iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 **Issue:** IV **Month of publication:** April 2015

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Optimization of Co-ordination Control of FACTS Devices by Using Fuzzy Lead-Lag Controller

Anand Chandrashekaran[1], Anbalagan.A[2], Bibin Jose.J.S[3]
[1,2,3]PG Scholar, Department of Electrical and Electronics Engineering,
Anna University, Regional Centre, Coimbatore - 47

Abstract*— Power system stability control is an important task in power system operation. Several factors, such as external disturbances or internal mechanical torques, may easily affect the power system stability. Hence, the structural control of electric power networks has recently attracted more attention. FACTS devices are used to dynamically adjust the network configuration to enhance steady-state performance as well as dynamic stability. FACTS devices provide series or shunt compensation, but they interfere with one another when they are made to work together in a power system, causing damping oscillations in the line. In this paper, Thyristor-controlled series capacitor (TCSC) and the Static VAR compensator (SVC) are used for improving the power system stability. A novel approach of designing a controller which adaptively determines the parameters of two controllers at each control step according to the deviations of generator rotor speeds of the power system is developed to reduce the damping oscillations. The parameters are estimated by using the generator speeds and the monotonous time consuming and inaccurate process of human calculations is avoided, which has been used is proved to be more accurate than the conventional approach thus providing active power flow regulation and reactive power compensation.
IndexTerms*—Flexible AC transmission system (FACTS), fuzzy control, static VAR compensator (SVC), thyristor controlled series capacitor (TCSC).

I. INTRODUCTION

Day by day the demand on power system increasing substantially due to increase in population and change in living standard of the people and also substantial growth in industry, while the modification and expansion of existing power system, that is generation, transmission and distribution network has been several restrictions, due to environmental restrictions and limited resource. Due to limited resources and environmental restrictions, existing transmission lines are getting highly loaded, and system stability becomes a power transfer-limiting factor. So for better utilization of available orpresent power system, flexible AC transmission systems (FACTS) controllers have been implemented. With the help of multiple FACTS controllers, we can easily control various parameters of transmission line such as line impedance, terminal voltage, and voltage angles. FACTS devices furnishes secure tie line connection with neighbouring utilities by diminishing generally speaking crop save prerequisites on either sides. Operation speed of whole power system get improved with help of FACTS devices, interconnection of renewable and distributed generation and storages.Dynamic devices and fixed capacitance devices are the first generation of the FACTS devices. The typical devices are including tap changing and phase changing transformer, synchronous generator and series capacitors. Except the series capacitors, which could also be called capacitor bank, others are dynamic devices. These devices are mainly controlled at the generation side of the power grid and the cost is typically expensive. The series capacitor is made up of many fixed-capacitance capacitors; it could hardly be controlled to give the real not-fixed capacitance to the grid. Static state compensator is the second generation of the FACTS devices. It could be classified into two categories, thyristor-based devices and fully-controlled devices based compensator. The thyristor is called half-controlled device, because it can only be controlled to switch on but not to cut off. There are several different methods proposed in literatures for optimal location of FACTS controllers in both deregulated and privatization power systems by considering there different operating conditions viewpoint. There are three main techniques for the placement of FACTS controllers from different operating conditions viewpoint in multi-machine power systems, such as a sensitivity based methods, optimization based method, and artificial intelligence based method.The main function of FACTS controller coordination is to provide additional degree of freedom to control power flows and voltages in existing power system at key location of network. There are numbers of approaches proposed in literatures for coordination of multiple FACTS controllers in multi-machine power systems from different operating conditions viewpoint. There are three broad categories such as a sensitivity based methods, optimization based method and artificial intelligence based techniques for coordination of FACTS controllers from diverse managing conditions in multi-machine power systems. Other FACTS controllers such as thyristor-controlled voltage limiter (TCVL), thyristor-controlled voltage regulator (TCVR), and hybrid flow controller (HFC) are also used. The installation of one

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

FACTS device in the power system does not improve voltage stability and reduction in power system losses. So multi-type FACTS devices are used to enhance both voltage stability margin and reduce losses in the system. For the better utilization of existing power system the proper coordination of one FACTS devices or multi-FACTS controller is necessary.

