Integration of Wind Farm into A Weak Distribution Network

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Abstract—Wind generation is most rapidly increasing resource in the renewable energy field. Wind farm has a large installed capacity in the world now days. The wind power integration have some effect into the power system grids as power system issues: transmission congestion, optimal power flow, system stability, power quality, system economics and load dispatch. The integration of wind farm into power system mainly in weak distribution is a challenge because of the voltage control, reactive power compensation, under voltage tripping and voltage collapse problem occur in the weak distribution network. STATCOM is apply in the system for dynamic reactive power compensation then the system absorb the reactive power without the tripping and the wind farm is also use in the system and voltage profile is also maintaining.

Keywords-- STATCOM, Wind farm, Integration effect, Voltage control, Reactive Power.

I. INTRODUCTION

Since early times, man has harnessed the power of the wind for a series of tasks. More the 4000 years, wind energy have been used in their daily work as used in to grind grain, while others used the wind to transport armies and goods across oceans and rivers. The share of wind farm with respect to total installed power capacity is increasing worldwide. India’s electricity demand continued to rise from last few years. Electricity shortage is common, and over 40% of the population has no access to present energy services [1,2].

The growth of wind energy has been driven by a diversity of factors including government subsidies on the renewable energy and tax incentives, improved technology, higher fossil fuel prices and investor concerns about potential federal action to reduce carbon emissions, which could make electricity from fossil fuels more expensive now a days [3,4].

Conversion of wind energy system is more important because it converting wind energy in to the electrical energy. The generated electrical power and loss in wind turbine generation system (WTGS) change corresponding to the wind speed variation, and consequently the efficiency and the capacity factor of the system also change [5-7].

Every wind energy system transforms the kinetic energy of the wind into the mechanical or electrical energy. There are huge variations in size, but all wind turbine from the smallest to the largest work in the same way. The vast majority of commercial turbines now operate on a horizontal axis with three blades. These are attached to rotor from which power is transfer through a gearbox to a generator. Some turbine designs avoid a gearbox by using direct drive [8]. The conversion system has three components: aerodynamics, mechanical, and electrical as shown in Figure 1 below [9].

Wind turbines classification is based on the basis of operating principle. The kinetic energy of the wind is converted into mechanical energy and then mechanical energy is converted into the electrical energy.

- Lift is the push that allows something to move up
- Drag is a force that tries to slow something down.

The magnitude of the lift and drag forces depends on the angle of attack, but each angle their value can be defined in terms of the aerodynamic force.

The integration issues is present in the system moreover, the supply system is being supply in the network.
The power quality related issues mainly consist of voltage regulation and reactive power compensation in the power system [10, 11].

Wind Energy System is to encourage support on wind energy research and development and to offer high quality information and analysis to member governments and commercial sector leaders addressing technology development and deployment and its benefits, markets and policy instruments. A new source of generating power wind energy is most hopeful source in the near world. Most of the countries are promoting the wind energy by introducing national programs and market incentives. The International Energy Agency (IEA), with funding from 14 countries, supports joint research projects and information exchange on wind-power development [12].

The grid connected wind energy is also increasing in the extremely fastest rate growth of electricity generation in the last few years. The growth renewable has some effect on the financial support mechanisms of various kinds. Output energy is improved due to reliability and the development of large machines. The wind energy is increasing continuous throughout world is the last few years. The world installed capacity of wind energy in last few years is shown in figure 2 and from the figure we see that the every year capacity of wind farm is increasing.

During the last 30 years there has been a significant shift away from oil and towards natural gas [13]. The grid connected wind energy is also increasing in the extremely fastest rate growth of electricity generation in the last few years.

The growth renewable has some effect on the financial support mechanisms of various kinds. Output energy is improved due to reliability and the development of large machines. The turbine is used for the residential purpose called the small wind turbine, and the turbine that is use for the commerical purpose called the large wind turbine. The range of the turbine as small wind turbine is low 300KW. Small wind farm units can be used in combination with other energy sources such as photovoltaic power or diesel generator off grid where the power transmission is very costly [14].

