iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** XI **Month of publication:** November 2017

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

VSC Based HVDC Active Power Controller to Damp out Resonance Oscillation in Turbine Generator System

Rajkumar Pal[1], Rajesh Kumar[2], Abhay Katyayan[3]
[1, 2, 3] *Assistant Professor, Department of Electrical and Electronics Engineering, Rajarshi Rananjay Sinh Institute of Management and Technology, Amethi (U.P), India*

Abstract: Power industry taken severe torsional oscillations induced in turbine-generator shaft systems due to Sub synchronous Resonance (SSR). SSR occurs when a natural frequency of a series compensated transmission system coincides with the complement of one of the torsional modes of the turbine-generator shaft system. The frequency can be oscillationates corresponding to the torsional mode frequency and unless corrective action taken. , the torsional oscillations can grow and may result in shaft damage in a few seconds The problem is a control scheme for a VSC-HVDC back to back active power controller to damp all SSR torsional oscillations. In this context are conducted on a HVAC/DC system incorporating a large turbine-generator and a VSC HVDC back-to-back system. The results of the investigations conducted in this thesis show that the achieved control design is effective in damping all the shaft torsional torques over a wide range of compensation levels.
Keywords: Voltage Source Converter, Turbine Generator System, HVDC Back-to-Back Controllers.

I. INTRODUCTION

Transmission system expansion is needed, but not easily accomplished. Factors that contribute to this situation include a variety of environmental, land-use and regulatory requirements. As a result, the utility industry is facing the challenge of the efficient utilization of the existing AC transmission lines. (FACTS) technology is an important tool for permitting existing transmission facilities to be loaded, at least under contingency situations, up to their thermal limits without system security.

The most features is directly control flow of transmission lines by Changing parameters of the grid and to implement high-gain type controllers, based on fast switching.

Thus, Voltage source converter is the active power controller improves the security of a power system and transient stability or by damping the sub synchronous resonance oscillations.

A. Flexible AC Transmission Systems

FACTS and FACTS controller are defined by the IEEE as [5]: "*Flexible AC Transmission System (FACTS):* Alternating-current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability." "*FACTS Controller:* A power electronic-based system and other static equipment that provide control of one or more AC transmission system parameters." The availability of the modern semiconductor devices such as the Gate Turn-Off thyristor (GTO), and the Insulated Gate Bipolar Transistor (IGBT) [6], has led to the development of a new generation of power electric converters. These devices, unlike the conventional thyristors which have no intrinsic turn-off ability, are of the fully controlled type. The most common converters, which employ the self commutating, high voltage, high current, and high switching frequency power electronic devices, are the Voltage Source Converters (VSCs). A number of FACTS controllers which use VSCs as their basic building block have been already in operation in various parts of the world. The most popular controllers are: the Static Compensator (STATCOM) [7,8], the Static Synchronous Series Compensator (SSSC) [9,10], the Unified Power Flow Controller (UPFC) [11,12], and the Voltage Source Converter High-Voltage Direct-Current (VSC HVDC) [3,13,14].

B. Voltage Source Converter

Several VSC topologies are currently used in actual power system operations, such as the single-phase full bridge (H-bridge), the conventional three-phase, two-level converter, and the three-phase, three-level converter based on the neutral-point-clamped converter [2]. There are other VSC topologies that are based on combinations of the neutral-point-clamped and multilevel converters. The common purposes of these topologies are: to minimize the operating frequency of the semiconductors inside the VSC and to produce a high-quality sinusoidal voltage waveform with minimum or no filtering requirements.

The topology of a conventional two-level VSC using IGBT switches is shown in Figure 1. It consists of six IGBTs, with two IGBTs placed on each leg. Moreover, each IGBT is provided with a diode connected in an anti-parallel connection to allow bidirectional current flow. Two equally sized capacitors are placed on the DC side to provide a source of reactive power.