In this project, two FACTS devices namely the Thyristor-controlled series capacitor (TCSC) and the Static VAR compensator (SVC) are used for improving the power system stability. A novel approach of controlling these two devices simultaneously to reduce the damping oscillations has been developed. The controller used adaptively determines the parameters of two lead-lag controllers at each control step according to the deviations of generator rotor speeds of the power system. The parameters are estimated by using the generator speeds and the monotonous time consuming and inaccurate process of human calculations is avoided. This parameter estimation technique which has been used is proved to be more accurate than the conventional approach. The impact of individual FACTS controllers on control centre operations is not very significant. However, as multiple FACTS systems are added to a transmission system, it becomes necessary for the control activities to be integrated and centrally coordinated. This is to avoid unforeseen interactions between control operations in one area with that in another area.

A Thyristor-controlled series capacitor (TCSC) is made up of a Thyristor controlled reactor in parallel with a fixed capacitor. Compared to TCR and SVC, TCSC is a series connected controller instead of a shunt-connected device. Hence, TCSC is always represented in single-phase form instead of three-phase form, and is always comprised of one or more sub-modules. TCSC changes the electrical length of the existing transmission line with negligible delay. This characteristic makes TCSC be used to perform the fast active power flow regulation. But adding TCSC into the existing system will change the phase angle of the buses. The Static VAR compensator (SVC) typically consists of a Thyristor-Controlled Reactor in parallel with a capacitor bank, which acts as a shunt connected variable reactance. The SVC cannot only generate but also absorb reactive power. When system voltage is low, the SVC generates reactive power (SVC capacitive). When system voltage is high, it absorbs reactive power (SVC inductive). Thus in this project the TCSC and SVC are operated together in a power system and they are co-ordinated to operate together so as to provide both active power flow regulation and reactive power compensation. The model is developed, simulated and validated with results to show the operations of both the FACTS devices together in a same power system.

II. FLEXIBLE AC TRANSMISSION SYSTEMS

FACTS is defined by 'IEEE' as power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and power transfer capability. The FACTS can be classified broadly into two main types. It is as follows:

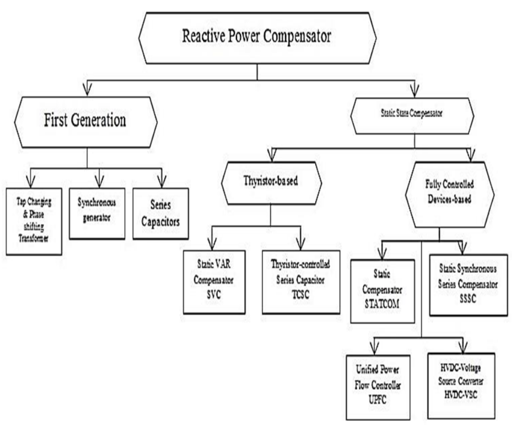
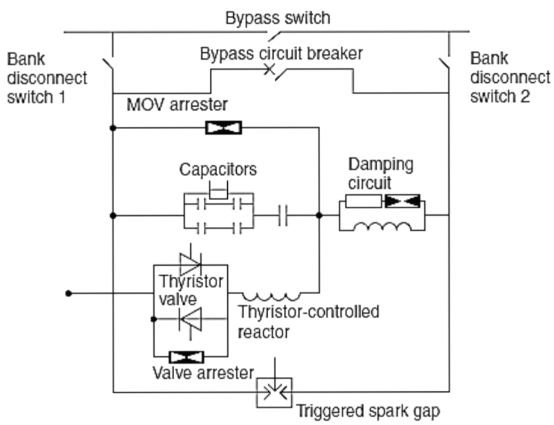


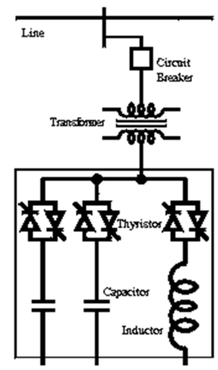
Fig. 1Classification of FACTS devices

A.Thyristor Controlled Series Capacitor (TCSC)

The basic thyristor controlled series capacitor scheme proposed in 1986 by Vithayathil with others as a method of rapid adjustment of network impedance is shown in Fig 2. It consists of the series compensating capacitor shunted by a thyristor-controlled reactor. In a practical TCSC implementation several such basic compensators may be connected in series to obtain the desired voltage rating and operating characteristics. TCSC is a capacitive reactance compensator which consists of a series capacitive bank shunted by a thyristor controlled reactor in order to provide smoothly variable capacitive reactance.



a.



b.

