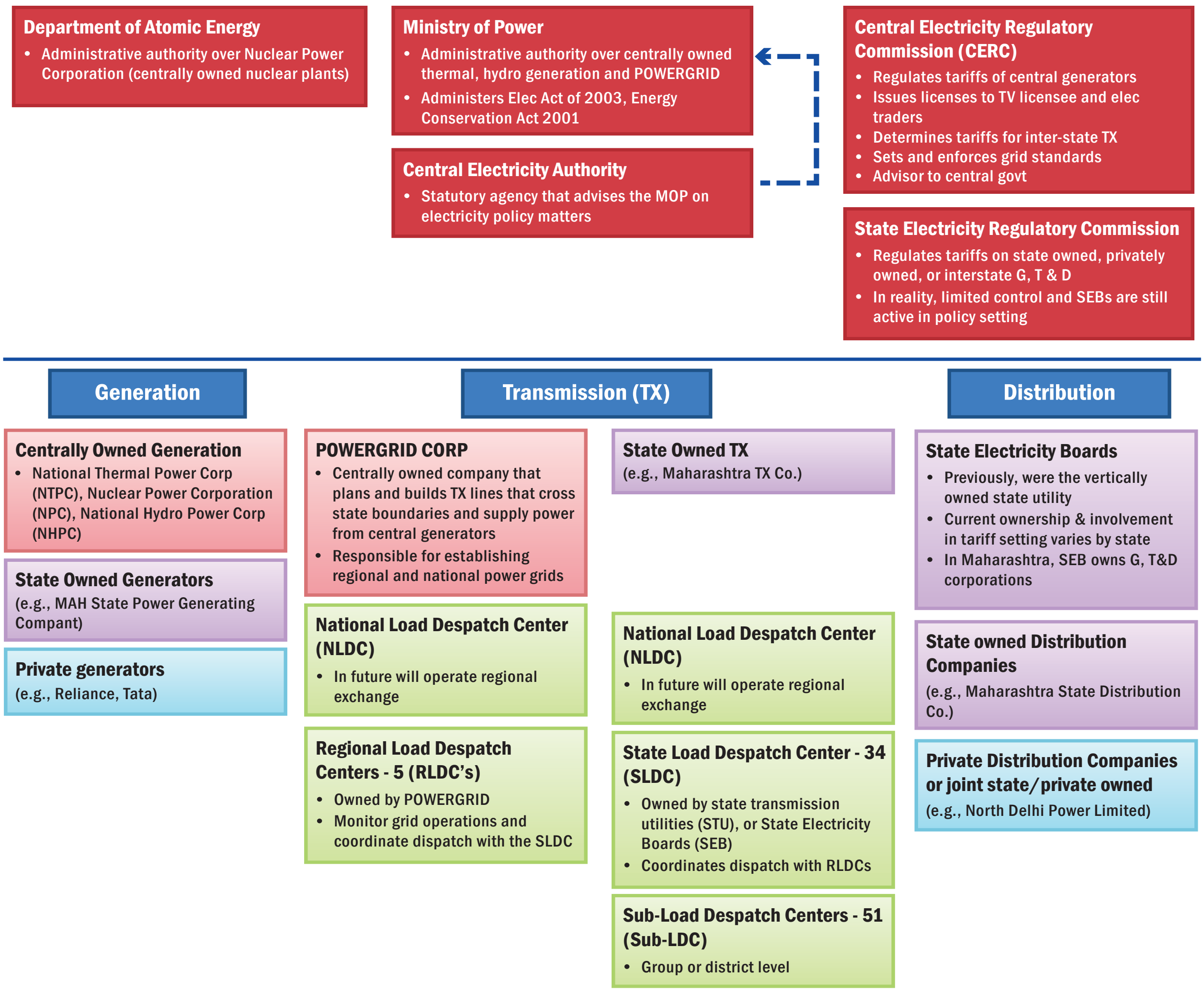
122 This was the installed capacity way back in July 2011, while the Green Energy Corridors report was released in September 2012. As stated in the 29-Aug-2011 Business Line "20-grid connected solar power plants on-stream" article – Total of 20 grid connected solar power plants with capacity of 1 megawatt (MW) or more have been commissioned in the country by July 2011. Of the total capacity of 45.5 MW commissioned, Gujarat has 11 MW, Rajasthan 7.5 MW, TN 7 MW, Ka 6 MW, and Maharashtra 5 MW. Andhra Pradesh, Punjab and Delhi have 2 MW each, while Haryana and West Bengal have 1 MW respectively. These are solar photovoltaic projects.

transmission and co-ordinates with the State Transmission Utilities (STU). The CTU also plays an important role in the planning of new transmission systems and strengthening existing systems at the central level. The STUs wheel the power generated from the state generating utilities and state level IPPs and co-ordinates within the state.

Table 12 : PGCIL transmission capacity

Transmission Utility	Transmission line (Kms)	Substations	Transformation capacity	Inter-regional power transfer capacity
PGCIL[123] (CTU)	95,846circuit per km (Ckt)	157 EHVAC/HVDC	1,44,303 MVA	28,000 MW

Figure 9 : Organizational Structure of the Indian Grid System



Source: Electricity Grid Evolution in India - A scoping study on the technical and planning needs to support the National Action Plan, September 2011

123 Data as of 31 August 2012

Load Despatch Centres[124]: The five regional grids are managed by the Regional Load Despatch Centres (RLDC).

