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Analysis and modeling of thyristor controlled series capacitor for the reduction of voltage sag

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Abstract: **Power quality is the main problem that the industry is facing today. In this paper, an issue i.e. voltage sag of power quality in an isolated power system is considered. The series compensators device thyristor controlled series capacitor is used for improving power quality of isolated power system. The role of the compensator is to mitigate the effects of voltage sag. A control strategy for the SC is developed to regulate power flow. This is achieved through phase adjustment of load terminal voltage. It leads to an increase in the ride through capability of loads to the voltage sags/swells. In this paper Simulation results shows a comparative study of output voltage across a sensitive load without and with Series Compensation. This method of reducing the voltage sag by voltage injection using Series Compensation is more effective. Simulation results using MATLAB/Simulink have been presented. The modeling and simulation of series compensator was implemented in matlab simulink work space. simulation results showed that the proposed series compensator was efficient in mitigating voltage sags and improve the power quality of isolated power system. this approach is different from conventional methods and provide effective solution. If this method is enhanced in future, it could provide much more improved power quality.**

Keywords: Power Quality Problems; thyristor controller series capacitor; Voltage Sag; MATLAB.

I. Introduction

In the recent past, one of the problems that got wide attention is the power system instabilities. With the lack of new generation and transmission facilities and over exploitation of the existing facilities geared by increase in load demand make these types of problems more imminent in modern power systems. Demand of electrical power is continuously rising at a very high rate due to rapid industrial development. To meet this demand, it is essential to raise the transmitted power along with the existing transmission facilities. Flexible AC Transmission Systems controllers are used to control various power system problems. Power quality in electric network is one of today's most concerned areas of electric power system. Power quality is the combination of voltage quality and current quality. Power quality is the set of limits of electrical properties that allows electrical systems to function in their intended manner without significant loss of performance or life. The electrical power quality is more concerned issue. The main problems are stationary and transient distortions in the line voltage such as harmonics, flicker, voltage swells, voltage sags and voltage asymmetric. Among power system disturbances, voltage sags, swells and harmonics are some of the severe problems to the sensitive loads, because the occurrence of voltage sag in the system can cause devices/process down time, effect on product quality, failure/malfunction of equipments etc., the occurrence of voltage sag in the system can cause excessive losses and heavy loading ,nonlinear load. To avoid those undesirable affects the proposed method mitigates the problems caused by voltage sag. System, followed Simulink model and comparative study of output across heavy load without and with thyristor applied to the power system. It is followed by control of voltage sag and finally simulation results are shown. This paper analyses the key issues in the voltage sag problem and power quality using series compensator type of TCSC device. Voltage sag occurs due controlled series capacitor to the connection of the main drive load (non linear load). All these factors affect the heavy load which is connected in parallel to the main drive load. So the proposed system protects the sensitive load by mitigating the voltage sags using thyristor controlled series capacitor device technique.

II. RESEARCH METHODOLOGY

Among the power quality problems (sags, swells, harmonics) voltage sags are the most severe disturbances. In order to overcome these problems the concept of series compensator devices TCSC is introduced recently. The function of series compensation, the FACTS is connected in series with the power system. It works as a controllable voltage. Series inductance exists in all AC transmission lines. On long lines, when a large current flows, this causes a large voltage drop. To compensate, series capacitors are connected, decreasing the effect of the inductance. The simple power system model shown in Figure 1 is used to explain the principle of the proposed represents the equivalent source impedance.

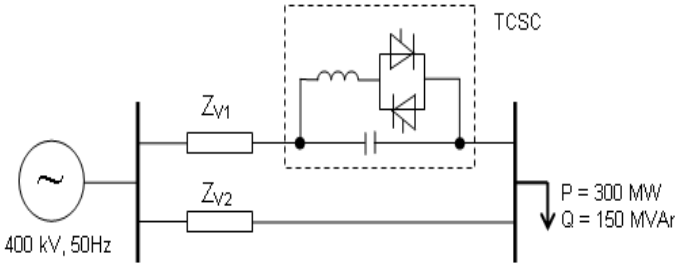

Figure 1: Block diagram of the model of electrical network with TCSC

I. Power Quality Parameters

Even the best distribution systems are subject to changes in system voltage from time-to-time. Voltage changes can range from small voltage fluctuations of short duration to a complete outage for an extended period of time. The following industry terms can be used to describe given voltage conditions.

