IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.301

Volume 3, Issue 5, June 2023

Design of Static Var Compensator Model for Long Transmission Line

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Abstract: *In general, transmission lines were operated at very unbalanced conditions in power systems. Some lines were operated at overloaded conditions at all times, pushing them closer to their stability limitations. This is a result of the rising energy demand and concurrent economic restrictions placed on the generation of electricity. Additionally for stability purposes, the transmission lines' power flow must be restricted. Voltage stability is one of the most difficult studies and even with tried- and-true methods and technology for enhancing power system security, this challenge still requires extra work to ensure the stability of the system. One approach being examined to address issues with power system stability is the use of flexible AC transmission system (FACTS) devices. In this paper, comparative study of a 66kV system consisting of 400 km long transmission line under various load conditions and their voltage profile improvement using shunt compensation type of FACTS known as Static VAr compensator (SVC) is demonstrated using MATLAB SIMULINK software.*

Keywords: FACTS, FC-TCR, Static VAr Compensator, modelling.

I. INTRODUCTION

The main objective in electrical power system is the op- timum operation of transmission assets. But there are limits as to how much power a transmission line can transfer and these limits/constraints are divided mainly into three types viz. thermal, dielectric, and stability. Thermal and dielectric limitations are specific to transmission line conductors and very little can be done in terms of performance improvement. Stability issues can include dynamic/transient stability, steady-state stability, frequency collapse, sub-synchronous resonance, etc. Implementation of FACTS controllers can help to over- come stability limitations . With the use of FACTS devices, the transmission experiences reduced line losses and optimum operation [1].

Flexible AC Transmission system or FACTS is defined by the IEEE as "A power-electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability" [2]. There are variety of compensation devices within FACTS family that operate of principles based on load angle control or reactive power control. Within shunt compensation technique, static Var com- pensators (SVC) are used to control the power flow for several voltage profiles. Thyristor-controlled reactor (TCR), Thyristor- switched capacitance (TSC) and Thyristor-switched reactor (TSR) are few devices in the SVC family. Among them, TSC provides compensation for heavily loaded power system while TCR being used for heavily loaded condition. In [3], the authors modelled SVC for p.f. correction of the power line model. In this paper, we will be focusing on Fixed- capacitor Thyristor-controlled reactor (FC-TCR) to improve voltage profile of transmsiion line for its apparent benefit of its ability to perform under both conditions.

II. METHODOLOGY

In FC-TCR, a capacitor is placed in parallel with a thyristor- controlled reactor. I_Q, I_L, and I_C are system current, reactor current and capacitor current respectively which flows through the FC-TCR circuit. FC-TCR is capable for supplying contin- uous lagging and leading VAr to the system.

Fig.1 depicts the typical FC-TCR arrangement and their VAr demand/output characteristics. Circulating current through the reactor ($I_L(\alpha)$) is controlled by controlling the firing angle of back-back thyristor valves connected in series with the reactor as shown in fig.1 (a).

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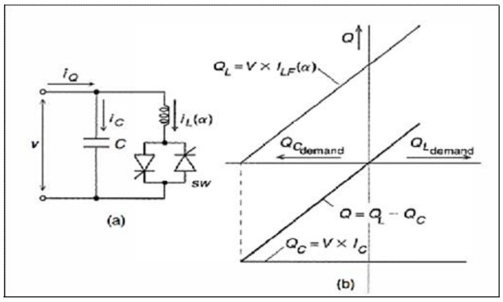

Fig. 1. FC-TCR arrangement and characteristics

Leading VAr to the system is supplied by the capacitor. For supplying lagging VAr to the system, TCR is generally rated larger than the capacitor. Current in the reactor is varied by the method of firing delay angle control method. The constant capacitive VAr generation (Q_C) of the fixed capacitor is opposed by the variable VAr absorption (Q_L) of the thyristor controlled reactor, to yield the total VAr output (Q) required fig.1 (b). For controlling the current supplied by reactor the equation is given as

$$I_L(\alpha) = \frac{Vm}{\omega L} * [1 - \frac{2\alpha}{\pi} - sin(\frac{2\alpha}{\pi})] \qquad (1)$$