- Northern Region Load Despatch Centre (NRLDC) located in New Delhi
- Eastern Region Load Despatch Centre (ERLDC) located in Kolkata
- Western Region Load Despatch Centre (WRLDC) located in Mumbai
- North Eastern Region Load Despatch Centre (NERLDC) located in Shillong
- Southern Region Load Despatch Centre (SRLDC) located in Bangalore

The RLDCs are the apex bodies for operation of the integrated grid in the respective region. The center's co-ordinate the use of transmission systems within each region.

There is a national load despatch centre (NLDC) in New Delhi which supervises the functioning of the RLDCs and schedules and despatches inter regional transfers. The five RLDCs and one NLDC is owned, operated and maintained by Power System Operation Corporation of India Limited (POSOCO), a fully owned subsidiary of POWERGRID (CTU). The CTU is responsible for the integrated operation of these regional grids.

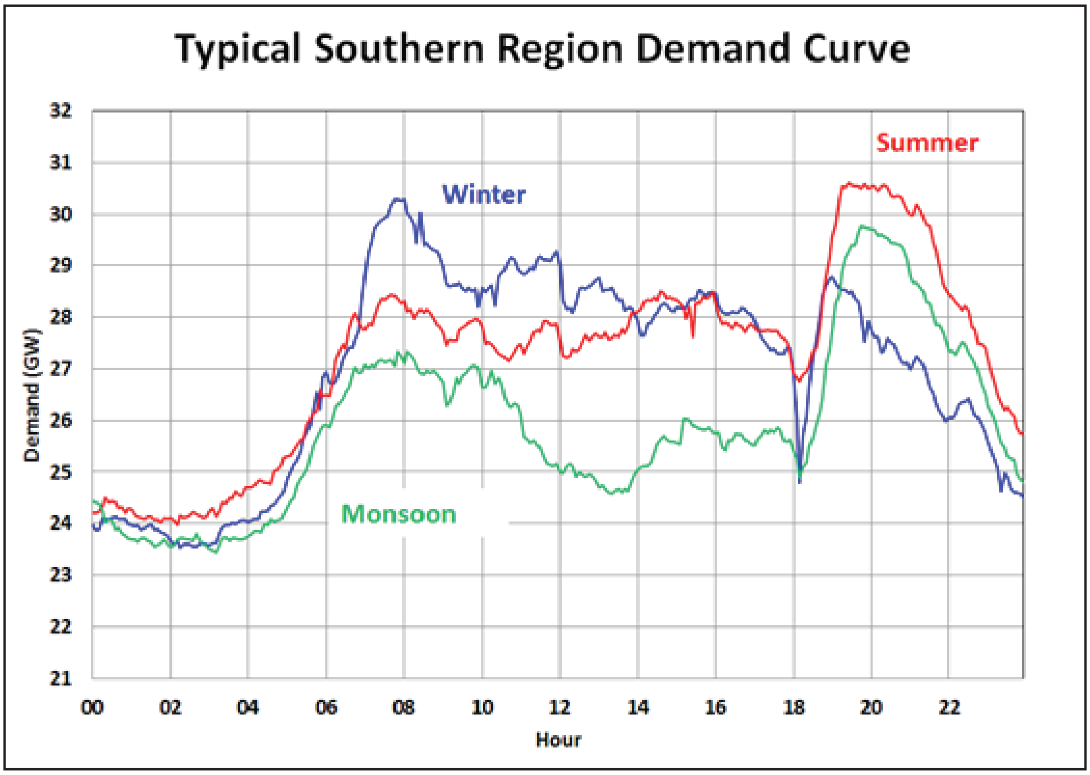
At the state level, the 34 state grids are managed by State Load Despatch Centres (SLDC). The SLDCs are owned by the State Transmission Utilities (STUs). The SLDC co-ordinates the use of transmission system within the state and report the data to the overseeing RLDC.

3. Southern Region: Ka and TN grid

The Southern Region (SR) comprises of four states – Ka, TN, Andhra Pradesh, Kerala and one union territory – Pondicherry. Overall demand/power requirement in SR has gone up at a CAGR of 8.1%125 over the five years from 2007-08 to 2012-2013 (anticipated figures for 2012-13) vs. all India demand growth of 5.9% over the same period. Annual electricity demand patterns have been analysed based on the data from RLDC and NLDC. As seen in the figure below, on a seasonal basis, the maximum demand in SR has been observed in the months of January, February and March i.e. the summer months (red curve). On a daily basis, during the summer and monsoon seasons, peak demand is seen during the evening hours from 7pm to 10pm. However, during the winter months, demand is more stable throughout the day.