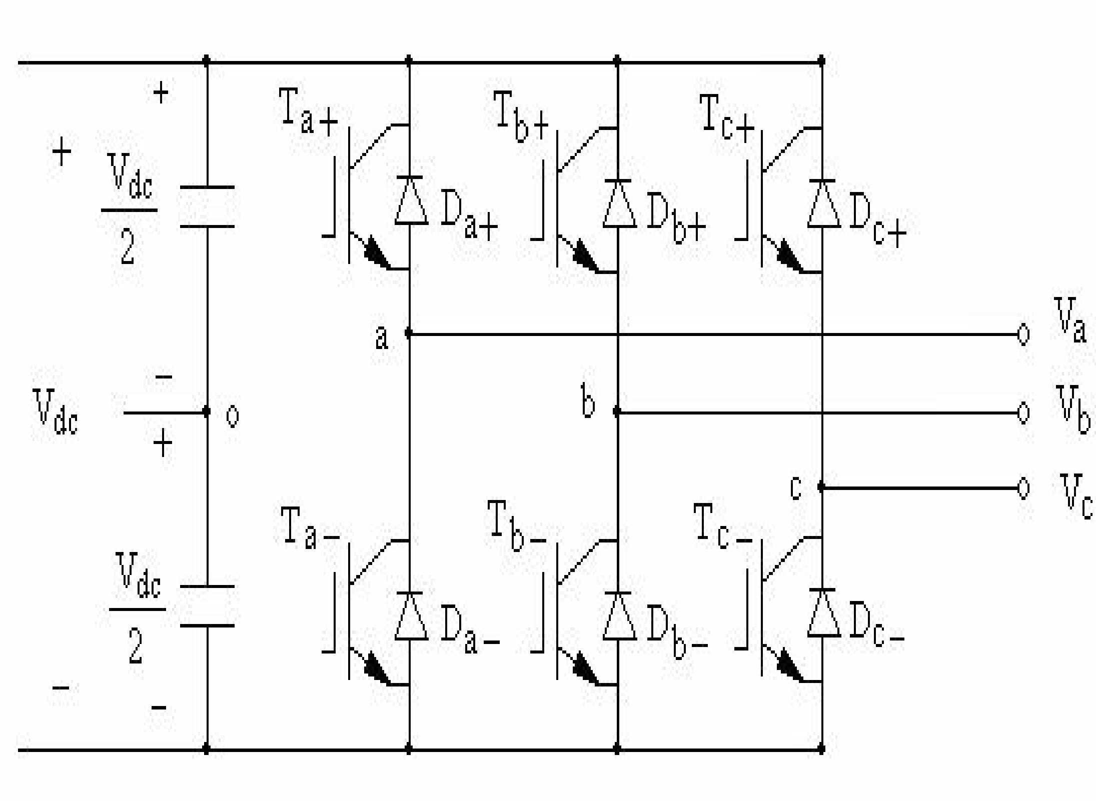


Figure 1 Topology of a three-phase, two-level VSC using IGBTs.

The switching control module, not shown in the circuit of Figure 1, is an integral component of the VSC. Its duty is to control the switching sequence of the various semiconductor devices in the VSC, aiming at producing an output voltage waveform, which is close to a sinusoidal waveform as near as possible, with high power controllability and minimum switching loss. The current VSC switching strategies aimed at utility application may be classified into two main categories [15]:

Fundamental frequency switching: the switching of each semiconductor device has only one turn-on, turn-off per power cycle. The output waveform is a quasi-square wave which often has an unacceptable high harmonic content. It is current practice to use several six-pulse VSCs, arranged to form a multiple structure, to achieve better waveform quality and high power ratings [2].

Pulse-Width-Modulation (PWM): the switches are forced to be turned on and off at a rate considerably higher than the fundamental frequency. The output wave is chopped and the width of the resulting pulse is modulated. Undesirable harmonics in the output waveform are shifted to the higher frequencies, and filtering requirements are much reduced. The sinusoidal PWM scheme remains one of the most popular because of its simplicity and effectiveness [6].These switching techniques are, however, far from perfect. The fundamental frequency switching technique requires complex transformer arrangements to achieve an acceptable level of waveform distortion. The PWM technique incurs high switching loss, but it is expected that future semiconductor devices will reduce this by a significant margin, making PWM the perfect switching technique.

