Improving Power Quality using Thyristor Controlled Series Capacitor

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Abstract

Thyristor Controlled Series Capacitor (TCSC) as a dynamic system, similarly its ability in increasing power allocation in transmission lines, can be used to advance different power system problems. TCSC's dissimilar advantages can be categorised as steady-state and transient ones. During a fault, TCSC can increase power quality by reducing the current and benefit to retain the voltage as high as possible. In this paper, the application of TCSC to improve one of the vigorous power quality issues, i.e., voltage sag is examined. Dissimilar operating modes of TCSC have different impacts on the voltage of the bus that the line equipped with TCSC is connected to. Repositioning to bypass mode upon appearance of a fault is a important feature of TCSC to advance voltage sag. The simulations on a trial network reveal these facts.

Keywords: *TCSC, FACTS Devices, Voltage Sag, Power Quality.*

I. INTRODUCTION

The practise of power electronics devices to improve the power transfer proficiency of long transmission lines customs the origin of the concept of FACTS. Thyristor Controlled Series Capacitor (TCSC) is one of the most extensive devices of the FACTS [1]. Series capacitor compensation is an approach to increase stability limits and increase transfer capabilities. The transmitted power through a line is inversely relative to the transfer impedance. TCSC may similarly be used for regulatory fault current by altering its impedance value to a large inductive value that hinge on the TCSC design

Power quality is a matter that is presently gaining chief consideration to both electric utilities and end users. Maximum power quality grievances are fretful with voltage sags, which are primarily caused by short circuits on transmission and distribution systems. These sags be able to weakened by different resources that include reserves on the power systems over aids; the usage of power conditioners to protect the load against these sags. Awaiting a few years ago, the voltage sags due to faults were of slight significance. Use of modifiable speed drives and programmable logic-based process control in mining, pulp and paper, and electronic chip manufacturing plants has intensified over the last years. It has made power quality problems related with voltage sags an significant design issue. Voltage sags of as little as 10% of the nominal voltage and of duration as short as 2 or 3 cycles can disturb critical equipment and adversely impact the production processes. As an example, ac voltage is rectified and transformed to pulsed dc when it is applied to an adjustable speed drive. This pulsing dc is stored in a capacitor, which in turn supplies smooth dc. Since the capacitor stores energy, it permits the system to ride through some sag. But if voltage sag is of enough depth and duration, the capacitor voltage will drop below a critical level, at which point the drive may misoperate or simply shut down, resulting in process disturbances. Outages due to poor power quality can have harmful impact as continued power interruptions [2].

There are a few papers examining the effect of TCSC on the voltage sag [3], but they have chiefly considered the TCSC in its steady-state operating conditions.

Ignoring the dynamics of TCSC in disturbances prevent observing the transients and exact system behaviour. The foremost objective of this paper is to demonstrate in detail how the dynamics of a TCSC impact the voltage of the bus that the transmission line armed with TCSC is connected to. It is shown if TCSC's control system is well designed, it will help to mitigate the voltage sag consequences during emergencies. Alternative point is the oscillations created during and after TCSC's transfer from one mode to the other. These oscillations could only be observed if TCSC is presented by refined models. TCSC's operation as a fault current limiter to diminish voltage sags is likewise examined.

II. ARRANGEMENT OF A TCSC

The elementary arrangement of TCSC is shown in Fig.1. The degree of TCSC basic compensation is exact by the size of capacitor. The foremost purpose of bypass inductance is to decrease the short circuit current and the energy absorbed by MOV. Bi-direction thyristor SCR is used to transform the equivalent impedance of TCSC which satisfy the needs in all types of power system condition, such as refining the stability, increasing the transmission ability, defensive hypo synchronization resonance [4].

By controlling the triggering pulse, TCSC can change the triggering angle of thyristor. Consequently, the current value of inductance sub-circuit which controlled by TCSC, and then the total equivalent impedance will be changed endlessly. Usually, when the trigger angle is 55°~90°, measuring from the peak of capacitor voltage, the corresponding impedance of TCSC is seemed as capacitance. When the trigger angle is 0°~50°, the equivalent impedance of TCSC is achieved as inductance as which characteristic can limit short circuit current in system failure.