India has the large installed capacity of wind energy in the coastal area. India has the 5th rank in the wind generation throughout the world. In India, the wind energy is the most increasing resource in all the renewable resources. The wind energy is contributed around 70% of the total generation from the renewable resources. The growth of the wind energy in India is from last few years. The government has also some promotional work in the field of renewable energy and gives some incentive to the company. In figure 3, the total wind installed capacity of wind farm from last few years is shown as below.

![Installed Capacity of Wind (MW) in World](image1)

**Source:** Global Wind Energy Council (GWEC)

**Figure 2:** Year wise Installed Capacity of Wind Generation (MW) in World

World primary energy demand almost doubled between 1971 and 2003 and is expected to increase by another 40 per cent by 2020.

![Installed Capacity of Wind (MW) in India](image2)

**Source:** MNRE

**Figure 3:** Year Wise Capacity of Wind Generation in India
The state wise capacity of wind farm in India is shown in table 1. The Tamil Nadu is the first state that holds the first position in the installed capacity of wind farm. The total installed capacity of wind farm is 18,551 MW.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>State</th>
<th>Capacity (in MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Tamil Nadu</td>
<td>7154</td>
</tr>
<tr>
<td>2.</td>
<td>Gujarat</td>
<td>3093</td>
</tr>
<tr>
<td>3.</td>
<td>Maharashtra</td>
<td>2976</td>
</tr>
<tr>
<td>4.</td>
<td>Rajasthan</td>
<td>2355</td>
</tr>
<tr>
<td>5.</td>
<td>Karnataka</td>
<td>2113</td>
</tr>
<tr>
<td>6.</td>
<td>Madhya Pradesh</td>
<td>386</td>
</tr>
<tr>
<td>7.</td>
<td>Andhra Pradesh</td>
<td>435</td>
</tr>
<tr>
<td>8.</td>
<td>Kerala</td>
<td>35</td>
</tr>
<tr>
<td>9.</td>
<td>Other</td>
<td>4</td>
</tr>
<tr>
<td>Total Capacity</td>
<td></td>
<td>18551</td>
</tr>
</tbody>
</table>

Wind energy growth has some effect in the planning and operation for existing power system network. The voltage regulation and reactive power compensation is held when the wind is integrated into the power system. The wind turbines are composed of an aerodynamic rotor, a mechanical transmission system, squirrel cage induction generator, a control system, limited reactive power compensation and a step-up transformer.

Wind farm integration presents challenges for power system planners and operators, because of the natural characteristics of wind plants. Grid codes are certain standards set by regulating agencies. Wind power systems should meet these requirements for interconnection to the grid. Different grid code standards are established by different regulating bodies, but some grid codes are becoming increasingly popular [15,16].

This is also true for wind farms with all fixed speed wind turbines with no dynamic control or reactive power compensation. The power quality and voltage control related issues is present in the wind farm integration into the distribution network [17].

Such integration affects several power system related issues as

- Optimum Power Flow
- Transmission Congestion
- Power Quality
- System Stability
- System Economics and Load Dispatch

Large-scale integration of both onshore and offshore wind raises challenges for the various stakeholders involved, ranging from generation, transmission and distribution to power trading and consumers [18,19].

II. TEST SYSTEM

In the test system the discussion about the study model that is used in the dissertation, there is a single line diagram of a test system is shown in Figure 4 as below. The network consists of a 132 kV, 50 Hz, grid supply point that is feed a 33 kV distribution system through 132/33 kV, 62.5 MVA step down transformer [20].

Two load on this system as in figure; one load of 50 MW, 0.9 pf (lag) near to the grid supply point and another load of 6 MW, 0.9 pf (lag) at 50 km from the load one that is connected to the bus no.1. A 33 kv, 50 KM transmission line is modeled for this system. A 9 MW wind farm consisting of six 1.5 MW wind turbines is to be connected to the 33 kV distribution network at 6 MW load point. The 9 MW wind farm have conventional wind turbine systems consisting of squirrel-cage induction generators and variable pitch wind turbines. In order to limit the generator output power at its nominal value, the pitch angle is controlled for wind exceeding the nominal speed of 9 m/s [21, 22]. Each wind turbine has a protection system monitoring voltage, current and machine speed. Dynamic compensation of reactive power is provided by a STATCOM located at the point of wind farm connection to provide the reactive power for the induction generator.