C. Pulse-Width Modulation Control

The basic PWM switching scheme can be explained using the simple one-leg switch mode inverter shown in Figure 1.2.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

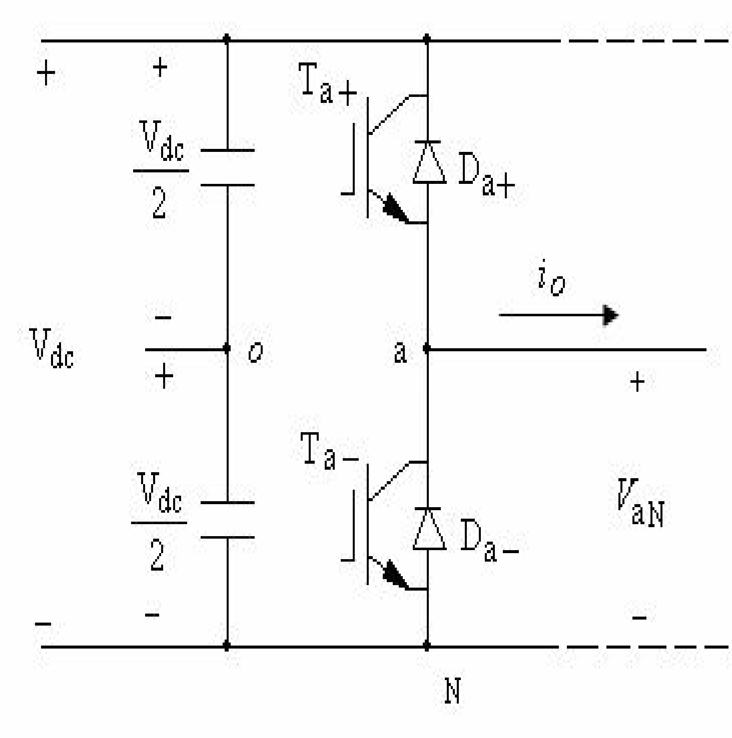


Figure 2 One-leg switch-mode inverter.

In order to produce a sinusoidal output voltage waveform at a desired frequency, a sinusoidal control signal at the desired frequency is compared with a triangle waveform, as shown in Figure 3(a). The frequency of the triangular waveform establishes the inverter switching frequency f_s, and is generally kept constant along with its amplitude V_{tri}. The frequency f_s is also called the carrier frequency. The control signal $V_{control}$ is used to modulate the switch duty ratio and has a frequency
f_1, which is the desired fundamental frequency of the inverter voltage output (f_1 is also called the modulating frequency), recognizing that the inverter output voltage will not be a perfect sine wave and will contain voltage components at harmonic frequencies of f_1. The amplitude modulation ratio m_a is defined as-

$$ma = \frac{Vcontrol}{Vtri}$$

Where, $V_{control}$ is the peak amplitude of the control signal.
The frequency modulation ratio m_f is defined as

$$mf = \frac{fs}{f1}$$

In the inverter of Figure 2, the switches *Ta+* and *Ta-* are controlled based on the comparison of $V_{control}$ and V_{tri}, and the following output voltage results, independent of the direction of the current i_o:

$V_{control} > V_{tri}$, *Ta+* is on, $V_{ao}=V_{dc}/2$

or

$V_{control} < V_{tri}$, *Ta-* is on, $V_{ao}=-V_{dc}/2$

Since the two switches are never off simultaneously, the output voltage V_{ao} fluctuates between two values ($V_{dc}/2$ and- $V_{dc}/2$). The voltage V_{ao} and its fundamental frequency component (dashed curve) are shown in Figure 3 (b).