Fig. 2a Single Line Diagram of TCSC
Fig. 2b Single Line Diagram of SVC

B. Static VAR Compensator (SVC)

The SVC regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the SVC generates reactive power (SVC capacitive). When system voltage is high, it absorbs reactive power (SVC inductive). An SVC can improve power system transmission and distribution performance in a number of ways. Installing an SVC at one or more suitable points in the network can increase transfer capability and reduce losses while maintaining a smooth voltage profile under different network conditions. The dynamic stability of the grid can also be improved, and active power oscillations mitigated.

III. MODELLING OF TCSC AND SVC

A. Modelling of SVC

The SVC is a shunt device of the FACTS family using power electronics to control power flow and improve transient stability on power grids. The output of the compensator is controlled in steps by sequentially switching of TCRs and TSCs.By stepwise switching of reactors rather than continuous control, the need for harmonics filtering as part of the compensator scheme is eliminated. SVC application studies require appropriate power system models and study methods covering the particular problems to be solved by the SVC application.

The parameters of the SVC have to be selected to SVC rating and performance criteria taking into account the power system behaviour under various operating conditions.

Table 1: Typical Parameters for SVC Models:

Module	Parameters	Definition	Typical Value
Measuring	T_m	For Time Constant	0.001-0.005s
Thyristor Control	T_d T_b	Gating Delay Firing Delay	0.001s 0.003-0.006s
Voltage Regulator	K_i	Integrator Gain	K_i can be adjusted
Slope	X_{SL}	Steady-state error	0.01-0.05 p.u

1) *Simplified Transfer Function of SVC:* The system stability studies narrate how to get the substantial results by means of SVC to stabilize system voltages. For this situation the power system is represented by a source voltage in series with an equivalent system reactance X_e in p.u. Fig. 4 shows a simplified block diagram of the SVC with closed lope terminal voltage control.

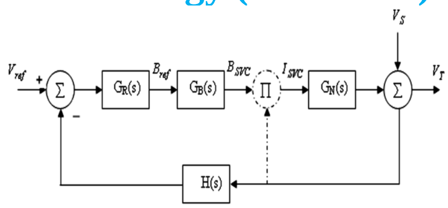


Fig.3 Simplified Transfer Function of SVC

In the simplified model:

$H(s) = \frac{1}{1+sT_m}$: transfer function of the voltage measuring device.

$G_R(s) = \frac{K_{SL}}{1+sT}$: transfer function of voltage regulator and slope unit.

$G_B(s) = \frac{1}{1+sT_d}$: transfer function of compensator main circuit.

$G_N(s) = X_e$: transfer function of the network.

The slope of the steady-state characteristics is related to transfer function gain, $K_{SL} = \frac{1}{X_{SL}}$

For simplified model, we have:

$$\Delta V_T(s) = \frac{G_R(s)G_B(s)G_N(s)}{1 + G_R(s)G_B(s)G_N(s)H(s)}\Delta V_{ref}(s) + \frac{1}{1 + G_R(s)G_B(s)G_N(s)H(s)}\Delta V_s(s)$$

2) *Effects of location of SVC in transmission line:* Location of an SVC strongly affects controllability of the swing modes. In general the best location is at a point where voltage swings are greatest. Normally, the mid-point of a transmission line between the two areas is a good candidate for placement. Thyristor Controlled Reactor (TCR): is a fixed reactor in series with bidirectional Thyristor valve. The amplitude of the TCR current can be changed continuously by varying the Thyristor firing angle from 90° to 180°. The TCR firing angle can be fully changed within one cycle of the fundamental frequency, thus providing smooth and fast control of reactive power supply to the system. Thyristor Switched Capacitor (TSC): comprises of a capacitor in series with bidirectional thyristor valve and a damping reactor, used to switch on and off the capacitor bank. The TSC can operate in coordination with the TCR so that the sum of the reactive power from the TSC and the TCR becomes linear.

