ISSN 2229-5518

Renewable Energy Integration into Smart grid: Problems and Solutions Based on Indian Power Scenario

Abhilash M G[1], Parvathy P[2], Divyasree dinesh[3]

[1]M.Tech Power System, Department of Electrical and Electronics Engineering,
Thejus Engineering College,Vellarakad,Thrissur (Dist), Kerala
abispash@gmail.com

[2]M.Tech Power System, Department of Electrical and Electronics Engineering,
Thejus Engineering College,Vellarakad,Thrissur (Dist), Kerala
parvathy.minipradeep@gmail.com

[3]M.Tech Power System, Department of Electrical and Electronics Engineering,
Thejus Engineering College,Vellarakad,Thrissur (Dist), Kerala
divyasreedinesh1@gmail.com

Abstract: ***On account of unevenly distributed renewable resources with more than 72,422 MW installed capacity with an estimated potential of about 189,000 MW it is really a challenge to integrate the same into the smart grids in a country like India. Of course with major sources of generation being thermal, entire thrust has been put in recent years on the development of renewable resources so that it would run side by side to the conventional ones. At the same time vast assets created in transmission and distribution will also continue to be gainfully used. The paper discusses the problems and solutions regarding the integration of nonconventional energy sources into the smart grid based on the current scenario. It outlines the systemic approach that is required to address both the technical and non-technical issues associated with the implementation.***

Keywords: Smart grid, Renewable energy sources, spinning reserve, frequency regulation.

1. Introduction

We are at the crossroads of a great transformation in the way electricity was perceived traditionally. A revolutionary make over from a central, utility controlled network to a grid that is less central and more interactive with the consumers is coming. The upgrade to a smart grid promises to widely affect the industry's entire business model that consisted of vertically integrated entities and its relationship with all stakeholders in the service chain affecting and involving utilities. Energy service provider's regulators, technology and control dealers, and users will all be impacted. Integration of Renewable Energy Sources to Smart Grids has already drawn due attention of the nation. India is at a preliminary stage of its smart grid deployments with many technologies, such as advanced metering and remote sensing of renewable generation, still at a very crucial juncture. Its deployment is being reviewed and tested at certain pilot's sites around the country. Such technologies are undergoing various trials and advanced testing before they could be deployed around the country.

The coherence of many factors would drive India's adoption of smart grids, such as reducing all technical and commercial losses to resolve the ongoing supply/demand gap. India is upgrading its infrastructure to a more advanced electricity supply solution that has sustainable, low carbon, high growth economic development goals. Certain factors will drive the adoption of India's smart grid. All the sectors of renewable energy are being developed. However, the wind power program has been the fastest growing that contributes to about two-third of the grid connected renewable energy power installed capacity, as of now. Of course with the potential estimated on solar power, total of off-grid and on-grid of this form of renewables would lead in the long run. Initial development of renewables concentrated following isolated systems. But with the advancement of technology with higher size and more number of units, particularly with wind power plants, being feasible at place grid connectivity has improved. At the same time gradual evolution of intelligent or smart grid employing extensively communication and information technology is paving the way for connection to the grid even for the remotely located plants. However, unlike developed countries, as India is still away from the use of Electric Vehicles, immediately on account of this use of battery storage is not possible. Of course in some areas battery storage is in use (particularly with computer and communication facilities), mainly due to overall shortage in peak power and to some extent on quality of supply [1].

2. Smart grid technology

With the restructuring and broadening of power sector infrastructure; introduction of new regulations; open sourcing; and increasing the share of renewable energy in energy transactions, it is very important to design and operate the Indian grid as a centralized national smart grid. The combined total capacity of the centralized grid is estimated to be in the range of 300 GW, consisting of about 40 –50 GW of renewable energy in the next few years. Integrating renewable energy, with wind as

ISSN 2229-5518

the main energy source would lead to an increase in the complexity of monitoring and control of such a large grid, because wind is intermittent rather than constant. Application of advanced synchrophasor measurement technology, rather than the traditional electric meter, may to some extent provide the needed interface for the wide area monitoring of such a widespread grid[2].