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

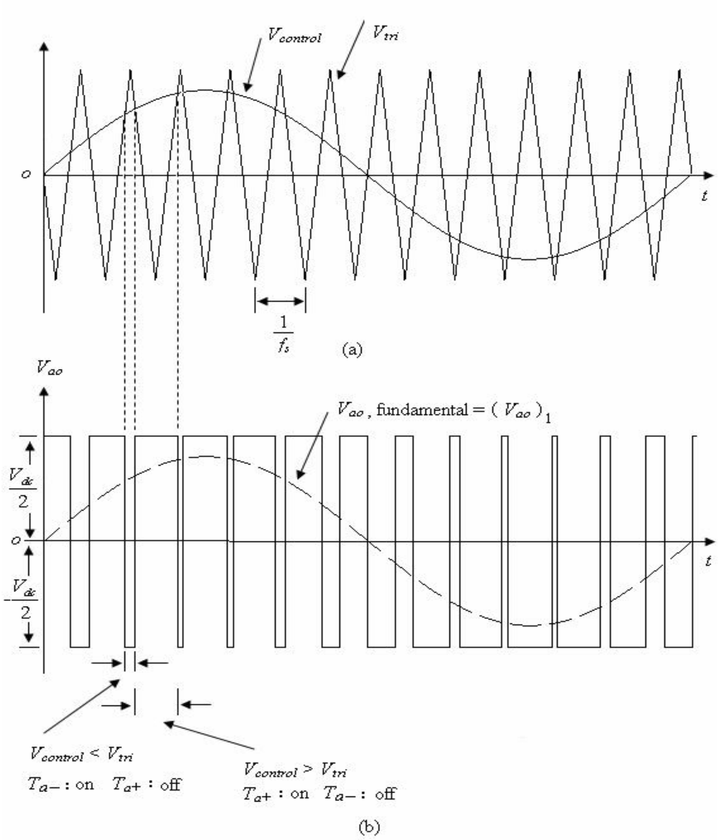


Figure 3 Operation of a pulse-width modulator: (a) comparison of a sinusoidal

Fundamental frequency with a high frequency triangular signal; (b) resulting train of square-waves. With PWM, it is possible to create any phase angle or amplitude (up to a certain limit) by changing the PWM pattern, which can be done almost instantaneously. Hereby, PWM offers the possibility to control both the active and the reactive power independently. This makes the PWM VSC close to an ideal component in the transmission network. From a system point of view, it acts as a motor or generator without a mass that can control the active and the reactive power almost instantaneously. Furthermore, it does not contribute to the short circuit power as the ac current can be controlled [16].

D. Principle of Voltage Source Converter Operation

Consider a VSC connected to an AC system through a lossless reactor as illustrated in Figure 4. The converter produces an AC voltage with a fundamental frequency equal to that of the AC reference voltage. The voltage at the supply bus is assumed to be $V_s\angle 0$, and the AC voltage produced by the VSC is taken to be $V_{sh}\angle\delta$. X_l is the reactance of the converter reactor

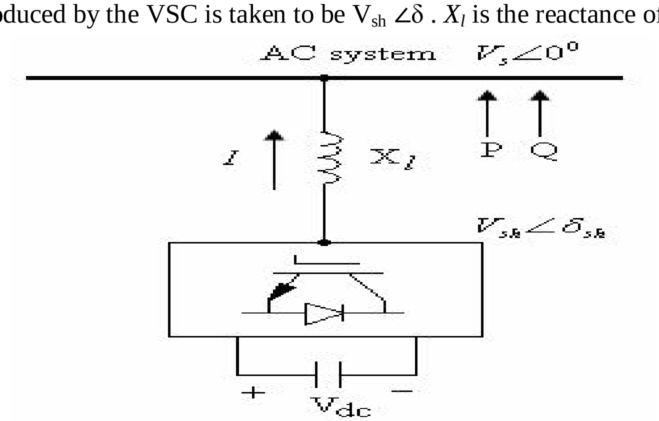


Figure 4 A VSC connected to an AC system.

The active and the reactive power can be expressed respectively as

$$P = \frac{VshVs}{Xl} Sin\delta sh \quad (1)$$

$$Q = \frac{VshVs}{Xl} Cos\delta sh - \frac{V^2}{Xl} \quad (2)$$

A complete derivation of Equations (1.4) and (1.5) is given in Appendix A. With respect to these two Equations, the following observations are noticed: 1. The active power flow between the AC source and the VSC is controlled by the phase angle δ_{sh}. The active power flows into the AC source from the VSC for $\delta_{sh} > 0$, and flows out of the AC source from the VSC for $\delta_{sh} < 0$. The reactive power flow is determined mainly by the amplitude of the AC source voltage, *Vs*, and the VSC output fundamental voltage, V_{sh}, as the angle δ_{sh} is generally small. For $V_{sh} > V$, the VSC generates reactive power and while it consumes reactive power when $V_{sh} < V$. Because of its key steady-state operational characteristics and impact on system voltage and power flow control, the VSC is becoming the basic building block employed in the new generation of FACTS controllers.

