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A Review on UPQC for Sag Compensation in Wind Generation System

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Abstract-In the previous year's wind power generation system incorporated in to standard grids has been increased significantly. This situation forced the revision of grid connection code requirements, to guarantee the reliability in system with high wind power penetration. Voltage sag are observed near the point of failure in case of three phase short circuit fault and characterized by sudden voltage reduction and lagging phase jump.for induction generator based wind farms connected to weak grids ,such sag may lead to wind farm outage . In this work compensation strategy for voltage sag is proposed for amplitude and phase jump restoration. And it is compared with amplitude only compensation strategy. These strategies were implemented using an Unified Power Quality Compensator UPQC. UPQC has the feature of active power sharing between shunt and series converters through DC link rather than devices like DVR and D-Statcom ;thus series voltage injection with any phase angle may be maintained without the need of any other power source installed in DC bus. Result shows a better wind farm performance in proposed strategy than that found in magnitude only compensation schemes.

Thus, Considering the improvement in performance, the proposed strategy is recommended in retrofitting the existing installed fixed speed induction generators based wind farms.

Index Terms- Power Quality, UPQC,DVR D-Statcom

1. INTRODUCTION

In recent years, with the increasing application of power electronic device which behave as a nonlinear load, power quality problems such as harmonic, voltage sag and imbalance have become serious issues. Any problem related with voltage, current or frequency deviation that results in failure of customer equipment is known as power quality problem. The extensive use of nonlinear loads is further contributing to increased current and voltage harmonics issues. It also prevents the harmonics present in the system. Power quality problems associated with an extensive number of electromagnetic phenomena in power systems with broad ranges of time frames such as long duration variations, short duration variations and other disturbances. Short duration variations are mainly caused by either fault conditions or energisation distance related to impedance type of grounding and connection of transformers. between the faulted location and node, there can be temporary load of voltage reduction (sag) Voltage sag is most important power quality problems challenging the utility industry can be compensated and power is injected into the distribution system.Voltage sag is defined as a sudden reduction in supply voltage to between 90% and 10% of the nominal value, followed by a recovery after a short interval. The standard duration of sag is between 10 milliseconds and 1 minute. Voltage sag can cause loss in production in automated processes since voltage sag can trip a motor or cause its controller to malfunction. With the help of FACTS device and custom power device are capable to reduce the power quality problems. Among the custom power device UPQC is an effective device for solving the power quality problems.

The main of UPQC is to mitigate the disturbance that affects the performance of load line through a transformer to mitigate the voltage related problems and shunt active filter is connected across the load to solve current related problems UPQC is the combination of series and shunt active filter with a common DC link. The series active filter is connected in series with the. UPQC is the most attractive solution for solving voltage and current related problems. It is capable of mitigating the effect of voltage sag at the point of common coupling. It also prevents the harmonics present in the system. It contain two voltage source inverter, connected back-to-back sharing a common DC capacitor. The series active filter is responsible for the mitigation of voltage sag and shunt active filter is responsible for the compensation of harmonics present in the system.The voltage sag can be effectively compensated using a dynamic voltage restorer, series active filter UPQC, etc. Among the available power quality enhancement devices, the UPQC has better sag compensation capability.

2. PROPOSED METHODOLOGY

UPQC is the most attractive solution for solving voltage and current related problems. It is capable of mitigating the effect of voltage sag at the point of common coupling.
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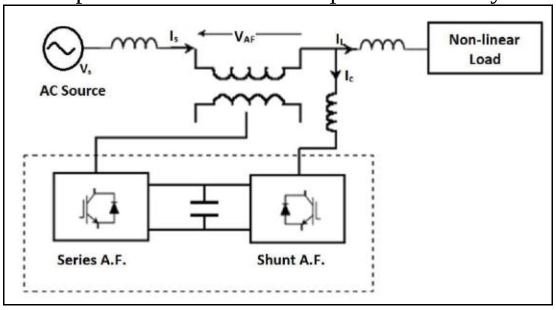

Fig.2.1 Basic Configuration of UPQC.