The information and communication technology in the smart grids enables it to make envisioned benefits a reality. These technologies encompass a wide range of operations, such as detecting and identifying faults and a quick response to power outages; providing consumers with near real-time information on the amount and cost of the power they use; improving the security of the system; and linking all elements of the grid to enable better decision making on resource use. With continual up-gradation and modifications these technologies will produce more and better quality data that will give the utilities more flexibility and new opportunities to improve their analysis in areas, such as customer load patterns and tariffs, and thus offer better services to their customers. The technology makes more efficient use of the grid to identify and correct supply and demand imbalances instantaneously and detect faults in a self-healing process that improves service quality, enhances reliability, and reduces costs [3].

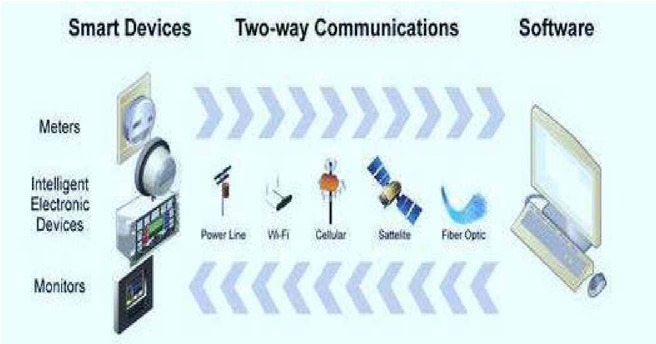

Figure 1: Smart Grids Provide Two-way Communication

Several of the initiatives that have already been introduced into the system include Supervisory Control and Data Acquisition (SCADA), Distribution Management System (DMS), Distribution Automation System (DA), Energy management System (EMS), Automated Meter Reading (AMR), Outage Management System (OMS), Enterprise Resource Planning (ERP) and Geographical Information System (GIS). Installing the latest technology and systems in the power system promises a decrease in loss levels and a subsequent increase in the reliability of the network. Successful implementation of the smart grid would also require introduction of a Wide Area Measurement System (WAMS) based technology for achieving grid performance. Installation of Phasor Measurement Units (PMU's) at the utilities is a prerequisite for WAMS [4].

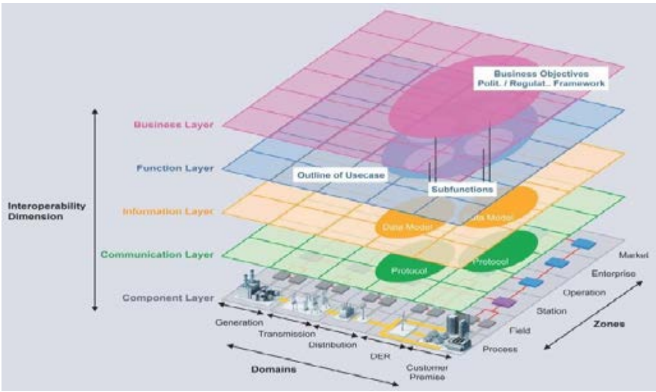

Figure 2: Various Layers of Smart Grid Infra-Structure

3. Large scale wind and solar into the grid

Integrating wind and solar energy into the grid will allow the grid to be far more reliable, independent, and efficient and self-remedial in case of power system breakdowns and blackouts; allowing clusters of local communities to receive power from the local renewable generation and lead to a grid transition from a non-self-healing infrastructure to a detection and control infrastructure. To a large extent, this integration is directed towards managing peak loads; offering new services to meet user needs at an individual level; and improving asset use. It involves a systems approach to develop and demonstrate the technical, regulatory, economic and other barriers in the use of renewable energy and distributed generation [5].