E. Modeling of the Turbine-Generator Mechanical System

The turbine-generator mechanical system [17,18], shown in Figure 5, consists of a high-pressure turbine (HP), an intermediate-pressure turbine (IP), two low-pressure turbines (LPA & LPB), the generator rotor (GEN) and the exciter (EXC). They together constitute a linear six-mass-spring system.

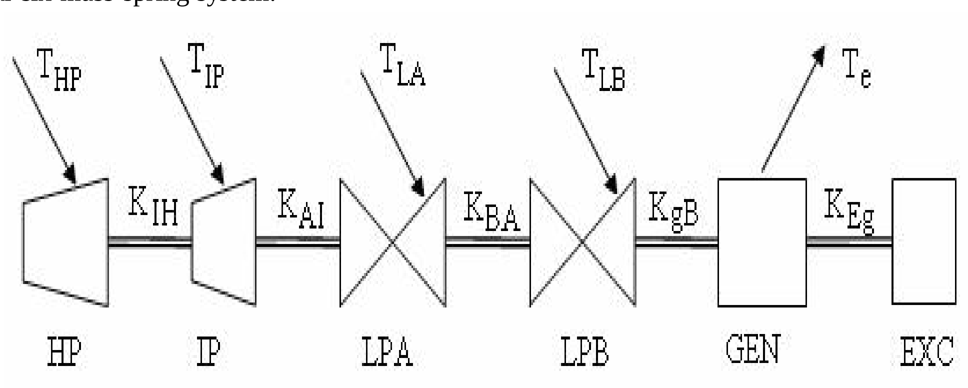


Figure 5 Structure of a typical six-mass shaft system model.

Assuming that *M* is the inertia constant in seconds, *D* is the damping coefficient in p.u. torque/p.u. speed for each rotating mass and *K* is a stiffness in p.u. torque/rad for each shaft section, the equations of the i^{th} mass of an N-mass spring system shown in Figure 6 are given by

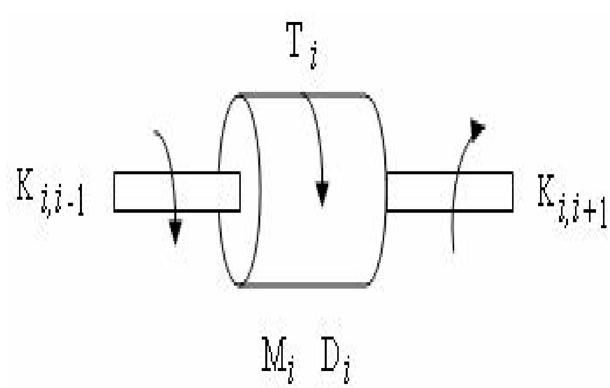


Figure 6 The ith mass of an N-mass spring system.

F. Governor and Turbine System

The block diagram of the four-stage turbine and the associated electro-hydraulic governor [19] is shown in Figure 7. The corresponding data are given in Appendix B.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

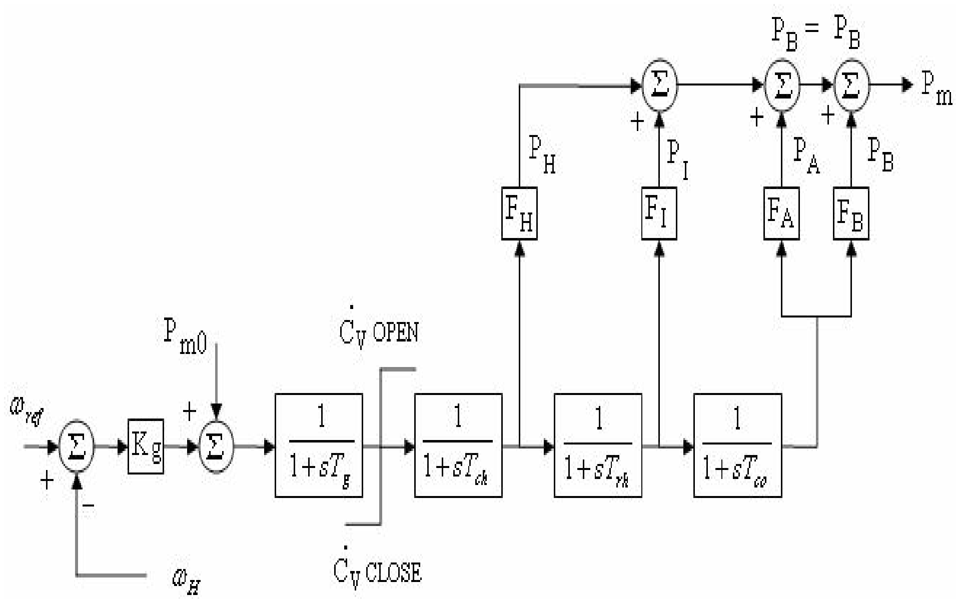


Figure 7 block diagram of the four-stage turbine and the associated electro-hydraulic governor

