Mitigation of Harmonics by using STATCOM

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Abstract- **This paper discusses the modeling of linear and nonlinear load used in wind power plant.Harmonis analysis of the wind farm system is essential to study the behavior of equipments connected in the non sinusoidal system environment for designing and optimal location of STATCOM.**
Simulation models are developed for linear and nonlinear load. Analysis of voltage and current harmonics is performed for these loads individually. Wind turbine connected to synchronous generator is modelled using PSCAD simulation software to analyse the said issues where STATCOM is introduced as an active voltage and reactive power supporter to increase the power system stability. STATCOM can significantly mitigate the harmonis issues.STATCOM unit is developed to inject reactive power for mitigation of harmonis issues and to get stable grid operation.

Keywords – **Synchronous generator; PSCAD; Wind Turbine Generator (WTG); Static Synchronous Compensator (STATCOM); harmonics analysis.**

I. INTRODUCTION

It is the objective of the electric utility to supply its customers with a sinusoidal voltage of fairly constant magnitude and frequency. The generators that produce the electric generate a very close approximation to a sinusoidal signal.However, there are loads and devices on the system which have nonlinear characteristics and result in harmonics distortion of both the voltage and current signals. As more nonlinear loads are introduced within a facility, these waveforms get more distorted.

In recent years wind power generation has experienced a very fast development in the whole world. As the wind power penetration into the grid is increasing quickly, the influence of wind turbine on the power quality is becoming an important issue. Induction generator is more attractive than synchronous generator for wind turbines due to their robust construction, low cost, low maintenance, long life and low power to weight ratio. Wind power penetration is the impact on power system stability. To facilitate the investigation of the impact of a wind farm on the dynamics of the power system to which it is connected, an adequate model is required. In order to avoid the necessity of developing a detailed model of a wind farm with tens or hundreds of wind turbines and their interconnections, aggregated wind farm models are needed [1].

Two of the main requirements are reactive power control in normal operation conditions [2] and fault ride-through capability during fault conditions [3].
The main purpose of normal operation requirements is to maintain the voltage between admissible limits both for security and power quality purposes. Since reactive power cannot be transmitted over long distances, it has to be provided locally. Therefore, in grid connection specifications, wind farms are generally required to contribute to reactive power (and sometimes voltage) control. Concerning fault condition requirements, they are aimed at avoiding as much as possible the loss of generation capacity in case of a fault in the transmission grid.

There are a number of possible interconnection structures for wind farms and thus it is not possible to cover every type of network configuration, load, and interconnection point of the wind farm. Frequently wind parks are connected to weak systems, as they are typically located far from major load centres and central generation. This reflects itself in the short circuit ratio (SCR) of the interconnection. For weak systems the SCR will usually be less than 6 having over speed of generator [4].

Reactive power is the most important aspect in today's condition. Reactive power consumption in a Wind farm is mainly due to the use of induction generators for energy conversion. The basic principle of induction generator is that they consume reactive power in order to generate real power. The magnetizing currents drawn by step up transformers also contribute to reactive power consumption to some extent. This reactive power consumption leads to increased T & D losses, poor voltage profile over loading of T & D equipment and blocked capacity and over loading and reduction in life of T & D equipment [5].

With the rapid increase in penetration of wind power in power grids, tripping of many turbines in a large wind farm during grid faults may begin to influence the overall power system stability [6].

Indian grid system is very weak also having poor infrastructure. Considering the increasing share of wind generation interfaced to grid it is necessary to study an overall prospective on various types of existing wind generator systems and possible generator configuration, critical power quality issues, problems related with grid connections [7].Use of more intelligent controller for STATCOM and its interface to large power systems addressing various issues such as security, stability, and voltage profile improvement and power quality [8].It was found that STATCOM considerably improves the stability during and after disturbances especially when network is weak [9].STATCOMs have been used for transmission applications since the beginning of the 1990s. In order to achieve transmission voltage and power levels, transmission level STATCOMs are generally based on GTO semiconductors and use 2 main topologies: Multipulse and Multilevel [10], even if most existing STATCOMs rated above 80 MVAr use either 24 or 48 pulse converters.

As the speed during induction generator operation is not synchronous, it is also called an asynchronous generator. Variation in "δ" changes both active power and reactive power flow at the SEIG terminals there by simultaneously changing both terminal voltage and frequency of the Self Excited Induction Generator [11].The use of STATCOM shall be considered for stability improvement as well as improvement of power quality taking considering techno economic aspects [12].With the rapid increase in penetration of wind power in power grids, tripping of many wind turbines in a large wind farm during grid faults may begin to influence the overall power system stability [13].

In this paper a wind turbine fed synchronous generator is modelled using PSCAD and harmonics for linear load & nonlinear load, are analysed. The STATCOM used as a device for mitigate these problems and simulation results prove that STATCOM is an effective means to mitigate these problems during continuous operation of grid connected wind turbine.

II.SIMULATION OF WIND FARM SYSTEM INCLUDING SYNCHRONOUS GENERATOR

A wind farm typically consists of a large number of individual wind turbine generators (WTGs) connected by an internal electrical network. To study the impact of wind farms on the dynamics of the power system, an important issue is to develop appropriate wind farm models to represent the dynamics of many individual WTGs. The major issues considered for the work for grid connected wind turbine generators (WTGs), equipped with synchronous generators are harmonics.

