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Use of FACTS Devices for Power Quality Improvement

Kishankumar V Dave

Lecturer-A.V.P.T.I. Rajkot

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Abstract

Power quality refers to the degree to which a system facilitates the consistent operation of its loads. An occurrence of power disturbance can entail fluctuations in voltage, current, or frequency. Within the scope of this paper, a subset of FACT controllers is examined, and their performance is assessed through simulation using Simulink software, considering both steady-state and dynamic effects. The simulation employs detailed and average models, encompassing simple systems to demonstrate performance. This study emphasizes the importance of analyzing both types of controllers, a task undertaken within this research effort.

Keywords: Thyristor-controlled reactor, Thyristor-controlled Compensator, Synchronous compensator, Static synchronous series compensator.

INTRODUCTION

Power quality is an increasingly significant concern for electricity consumers across all usage levels. In electrical environments commonly used sensitive equipment and for loads having non linear charcatristics and load in nature having changing speed, automotive applications and the big capacity induction motors. Disruptions stemming from these burdens, encompassing voltage oscillations, shimmering, dip, expansion, waveform surges, harmonic defilement, and asymmetry, embody common power caliber concerns. Inadequate power caliber can be described as any occurrence within the power grid that results in tangible economic setbacks. The consequences of subpar power caliber encompass equipment breakdowns, glitches, excessive heating, impairment to delicate machinery, communication disruptions in electronics.

One strategy involves utilizing FACTS devices. FACTS devices consists of various regulators which will be employed either autonomously / alongside others regulators within the network. These FACTS regulators provide notable moment to overcome the AC current of transmission line, allowing for the amplification and easing connections between networks lacking adequate interconnection. this will improve the power quality and protects grid failure by increasing reliability. This paper involves analysis of various types of FACTS devices for improvement of power quality in the field of electrical power engineering.

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USE OF SHUNT COMPENSATOR

The mainly use of shunt compensator is, to modify the intrinsic traits of line to deeply close match fluctuations in load demands. bank of inductors / bank of capacitors which are added with line work to stabilize rise in voltage during low load conditions and alleviate low voltage condition under various kind of load conditions.

Use of TCR

The Thyristor controlled reactor consist from an air cored inductor as well valve of bi-directional thyristor. For different rating of voltage as well current rating, a number of thyristors either connected in parallel or series as per requirement meet required current capacity as well blocking capacity of voltage. The range of current control varies from zero to maximum by controlling firing angle of of thyrister.the value of firing angle can be depends on required reactive power demand by the load.the maximum valu of alphas rangs from zero to 3.5 degree, due to firing system of thyristor there may be communication issue in thyristor, figure 1 shows the waveform regarding voltage and current at different firing angle. Figure 3 shows behavior of 1-Φ Thyristor controlled reactor as a finest performance. as shown in figure 4. Change in firing angle with input step, by setting alpha at one value the which can activated to other, resulted to make source rective power demand to zero. Set rective power in floating means not to zero. At this instant thyristor absorb reactive power at maximum value and total reactive power also negative,

In case no 2 thyrister absorbe more and more reactive power beyond its need, due to this little bit reactive power demand can be fulfilled by the source. The deviation regarding to errors in the reading of measurement of reactive current, resulted to changing in the value of alpha tends to very less nearer to 0.2-degree appox. Which can result variation of 2000 VAR magnitude nearer to mean value say peak to peak value.