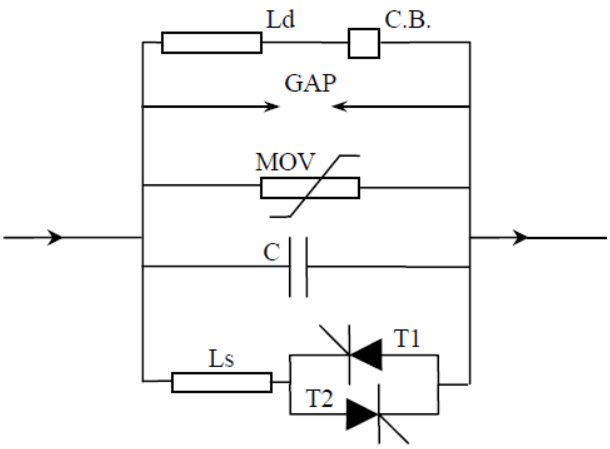

Figure 1 Configuration of TCSC

III. TCSC'S DIFFERENT MODES OF OPERATION

The Thyristor valve is not triggered and they are well-maintained in non-conducting mode, the TCSC is functioning in blocking mode. In this mode, the TCSC achieves like a fixed series capacitor.

In bypass mode the Thyristor valve is stimulated endlessly and the valve stays conducting all the time; so the TCSC performs like a parallel connection of the series capacitor with the inductor. In this mode, the succeeding voltage in the steady state across the TCSC is inductive and the valve current is slightly greater than the line current owing to the current generation in the capacitor bank. For practical TCSCs with X_L/X_C ratio between 0.1 to 0.4 ranges, the capacitor voltage at a stated line current is much smaller in bypass than in blocking mode. Consequently, the bypass mode is established as a means to decrease the capacitor strain during faults. In capacitive boost mode a trigger pulse is provided to the Thyristor consuming forward voltage just before the capacitor voltage crosses the zero line, the capacitor discharge current pulse will flow through the parallel inductive branch. The capacitor peak voltage thus will be enhanced in proportion to the charge that permits over the Thyristor branch. The vital voltage also rises closely proportionally to the charge. From the system view, this mode supplements capacitors to the line up to closely three times the fixed capacitor. This is the normal operating mode of TCSC. In inductive boost mode the circulating current in the TCSC is greater than the line current. In this mode, huge Thyristor currents effect and advance the capacitor voltage waveform is partial from its sinusoidal shape. The peak voltage seems close to the turn on. The unfair waveform and the high valve stress make the inductive boost mode less attractive for steady state operation. This mode rises the inductance of the line, so it is in dissimilarity to the advantages associated with the application of TCSC.

IV. SIMULATION RESULTS

In order to show the effect of TCSC on the voltage of the buses with sensitive loads, a sample network as Figure 2 is used. The transmission line A_1-B_1 is compensated by a TCSC. Sensitive load is connected to bus B_1. The nominal compensation is 76%.

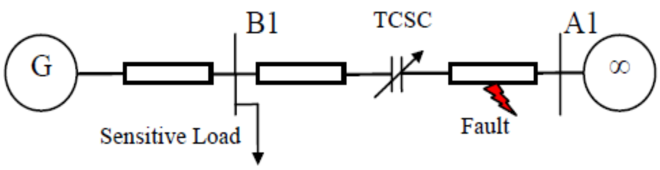

Figure 2 Sample network used for simulation

The normal oscillatory frequency of the TCSC is 170Hz, which is 2.8 times the fundamental frequency. The impedance of line A1-B1 is 6.0852+j163Ω. The left source voltage is 549 kV and the right is 488.8kV. System frequency is 60Hz. The ratio of TCSC, i.e., X_l/X_c is 0.1243; C=23.977μF and L=0.033H. This sample system is described in [10]. Without the TCSC the power transfer is around 110MW, as seen throughout the first 0.6s of the simulation when the TCSC is out of service by the bypass C.B. operation, as seen in Figure 3. The resonance for this TCSC is around 57° firing angle, the operation is forbidden in firing angle range 47° - 63°. Note that the resonance for the total system is around 64°. The capacitive mode is achieved with firing angles 64°-90°. The impedance is lowermost at 90°, and hence power transfer increases as the firing angle is reduced. In capacitive type the collection of impedance values is nearly 120-133Ω. This range corresponds to approximately 480-860MW power transfer range. Identical with the power transfer of 110 MW with an uncompensated line, TCSC permits foremost development in power transfer level. The inductive mode corresponds to the firing angles 0°-53°, and the least impedance is at 0°. In the inductive operating mode, the range of impedances is 17-75Ω, which agrees to 82-100 MW superior of power transfer level. As can be seen from figure, the voltage of bus B_1 is constant and during the first second of simulation time.