124 Electricity Grid Evolution in India
125 CEA Annual Reports Annexure 4A

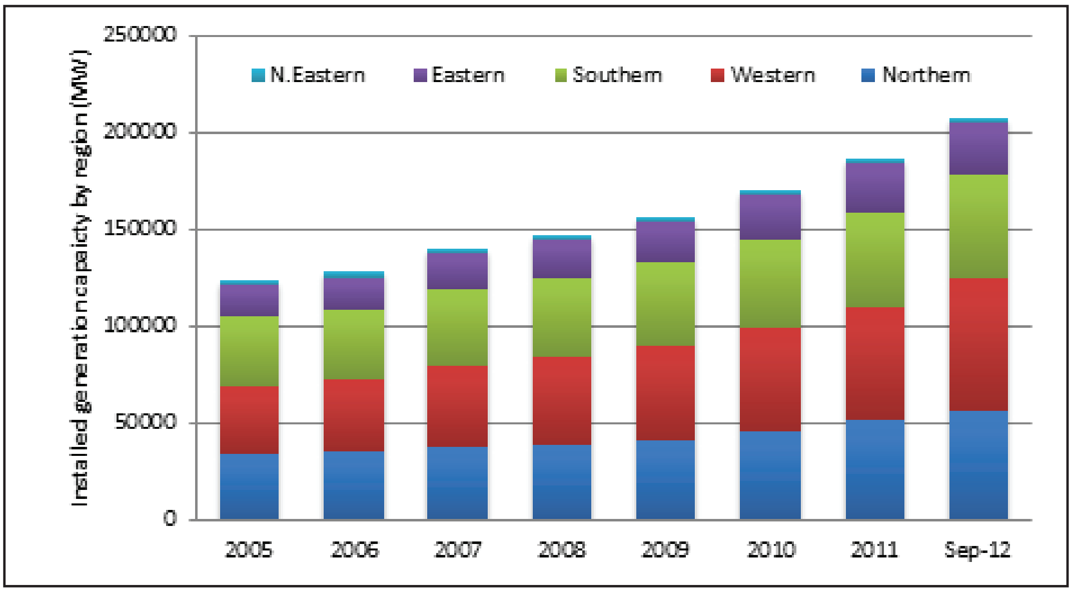
Figure 10 : Southern region demand curve



Source: Green Energy Corridor report

To meet this demand the SR has an installed capacity of 53.5GW[126] (26% of the total generation capacity in India). The total installed capacity in India has gone up from 123.7GW in 2005 to 207.8GW in September 2012 at a CAGR of 7.7%. Installed capacity has gone up at a CAGR of only 5.9% in the SR over the same period from 35.8GW to 53.5GW.

Figure 11 : Installed generating capacity by region



126 CEA All India Region wise Generating Installed Capacity of Power

Of the installed generation capacity, private sector accounts for 47.6% of the installed capacity in TN and 33.8% in Ka

Table 13: Southern Region Summary

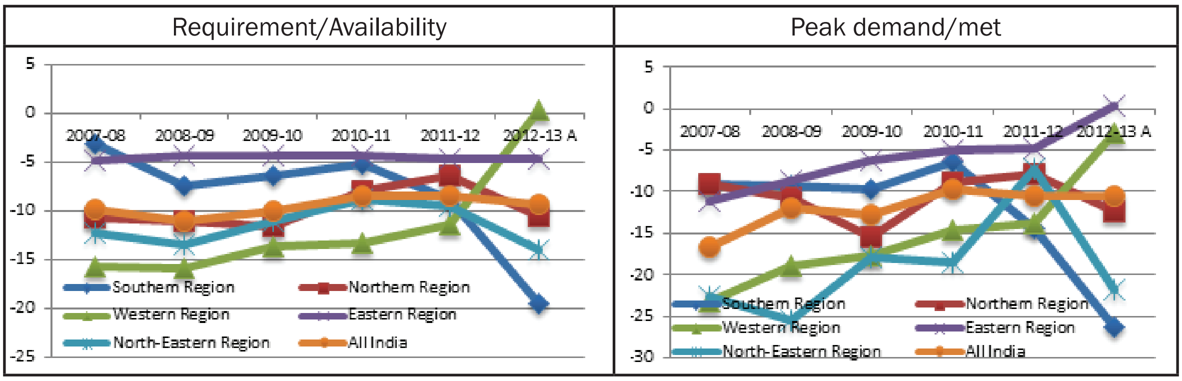
Parameter	Ka	TN	Andhra Pradesh	Kerala	Pondicherry
% of Private Sector in total installed capacity - 2012	33.8	47.6	24.5	5.1	0.01

Source: CEA monthly reports compiled in the CII Ka Conference on Power Report

Along with the slow growth in addition of new generation capacity, SR also faces issues related to limited inter-regional transfer capacity as discussed in the section on Limited transmission infrastructure and planning for RE evacuation.

With the increasing demand, slow addition of generation capacity and limited inter-regional transfer capacity, the supply demand deficit is widening in South India. Until 2010-11, SR had a lower supply deficit versus the western, north-eastern and northern region. The situation started deteriorating in 2011-12 and a sharp deficit in the availability vs. requirement was anticipated in 2012-13.