While the 3-ϕ capacitor bank will supply a pre-determined amount of leading current to the system, the TCR requires a control circuit that controls the firing angle of all the thyristors according to reactive power demand. The control circuit has two main block as mentioned above viz. firing angle calculation and firing signal generator block. The firing angle calculation block receives reactive power (Q) as the input and gives firing angle (FA) as output by simultaneously comparing the reactive power with the reference reactive power (Qref =0). The firing signal generator block uses receiving end voltage for reference to generate gate pulses. The comparator block is used to differentiate between positive and negative cycle and thus triggering the respective thyristor in each phase.

We require a control circuit that senses the compensation reactive power required and line voltage zero-crossing for the firing angle control of TCR. Since we are implementing PI control for FC-TCR, the first-order approximation of the transfer function of the PI controller is written as,

$$G(s) = \frac{1}{1 + sT_{ds}} \qquad (2)$$

III. DESIGN & ANALYSIS

In this section, we will examine the power system rated as 3-ϕ, 66 kV employing the distributed parameters long transmission line model having length 400 km. The primary objective is to minimize voltage regulation by compensating for reactive power in the circuit with capacitors and reactors.

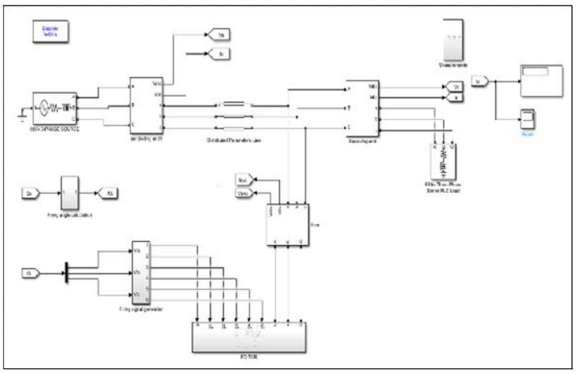

Fig. 3. Simulation model

The transmission line is represented by distributed parameter block and measurement blocks are added to measure sending- end and receiving-end voltages and currents. A measurement block is deployed between FC-TCR block and transmission line. The firing angle calculation block has comparator, PI controller and a saturation block which has capabilities of zero-crossing detection. The firing signal generator block utilizes the firing angle as well as phase voltages in order to provide gate pulses to the 6 - pulse thyristor arrangement. The block diagram of the control circuit is shown below.

The designing of the system is as follows:-For the given system, the blocks in Simulink contain the following parameters, Line voltage(V)= 66 kV, Active power of the line (P) = 20 MW, cosϕ = 0.8, F= 50 Hz To calculate for reactor and capacitors used in SVC, reactive power required is used. Hence,

$$Q_L = \frac{V_m^2}{\omega L} \quad (3)$$

$$Q_C = V_m^2 * \omega C \quad (4)$$

Where, Vm = Peak magnitude of line voltage in V.

Using these formulae, the ratings of capacitor and inductor are calculated to be 19.49 µF and 10.5 mH. The constants consideration for PI controller are as follows:

Module	Parameter	Definition	Typical Value
Thyristor control	Td	Gating Angle	0.001s
	Tb	Firing angle	0.003-0.006s
Slope	Xsl	Steady-state error	0.01-0.05 p.u.

TABLE I: TYPICAL PARAMETERS FOR SVC MODEL

The parameters of the SVC have to be selected to SVC rating and performance criteria taking into account the power system behavior under various operating conditions. To improve SVC strategic operation, these parameters are viable.

Let X_{sl} be 2%,

$$K = 1/X_{sl} \quad (5)$$

∴ K = 50

Thus, the transfer function of the svc model is initially calculated to be:

$$G(s) = \frac{50}{1+0.001s}$$

After tuning the PI controller to the desired value, the simulation results that are obtained in the following section.