It contain two voltage source inverter (VSIs), connected back-to-back sharing a common DC capacitor. The series active filter is responsible for the mitigation of voltage sag and shunt active filter is responsible for the compensation of harmonics present in the system The UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems. The UPQC therefore is expected to be one of the most powerful solutions to large capacity loads sensitive to supply voltage flicker/imbalance. With ideal compensation, the voltage at PCC is the fundamental positive sequence sinusoidal voltage of the power source side. The currents of the source are sinusoidal current and the phase angles of them are the same as the fundamental voltage in phase respectively. In another words, with the function of the UPQC, the load is equal to a resistance. As the UPQC is a combination of series and shunt active filters, two active filters have different functions. The series active filter Suppresses and isolates voltage-based distortions. The shunt active filter cancels current-based distortions. At the same time, it compensates reactive current of the load and improves power factor. There are many control methods to determine the reference value of the voltage and the current, the most famous is the instantaneous active and reactive power theory (the *pq* theory) that Akagi proposed in and now the most popular is the *dq0* method developed from the instantaneous reactive power theory. But the method of them needs Transformation like Clarke Transformation (*abc*to ab), Park transformation (*abc*to *dq0*) and the control circuits are more complex, the calculation is huger. The simpler, the more robust to the control system, so the new methods are developed incessantly in recent years.

2.1. *Series controller*

A Series controller is a solid-state voltage source inverter, which generates a controllable AC voltage source, and connected in series to power transmission lines in a power system. The injected voltage (*Vinj*) is in quadrature with the line current I, and emulates an inductive or a capacitive reactance so as to influence the power flow in the transmission lines. The compensation level can be controlled dynamically by changing the magnitude and polarity of (*Vinj)* and the device can be operated both in capacitive and inductive mode. The main purpose of the series-active filter is harmonic isolation between a sub transmission system and a distribution system. In addition, the series-active filter has the capability of voltage. Flicker imbalance compensation as well as voltage regulation and harmonic compensation at the utility-consumer point of common coupling (PCC). The series component of the UPQC inserts voltage so as to maintain the voltage at the Point of Common Coupling (PCC) balanced and free of distortion. The injected voltage is in quadrature with the line current I, and emulates an inductive or a capacitive mode. Reactance so as to influence the power flow in the transmission lines. The compensation level can be controlled dynamically by changing the magnitude and polarity of injected voltage and the device can be operated both in capacitive and inductive mode. The voltage injected in series with the load by series APF is made to follow a control law such that the sum of this injected voltage and the input voltage is sinusoidal. Thus, if utility voltages are non-sinusoidal or unbalanced, due to the presence of other clients on the same grid, proper selection of magnitude and phase for the injected voltages will make the voltages at load end to be balanced and sinusoidal.

2.2. *Shunt Controller*

The main purpose of the shunt active filter is to absorb current harmonics, compensate for reactive power and negative sequence current, and regulate the dc link voltage between both active filters. Shunt APF can also compensate the voltage interruption it has some energy storage or battery in the dc link. The shunt APF is usually connected across the loads to compensate for all current related problems such as the reactive power compensation, power factor improvement, current harmonic, compensation, and load unbalance compensation. Two functions of the shunt inverter are to compensate the current harmonics and the reactive power, and to supply the active power to the load during voltage interruption. The configuration of shunt inverter control, which includes the current control for harmonic compensation, and the output voltage control in voltage interruption. In normal operation the shunt control calculates the reference value of the compensating current for the harmonic current and the reactive power, considering the power loss due to the system and inverter operation. This loss should be compensated to maintain the dc link voltage during operation of the series inverter. The reference value of the compensating current is derived. The reference voltage is calculated by the PI controller. The shunt component of the UPQC injects currents into the AC system such that the currents drawn the UPQC from supply are balanced, undistorted and phase with the supply voltages. Also, the shunt device provides a path for real power flow to aid the operation of the series compensator and to maintain constant average voltage across the dc storage capacitor. The shunt APF acts as a current source and injects a compensating harmonic current in order to have sinusoidal, in phase input current