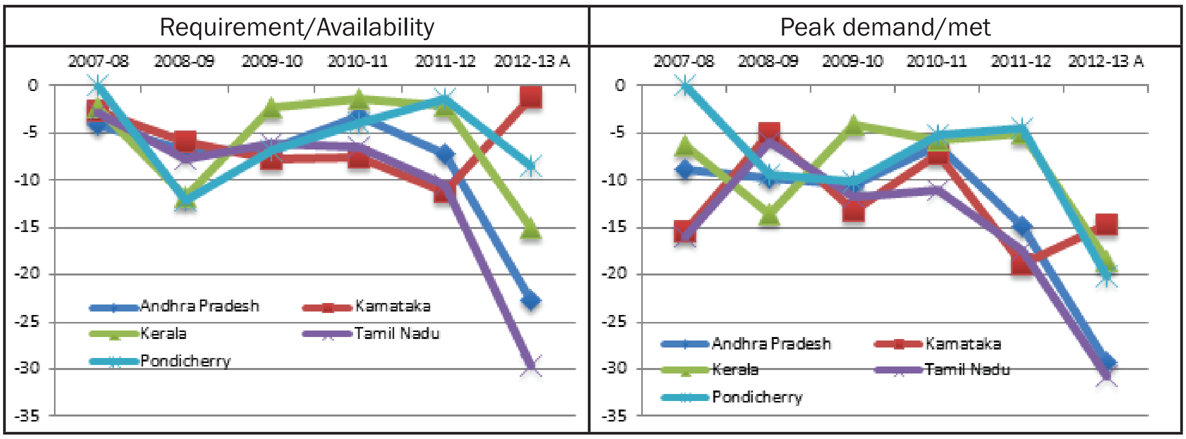
Figure 12: All India Surplus/Deficit



Source: CEA annual reports, Annexure 4A

In Ka (which has suffered from a supply deficit for over a decade) the supply, demand gap widened to 11% in 2012 from 8% in 2011 and 2010. In TN, the deficit was 10.5% in 2012. In Ka, a surplus of 4.8% was anticipated. The lower availability of energy compared to anticipated resulted in a deficit finally. However, the deficit in TN in 2011-12 was lower than anticipated value of 18% due to higher availability than forecast.

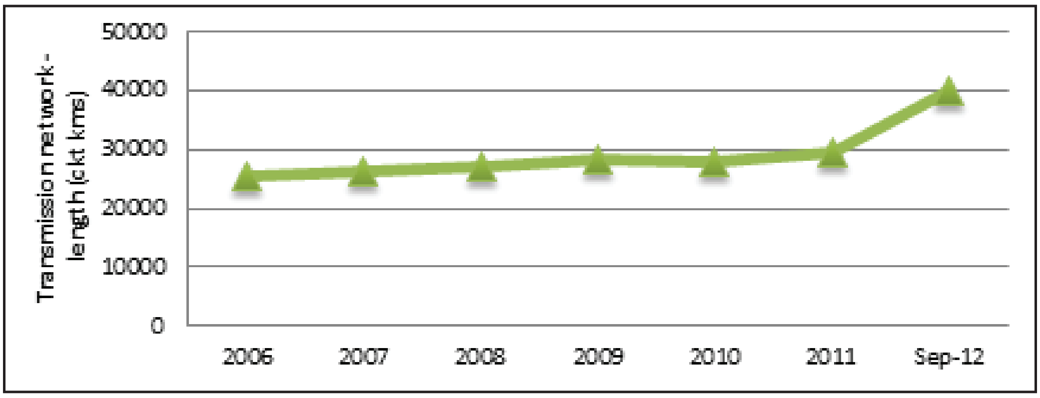
Figure 13: Southern Region Surplus/Deficit



Source: CEA annual reports, Annexure 4A

KPTCL is responsible for transmission and load despatch in Ka. Over the five years from2006 to 2011, the transmission network[127] length in Ka has grown at a CAGR of 3% only vs. 7% growth of the all India transmission network.

Figure 14 : Transmission network in Ka



Source: KPTCL annual reports and website

Between March 2011 and September 2012, KPTCL added new substations and transmission lines. As of September 2012, KPTCL had 1325 transmission substations and 39988ckt kms of transmission lines.

Table 16 : KPTCL transmission network as of September 2012

	No. of receiving substations	Length of transmission lines (ckt.kms)
400kV	4	2650.022
220kV	90	9765.860
110kV	333	9123.450
66kV	545	9856.040
33kV	353	8593.03
Total	**1325**	**39988.397**

Source: KPTCL website http://110.234.115.69/Statistics/Substation%20and%20Tr%20Lines.pdf

127 From KPTCL annual reports and website. Data is as of March for the corresponding year. Network includes 66, 110, 200, 400kV lines. Number of substations were 573, 642, 767, 874, 904, 945 in 2006, 2007, 2008, 2009, 2010, 2011 respectively

TN Transmission Corporation Limited (TANTRANSCO) is responsible for transmission in TN. The TANTRANSCO network has EHT of 24,497 kms and 842 substations[128].

On the distribution front, there are twelve distribution companies in the southern region covering the four states and one union territory. Other than Kerala, all other state electricity boards have been unbundled.

Table 17 : South India Distribution companies

State	Distribution Companies
Ka	• Bangalore Electricity Supply Company (BESCOM) • Mangalore Electricity Supply Company (MESCOM) • Hubli Electricity Supply Company(HESCOM) • Gulbarga Electricity Supply Company (GESCOM) • Chamundeshwari Electricity Supply Company (CESC)
TN	• TN Generation and Distribution Corporation Limited (TANGEDCO)
Andhra Pradesh[129]	• Eastern Power Distribution Company of Andhra Pradesh (APEPDCL) • Southern Power Distribution Company of Andhra Pradesh (APSPDCL) • Northern Power Distribution Company of Andhra Pradesh (APNPDCL) • Andhra Pradesh Central Power Distribution Company (APCPDCL)
Kerala[130]	• Kerala State Electricity Board (KSEB)
Pondicherry[131]	• Pondicherry Electricity Supply Company Limited (PESCO)

Ka[132] : The State Electricity Board dealing with the transmission and distribution of electricity - the Ka Electricity Board (KEB) was "unbundled" and corporatized in 1999. The public sector generation utility is the Ka Power Corporation Ltd. (KPCL). During the unbundling process, The Ka Power Transmission Corporation Ltd. (KPTCL) retained charge of transmission and distribution. KPTCL in turn was unbundled in June 2002, with the distribution segment split between the main geographical zones. As of 31 August 2012, the total HT lines in Ka were 230406.606 Ckt kms and LT lines were 477386.439 Ckt kms[133].