B. Modelling of TCSC

A TCSC involves continuous-time dynamics, relating to voltages and currents in the capacitor and reactor, and nonlinear, discrete switching behaviour of thyristor. Deriving an appropriate model for such a controller is an intricate task. A TCSC model for transient and oscillatory-stability studies, used widely for its simplicity, is the variable-reactance model, the TCSC dynamics during power-swing other dynamics of the TCSC model, the variation of the TCSC response with different firing angles are neglected. It is assumed that the transmission system operates in a sinusoidal steady state, with the only dynamics associated with generators and PSS. This assumption is valid, because the line dynamics are much faster than the generator dynamics in the frequency range of 0.1-2Hz that are associated with angular-stability studies.The variable reactance TCSC model assumes the availability of a continuous-reactance range and is therefore applicable for multi-module TCSC configurations. This model is generally used for inter-area model analysis and provides high accuracy when the reactance-boost factor (X_{TCSC}/X_c) is less than 1.5.

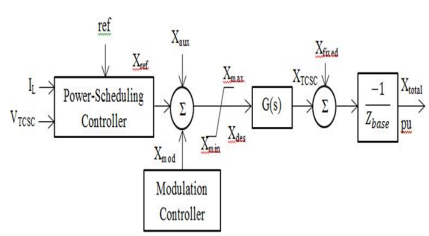


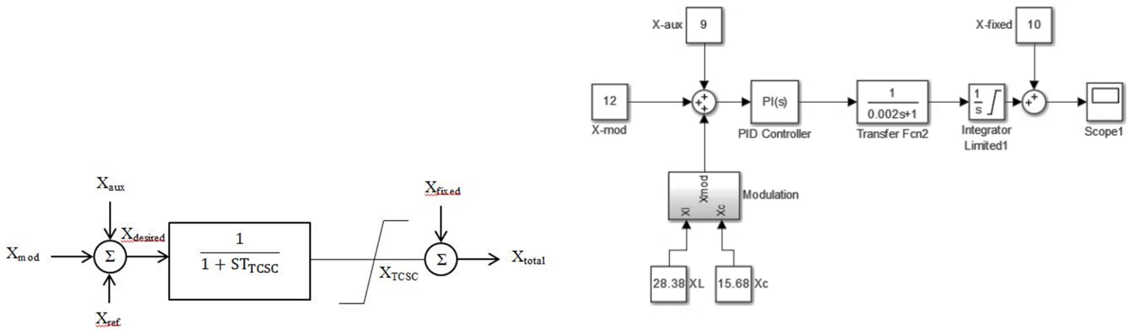
Fig.4 Simplified Transfer Function of TCSC

Volume 3 Issue IV, April 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

IV. RESULTS

A. Simulation of TCSC

The simulation of the TCSC is carried out by developing the transfer function model of the TCSC. The TCSC contains only one main block. The PID controller is used for controlling the output with the change in the input parameters. The output obtained is the X_{total} which is the total reactance.



a. b.

Fig. 5a Block Diagram of TCSC

Fig. 5b Simulation diagram of TCSC

B. Simulation Output of the TCSC

The simulation of the TCSC is carried out in the MATLAB by developing the transfer function model as shown in the Figure 7 and the inputs are X_{mod}, X_{aux}, X_L and X_C. The output is obtained as shown in the Figure 8. The output depicts the value of X_{total} which is the total net reactance. The values of the various input parameters are as follows:

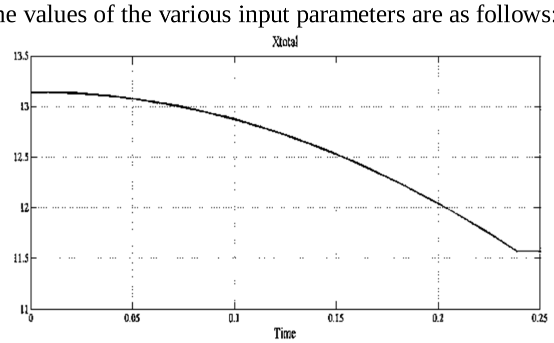


Fig.6 Simulation output of TCSC (X_{total})

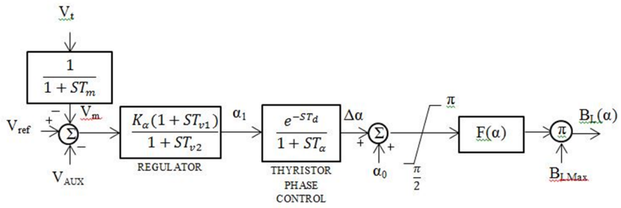
Table 2: Input Parameters for TCSC:

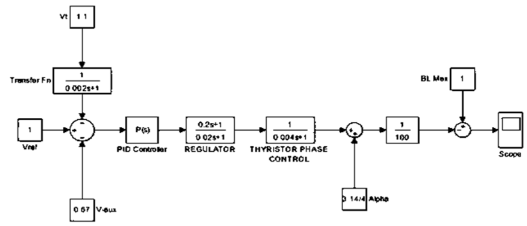
X_{mod}= 12 Ω	X_{aux}= 9 Ω	X_L= 28.38 Ω
X_C= 15.68 Ω	T_{TCSC}= 0.002 ms	Time = 0.25 s

C. Simulation of SVC

The simulation of the SVC is carried out by developing the transfer function model of the SVC. There are mainly two blocks, namely the regulator and the thyristor phase control. These two blocks are the main components of the SVC transfer function model. The inputs are V_t, V_{ref} and V_{aux}. The output is V_{t1} which is the terminal voltage.

Volume 3 Issue IV, April 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)





a. b.

Fig.7a Block diagram of SVC

Fig. 7b Simulation diagram of SVC

D. Simulation output of the SVC

Thus the simulation of the SVC is carried out in the MATLAB by developing the transfer function model as shown in the Figure 10 and the inputs are V_t, V_{ref} and V_{aux}. The output is obtained as shown in the Figure 11. The output depicts the value of V_{t1} which is the terminal voltage. The values of the various input parameters are as follows:

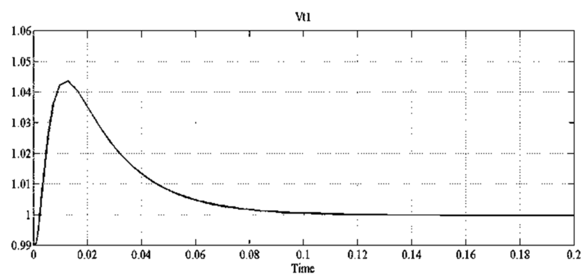


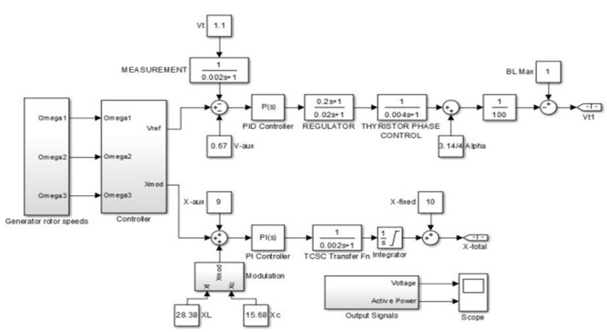
Fig. 8 Simulation output of the SVC

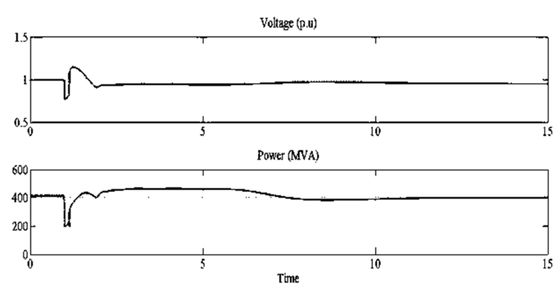
Table 6.2: Input Parameters for SVC

V_t= 1.1 p.u	V_{ref}= 1 p.u	V_{aux}= 0.67p.u	T_m= 0.002ms
T_{v1}= 0.2ms	T_{v2}= 0.02ms	T_α= 0.004ms	B_{Lmax} = 1

