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STUDY OF COMPENSATION OF POSITIVE AND NEGATIVE SEQUENCE VOLTAGES AT WIND FARMS USING STATCOM

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Abstract—* StatCom is a type of device that can be used for controlling as well as reducing positive and negative sequence voltages produced in a system. It is a static synchronous generator which controls capacitive or inductive output current irrespective of the ac system voltage. The main source of arising of positive and negative sequence voltages are generation of unsymmetrical faults in a wind farm. Positive sequence voltage causes voltage instability and negative sequence voltage causes heavy generator torque oscillations which leads to mechanical vibration. Unbalanced voltage causes unbalanced heating in the machine winding.Therefore at first, current capability of StatCom can be controlled for removing positive sequence voltages for improving voltage stability and then remaining current is controlled for eliminating negative sequence voltages.

***Keywords*—StatCom, windfarm, PWM technique, positive sequence voltage and negative sequence voltage.**

I. INTRODUCTION

The wind farms which are recently installed are of variable speed type. Variable speed type generators are of two types, doubly fed induction generator (DFIG) or permanent-magnet synchronous generator. But out of these, still 15% of wind farms works on fixed speed induction generator (FSIG) in Europe in 2010 [3].Whenever there is a voltage dip in a system, the induction generator may consume a large amount of reactive power because their speed deviates from synchronous speed which can results into progression of faults and voltage collapse [4].Whenever unsymmetrical faults occurs in a wind farm, positive and negative sequence voltages are generated. Positive sequence voltage causes voltage instability and negative sequence voltage causes heavy generator torque oscillations which leads to mechanical vibration. StatCom is a FACTS device that can be used for eradicating positive and negative sequence voltages produced in a wind farms. StatCom is a type of static synchronous generator. It is a device whose capacitive or inductive output current can be controlled irrespective of its ac voltage [1]. For different output power distributions, StatCom may be applied by different current injection methods based on symmetrical components [16]. The main aim of using StatCom in a transmission network is the fast regulation of voltage at a load or an intermediate bus. Available transfer capacity (ATC) and power transfer capacity can also be increased with the help of application of StatCom [2]. For stabilization of fixed speed generator system, different efficient methods can be used. Some of them are StatCom, pitch control system, braking resistor (BR) and superconducting magnetic energy storage (SMES).Out of these methods, StatCom has been identified to provide the best dynamic stability enhancement capability [5].

After comparison with various converter topologies, the chain converter is found to be most attractive choice for implementation of static compensator (StatCom) [6]. By comparing various parameters of StatCom and SVC, it is found out that StatCom has low losses, better performances, improved wind farm stability and better reactive power support to network [7-10]. Double fed induction generator has many advantages over fixed speed induction generator [11]. The degree up to which the StatCom can compensate the voltage depends largely on the choice of current rating of StatCom and impedance of power system. If power system is weak and high current rating is applied to StatCom then capability of voltage compensation of StatCom is also increased [12]. While designing and dimensioning machines and converters, negative sequence voltages and currents resulting from system faults have to be considered as they cause oscillating torques and damping which may structural load to gear box as well as drive train [13]. In DFIG if there is condition of unbalanced grid voltage, then the major problem are the dc voltages ripples in the back to back VSCs and torque pulsations [15].

II. STATCOM

A StatCom is shown in fig.1 as below. A static synchronous compensator (StatCom) is also called static synchronous condenser. It is member of FACTS family of devices. It is type of regulating device which is used on alternating current electricity transmission networks. StatCom can operate as either a source or sink of reactive AC power to an electricity network and the basis of this device is power electronics voltage source converter [3]. It is modular and electable. StatCom is installed in a wind farm in order to improve power factor and voltage regulation therefore

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StatCom can be used for voltage stability. The active power capability of StatCom is very less. Therefore if an appropriate energy storage device is inserted across DC capacitor then its active power capability can be improved. The response time of StatCom is less than SVC. Better reactive power support at low AC voltages can be provided by StatCom. To improve power flow and transient stability in power grids StatCom is used which works on power electronics devices. StatCom generates reactive power if system voltage is low and it absorbs reactive power if system voltage is high [2].

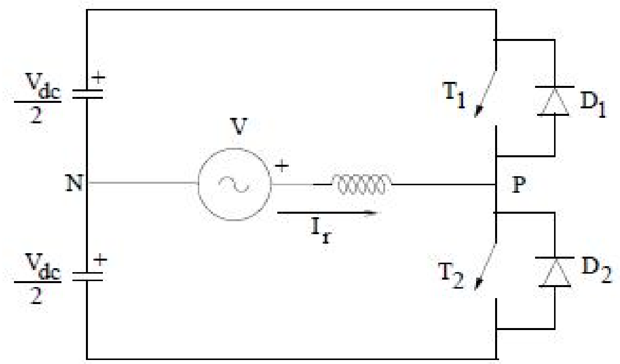

Fig 1 : A single phase StatCom

III. PRINCIPLE OF OPERATION OF STATCOM

The principle of operation of StatCom is shown in below fig. 2. In this figure power transfer between active and reactive power between source V1 and V2 is shown where V1 is system voltage to be controlled and V2 is voltage generated by VSC.

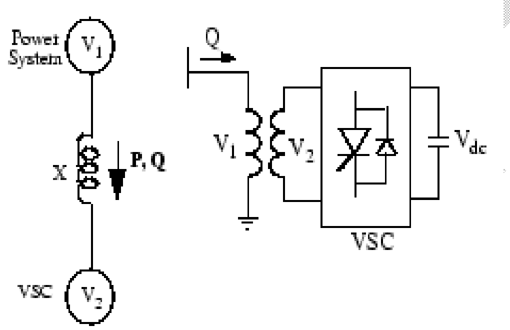

Fig 2 : Priniciple of operation of StatCom

$P=(V1V2)\sin\delta/X$

$Q= V_1(V_1 - V_2\cos\delta)/X$

V1= Line to line voltage of source 1.

V2= Line to line voltage of source 2.

X= Interconnecting transformer and filters reactance.

δ= Phase angle of V1 with respect to V2.

At δ=0, V2 is in phase with V1and therefore only reactive power flows. This is the condition during steady state.

If V2 is less than V1 then StatCom will absorb reactive power. If V2 is greater than V1, the StatCom will generate reactive power.

Reactive power is

$Q= (V1(V1-V2))/X$

A capacitor connected on the DC side of the VSC acts as a DC voltage source. In steady state the voltage V2 has to be phase shifted slightly behind V1 in order to compensate for transformer and VSC losses and to keep the capacitor charged.

IV. NEED OF POSTIVE SEQUENCE VOLTAGE COMPENSATION AND NEGATIVE SEQUENCE VOLTAGE COMPENSATION

Compensation of positive sequence voltage is required for system stability. For improving voltage instability and dynamic instability of wind farm, compensation of positive sequence voltage is required. To reduce unbalanced heating in the machine windings and torque which causes pulsation, which leads to mechanical vibration and additional acoustic noise, compensation of negative sequence voltage is required. Reduction of torque ripple increases the lifetime of the generator drive train.

V. PWM TECHNIQUE USED IN STATCOM

Sinusoidal PWM technique

Fundamental line to line converter voltage is controlled by sinusoidal PWM technique. The three phase converter voltage can be obtained by comparing sinusoidal voltage waveform with triangular voltage waveform. The modulating frequency is equal to the supply frequency in StatCom. The Amplitude modulation ratio is given by,

$$m_a = V_{control}/V_{tri}$$

Where $V_{control}$ is the peak amplitude of the control voltage waveform and V_{tri} is the peak amplitude of triangular voltage waveform. The range of SPWM is $0 \le m_a \le 1$. The Dc link voltage value is regulated by StatCom to a fixed one in all modes of operation in constant DC link scheme. The peak StatCom fundamental voltage from full inductive mode of operation to full capacitive mode of operation at minimum nad maximum voltage value determines this fixed value. So for $0 \le m_a \le 1$, the fundamental voltage is varied by varying m_a in the linear range.

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VI. SYSTEM CONFIGURATION AND CONTROL MODEL OF STATCOM

The block diagram of the system and control model is shown in below fig. 3. The control scheme used for StatCom control structure is voltage oriented vector control method. The wind farm structure consists of StatCom, transformers, transmission lines and grid lines. The StatCom is coupled with transformers in order to compensate positive and negative sequence voltages. The sinusoidal pulse width modulation is applied to StatCom control model.

The sinusoidal pulse width modulation consists of adder circuit and gate devices [15]. The gate devices are triggered by triggering pulses and adder circuit provide signals to in SPWM model. In this control structure with inner proportional integral (PI) current controllers, grid voltage orientation is in a rotating d-q frame [4].

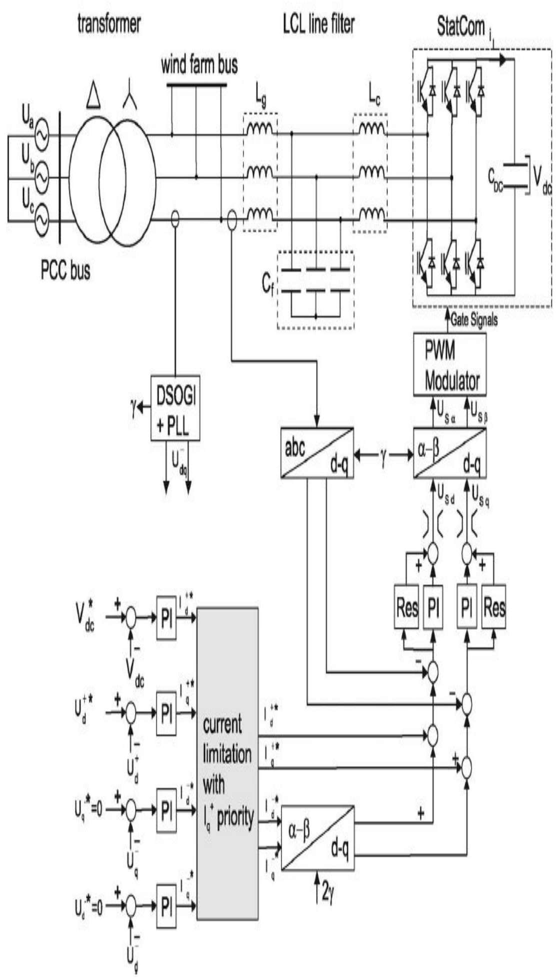

Fig 3: System configuration and Control structure of StatCom

6.1 CALCULATIONS

Positive Sequence Voltage

Positive sequence voltage is shown below in fig.3. Positive sequence voltage is calculated as follows:-

$Er1=(E_r+aE_y+a^2E_b)/3$

Negative Sequence Voltage

Negative sequence voltage is shown below in fig.3. Negative sequence voltage is calculated as follows:-

$Er2=(E_r+a^2E_y+aE_b)/3$

Where
E_r is the voltage across r phase.
E_y is the voltage across y phase.
E_b is the voltage across b phase.
a is the unit vector.

6.2 Simulation Results

The simulation results for StatCom using PWM technique must give high positive and negative voltage compensation for system stability and for reducing damping oscillations. At first current capability of StatCom is used for positive voltage compensation. After that, remaining current capability is used for negative voltage compensation.

VII. CONCLUSION

A voltage control structure at wind farm is analyzed. The proposed system compensates positive and negative sequence voltage with the priority to compensate positive sequence voltage at first. Positive sequence voltage compensation is done for improving stability of system and negative sequence voltage compensation is done for reducing torque ripples. By reducing torque ripples, lifetime of generator drive train can be increased. For increasing overall efficiency of the system both positive and negative sequence voltage are needed to be compensated. Positive sequence voltage is compensated prior to negative sequence voltage for system stability.

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