128 TANTRANSCO network information from http://www.tantransco.gov.in/template_4.php?tempno=4&cid=0&subcid=209. Date not available

129 Andhra Pradesh had completed the unbundling process in accordance with the Electricity Act of 2003

130 Kerala State Electricity Board (KSEB), established in 1957 is a public sector agency under the Government of Kerala, India that generates and distributes the electricity supply in the state. Instead of unbundling, the SEB is to be re-organized into three profit centres (http://www.powermin.nic.in/acts_notification/status_reforms_in_states.htm)

131 "PESCO" shall mean Pondicherry Electricity Supply Company Limited, a company established by the Government of Pondicherry with the principal object of taking over the existing Distribution under the control of the Department and engaging in the business of Distribution of Electricity in the Union Territory
Under the power sector reform programme undertaken by the Government of Pondicherry (GoP), PED has been corporatized and unbundled into the Pondicherry Electricity Supply Corporation (PESCO) and Pondicherry Electricity Transmission Corporation (PETCO) with effect from April, 2010..

132 International Energy Initiative - Ka's power sector & suggested ways forward (2002)

133 HT and LT lines update from KPTCL Power Sector at a glance http://110.234.115.69/Statistics/KPTCL%20at%20a%20Glance.pdf

Table 18 : Ka DISCOM details

Ka DISCOMs	Population / Districts in area covered	Distribution network
BESCOM[134]	73.2 lakhs in 8 districts	68,692 Ckt. km of HT lines 143,544 Ckt. km of LT lines
MESCOM[135]	18.7 lakhs in 4 districts	26,706 km of HT lines 70,673 km of LT lines
HESCOM[136]	36.75 lakhs in 7 districts	55,175 Ckt. kms of HT lines 10,718 Ckt. kms of LT lines
GESCOM[137]	23.97 lakhs in 6 districts	37,370 kms of HT lines 75,609 kms of LT lines
CESC[138]	24.95 lakh consumers in 5 districts	31,871 kms of 11kV lines 70,741 kms of LT lines

TN: Electricity Act of 2003 mandated the **unbundling** of the State Electricity Boards. In October 2008, the TN Electricity Board (TNEB) was unbundled and split into three companies. Since 2010, TNEB acts as three companies, TNEB Limited (TNEBL), a holding, an administrative company, with two subsidiaries, TN Generation and Distribution Corporation Limited (TANGEDCO) and TN Transmission Corporation Limited (TANTRANSCO). These two subsidiaries would be fully owned by the government.

Table 19 : TN DISCOM details

TN DISCOM	Distribution network
TANGEDCO[139]	231.8 lakh consumers 1.80 lakh Ckt kms of EHT/HT lines 5.67 lakh kms of LT lines
	5.67 lakh kms of LT lines

4. Technical Standards for RE connection to the grid – Indian Electricity Grid Code

These standards were meant to be effective from 1st April 2010

General Conditions for connectivity of Renewables

I. A generating station of renewable sources can be connected at the distribution level (below 33 kV) or transmission level (at or above 33 kV) of the State depending upon policies of the State Electricity Regulatory Commissions.

II. A generating station of renewable sources can also be connected to the ISTS.

134 http://www.bescom.org/Performance_of_BESCOM.pdf data from 2009-2010
135 http://www.mesco.in/aboutus/index.asp as of Aug 2012
136 http://www.hescom.co.in/Aboutus.html as of Mar 2011
137 http://www.gescom.in/aboutus/achievements.html as of Mar 2011
138 http://cescmysore.org/about/cescprofile as of Aug 2012
139 www.tangedco.gov.in , TANGEDCO Data Handbook as of 31-March-2012

A. Special Technical Requirements for of Wind Generators connected to the grid

Following features are mandated for connectivity of wind turbines at a connection point of 33 kV and above, if the collective capacity of the wind generator at the connection point exceeds 10 MW and where PPA has not yet been tied up.

I. Wind farms shall have the ability to limit the active power output at grid connection point as per system operator's request. (Explanation: -During system operations, grid operator in extreme conditions may ask the wind farms to limit the power injection into the grid.)

II. The grid connected wind farms shall have the ramp up/ramp down capability

III. The reactive compensation system of wind farms shall be such that Wind farms shall maintain power factor between 0.95 lagging and 0.95 leading at the connection point.

IV. The wind generating machines shall be equipped with fault ride through capability. The Wind generating machines shall have the operating region as shown in Figure given below during system faults. Wind farms can be disconnected if the operating point falls below the line in the Figure.