2.3. *Dc Link Voltage Control*

The dc link voltage of the Unified Power Quality Conditioner (UPQC) can significantly deviate from its reference during a transient event, caused by load connection/disconnection or supply side voltage sag, though in the steady state the average dc link voltage is maintained at a certain preset level. During such transients, due to considerable dc link voltage deviation, the magnitude of the series injected voltage cannot be constant and this has an effect on the load voltage magnitude, which fluctuates. An improved sinusoidal pulse width modulation (PWM) voltage controller for the series compensator is proposed which adjusts continuously the amplitude modulation ratio in response to the dc link voltage deviations. Also, an adaptive dc link voltage controller is proposed which limits the dc link voltage deviation during transients and assures a negligible steady-state error. In compensation process, the DC side voltage will change because UPQC compensates the active power and the losses of switches, etc. If the DC voltage is not the same as the rating value, the output voltage of the series active filter will not equal to the compensation value. The compensation will not correct. It is the same with the shunt active filter. The DC voltage regulator is used to generate a control signal to keep the voltage be a constant. It forces the shunt active filter to draw additional active current from the network.

3. CONTROL STRATERGY

3.1 SRF based control Algorithm

SRF method can be used for the mitigation of power quality problems from the supply voltage and current. In the case of UPQC the voltage and current signals are transformed from a-b-c quantities to d-q frame. In the case of SRF theory d-q coordinates rotates with supply voltage. In the SRF, the load current signals are transformed into the conventional rotating frame d-q. If γ is the transformation angle, the transformation is defined SRF theory is based on the transformation of currents in synchronously rotating d–q frame. Sensed inputs are fed to the controller .Voltage signals have been processed by a phase-locked loop (PLL) to generate unit voltage templates (sine and cosine signals). Current signals have been transformed to d–q frame, where these signals are filtered and transformed back to a-b-c frame, which are fed to a hysteresis-based PWM signal generator to generate final switching signals fed to the UPQC.

3.2 Control Algorithm for series active filter

The fig.2.2.2 below shows the control block of series active filter. The voltage at the point of common coupling is converted in to the rotating frame by using abc-dqo conversion. With the help of low pass filter (LPF) the harmonics and oscillatory components of voltage are eliminated.

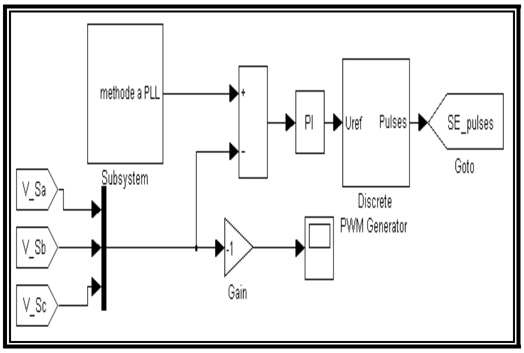

Fig.3.2 Control Algorithm for series active filter

The series active power filter is provided the voltage compensation. It generates the compensation voltage that synthesized by the PWM converter and inserted in series with the supply voltage, to force the voltage of PCC to become sinusoidal and balanced. A Series controller is a solid-state voltage source inverter, which generates a controllable AC voltage source, and connected in series to power transmission lines in a power system. The injected voltage (*Vinj*) is in quadrature with the line current I, and emulates an inductive or a capacitive reactance so as to influence the power flow in the transmission lines. The compensation level can be controlled dynamically by changing the magnitude and polarity of (*Vinj) s*and the device can be operated both in capacitive and inductive mode. The main purpose of the series-active filter is harmonic isolation between a sub transmission system and a distribution system. In addition, the series-active filter has the capability of voltage. Flicker imbalance compensation as well as voltage regulation and harmonic compensation at the utility-consumer point of common coupling (PCC). The series component of the UPQC inserts non Coupling (PCC) balanced and free of distortion. The injected voltage is in quadrature with the line current I, and emulates an inductive or a capacitive mode. Reactances as to influence the power flow in the transmission lines. The compensation level can be controlled dynamically by changing the magnitude and polarity of injected voltage and the device can be operated both in capacitive and inductive mode.