(a) Voltage dip**:** A voltage dip is used to refer to short-term reduction in voltage of less than half a second.
(b) Voltage sag**:** Voltage sag is used to relate long-term reduction in voltage. Voltage sag is a brief decrease in the rms voltage at power frequency of 0.1 to 0.9 pu of the nominal voltage value.the duration of a voltage sag is 0.5 cycle to 1 minute. Voltage sag obtained in the system when low voltage (less than 80%),f or more than one period.
(c) Voltage swell**:** Voltage swell is an increase in voltage outside normal rated tolerance of an equipment.
(d) Voltage dips, sags and surges**:** Most electrical power generating authorities have an obligation to supply consumers from the grid at a constant voltage (typically within +/- 6% of nominal). However, sometimes this is not practical, particularly in rural locations. Sometimes voltage sags are caused by the power supplier during times of heavy demand, while dips are often caused by auto closers, operating within one second of fault detection.

II. Causes of dips, sags and surges

1. Rural location remote from power source
2. Long distance from a distribution transformer with interposed loads
3. Unreliable grid system
4. Power distributors tolerances not suitable for voltage sensitive equipment
5. Switching of heavy loads and nonlinear load.
6. Unbalanced load on a three phase system
7. Equipment not suitable for local supply.

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III. General benefits of power quality improvement

1. Reduction in line & equipment currents and losses and hence lower energy bills
2. Release of blocked capacity and consequent avoided cost of capital investment
3. Improvement in power factor and avoided penalty for low power factor or incentive for high power factor.
4. Reduction in maximum demand and reduction in demand charges.
5. Tax benefits such as accelerated depreciation benefits for installation of power conditioning /energy saving devices.
6. Improvement in voltage profile and consequent efficient operation of power equipment.
7. Reduction in harmonic distortion and consequent reduction in copper loss, core loss and stray loss.
8. Prevention of malfunction of equipment and avoided loss of production.
9. Elimination of unplanned outages and reduction in loss of production and revenue.
10. Reduction / elimination of failure of equipment due to reduced electrical and thermal stress.
11. Enhanced life / reliability of equipment due to lower operating temperature due to lower losses.

IV. Thyristor Controlled Series Compensator

It is obvious that power transfer between areas can be affected by adjusting the net series impedance. One such conventional and established method of increasing transmission line capability is to install a series capacitor, which reduces the net series impedance, thus allowing additional power to be transferred. Although this method s well known, slow switching times is the limitation of its use. Thyristor controllers, on the other hand, are able to rapidly and continuously control the line compensation over a continuous range with resulting flexibility. Controller used for series compensation is the Thyristor Controlled Series Compensator (TCSC).

1. TCSC controllers use thyristor-controlled reactor (TCR) in parallel with capacitor segments of series capacitor bank (Figure 1). The combination of TCR and capacitor allow the capacitive reactance to be smoothly controlled over a wide range and switched upon command to a condition where the bi-directional thyristor pairs conduct continuously and insert an inductive reactance into the line.
2. TCSC is an effective and economical means of solving problems of transient stability, dynamic stability, steady state stability and voltage stability in transmission lines. TCSC, the first generation of FACTS, can control the line impedance through the introduction of a thyristor controlled capacitor in series with the transmission line.

V. Modeling of Thyristor Controlled Series Capacitor by using Matlab Simpower system

The model of electrical network with TCSC device was prepared and simulated in Simulink. For demonstration of action TCSC device, from the viewpoint of voltage sag control has been created a simple model of electrical network, in which was subsequently implemented TCSC device. The model of simple electrical network consists of a voltage source, load, two parallel lines and units for measuring and displaying measured electric variables.