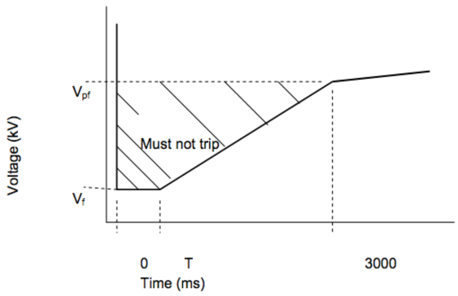


Figure: Fault ride through characteristics

Where,
Vf = 15% of Nominal System voltage
V_{pf} = Minimum voltages (80% of Nominal System Voltage)

The fault clearing time for various system nominal voltage levels is given in the following Table: Fault clearing time and voltage limits

Nominal system voltage (kV)	Fault clearing time, T(ms)	V_{pf} (kV)	V_f (kV)
400	100	360	60.0
220	160	200	33.0
132	160	120	19.8
110	160	96.25	16.5
66	300	60	9.9

During fault ride-through, the Wind turbine generators (WTGs) in the wind farm shall have the capability to meet the following requirements:

a) Shall minimize the reactive power drawl from the grid.

b) The wind turbine generators shall provide active power in proportion to retained grid voltage as soon as the fault is cleared. (Explanation: Wind farms connected to high voltage transmission system must stay connected when a voltage dip occurs in the grid, otherwise, the sudden disconnection of a large amount of wind power may contribute to the voltage dip, with adverse consequences. Wind farms must remain connected when the voltage dip profile is above the line shown in the figure. The per unit voltage at the point of connection to the grid is shown in the vertical axis and the duration (seconds) of the fault in the horizontal axis. This code requires Fault Ride-Through (FRT) capability during voltage drops in Transmission System to 15% of nominal voltage during 300 ms with recovery up to 80% of nominal voltage after 3 sec, with the slope shown in figure given above)

V. Wind turbine generator protection

a. All the grid connected wind farms must have protection systems to protect the wind farm equipment as well as the grid, such that no part system shall remain unprotected during faults.

b. The protection co-ordination for the wind farms shall be done by the SEB/ STU and RPC.

c. The following are the minimum protection schemes that shall be installed for wind farm protection:

i) under/over voltage protection

ii) under/over frequency protection

iii) Over current and earth fault protection

iv) Load unbalances (negative sequence) protection

v) Differential protection for the grid connecting transformer

vi) Capacitor bank protection

vii) Tele-protection channels (for use with distance protection) between the grid connection point circuit breaker and user connection point circuit breaker

VI. Wind farms shall have communication channel which is continuously available to system operator.

VII. Data Acquisition System facility shall be provided for transfer of information to concerned SLDC and RLDC

VIII. LighTNing protection of WTG system shall be according to IEC TR 61400-24 “Wind turbine generator systems – Part 24: LighTNing protection.”

IX. Wind turbine grounding systems shall follow the recommendations of IEC TR 61400-24.

X. The grid connecting transformer configuration shall be designed to provide:

i) A favourable circuit to block the transmission of harmonic currents.

ii) Isolation of transmission system side and wind farm side ground fault current contributions

The preferred configuration of the grid connecting transformer is delta connection on the wind farm side and grounded wye connection on the transmission system (grid) side. Delta connection on the high voltage side of the grid connecting transformer is not permitted. Alternate transformer configuration including wye-wye or wye-wye with a delta connected tertiary is also acceptable for the grid connecting transformer. If the wind farm is directly getting connected to the existing utility substation, the standard practice of utility shall be followed.

Issues from Factors Relevant to Utility Integration of Intermittent Renewable Technologies – NREL, US DoE.

For wind an induction generator, synchronous generator or variable frequency AC generator can be used. In case of the AC generator a static power converter is required to convert and regulate electric output into a form suitable for interconnection with utility system. A wind generation system can be connected at the distribution voltage level. PV systems produce DC electricity from sunlight. A static power converter is required to convert DC into AC for grid. Distributed PV systems are connected to utility distribution circuits. Centralized PV systems are connected to utility transmission lines - Factors Relevant to Utility Integration of Intermittent Renewable Technologies – NREL, US DoE

Voltage variation issues from ImprovingGridPowerQualityWithFACTSDeviceonIntegrationofWindEnergySystem and Power Quality of Wind Turbines doctoral thesis

5. TN Wind evacuation proposed Phases I & II

Phase I

- Establishment of Kanarpatti 400/ 230 KV SS & allied transmission lines.
- Establishment of Kayathar 400 / 230 - 110 KV SS & allied transmission lines
- 400 KV DC line link from Kayathar to Karaikudi
- 400 KV DC line link from Karaikudi to Pugalur
- 400 KV DC line link from Pugalur to Ottiambakkam.

Phase II

• Establishment of 400/110 KV SS at Thappakundu area.

• Establishment of 400/230 - 110 KV SS at Anikadavu area

• Establishment of 400/230 - 110 KV SS at Rasipalayam area

• 4 Nos. 400 KV Bay provision at Salem 765/400 KV SS for Rasipalayam – Salem 400 KV (PG-CIL) – Singarapet DC line.