The model is developed and compared by simulation studies in the PSCAD/EMTDC environment under different wind velocity and fluctuation conditions.

In this case study, large scale wind farm with synchronous generator having capacity 75 MW is connected to 33/132 kV substation to 220 kV electric grid system is modelled by PSCAD as shown in figure 1.

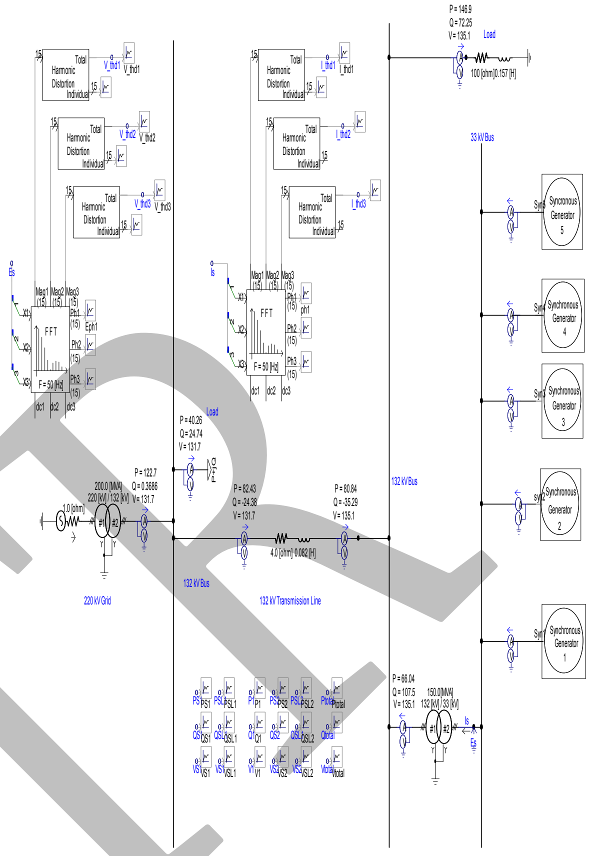

Fig.1. Large scale wind farm

III. HARMONICS ANALYSIS

Harmonics are sinusoidal voltages or currents that are integer multiples of the fundamental frequency. It is the objective of the electric utility to supply its customers with a sinusoidal voltage of fairly constant magnitude and frequency. The generators that produce the electric power generate a very close approximation to a sinusoidal signal. However, there are loads and devices on the system which have nonlinear characteristics and result in harmonic distortion of both the voltage and current signals. As more nonlinear loads are introduced within a facility, these waveforms get more distorted. The objective of this paper is to consider the effect of linear and nonlinear loads on the utility voltage and current harmonics. Some of the commonly used loads in the wind farm systems are modelled in PSCAD/ EMTDC, by considering the voltage and current waveforms. Harmonic analysis of complete wind farm system is performed.

TABLE I
SIMULATION RESULTS OF THDS OF INDIVIDUAL CURRENTS AND VOLTAGES OF LINEAR LOAD

Sr. No.	Voltage/ Current	THD (%)		
		Phase A	Phase B	Phase C
1	Current	3.85 %	5.77 %	7.78 %
2	Voltage	6.04 %	6.31 %	4.04 %

TABLE II
SIMULATION RESULTS OF THDS OF INDIVIDUAL CURRENTS AND VOLTAGES OF NON LINEAR LOAD

Sr. No.	Voltage/ Current	THD (%)		
		Phase A	Phase B	Phase C
1	Current	11.53 %	10.78 %	13.63 %
2	Voltage	8.98 %	10.62 %	12.05 %

Table I indicates the simulated results of THDs of Individual Currents and Voltages of Linear Load and table II indicates the simulated results of THDs of Individual Currents and Voltages of Non Linear Load.

IV. MITIGATION OF HARMONICS ISSUES BY USING STATCOM

The Static Synchronous Compensator (STATCOM) is a shunt connected reactive compensation equipment which is capable of generating and/or absorbing reactive power whose output can be varied so as to maintain control of specific parameters of the electric power system. It consists of VSC connected in shunt to a bus through a coupling transform. The static compensators are devices with the ability to both generate and absorb reactive and active power, but the most common applications are in reactive power exchange between the AC system and the compensator. The compensator control is achieved by small variations in the switching angle of the semiconductor devices, so that the fundamental component of the voltage produced by the inverter is forced to lag or lead the AC system voltage by a few degrees. This causes active power to flow into or out of the inverter, modifying the value of the DC capacitor voltage, and consequently the magnitude of the inverter terminal voltage and the resultant reactive power. If the developed voltage is higher than system voltage the STATCOM will supply reactive power like a rotating synchronous compensator and improve the voltage and conversely if lower it will remove reactive power. Figure 2 indicates large scale wind farm with Synchronous generator connected to the grid with STATCOM is modelled.