3.1. Challenges

The major focus for the integration of renewable energy is on wind and solar in India and while some development is already underway, wind and solar energy both suffer from a technical issue of intermittency; a variability that cannot be controlled; unpredictability to some extent; and location dependency. Grid operators and generation owners face three distinct issues in integrating wind and solar energy into the grid: non controllable variability, Extensive unpredictability and Dependency on locations

3.1.1Non controllable variability

In the context of renewable energy resources, variability refers to a non-steady output. It is different from unpredictability, in the sense that even if operators are able to predict wind and solar output perfectly, the output will still tend to be variable and pose challenges to the operator. Grid operators need to deal with fluctuations in voltage and frequency on a second to minute scale that, if left unchecked, can do significant damage to the system, including the equipment attached with it. A possible method of doing that may be to inject power (active or reactive) into the grid having a technical characteristic of balancing the actual to the forecasted power generation which is pivotal to maintaining a steady voltage as well as frequency on the grid. There may be a number of names and descriptions of such ancillary services.

An overview of the various services observed consists of:

- **Frequency regulation**: Mainly done by automatic generation control (AGC) signals to renewable generation and occurs on a seconds-to-minutes basis.
- **Spinning reserves**: When a generator goes down or deactivates abruptly in the system, the spinning reserves come into action providing power within few minutes.
- **Non-spinning reserves**: Even though observing the same function as the spinning reserves, the non-spinning reserves have a much slower response time.
- **Voltage support**: These generators are used for reactive voltage in order to increase the voltage whenever needed.
- **Black-start capacity**: In case of a cascading black-out these generators are available to re-start the power system.

In addition, grid operators also need to track the load deviations over the course of the day and ensure that supply always matches the demand. The load following function becomes more important at peak load times of the day when electricity demand increases significantly. On the flip-side, grid operators have always maintained the voltage and the frequency, following load shifts and maintaining reserves since the installation of the electrical grid. This is attributed to the varying nature of loads. Moreover, conventional generation also faces problems time and again and the scheduled performance is not obtained. Consume demands, while predictable, have some degree of variability. Wind and solar generation does not introduce problems that generation operators have never faced. While as at low penetrations, integrating the renewable energy introduces local grid specific and primarily device problems, such as harmonics and sub synchronous resonance; but, at relatively high penetrations, wind and solar generation adds more non-uniformity to the energy system that grid operators may not have faced before, thus introducing the need of ancillary services and energy balance over-all[5].

3.1.2. Extensive unpredictability

Unpredictability or uncertainty differs from variability in which solar and wind generation is present always, as a result of reliance on the ever changing sunlight or wind speed affecting the system on a moment to moment time scale. Unpredictability on the other hand, relates to our innate inability to predict whether the wind and sun will be available for energy generation an hour or a day later. Unit commitment is used by the grid operators to manage majority of energy on the grid and hence the hour to day uncertainty is not as significant. Unit commitment refers to the process of scheduling generation beforehand, generally around a day ahead, with the purpose of meeting the expected load. Consequently when production does not meet the demand, the grid operator employs ancillary services to meet the difference.

Renewable energy generation leads to an increase in the spread between supplied and predicted energy and hence leads to an increased cost. At present, unit commitment is largely deterministic implying that once a generator is run-scheduled, it is expected to run at full capacity. This practice shows in the relative predictability and controllability of traditional generation. Availability of resources is ensured by the operators, generators that hold the supply of energy in order to be ready to balance the supply and demand and hence protect against possible generator and transmission line outages.

A complex problem arises when the process of unit commitment and reserve calculation in order to ensure reliability is calculated based on hypothetical or random data and hence carries uncertainty. Weather predictions by forecasting technologies predicts the wind and solar resources at various time frames more accurately and consequently communicates the predictions to grid operators allowing the operators to schedule and dispatch resources more effectively. Anticipating solar and wind output levels properly allow the operators to modify the generator schedules more dynamically and result in optimal use of all the assets by the grid operator. Advanced unit commitment methods assist the operator in the processes that prepare the system for potentially uncertain outcomes not predicted by forecasting technologies [6].

3.1.3. Dependency on Locations

Long term planning, such as the utilization of new transmission lines, is not addressed to in the day-to-day management of the grid. Even though renewable energy generation plays a very important role in this scenario, it introduces new challenges. Wind and solar energy resources are often present in remote areas far from the areas of actual usage. Being far from load centers, development of sufficient transmission infrastructure is crucial for the integration of renewable energy into the grid. Transmission planning policies are highly varied and tend to be affected by regional politics. Capacity for energy production may be found in one state, pass through another and finally be utilized in another state. Such disparities in generation capacity, location of transmission capacity and variations in load size between various locations makes the development of renewable energy transmission complex, and more so with respect to cost allocation.

Since new transmission infrastructure that will be established will primarily carry renewable energy generation, variable electricity, certain technical needs come up regarding the technology used for transmission. Distributed energy resources provide for an alternative flexible version of the future grid where energy generation and use is local on a micro-grid thus preventing the transmission losses and capital costs of transmission lines. The electric grid can be conceptualized as a collection of n cluster grids spread all over the country and working together in order to significantly reduce drastically the energy transmission needs[7].

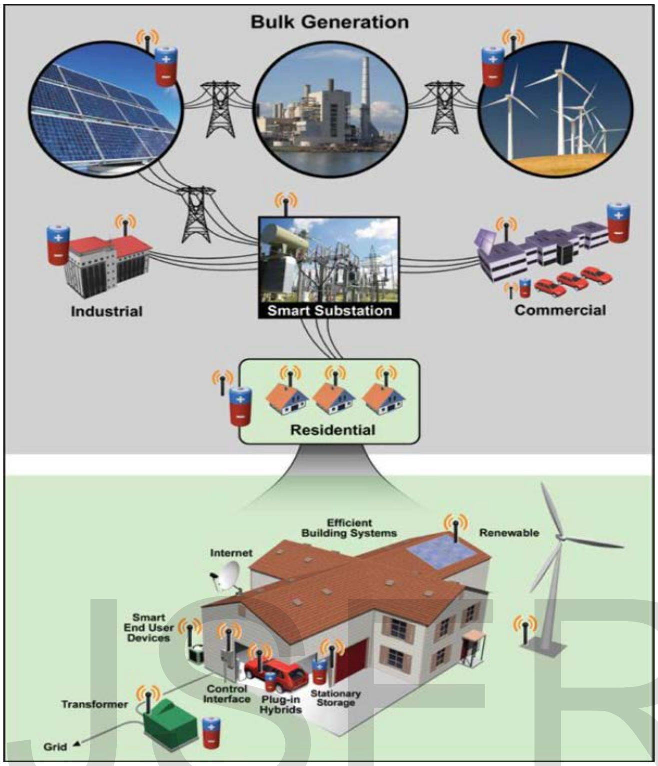

Figure 3: Renewable energy integration to smart grid

3.2. Solutions

Reactive compensation solutions that provide rapid response, such as dynamic static compensators (DSTATCOMs), have proven effective at mitigating some of the impact of fluctuating renewable energy output on power systems. Such systems are typically applied at wind and solar plants larger than 10-15 MW. Transmission system operators in many areas of the world have developed strict interconnection requirements for renewable energy plants to protect transmission systems against such output variability. DSTATCOMs are effective at providing VAR support, but real power is needed to smooth electricity generated by photovoltaic (PV) panels and to manage PV ramping.

New volt/VAR optimization (VVO) technology also can help address the impact of renewable energy resources on power grids. The latest solutions can provide a comprehensive solution by optimizing and adjusting voltage profiles for all distribution feeders served by a substation, thus helping address the voltage swings that can result from varying renewable energy output. VVO solutions also can use data from advanced meters to provide better monitoring of voltage levels at the customer level to ensure levels remain within the appropriate band to provide desired power quality levels.

Advanced metering infrastructure and associated home energy management solutions also might play roles in aligning intermittent renewable energy supply with demand in real time. The idea is that advanced meters, when paired with the appropriate in-home technology, can enable consumers to use energy only when renewable energy supplies are generated and thus can match demand with renewable energy supplies [8].

This approach, however, remains a theory. Such capabilities aren't available at this stage. Even if consumers could use this technology, it's unclear whether they would be willing to shift their electricity usage, often inconveniently, unless they would save a significant amount on their electricity bills. The savings would have to make up for the inconvenience. Moreover, utilities still would need to maintain backup energy supplies to continually balance electricity supplies with demand in real time because such balance is crucial to ensure grid stability.

4. Conclusion

With Renewables coming as big source of electric energy and due to its high potentials, particularly in the areas of wind and solar power, in the years to come it will form sizable part of generation feeding the grid. However, as it comes with unpredictable and variable contribution, while integrating smart grid utilizing advanced technologies of digital computing and communication has to operate and control the power system within the acceptable ranges of parameters. Regulatory

ISSN 2229-5518

mechanism in India, some already in vogue and others gradually coming to be in force encourages to promote distributed generation and renewables and protects the concerned green energy sources to meet the electricity demand at every instant of time along with centralized conventional thermal or nuclear generation. But at the same time stringent measures need to be complied with in operation while connected to grid, of course taking advantage of advancement in technologies as available to the smart grid which over the years has changed from what it was in the past in terms of operation and control.

References

[1]. Subrata Mukhopadhyay, "Towards Electricity for All," IEEE Power & Energy Magazine, vol. 3, pp.
[2]. Gupta Alok, “Distributed Generation and Renewables”, Central Electricity Authority, New Delhi, India, Report of Indian Smart grid.
[3]. Gurlin Singh Lamba, “Smart Grid and its Development Prospects In the Asia-Pacific Region,” Journal of Emerging Trends in Computing and Information Sciences, January, 2011
[4]. Roger N. Anderson, the Distributed Storage-Generation “Smart” Electric Grid of the Future, The Pew Center on Global Climate Change and the National Commission on Energy Policy, March, 2004
[5]. North Delhi Power Limited, Smart Grid Project in India, August, 2011
[6]. National Energy Technology Laboratory, Smart Grid Implementation Strategy, U.S. Department of Energy, 2008
[7]. Muhammad Qamar Raza, Muhammad Ali, Nauman Tareen, Waheed ur Rehman, Asadullah Khan, and Azam Ul Asar,“Intelligent Load Shedding Using TCP/IP for Smart Grids,”Energy and Power Engineering, November,2012
[8]. International Energy Agency, Technology Roadmaps – Smart Grid, February, 2013

Authors Profile

Abhilash M G currently pursing M.Tech in Power systems from Thejus Engineering College, University of Calicut, Thrissur, Kerala. He complteted B.E in Electrical and Electronics Engineering from Dr. M V Shetty Institute of Technology, Mangalore in 2012. His areas of interests includes Power system operation and control, micro controller, control systems and Renewable Energy.

Parvathy P holds a B.Tech.degree in Electrical Engineering from Amrita Viswa Vidyapeetam in 2012. Curently pursuing M.Tech in Power Systems from Thejus Engineering College, University of Calicut ,Thrissur, Kerala. Her areas of interests are Renewable energy, Power system, its protection, management and optimization; and Smart Grid.

Divyasree Dinesh received B.Tech.degree in Electrical Engineering from Amrita School Viswa Vidyapeetam in 2013., currently pursuing M.Tech in Power Systems from Thejus Engineering College, University of Calicut, Thrissur, Kerala. Her areas of interests are Power system optimization, Power Quality and Smart Grid.