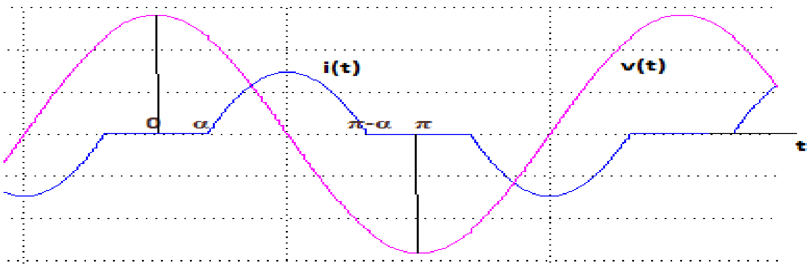

Fig-1 TCR V-I waveforms for given firing angle

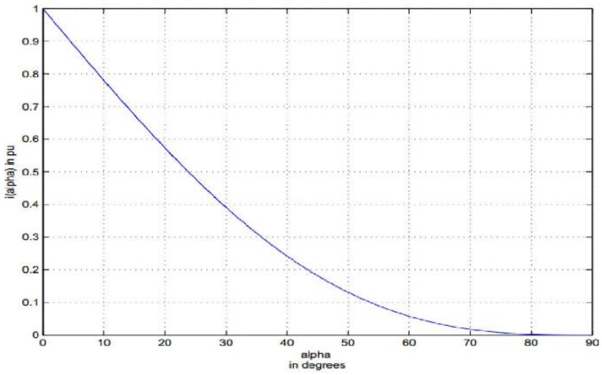

Fig-2 Waveform of firing angle Vs Current in Thyristor Controlled rectifier.

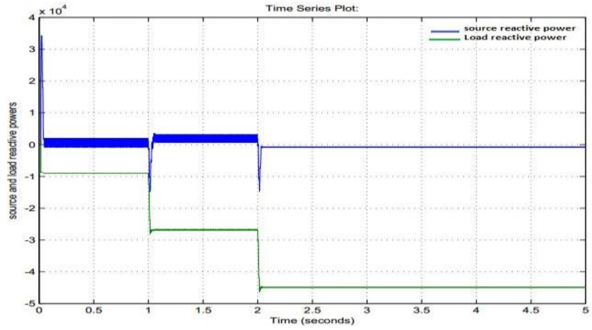

Fig-3 After optimization Thyristor Controlled Reactor's performance

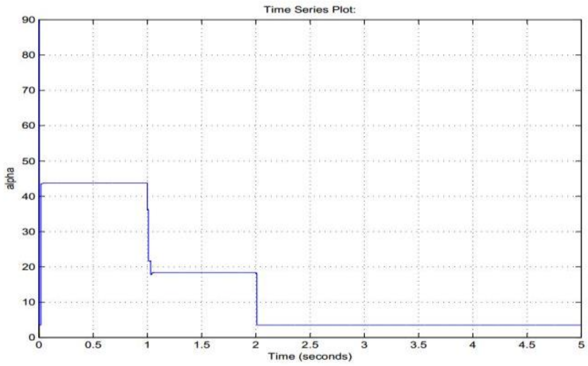

Fig-4: for various step inputs, nature of firing angles

3-Φ TCR (thyristor-controlled reactor)

3-Φ TCR is mainly used for compensating a 3-Φ system. For 3-Φ TCR the voltage value will either be line to neutral or say line to line, as per the types of connection means either star connected or delta connected. Here assumed that system used for experiment is symmetrical. Mostly very true for transmission line as

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compared to distribution line. Due to this alpha can be continuously maintain. Fig 5 depict the result of 3-Φ TCR and Fig 6 shows change of firing. From these results we can conclude that reactive power demand by the source near to zero value for some period. As a reality it can be vary in the range of 0.0005 p.u. nearer to zero. As per requirement high level accuracy, no of TCR to be connected in series or parallel as per situation.

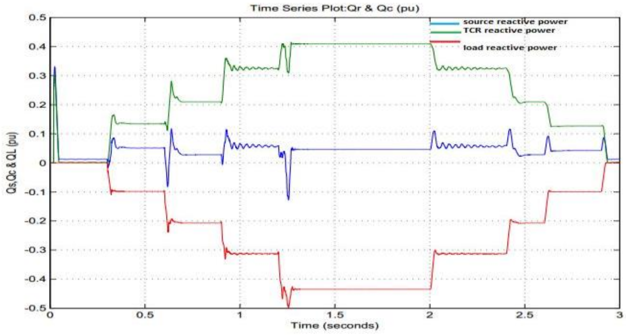

Fig-5 step input response of 3-Φ TCR

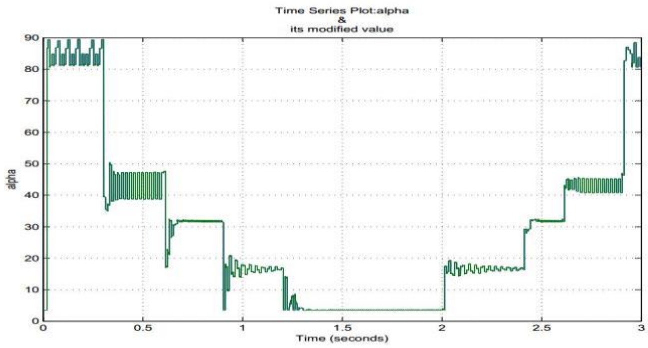

Fig-6 firing angle Divergence to step inputs

USE OF SERIES COMPENSATOR

A Series Compensator is a device used in electrical power systems to improve system performance by compensating for reactive power and voltage control issues. Series Compensators are used to regulate voltage levels in transmission lines, especially in long-distance power transmission systems. By injecting reactive power into the system, they help maintain voltage within acceptable limits, ensuring stable and reliable power supply to consumers. In high-voltage transmission systems, power flow can be controlled using series compensator. By adjusting flow of reactive power injected into the transmission line, they can

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optimize power flow, reduce losses, and improve the overall efficiency of the system. Series Compensators can enhance the stability of power systems by damping out oscillations and improving the transient response. They help mitigate issues such as voltage fluctuations, line overloads, and voltage sags, which can destabilize the grid. The current supplied by Shunt compensators into the line depends on line potential and other various parameter, this type of devices find best application in voltage compensation as well reactive power compensation for the system. In distribution networks, Series Compensators can be deployed to mitigate voltage drop issues, particularly in areas with high demand or long feeder lines. By injecting reactive power, they help maintain voltage levels and ensure consistent power delivery to customers.it should be take care at the time of voltage dip in system, which results fall in line reactance. Due to this power flow through line is limited by reactance which affect stability limits, result in prevention of wide phase differences between voltages.for maintaining the system voltage, bank of capacitor connected in series called series compensation, in which reactive power can be injected in the line which can improve system impedance. This type of T compensator works as current-controlled voltage sources, by injecting voltage in the given phase with the current so can manage voltage drop across it and improves power flow. series compensators are mainly two types: 1. variable impedance type and 2. Converter-based type. They are very important for optimizing power transmission and improve system stability by managing voltage profiles and power flow in the transmission lines.

A. Variable impedance type series compensators

An Variable impedance type series compensators falls under the category of variable impedance type series compensator,

Which ultimately changes the line reactance as well as resistance by supplying reactive as well real power respectively. By changing the capacitance which are added in the can ultimately change in line reactance, which results compensation of line parameter, which can responsible for power system stability.

B. series capacitor (Gate controlled)

GCSC consists of either no of fixed capacitor or variable capacitor i.e. switched capacitor in parallel mode either in a pair of anti parallel gate commuted switches/devices. The voltage across capacitor can be changed by changing firing angle whose value varies between 0 to 90. By giving the step input to this system the response is as shown in fig 7. here voltage control operation is limited. Due to lesser voltage drop GCSC plays an important role in stabilizing voltage. By minimal injection of voltage in the system harmonics also developed is 1% to 3% so no need of other filters in the system.

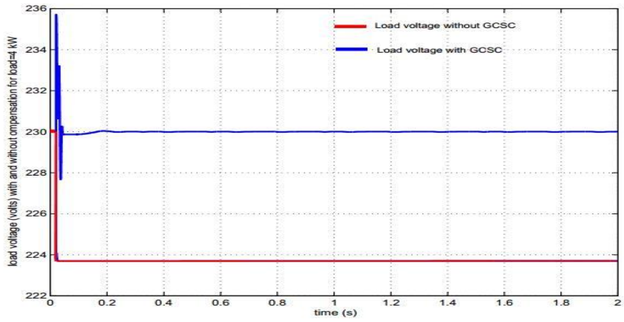

Fig 7 Response of Gate controlled series capacitor to reduce line drop

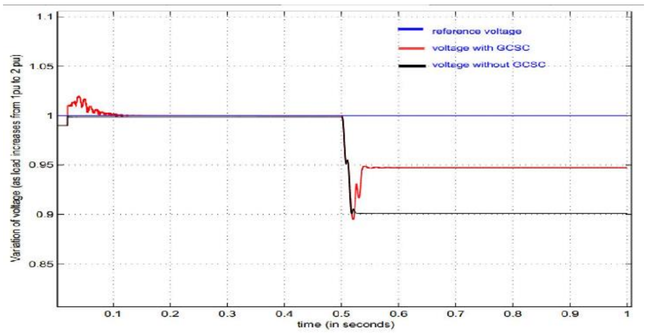

Fig 8 Gate controlled series capacitor response for unit step input

C.TCSC

TCSC (Thyristor Controlled Series Capacitor) made from series capacitor by shunting reactor in each phase and two pair to pair thyristors in parallel. Whenever these thyristor conducting, the equivalent impedance is determined by the equivalent of the capacitor as well inductor. By switching of thyristor fully, the total equivalent impedance reduces to that of the capacitor only. Due to this impedance adjustment, we can get more accurate control over line impedance which results in improvement of system stability. TCSC also are two types. This also known as SSSC (Static Synchronous Series Compensator). which plays important role for improving power system stability and controlling line impedance by injecting or absorbing reactive power into the line. this will improve system stability and power flow in transmission line. Here by take the step output from the SSSC, effect of power transfer in line can be studied with voltage injection into the bus.

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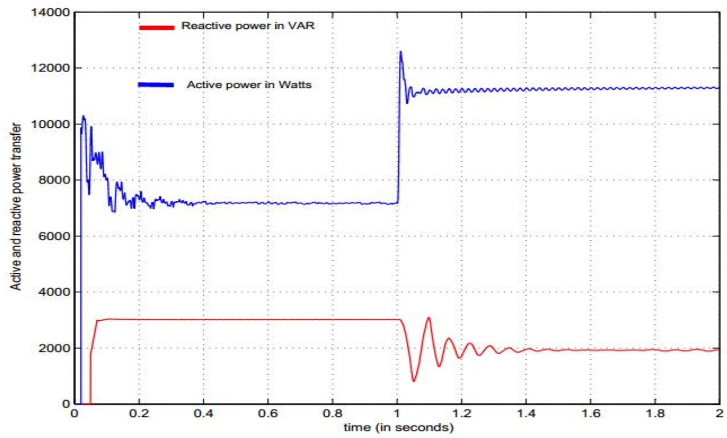

Fig 9 voltage injection effect on active and reactive power flow

So, this voltage injection into the line ultimately improve power system stability.

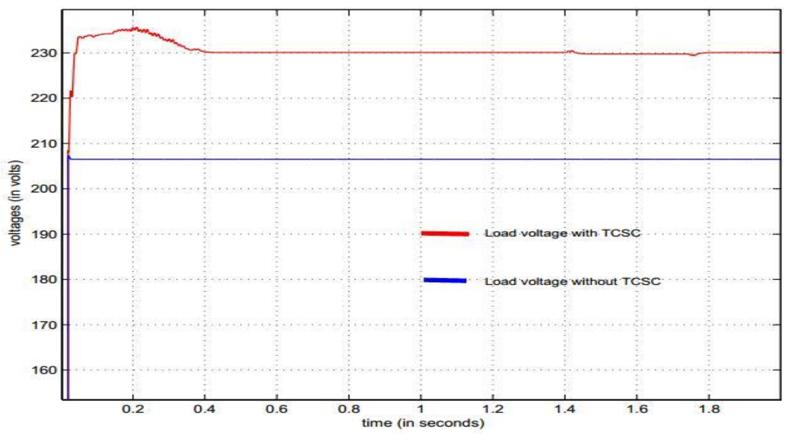

Fig 10 stabilizing voltage effect of Thyristor controlled series capacitor

D. Converter based Series Compensator

The SSSC uses the variant known as converter-based series compensator which uses capacitor as storage element, series compensator, converter known as a voltage source as well transformer which is used in line in series mode. The SSSC injects voltage in phase the line current can be increase e power transfer(flow) capacity by reducing line voltage drop. Here by injecting bus voltage and by taking step output from SSSC, power transfer through is studied.

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CONCLUSION

Up to this point, we've discussed series and shunt type of compensators. A general question that arises is how to choose between these compensators — when to use which one. This decision hinges on a thorough examination of system requirements. For instance, does the system experience overvoltage or under voltage conditions? Is there a demand for lagging or leading VARs? What about transient stability and other system dynamics? Additionally, economic considerations play a significant role. Deciding which compensator to employ is far from straightforward; it involves a complex evaluation process. Optimization is essential in determining the type and rating of compensators, considering both cost and security considerations. Finding the right balance between performance, cost-effectiveness, and system security is crucial in making informed decisions regarding compensatory selection. In VSC based compensators performances, dynamic behavior and the harmonics contents are taken into consideration. An example of this is multilevel inverter topology which gives tremendous performances for both dynamic and steady state.

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