G. Behaviour of the VSC HVDC Back-to-Back Controllers in Damping SSR Oscillations at the Critical Compensation Levels-

To demonstrate the effectiveness of VSC HVDC back-to-back controllers in mitigation of SSR oscillations under large disturbances at the critical compensation levels, several studies of a three-cycle, three-phase faults at the generator terminals are carried out on the system under investigations for the following two cases:

1) *Case I:* The active power controller is in service and the supplementary controller is out of service.
2) *Case II:* Both the active power and the supplementary controllers are in service.

II. CONCLUSION

The studies conducted in this paper yield the following conclusions:

A. The designed controllers for the VSC HVDC back-to-back system considered in this paper are robust with respect to the critical compensation levels and a wide range of loading conditions

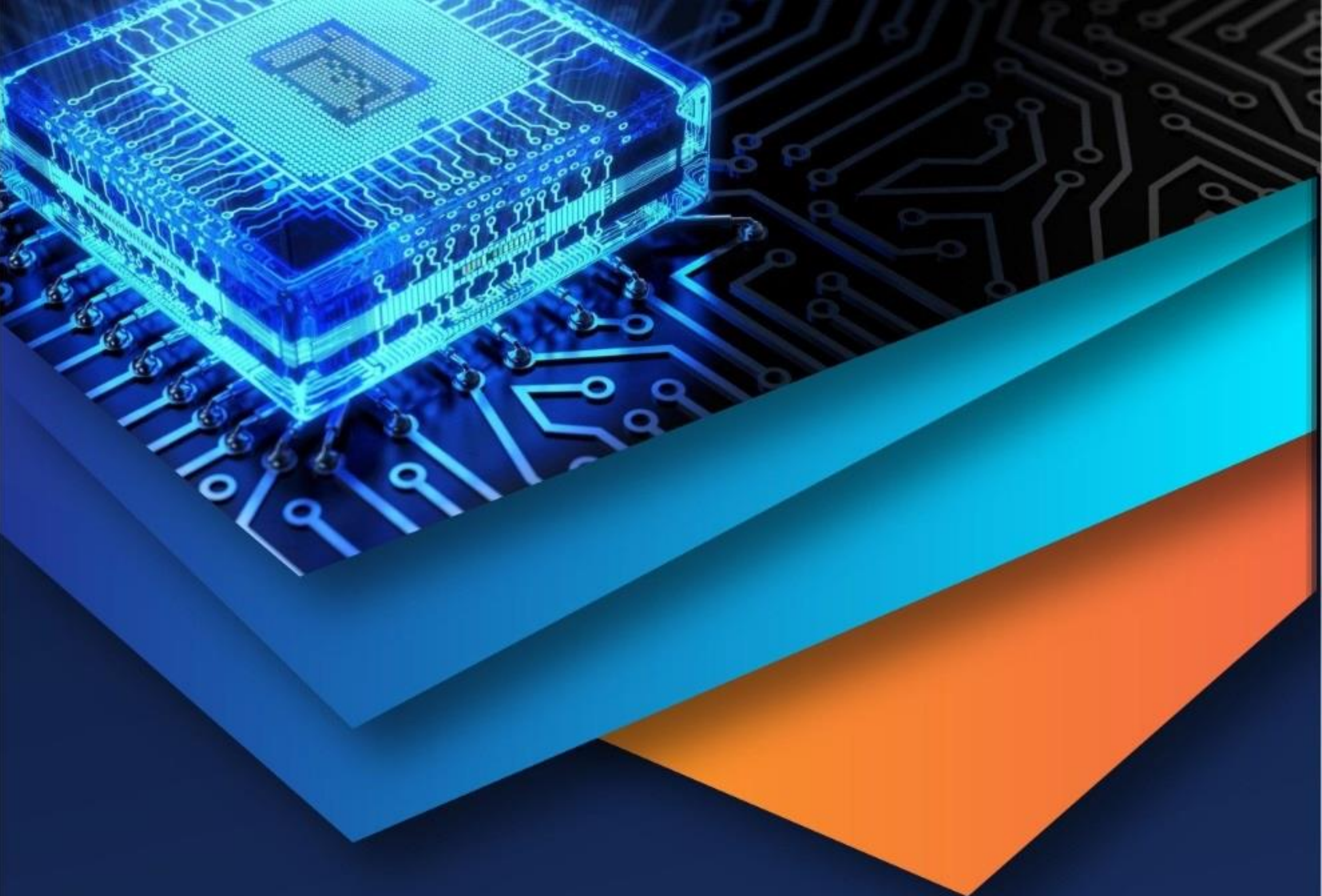
B. The designed active power controller of the VSC HVDC back- to-back system is capable of damping SSR oscillations when the compensation levels are 41.1% and 54.7% corresponding to the unstable torsional Modes 3 and 2 respectively. These oscillations, however, are poorly damped by the active power controller. The supplementary controller provides better damping in corporation with the active power controller