The parameters of the model are as follows:

- Ideal Three-Phase Voltage Source
  - Line to-line voltage *U*N = 400 kV,
  - Phase angle L1 _ = 0°,
  - Frequency *f* = 50 Hz,
- Three-Phase RL Load
  - Active power *P* = 300 MW,
  - Reactive power *Q* = 150 MVAr,
  - Configuration Y (grounded),
- Three-Phase transmission line
  - Line resistance *R* = 0.028 _/km,
  - Line inductance *L* = 0.904 mH/km,,

This TCSC device are designed in matlab simulink, firstly design the three phase voltage source 400 Kv voltage are consider in this system than transmission line design with R L parameter are taken in the system. TCSC device design in matlab two anti parallel connection thyristor with series connection of inductance and capacitor connected in parallel of the thyristor and inductance. Then, Connection of the heavy load three phase breaker with series connection of RL load. after that measure the transmission line voltage and current though the discrete PWM generator 6 pulses, are observed voltage sag in the power system. Check the effect of heavy load then voltage sag and losses occur in the system and the reduction of voltage sag. In the fig. 2 Series Compensator is absent. It is observed that voltage and current across the sensitive load are not pure sinusoidal. Fig. 3 shows the matlab/simulink model of power system with series compensator thyristor controlled series capacitor for reduction voltage sag is to connected at the sensitive load terminals. The challenge is to regulate the sensitive load terminal voltage so that magnitude is increase and voltage sag is reduced to an acceptable level.

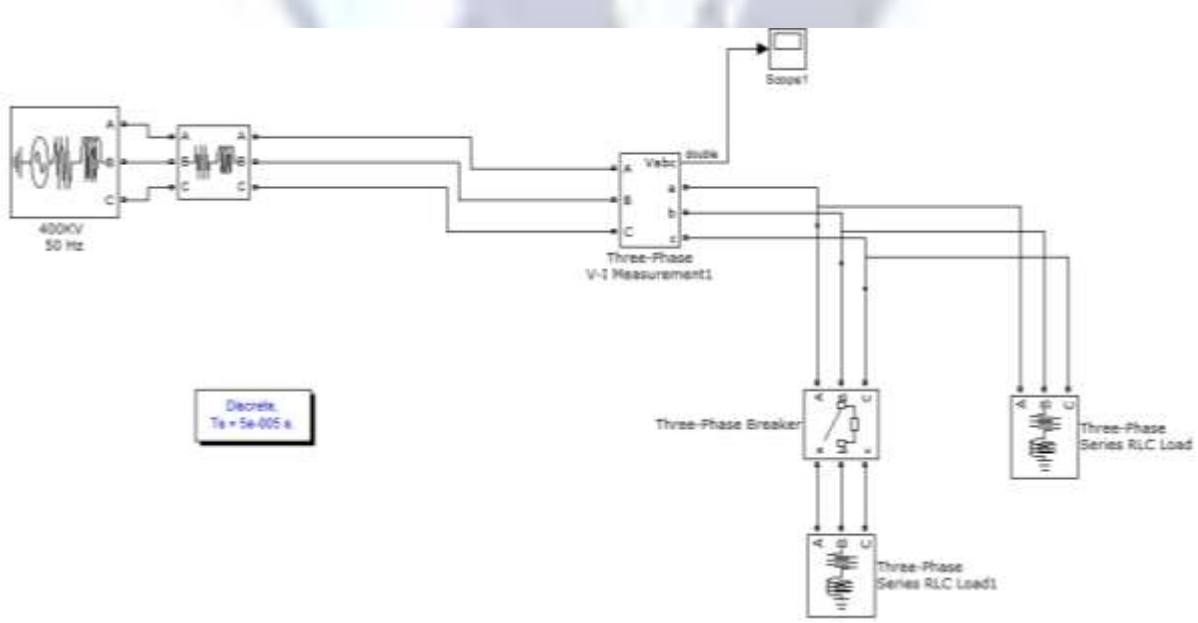

Fig. 2: Simulink diagram of isolated power system without thyristor controlled series capacitor series compensator

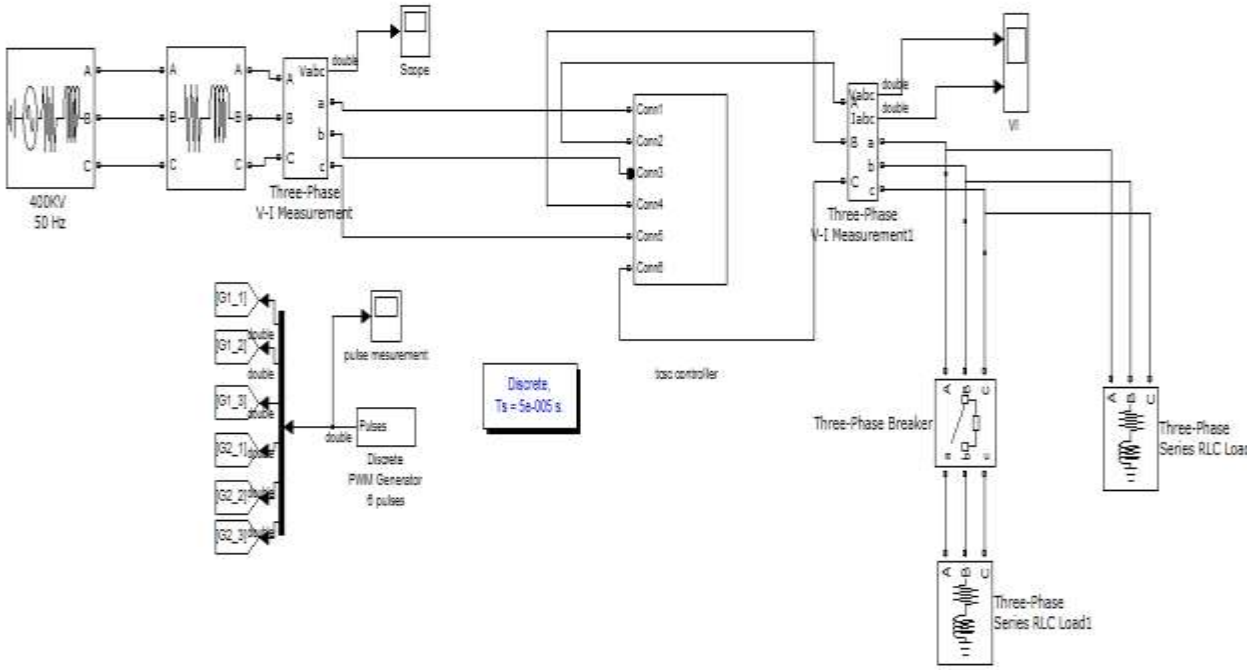

Fig. 3: Simulink diagram of isolated power system with thyristor controlled series capacitor series compensator

III. EXPERIMENTAL RESULTS

The waveforms of the voltage in 400 kv transmission line using thyristor controlled series capacitor for reduction of voltage sag. In this paper, discuss in Matlab designing of thyristor controlled series capacitor device to reduction of voltage sag using PWM Generator pulse controller. TCSC controller through reduction of voltage sag in the system and minimize system losses. This paper present an work on matlab simulink modeling of TCSC for reduction of voltage sag in transmission line system. The result waveforms are given below:

This paper discuss design and simulation of transmission system in use in power electronics switching device series compensator in thyristor controlled series capacitor for reduction of voltage sags issues due to the presence of nonlinear loads and heavy load condition. In simulink model when the fault is introduced at the point of common coupling, sag appears at the period 0.6 to 0.7 secs in all the three phases is shown in figure 4(a). When the series compensator is connected to the system the appeared sag is mitigated is shown in figure 4(b).

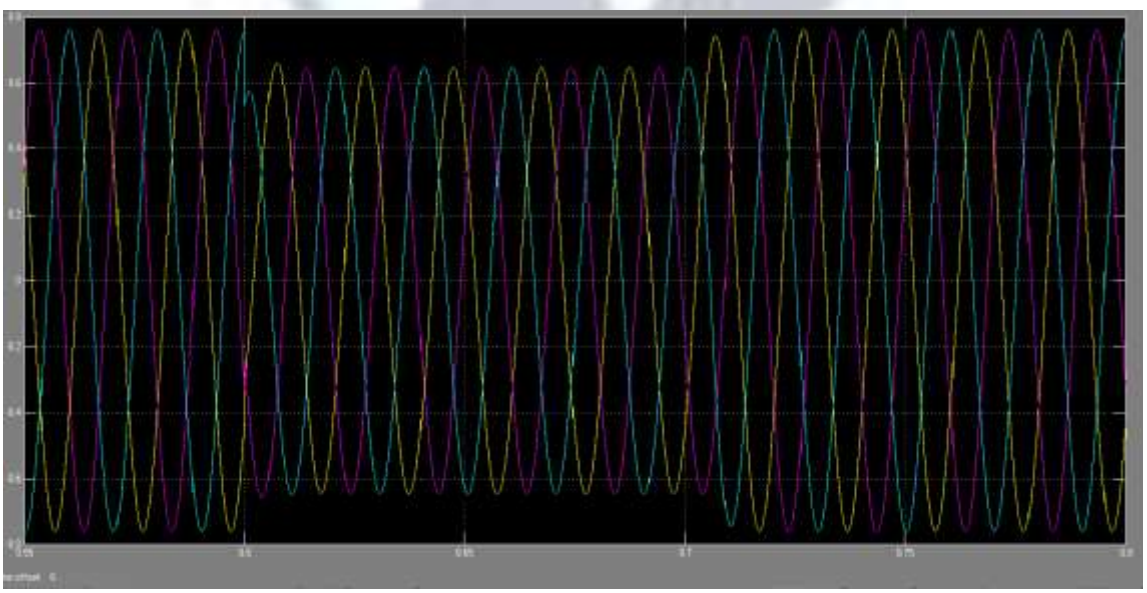

Fig 4(a): Three phase voltage sag

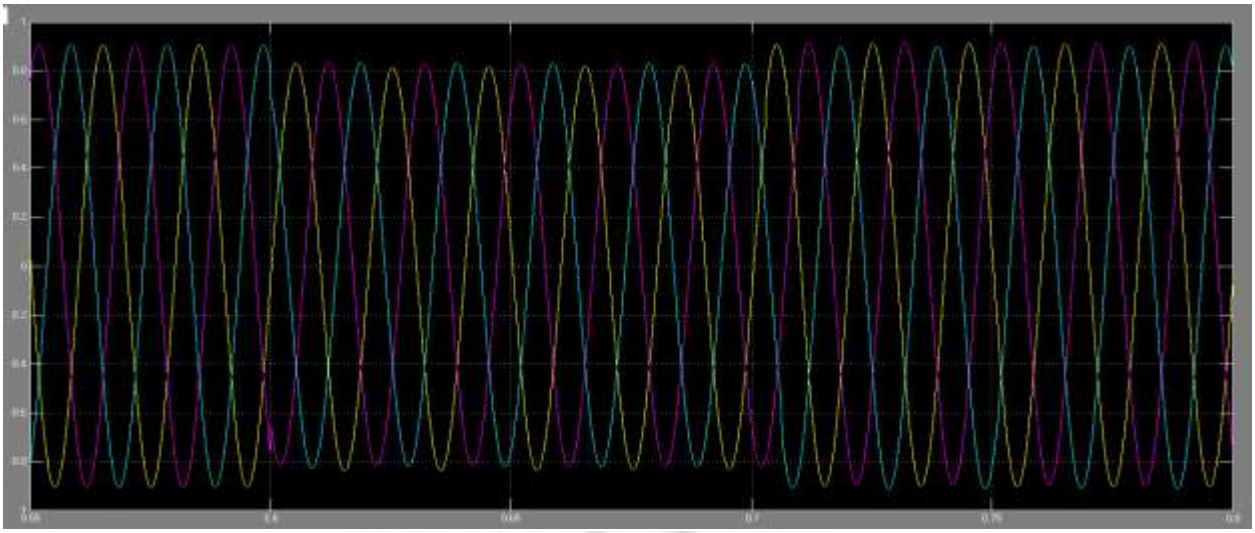

Fig 4(b): Sag mitigation

CONCLUSION

Voltage sag improvement in an isolated power system through thyristor controlled series capacitor is a series compensation has been investigated. Voltage sag produced by the nonlinear load. In this paper a method to reduce voltage sag & increase voltage quality using series compensation is considered, PWM generator six pulses based TCSC series Compensator is used to reduce the voltage sag produced by non linear loads. The SC is also designed to maintain the fundamental frequency component of the terminal voltage of protected sensitive load. In this paper, a complete simulated series compensator system has been developed by using Matlab/Simulink software. It is shown that the simulated SC developed works successfully to improve voltage quality. The proposed system performs better than the traditional methods in Mitigating voltage sags. As already highlighted, the various power disturbance parameters can have very serious cost implications if not tackled. Equipment manufacturers are saddled with the responsibility to incorporate, from design stage, devices that could help minimize the effects of poor voltage quality. This could be expensive but in special cases where the need justifies the expense, it may be possible to arrange an alternative power source aside the grid where the various disturbance parameters could be minimized. In this paper in reduction of voltage sag in nominal voltage reduction up to 80 percentage reduction are result obtained in the matlab model. this effect reduction is show in the waveform.

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