6. India Smart Grid Task Force Mission and National Smart Grid Mission

India Smart Grid Forum lists out the stakeholder expectations from a smart grid

Customers:

- *Expand access to electricity – "Power for All"*
- *Improve reliability of supply to all customers*
- *Improve quality of supply*
- *User friendly and transparent interface with utilities*

Utilities:

- *Reduction of T&D losses in all utilities to 15% or below*
- *Peak load management – multiple options*
- *Reduction in power purchase cost*
- *Better asset management*
- *Increased grid visibility*
- *Self-healing grid*
- *Renewable integration*

Government & Regulators:

- *Satisfied customers*
- *Financially sound utilities*
- *Tariff neutral system upgrade and modernization*
- *Reduction in emission intensity*

The mission of the India Smart Grid Forum is to create smart customers, utilities, generation & transmission and policies over a period of 25 years from 2012 to 2027. All households will be electrified by 2020 and smart meters will be installed in all households by 2022. For providing access to electricity to all, microgrids have also been proposed as a solution – both isolated and those connected to the grid. AT&C losses will be reduced to below 15% by 2017 in distribution utilities and transmission losses will be below 3% by 2017. Losses will be reduced by investing in monitoring, controlling, auditing. Investments in automation, metering will help in power quality improvement. Utility specific strategic roadmaps will be developed before 2013 for developing reliable grid infrastructure with communication infrastructure. Pilots have been proposed and already allocated (next section). For demand side management, customers with load > 1MW by 2013, 500kW by 2015, 100kW by 2017 and 20kW by 2020 will be mandated to have a Demand Response (DR) infrastructure.

For RE, the National Smart Grid Mission (NSGM) aims to facilitate integration 30GW RE capacity by 2017 and 70GW by 2022 and 120GW by 2027. Along with microgrids, energy storage and better load and generation forecasting measures will be used to promote RE integration. The target for Electric Vehicle penetration is 2% nationwide and 5% in urban areas. To achieve energy efficiency, mandatory Building Management Systems (BMS) for commercial and industrial units with loads > 100kW and its integration with utility DMS have been proposed. Mandatory auditing for customers with >20kW, benchmarking, LED replacement, life cycle assessment of electrical equipments, promotion of CHP projects will also help in improving efficiency (Refer to Annexure 4 for detailed road map from ISGF).

NSGM road map

12th plan (2012-17)	**13th plan (2017-22)**	**14th plan (2022-27)**
1. Access to "Electricity for All" 2.Reduction of transmission losses (>66 kV) to below 3% 3.Reduction of AT&C losses in all Distribution Utilities to below 15% 4.Reduction in Power Cuts; Life line supply to all by 2015; grid connection of all consumer end generation facilities where feasible 5.Renewable integration of 30 GW; and EV trials 6.Improvement in Power Quality and Reliability 7.ToU (Time of Use) Tariff 8.Energy Efficiency Programs	1.Reduction of transmission losses (>66 kV) to below 2% 2.Reduction of AT&C losses to below 12% in all Utilities 3.Improvement in Power Quality 4.End of Power Cuts; Peaking power plants; Electrification of all households by 2020 5.Nationwide smart meter roll out 6.Renewable integration of 70 GW; 5% EV penetration 7.Standards Development for Smart Infrastructure (SEZ, Buildings, Roads/Bridges, Parking lots, Malls) and Smart Cities	1.Reduction of AT&C losses to below 10% in all Utilities 2.Financially viable utilities 3.Stable 24x7 power supply to all categories of consumers all across the country 4.Renewable integration of 120 GW; 10% EV penetration 5.Smart Cities and Smarter Infrastructures 6.Export of SG products, solutions and services to overseas 7.Research & Development; Training & Capacity Building 8.Active Participation of "Prosumers"

9.Standards Development for Smart Grids including EVs 10.Strengthening of EHV System 11.Efficient Power Exchanges 12.Research & Development, Training & Capacity Building 13.Customer Outreach & Participation 14.Sustainability Initiatives 15.SG Pilots, SG roll out in major cities	9.Research & Developments; Training & Capacity Building 10.Export of SG products, solutions and services to overseas 11.Customer Outreach & Participation 12.Sustainability Initiatives & Public Safety	9.Sustainability Initiatives & Public Safety

Source: ISGF

7. SCADA components

SCADA has software and hardware components for data acquisition, communication, presentation and control of processes/sites/systems in the electrical network. The over-riding manual control is always provided for manual intervention.

- A human–machine interface or HMI is the apparatus or device which presents process data to a human operator, and through this, the human operator monitors and controls the process.
- A supervisory (computer) system, gathering (acquiring) data on the process and sending commands (control) to the process. Or they are known as SCADA Master Units - These are larger computer consoles that serve as the central processor for the SCADA system. Master units provide a human interface to the system and automatically regulate the managed system in response to sensor inputs.
- Remote terminal units (RTUs) connecting to sensors in the process, converting sensor signals to digital data and sending digital data to the supervisory system. These are small computerized units deployed in the field at specific sites and locations. RTUs (Remote Telemetry Units) serve as local collection points for gathering reports from sensors and delivering commands to control relays.
- Programmable logic controller (PLCs) used as field devices because they are more economical, versatile, flexible, and configurable than special-purpose RTUs. PLCs are used for data acquisition

- Communication infrastructure connecting the supervisory system to the RTUs in the field.
- Various process and analytical instrumentation. This would include the Sensors (either digital or analog) and control relays that directly interface with the managed system.

Source: Wikipedia - http://en.wikipedia.org/wiki/SCADA; http://www.dpstele.com/white-papers/scada/page8.php – White Paper on SCADA

8. RAPDRP Project

The all-India Restructured Accelerated Power Development & Reforms Program (RAPDRP) aims to reduce all-India average AT&C losses from 27% in 2009-10 to 15% levels[140]. Utilities with losses greater than 30% have to reduce their losses by 3% per year. All other T&D utilities that have less than 30% losses are expected to reduce losses by 1.5% per year[141].