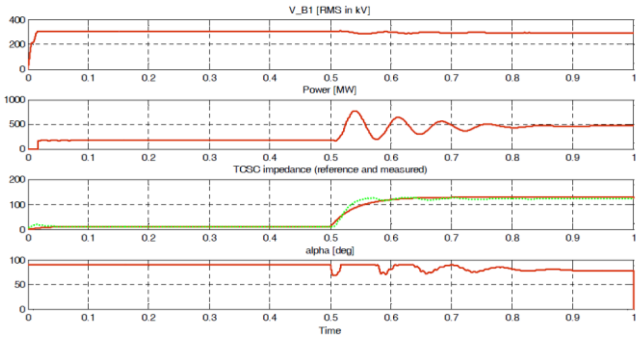

Figure 3 Sample system initialization from t=0 to t=1 Sec.

As Figure 4 shows, at t=1.0 Second, a three phase fault occurs on line A_1-B_1 at 76% from the commencement of the line. TCSC transfers to bypass mode to save the capacitor from overvoltage. As can be seen from the figure, the voltage of bus B_1 with sensitive loads does not drop significantly; voltage sag is at a permissible level. At t= 1.3 Second, TCSC transfers to Circuit breaker bypass operation in order to except itself from heavy current flow for long time. Voltage sag is higher than the TCSC bypass mode. This transfer is only for protest, because in real cases, the fault is cleared much faster, and rarely it is necessary to operate bypass Circuit breaker between t=0 to t=1.0, the firing angle α is zero, and after t=1.3 Second firing angle will remain 90° for easy transfer of TCSC to capacitive boost mode. Figure 5 shows the operation of TCSC for the same fault, but without C.B. bypass operation. Voltage sag of bus B1 is at its lowest value, but the same figure shows oscillations before reaching to a stable situation. Figure 6 shows the voltage sag of B1 without the presence of TCSC on line A_1-B_1. As can be inferred from this figure, the voltage sag is substantial and would interrupt the sensitive loads connected to bus B_1.

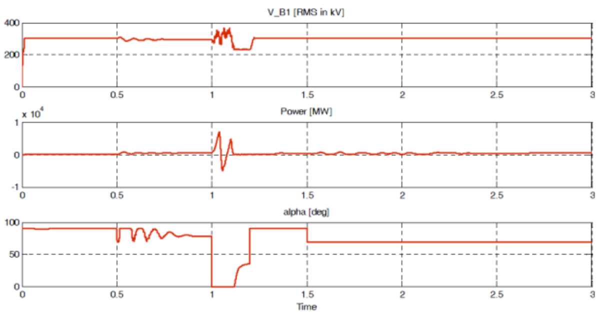

Figure 4 Sample system behaviour for TCSC bypass operation followed by bypass C.B. closing

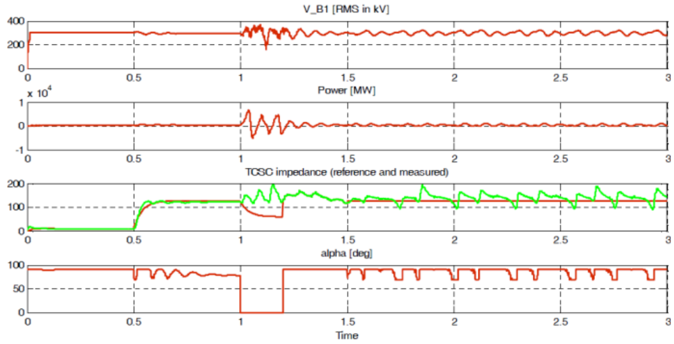

Figure 5 Sample system behaviour for TCSC bypass operation without bypass C.B. closing

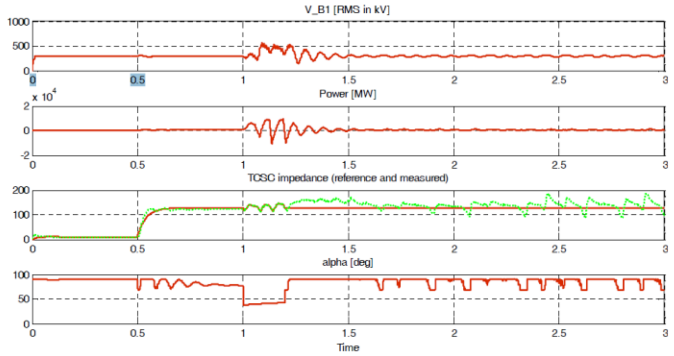

Figure 6 Fault Current Limiting with firing angle 49°

V. CONCLUSIONS

This paper examines the TCSC's significance on the voltage sag of the buses with penetrating loads. The simulation results demonstrate one of the noticeable features of TCSC, i.e., enhancement of voltage sag during disturbances, as one of the important issues of power quality. This is attained by transferring of TCSC to suitable modes during instabilities. For examining the voltage condition of the desired buses during system instabilities, a complete dynamic model of the TCSC is essential. Else, the examination does not show the transients occurring during TCSC's mode transfer.

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