![Figure 4: Single Line Diagram of a Test System](image-url)
III. SIMULATION RESULT

The integration of wind farm in weak distribution with the help of the dynamic power compensation (STATCOM) and then analyses the results in to two different techniques as

- Analysis of the results without integration
- Analysis of the test system with wind farm integration and STATCOM

The result describe the behavior of the weak distribution into wind farm that is connected with the load side, and shows the effect of the STATCOM connected to the load side then the output power of wind turbine is increase and the reactive power compensation is complete by the STATCOM.

The result of the system is having different phases as shown below one by one.

3.1 System Run without Wind Farm

The system is run without any renewable resource (wind farm) and no compensation device is used in the first stage. The Simulink model of the system is shown in figure 5 as below.

![Simulink Model of System without Wind Farm](image)

The purpose of the running the simulation in the model is to find the voltage and determine that the system is weak. The result of the system is shown in figure 6 as below.

![Voltages at Bus No. 1 and 3](image)

The voltage of bus no. 1 and 3 show in the figure. The value of bus voltage 1 is approximate 0.94 pu, and after the 50 km transmission the voltage at bus no. 3 is 0.9 pu. This result shows the system is weak because the voltage of the system is not in the limit means not above the 0.95 pu.

3.2 System With Integration of Wind Farm

The simulation diagram of this system is shown in figure 7 as below with integration of wind farm. The STATCOM is applied into the system to provide the reactive power for the induction generator and helpful to integrate the wind energy into the distribution network. The STATCOM is provided or absorb the reactive power as per the system requirment. In this model the study done without the fault condition across the network.

![Simulation Result](image)
The active power supplied by the wind turbine generator to the distribution network is shown in figure 8 as below.

Figure 8: Active Power Supplied by Wind Turbine Generator

In initially the wind active power is zero and also goes in the negative because of the integration of the turbine into the grid but by the support of the STATCOM the active power is supplied into the network.

As seen in the figure the active power in the early stage the supplied power is not as much the wind generation, but after some time the power is trying to reach its maximum values. The redundancy in the output of the turbine because the wind farm in integrate with the distribution system, and in the last the total active power from wind is as per the maximum value of the wind i.e that power supplied by wind generator is equal to the full capacity of wind farm (3x3=9 MW).

Figure 9 shows the reactive power consumes by the induction generator form the distribution network. The induction generator takes the reactive power from network in the starting for the integration into the grid and the power is fulfil by the STATCOM and the result of the power consumed is shown if the figure.

Figure 9: Reactive Power Consume by the Induction Generator

The voltage profile is very important for the distribution network especially for the weak distribution network. The voltage of the system at different bus is shown in figure 10 as below.
The result has discussed in the different farm and describe one by one, in the weak distribution, the different voltage and power at various points. In the first case the voltage at bus no. 1 and 4 is differ and not within the acceptable limit because the total load is approximate the generation and the losses is occur in the network. The voltage at bus 1 is about 0.94 pu and after the 50 km line the voltage is 0.90 pu if any disturbance occur then the system may be shut down.

When wind turbine using STATCOM is used to compensate the reactive power and the wind turbine is integrated with the distribution network and all power generate from the wind turbine is occupies in the weak distribution network. When the STATCOM is applied then the voltage of the bus no. 4 is also improved very fast, and the power supplied into the network that why the distribution network, improved and the wind farm is integrate in the system.

### IV. CONCLUSIONS

This paper is to address the importance of the wind energy for the end user, where the distribution network is weak. Some integration problem is associated with the wind energy because of the variability of the wind speed. In this work STATCOM is apply to integrate the wind energy into the grid. The role and impact of external device for reactive power compensation is analyze in this work, and modeling of the proposed system was successfully in the simulink.

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### REFERENCES