The program has two parts – Part A and Part B. Part A involves establishment of baseline data and IT applications for energy accounting/auditing in towns and cities with population > 30,000 and SCADA for big cities (population > 4 lakh and Energy Input > 350 MU). Part B involves strengthening of 11kV distribution systems and will cover system improvement, strengthening and augmentation. New breakers, numerical relays, bay controllers and transformer monitors will be added to modernize the distribution system. There will be an improvement in HT: LT (High Tension: Low Tension) ratio. The desired ratio is 1:1. Generally the ratio is much lower i.e. LT>HT. High HT/ LT ratio indicates lower losses. The losses for a given quantum of power supplied by a line are inversely proportional to the square of its operating voltage. Therefore, by increasing the HT lines the losses will be reduced since HT lines relay power at high voltages[142]. Addition of Volt-VAR Compensation systems[143] to regulate the transmission voltage and improve power quality will be taken care of under Part B.

In exceptional cases, where sub-transmission is weak, strengthening of 33kV and 66kV levels may also be considered. The RAPDRP scheme was approved by the Centre in 2008. Implementation period for Part A was 3 years and for Part B was 5 years from the date of sanction. Part C will be an enabling component for implementation of RAPDRP and Part D will allow for a provision for incentive for utility staff in towns where AT&C losses will be brought below 15% target[144]. For financing, Government of India will provide 100% loan for Part A and up-to 25% loans for Part B. The total expected outlay is Rs51,577 Cr. Outlay for Part A is Rs10,000 Cr. and for Part B is Rs40,000 Cr[145].

140 PFC (Power Finance Corporation) is the nodal agency for operationalization and implementation of the program
141 State utilities target from http://www.apdrp.gov.in/Forms/Know_More.aspx.
142 Concept of HT:LT – reference from Loss Reduction and Efficiency Improvement: A Critical Appraisal of Power Distribution Sector in India report, IIT Bombay
143 Modernization project information from Smart Grid Vision and Roadmap for India from India Smart Grid Forum. Benefits of VAR compensation from Wikipedia
144 Information on enhanced RAPDRP scheme for 12th plan from Working Group on Power for 12th Plan (2012-17)
145 Outlay and all India sanctioned and disbursed figures from Working Group on Power for 12th Plan (2012-17)

At a national level, as per the 2011 Census, 1401 towns have been covered under RAPDRP (of 7935 towns eligible for RAPDRP) has been successfully extended to smaller towns. The remaining 6534 towns are to be covered under 12th and 13th Five Year Plans of which 3250 towns have been proposed for the 12th Plan[146].

9. RPOs, RECs, exemptions and access to connectivity for private generators

Policy incentives for RE installation and generation include tax exemptions, feed-in-tariffs and subsidies. Besides this every state has to meet an obligation of sourcing a certain % of their energy from RE. This is called the Renewable Purchase Obligation (RPO). The RPO target depends on the available renewable capacity in the state. For 2011-12, BESCOM, MESCOM and CESC have a solar RPO of 0.25% and a non-solar RPO of 10%. In TN, the solar RPO was 0.05% and non-solar RPO was 9.95% for 2011-12[147]. The new solar policy mandates a 6% SPO for HT consumers and certain types of LT consumers.

RE generators are given the option to sell their power at "preferential tariff" rates. Others who wish to sell at Average Pooled Power Cost (APPC)[148] can benefit from Renewable Energy Certificates (REC) (APPC+REC rates). Captive generators can also use the "captive+REC" route for benefiting from RE generation. REC mechanism can be used for fulfilling the RPOs of the DISCOMs, open access and captive power plant users. RECs are traded on IEX, where one REC is equivalent to 1MWh (1000units). RECs can be solar or non-solar based on the generating source to meet the solar or non-solar RPOs. The solar RECs trade within the price band of Rs12,000-17,000/REC and non-solar RECs trade within the Rs1,500-3,000/REC band[149]. As of 27 October 2012, projects registered across India under the REC scheme had a cumulative capacity of 3291.798MW. Wind accounts for 56.93% of the total registered capacity. With 735MW of registered wind projects and 129MW of registered biomass projects, TN leads[150]. Ka has 127MW of registered wind projects. Ka government is working on the registration of solar projects under REC scheme.

Since RE installations are smaller in size, a group of generators with more than 50MW[151] of aggregate installed capacity can benefit from the access to connectivity. They can apply to the Central Transmission Utility (CTU) for direct connection with the interstate transmission system. If the capacity is more than 250MW, the transmission line to the point of connection will be taken care of by the CTU and CEA (the generator does not undertake the construction).

To promote solar investments, solar plants commissioned by 2014 will not need to pay the Inter State Transmission System (ISTS) charges.

146 RADRP status from Smart Grid Vision and Roadmap by India Smart Grid Forum

147 Ka and TN figures from REConnect-Newsletter-Volume-XV

148 APPC - 'Pooled Cost of Purchase' means the weighted average pooled price at which the distribution licensee has purchased the electricity including cost of self-generation, if any, in the previous year from all the energy suppliers long-term and short-term, but excluding those based on renewable energy sources, as the case may be – HP Regulatory Commission In TN – APPC price hike announced in September 2012 is expected to promote the APPC+REC route for wind generators. Current APPC is Rs.254 per unit vs. previous price of Rs 2.39 per unit – REConnect Energy website

149 Pricing band from REConnect Energy website

150 Registered projects data – India, TN and Ka from REConnect-Newsletter-Volume-XXVI

151 For 50 and 250MW, data from Green Energy Corridor report

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