C. Increasing the active power flowing from the turbine- generator to the VSC HVDC back-to-back link does not change the effectiveness of the VSC HVDC back-to-back controllers on the dynamic performance of the system. It only results in an increase in the amplitude of the active power controller output signals *mE* and *mB.*

REFERENCES

[1] Song, Y. H. and Johns, A. T., Flexible AC transmission systems (FACTS), London, Institution of Electrical Engineers, 1999.
[2] Hingorani, N. G. and Gyugyi, L., Understanding FACTS: concepts and technology of flexible AC transmission systems, New York, IEEE Press, 2000.
[3] Acha, E., FACTS: modelling and simulation in power networks, Chichester, Wiley, 2004
[4] Mathur, R. M. and Varma, R. K., Thyristor-based FACTS controllers for electrical transmission systems, Piscataway, NJ, IEEE, 2002.
[5] Edris, A. A., Adapa, R., Baker, M. H., Bohmann, L., Clark, K., Habashi, K., Gyugyi, L., Lemay, J., Mehraban, A. S., Myers, A. K., Reeve, J., Sener, F., Torgerson, D. R., and Wood, R. R., "Proposed terms and definitions for flexible AC transmission system (FACTS)," IEEE Transactions on Power Systems, vol. 12, no. 4, pp. 1848-1853, 1997
[6] Mohan, N., Undeland, T. M., and Robbins, W. P., Power electronics: converters, applications, and design, New York, Wiley, 1995.
[7] Gyugyi, L., Hingorani, N. G., Nannery, P. R., and Tai, N. "Advanced static Var compensator using gate turn-off thyristors for utility applications." , 23-203. 1990. Paris, France, CIGRE
[8] Gyugyi, L., "Dynamic compensation of AC transmission lines by solid-state synchronous voltage sources," IEEE Transactions on Power Delivery, vol. 9, no. 2, pp. 904-911, Apr.1994

[9] Gyugyi, L., Schauder, C. D., and Sen, K. K., "Static synchronous series compensator: a solid-state approach to 417, Jan.1997
[10] Sen, K. K., "SSSC-static synchronous series compensator: theory, modeling, and application," IEEE Transactions on Power Delivery, vol. 13, no. 1, pp. 241-246, Jan.1998
[11] Gyugyi, L., Schauder, C. D., Williams, S. L., Rietman, T. R., Torgerson, D. R., and Edris, A., "The unified power flow controller: a new approach to power transmission control," IEEE Transactions on Power Delivery, vol. 10, no. 2, pp. 1085-1097, Apr.1995.
[12] Nabavi-Niaki, A. and Iravani, M. R., "Steady-state and dynamic models of unified power flow controller (UPFC) for power system studies," IEEE Transactions on Power Systems, vol. 11, no. 4, pp. 1937-1943, 1996
[13] Schettler, F., Huang, H., and Christl, N. "HVDC transmission systems using voltage sourced converters – Design and applications." 2, 715-720. 2000.



10.22214/IJRASET

INDEX COPERNICUS
45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY