CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

With increase in demand for quality electricity, power production using various methods of Renewable Energy Sources (RES) has come into existence. This has increased to a greater extent in recent years and so addressing of associated problems with its integration into the existing system is required. Initially, installed capacity of wind energy was of a fraction of the existing system and so connection into the grid was not of a problem. But with increased share, requirement of continuous connection with greater reliability, stability of the system, and power quality need to be addressed of which voltage stability and Low Voltage Ride Through (LVRT) need to be concentrated more. In this chapter an introduction to wind energy and its integration into the grid is presented. In this chapter, discussion on objective, problem statement of the thesis and its organization is presented.

1.2 WIND ENERGY SCENARIO

Wind energy technologies are gaining day by day and this fast technological development is useful for scientists, electrical engineers, wind turbine manufacturers etc., There are many countries that are generating wind power like US, UK, France, Italy, India, Spain, Germany etc., In 2016, global wind power installed capacity increased by 63,330MW after crossing the 50GW production in the year 2015. As on 31st March 2016, India has an installed wind capacity of 26,769MW mainly spread across South, West and North regions[93] which accounts to 8.6% of India's total installed capacity. In wind energy production, Asia was found to be the largest market in the world[94] in which India was continued to be the second largest one. Initially in India only 3GW production was there till 2011 later the development has reached to a greater extent. The target of the Indian government by 2020 is of 175GW, with 100GW of solar power and 60GW of cumulative power. The cumulative capacity of
Japanese has reached to 3038MW whereas the South Korea with 225MW. US market reached to 74471MW, Canada of 11.2GW, Mexico with 3073MW and Europe with 147.8GW.

The total installed capacity in India by the end of 2017 March has reached to 32.17GW making India as the fifth largest electricity generator using wind. Out of this renewable power plants constituted 28% of total capacity and Non-renewable power plants constituted the remaining 72%[94]. The gross electricity generated by utilities is 1,106TWh and 166 TWh by captive power plants. In order to meet the demands of the customers and to meet the demand for power generation, production of electrical energy using RES has come into existence. The advantage by going for renewable energy is that it reduces losses at the distribution side, cost of the fuel, increase in economy, supply and monitoring of distribution by the villagers itself, and availability of required energy at the customer door step with reasonable prices. Out of the various renewable energy sources wind energy is one of the important sources of electrical power. Hence, importance must be given to study the stability concepts with wind farms. As the production of electrical power using wind energy is different from that of the conventional methods, integration of this into the existing system will be different from that of the regular methods.

Electricity generated using wind energy has been into existence since a long time for various purposes like water pumping, grinding, driving and pushing of boats etc. the development of wind power in India began in 1986 with its first farm being set up in the coastal regions. Since then the interest in wind power has increased with new demand for clean and sustainable energy sources. Wind power constitutes a significant alternative source as it is non-polluting. With these demonstration projects the capacity has significantly increased in last few years[91]. Although India is a relative new comer to Denmark or the United States, it has the fourth largest Installed power capacity in the world[91-92]. In the year 2009-10 India's growth rate was highest among the other top four countries.

As on 30 June 2016 in India wind energy has reached to 27,151MWs of that spread across northern region, southern region and western regions[82,93]. With increased reliability, high performance induction machines, and lesser time period for
installation of wind farms made production of electricity using wind as the preferred choice in India[94]. With the above benefits wind energy sector is growing across all states in India as shown in table 1.1.

**Table 1.1 State wise % of wind potential utilized in India (As on Oct'2016)**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Indian States</th>
<th>Installed Capacity in Wind Potential</th>
<th>% Utilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Tamilnadu</td>
<td>7684</td>
<td>33,800</td>
</tr>
<tr>
<td>2.</td>
<td>Maharashtra</td>
<td>4664</td>
<td>45394</td>
</tr>
<tr>
<td>3.</td>
<td>Gujarath</td>
<td>4227</td>
<td>84431</td>
</tr>
<tr>
<td>4.</td>
<td>Rajasthan</td>
<td>4123</td>
<td>187700</td>
</tr>
<tr>
<td>5.</td>
<td>Karnataka</td>
<td>3082</td>
<td>55857</td>
</tr>
<tr>
<td>6.</td>
<td>MP</td>
<td>2288</td>
<td>10484</td>
</tr>
<tr>
<td>7.</td>
<td>AP</td>
<td>1866</td>
<td>44229</td>
</tr>
<tr>
<td>8.</td>
<td>Telangana</td>
<td>98</td>
<td>4244</td>
</tr>
<tr>
<td>9.</td>
<td>Kerala</td>
<td>43</td>
<td>1722</td>
</tr>
<tr>
<td>10.</td>
<td>Others</td>
<td>4</td>
<td>3342</td>
</tr>
</tbody>
</table>

In order to have growth in economy and to have more wind power generation, state governments are also taking initiatives by providing incentives. Especially in Andhra Pradesh there are many stations commissioned and few more are planning to invest on the same.

As an example Greenko Group commissioned 51.2 MW in Balavenkatapuram in Anantapuramu district with GE 1.6XLE turbine. It is also planning to have additional 50MWs. Mytrah Energy Ltd is having 100MWs wind power project in Vajrakarur in Anantapuramu district and this company is also planning to have another project with 200 MWs capacity[95]. New and Renewable Energy Development Corporation of Andhra Pradesh(NREDCAP) is planning to setup 5.95MW wind power project in Rekalakunta, Anantapuramu district, AP, Wescare to setup 13.5MW in Kadavakallu in Putluru in Andhra Pradesh, Nalco has setup 50.4MW plant in Gandikota in Kadapa district, Hyderabad chemicals to set up
4.5MW at kadavakallu ridges in Anantapuramu district, Bhima Cements is planning to invest 5 wind power projects each of 1.5 MW (5X1.5MW) and Tirumala in Andhra Pradesh is having 6 wind turbines each of 1MW built by Suzlon for Tirupathi Temple. With pressing demand for electricity production many firms are planning to invest more on wind energy power generation.

In order to have considerable importance towards economy growth majority countries are supporting production of electricity using wind energy. In India during mid of 90's because of the reduction in tax and provision of subsidies provided by the government to the private sector, production of energy using wind has also improved to a greater extent. The installed wind power capacity was of 750MWs in Tamilnadu and 166MWs in Gujarat during 1990's. This was approximately as equivalent as Denmark's wind power system. Majorly power system in India is divided into 5 grids as on 2016, where Tamilnadu is a part of the southern grid associated with three other states Andhra Pradesh, Kerala and Karnataka.

1.3 GRID INTEGRATION CHALLENGES OF WIND POWER

Wind energy sector is growing more in India in spite of variations in economy and is considered to be as the most matured industry. In general in India, these farms will be located in rural regions, where distribution and transmission grids will be weak and will not be in a position to be interconnected with wind power. Because of this ineffective capabilities, the integration causes more variations on steady state voltages and causes power failures. As the sub stations will not be having automatic voltage compensating devices, the complications will be too high. Thus, insufficient capacity of the grid and equipment also affects the operation of the turbines. So, impacts of integration of the wind farms into the existing system need to be studied.

In addition to this, the Wind Energy Conversion System (WECS) also affects the system very badly due to variation in wind. Intermittent nature and diffused wind power causes more negative impacts on the integrity of the grid i.e., security, stability and quality of power. Conventional generation, and their integration into the grid is well understood by the utility operators. As the wind energy penetration is of only 20-
30% of the existing system, majority of the equipment to be used from the conventional ones and so one need to understand the concepts well.

This, Therefore, implies that certain new technologies need to be implemented for smooth and proper integration of the WECSs in to the existing grid.

Grid connected wind turbines will be very close to the consumers and so the voltage at PCC will mainly depends on the load of the consumer and the turbine used. Thus, the quality of power mainly depends on the level of penetration, voltage frequency and its ability to manage the reactive power consumption. The major parameters that need to be considered in an AC system are its system frequency, Active power(P) and Reactive power(Q), system voltage(V) and harmonics. These parameters can be controlled using different devices depending upon the quality required but implementation of these controlling devices depends upon the wind penetration levels.

Another major issue in the development of the WECS in India is its transmission capacity where they are built. Also, as they were limited to certain areas, strengthening of these areas and their integration into the existing system also affected the industry development in a fast manner. Later with the advancements in power electronic technology and new wind turbines wind power generation in India has ranked 6th in the world.

Thus generation, utilization and integration are the challenges that are in front of the researchers today[74]. In order to have large scale integration, knowledge on operation and planning of the grid are required. The major points that need to be concentrated after integration are its impacts on

1. Security of the system
2. Imbalances in power
3. Voltage Control
4. Reserve management
5. Power Quality
   5.1 Harmonics
   5.2 Flickers
5.3 Voltage Dips

5.3.1 LVRT

6 Stability

Thus the severity in integration of WECS can be reduced by[70]

- Choosing wide locations geographically
- Super grids and smart grids
- Better storage technologies
- More prediction methods
- More grid codes
- Strengthening of the existing grids
- WPP capabilities

Out of all power quality is the major issue in which maintenance of voltage plays a major role. In this thesis an attempt is made to investigate the major aspects of the power quality that are voltage fluctuations and reactive power compensation.

The purpose of an electric power system is to transmit the generated energy from generator terminals to distribution end. In order to achieve this voltage must be kept close to normal value conventionally is achieved by using different methods for transmission and distribution networks. However, implementation of more wind turbines challenge the traditional approach. Based on the characteristics of the transmission networks, voltage control can be achieved mainly by changing the reactive power(Q) production or absorption, by using dedicated equipments like FACTS, capacitors banks etc. Where as in the case of distribution networks it can be achieved by changing the turns ratio of the transformer and by using shunt reactors and capacitors.

Because of the recent developments in electricity sector i.e., liberalization and decentralization, conventional methods of voltage control are becoming less as the grid companies are responding by going for the implementation of reactive power controlling devices separately and by using dedicated controlling equipments. So, wind turbines(WT) also require controlling capabilities on their own. Thus large scale
wind farms must install voltage control devices in the transmission network on their own irrespective of the controlling capabilities of the wind turbine.

In most of the cases WT will be setup at faraway places whereas the existing power plants will be near a load center or a large industrial site. When this conventional plant must be replaced with wind power plant, it may not be able to maintain voltage at PCC and requires additional controlling devices.

Thus WT must focus on contribution to the voltage control when they are connected to transmission or distribution networks. The vast majority of the wind turbines uses either SCIG, DFIG and Direct-Drive wind turbine (DDWT).

Two important approaches towards voltage control in distribution grid are implementation of tap-changing transformers and usage of devices that can generate or absorb reactive power. Usage of tap changing transformers is a cumbersome procedure than implementing the reactive power devices i.e., FACTS devices.

1.4 OBJECTIVES OF THESIS

The main objective in this thesis is to enhance voltage profiles in a WECS using FACTS devices during dynamic and transient operating conditions. This work aims in identifying the suitable generator for the wind turbine during variable speed operation with better control, steady state stability of the system is analyzed on a test system. The simulation tests are conducted on the four bus test system during dynamic and transient stability conditions thereby enhancement of voltage profiles during these cases using the FACTS devices such as SVC and STATCOM with intelligent control like fuzzy logic controller. It is found that STATCOM performs better than SVC. Hence the concepts are extended to an IEEE 9 bus system.

1.5 ORGANIZATION OF THESIS

The organization of thesis is as:

In Chapter 1, wind power scenario and its challenges when integrated to grid is discussed. Also, in this chapter objectives, and thesis organization is presented.
In Chapter 2, literature reviewed for different types of generators used in turbines, reviewed about the grid integration challenges, state of art technologies i.e. about FACTS controllers in Wind farms for enhancement of different performance parameters.

In Chapter 3, wind farm is used a source for the system where an attempt is made in developing SIMULINK blocks for the distribution network. Identification of suitable induction generator is done based on the comparative results obtained by implementing Squirrel cage Induction Generator and Doubly fed Induction Generator. The proposed analysis is done on a test system and results are presented.

In Chapter 4, steady state stability and dynamic stability analysis on a four bus test system is presented using SIMULINK. The impact of the wind farm on the distribution network during load variation, improvement of voltage profiles using SVC, STATCOM with intelligent controllers like fuzzy controller is presented. From the identified better FACTS device, the simulation is extended to IEEE 9 bus system and the results are presented.

In Chapter 5, Transient analysis of the system is presented using SIMULINK. The impact of the wind farm on the distribution network during different types of faults and improvement of voltage profiles using SVC, STATCOM with fuzzy controller is presented. Based on the results, implementation of fuzzy based STATCOM is extended in an IEEE 9 bus system and the results are presented.

In Chapter 6, the results and detailed discussion of the work is presented and in Chapter 7, the conclusions and future scope of the thesis are presented.

1.6 CONCLUSIONS

Grid integration of wind farms and enhancement of voltages during disturbances in a system is considered to be as one of the important concept. The main wind energy scenario, objectives and organization of the thesis is projected in this chapter.