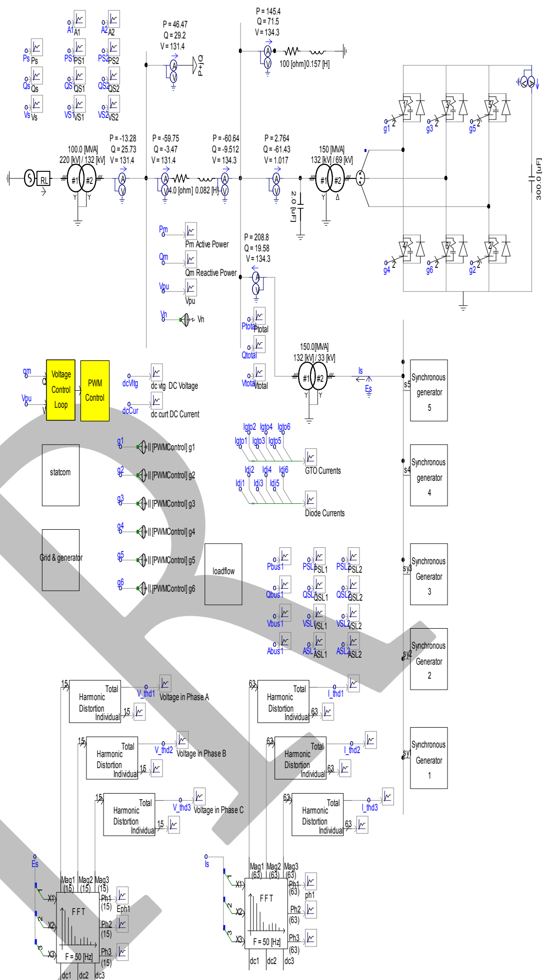

Fig.2. Large scale wind farm connected by STATCOM.

A. Mitigation of Harmonics

According to the guidelines IEC 61400-21 or IEEE STD 519-1992 harmonic measurements are not required for fixed speed wind turbines where the induction generator is directly connected to the grid. Harmonic measurements are required only for variable speed turbines with electronic power converter. The limits of V_{THD} for 132 kV systems are 3.0 % & individual harmonic of any particular frequency is 2.0%. Also I_{THD} having voltage level greater than 69 kV is 5.0%.

TABLE III
MITIGATION OF THDS OF INDIVIDUAL VOLTAGES OF LINEAR LOAD BY USING STATCOM

Sr. No	Voltage	THD (%)		
		Phase A	Phase B	Phase C
1	THD (%) After STATCOM	2.86 %	1.96 %	2.41 %
2	THD (%) Before STATCOM	6.04 %	6.31 %	4.04 %

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TABLE IV
MITIGATION OF THDS OF INDIVIDUAL CURRENTS OF LINEAR LOAD BY USING STATCOM

Sr. No.	Voltage	THD (%)		
		Phase A	Phase B	Phase C
1	THD (%) After STATCOM	3.03 %	2.25 %	2.71 %
2	THD (%) Before STATCOM	3.85 %	5.77 %	7.78 %

TABLE V
MITIGATION OF THDS OF INDIVIDUAL VOLTAGES OF NONLINEAR LOAD BY USING STATCOM

Sr. No.	Voltage	THD (%)		
		Phase A	Phase B	Phase C
1	THD (%) After STATCOM	3.00 %	2.72 %	1.98 &
2	THD (%) Before STATCOM	8.98 %	10.62 %	12.05 %

TABLE VI
MITIGATION OF THDS OF INDIVIDUAL CURRENTOF NONLINEAR LOAD BY USING STATCOM

Sr. No.	Currents	THD (%)		
		Phase A	Phase B	Phase C
1	THD (%) After STATCOM	2.31 %	2.90 %	1.67 %
2	THD (%) Before STATCOM	11.53 %	10.78 %	13.63 %

Table III and IV indicates the mitigation of THDS of individual voltages and currents of linear load by using STATCOM.

Table V and VI indicates the mitigation of THDS of individual voltages and currents of nonlinear load by using STATCOM

V. LOCATION OF STATCOM

The STATCOM is placed as close as possible to the load bus because:

1) Location of the reactive power support should be as close as possible to the point at which the support is needed.

2) Location of the STATCOM at the load bus is more appropriate because the effect of voltage change is the highest at this point.

3) To place a STATCOM at any load bus reduces the reactive power flow through the lines, thus, reducing line current and also I square R losses. Shipping of reactive power at low voltages in a system running close to its stability limit is not very efficient. Also, the total amount of reactive power transfer available will be influenced by the transmission line power factor limiting factors.

4) Hence sources & compensation devices are always kept as close as possible to the load as the ratio | Δ V/ V nom |will be higher for the load bus under fault conditions.

VI. CONCLUSION

This paper has investigated the application of STATCOM to wind farm equipped with Synchronous Generators for analysis of voltage and current harmonics of linear and nonlinear loads individually.A simulation on model of large scale wind farm is designed in PSCAD software to study the harmonics mitigation using STATCOM. Wind turbine connected to synchronous generator is modelled using PSCAD simulation software to analyse the said issues where STATCOM is introduced as an active voltage and reactive power supporter to mitigate the harmonics issues.

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