3.3 Control algorithm for shunt active filter

The shunt active power filter is provided the current and the reactive power (if the system need) compensation. It acts as a controlled current generator that compensated the load current to force the source currents drained from the network to be sinusoidal, balanced and in phase with the positive-sequence system voltages. The main purpose of the shunt active filter is to absorb current harmonics, compensate for reactive power and negative-sequence current, and regulate the dc-link voltage between both active filters. Shunt APF can also compensate the voltage interruption if it has some energy storage or battery in the dc link. The shunt APF is usually connected across the loads to compensate for all current-related problems such as the reactive power compensation, power factor improvement, current harmonic, compensation, and load unbalance compensation. Two functions of the shunt inverter are to compensate the current harmonics and the reactive power, and to supply the active power to the load during voltage interruption. The configuration of shunt inverter control, which includes the current control for harmonic compensation, and the output voltage control in voltage interruption abnormal operation the shunt control calculates the reference value of the compensating current for the harmonic current and the reactive power, considering the power loss pdue to the system and inverter operation. This loss should be compensated to maintain the dc link voltage during operation of the series inverter. The reference value of the compensating current is derived. The reference voltage is calculated by the PI controller.

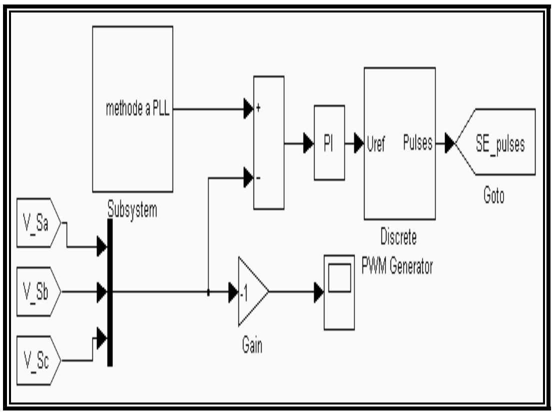

Fig.3.3 Control Algorith for Shunt Active Filter

4. VOLTAGE SAG & SYMPTOMS

Sag is decrease in voltage between 0.1 and 0.9 p.u at the power frequency for duration from 0.5 cycle to 1min. Voltage sags are usually associated with system faults but can also cause by energisation of heavy loads at starting of large motors.

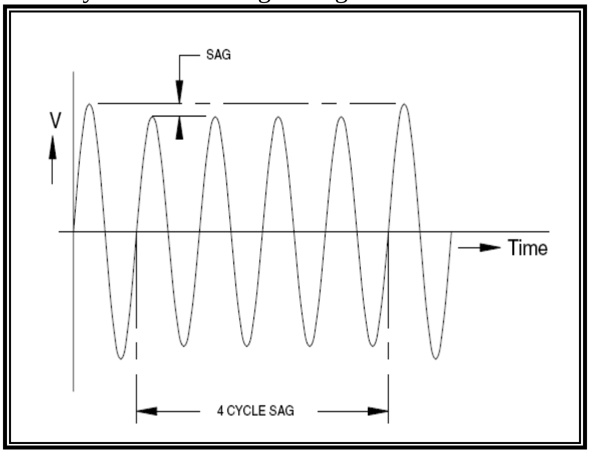

Fig. 4.1 Voltage Sag

The power quality community has used the term *sag* for many years to describe a short-duration voltage decrease. Although the term has not been formally defined, it has been increasingly accepted and used by utilities, manufacturers, and end users. The IEC definition for this phenomenon is *dip*. The two terms are considered interchangeable, with *sag* being the preferred synonym in the U.S. power quality community. Terminology used to describe the magnitude of voltage sag is often confusing. A "20 percent sag" can refer to a sag which results in a voltage of 0.8 or 0.2 pu. The preferred terminology would be one that leaves no doubt as to the resulting voltage level: "sag to 0.8 pu" or "a sag whose magnitude was 20 percent." When not specified otherwise, a 20 percent sag will be considered an event during which the rms voltage decreased by 20 percent to 0.8 pu. The nominal, or base, voltage level should also be specified. Voltage sags are usually associated with system faults but can also be caused by energysation of heavy loads or starting of large motors. Typical voltage sag that can be associated with a single- line-to-ground (SLG) fault on another feeder from the same substation.80 percent sag exists for about 3 cycles until the substation breaker is able to interrupt the fault current. Typical fault clearing times range from 3 to 30 cycles, depending on the fault current magnitude and the type of over current protection. Illustrates the effect of a large motor starting. An induction motor will draw 6 to 10 times its full load current during start-up. If the current magnitude is large relative to the available fault current in the system at that point, the resulting voltage sag can be significant. In this case, the voltage sags immediately to 80 percent and then gradually returns to normal in about 3 s. Note the difference in time this and sags due to utility system faults. Until recent efforts, the duration of sag events has not been clearly defined. Typical sag duration is defined in some publications as ranging from 2 ms (about one-tenth of a cycle) to a couple of minutes. Under voltages that last less than one-half cycle cannot be characterized effectively by a change in the rms value of the fundamental frequency value. Therefore, these events are considered transients. Under voltages that last longer than 1 min can typically be controlled by voltage regulation equipment and may be associated with causes other than system faults. Therefore, these are classified as long-duration variations.

Equipment used in modem industrial plants (process controllers, programmable logic controllers, adjustable speed drives, robotics) is actually becoming more sensitive to voltage sags as the complexity of the equipment increases. The proliferation of microprocessor-based equipment continues in the office environment, industrial plants, and residential homes. As the speed that the circuitry operates at continues to increase (100 MHz clocks are becoming more prevalent), and the voltage supplies decrease (3Vdc logic is also becoming more prevalent), the vulnerability to such disturbances increases. Reduction in ride-through times of power supplies increases the vulnerability of the equipment to sag. The effects of a sag are often more noticeable than those of a swell. Sag of duration longer than three cycles is often visible in a reduction in the output of lights. Sags often not distinguishable from momentary outages, as the effects to the equipment may be the same. Sensitive equipment, such as computers, may experience intermittent lockups or garbled data. Even relays and contactors in motor starters can be sensitive to voltage sags, resulting in shutdown of a process when the drop out occurs. A wide disparity has been found here, ranging from 20% to 65% sags for over 1000 cycles. For one industrial plant that extruded plastic pipe, voltage sags to 80% of the 480 V nominal line with durations of 40 m sec or greater would affect the production line control electronics, resulting in one or more extruder lines being shut down, and several hours of clean up before production could start again. The effects of a swell can often be more destructive than those of sag. The overvoltage condition may cause breakdown of components on the power supplies of the equipment, though the effect may be a gradual, accumulative effect. The increase in output from incandescent lighting may be noticeable, if the duration is longer than three cycles.

5. CONCLUSION

In this paper the UPQC scheme and its two controllers for the improvement of power quality in power distribution system is explained by eliminating the Voltage Sag. The simulation has been implemented using the SRF control strategy which gives the reference signals for series and shunt controllers. The objectives laid down for this paper have been successfully realized through analytical and simulation investigations. As part of this research activity also, a UPQC simulation mod-el has been built in Simulink, developing new control solutions. The effectiveness of the UPQC has been proved through simulation results.

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