IV. RESULTS

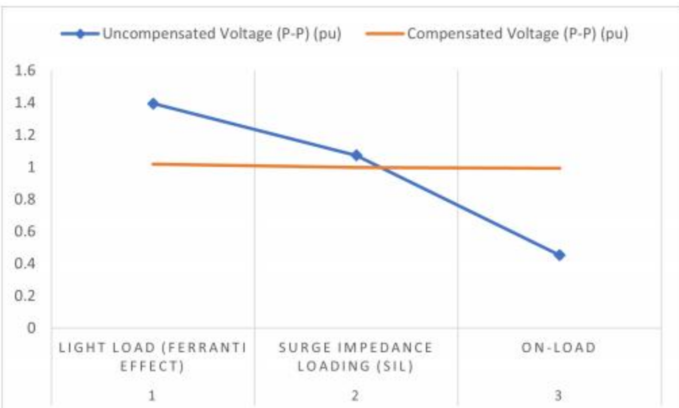

Fig. 4. Voltage profile improvement

In uncompensated system, we observed that receiving-end voltages (VR) had swelling condition during no-load condition, also at loading the voltage sag kept increasing as load increased. But, due to presence of SVC, the compensated system maintained the voltage to 1 pu at any load condition as seen in fig. 4.

The inductive current flowing through TCR is shown in the table below in table IV

Firing angle	Inductive current (I_L)(A)
180	0
162	10.221
145	15.57
135	20.06
111.4	53.75
90	55.25

TABLE II: CURRENT THROUGH TCR

V. CONCLUSION

To sum up, SVC belongs to shunt connected FACTS controllers. Its primary purpose is to compensate low power factor of loads, to control the reactive power and to improve voltage quality at the point of connection. We can conclude that if increase firing angle current through TCR decreases with increase of firing angle thereby increasing the Reactive Power output. This shows that reactive power is compensated and hence stability of power system is improved. It is able to compensate a Low power factor (both lagging and leading) in each phase Independently and automatically within a very short time Period (depending on the type of load and system conditions) as seen in the comparison 4.

VI. ACKNOWLEDGMENT

We are thankful to a number of individuals who have contributed towards our final year project and without their help; it would not have been possible. Firstly, we offer our sincere thanks to our project guide, Mrs. Megha Fernandes for her constant and timely help and guidance throughout our preparation. We are also grateful to the college authorities and the entire faculty for their support in providing us with the facilities required throughout this semester. We are also highly grateful to our Principal, Dr. Sincy George, for providing the facilities, a conducive environment and encouragement.

REFERENCES

[1] A. Meddeb, H. Jmii, N. Amor and S. Chebbi, ”Voltage Stability Enhancement Using FACTS Devices,” 2020 4th International Conference on Advanced Systems and Emergent Technologies (IC ASET), Hammamet, Tunisia, 2020, pp. 257-260.

[2] A. Gelen and T. Yalcinoz, ”The behaviour of TSR-based SVC and TCR-based SVC installed in an infinite bus system,” 2008 IEEE 25th Convention of Electrical and Electronics Engineers in Israel, Eilat, Israel, 2008, pp. 120-124, doi: 10.1109/EEEI.2008.4736670.

[3] D. Szab´ o, M. Regul’a, R. Bodn´ ar and J. Altus, ”Control of a SVC for power factor correction,” 2014 ELEKTRO, Rajecke Teplice, Slovakia, 2014, pp. 379-382.

[4] N. G. Hingorani, L. Gyugyi. ‘Understanding FACTS: Concepts and Technology Flexible Transmission Systems.’ New York: IEEE Press, 1999. Proposed terms and definitions for flexible AC transmission system (FACTS), IEEE Transactions on Power Delivery, Volume 12, Issue 4, October 1997, pp. 1848–1853.