E. Simulation of Coordination Control of TCSC and SVC:

As shown above, the TCSC transfer function model and the SVC transfer function model have been modelled and simulated individually. Since the outputs of the SVC and the TCSC have been different parameters, we cannot combine these both as it is. Thus we require a generator rotor variation. Thus a real time power system is considered and the implementation of the SVC and the TCSC is obtained. The controller is designed for the purpose of modelling the outputs of the generator rotor speeds and analysing the current situation of the power system. When the fault occurs, the generator rotor speeds go out of synchronism. Thus the values are compared and the output Voltage and Power is shown in the output.





a.b.

Fig.9a Simulation diagram of Coordination control of TCSC and SVC

Fig. 9b Simulation output of the Coordination control of TCSC and SVC

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

F. Simulation output of the Coordination control of TCSC and SVC

The outputs obtained are the voltage of the coordinated system and the power. The first graph indicates the output terminal voltage in per unit values. The second graph below indicates the power of the entire coordinated system. The fault occurs at the time t = 0.5s. This shows that the dynamic stability is achieved despite of large deviation in the rotor speeds of the generator which is caused because of the faults that occur in the power system. The generator rotor speeds block calculates the generator rotor speed that can be obtained from a multi-machine power system. The controller block controls the parameters of the input to the SVC and the TCSC by which a coordinated control can be obtained. The controller analyses the generator rotor speeds and the PID controller tunes the output with the obtained values of V_t, V_{ref}, etc. The fault occurs at 0.5s and it is observed that the voltage of the system is restored back to normal after quite some time. Thus the coordination control output is clearly obtained and the simulation diagram is shown in the Figure 12 and the output is shown in the Figure 13.

V. CONCLUSION

Thus the design of a controller which can control both the FACTS devices, Thyristor Controlled Series Capacitor (TCSC) and the Static VAR Compensator simultaneously was developed. The coordinated control of the two FACTS devices -Thyristor Controlled Series Capacitor (TCSC) and the Static VAR Compensator was successfully implemented. The TCSC and SVC was modelled individually and its results were observed and analysed. The coordination control of the FACTS devices requires analysing certain parameters. The generator rotor speeds is considered as the main parameter for obtaining the coordinated control of the TCSC and the SVC. The controller is designed such that the parameters are analysed on its own, instead of involving manual calculations which prove to be a maladroit technique. The development of the controller was carefully designed such that the damping inter-area oscillations are avoided. Thus the Coordination control of TCSC and SVC was achieved and theoretical and experimental results are presented to verify the new dispensation.

REFERENCES

[1] Y. Zhang and A. Bose (2008), "Design of wide area damping controllers for inter-area oscillations," IEEE Transactions on Power Systems, Vol. 23, No. 3, pp. 1136–1143, August 2008.

[2] Alisha Bangla and S.S. Kaushik (2011), "Modelling and Simulation of SVC controller for enhancement of Power System Stability", International Journal of Advances in Engineering & Technology.

[3] A.N.Tiwari, Bindeshwar Singh and N.K.Sharma (2013), "Coordinated Control and Interactions between FACTS controllers in Multi-Machine Power System Environments", the Fifteenth National Power Systems Conference (NPSC), IIT Bombay, December 2013.

[4] Chia-Hung Hsu, Chia-Fang Juaung and Chun-Fang Lu (2013), "Coordinated Control of Flexible AC Transmission System Devices Using an Evolutionary Fuzzy Lead-Lag Controller with Advanced Continuous Ant Colony Optimization", IEEE Transactions on Power Systems, Vol. 28, No. 1, February 2013.

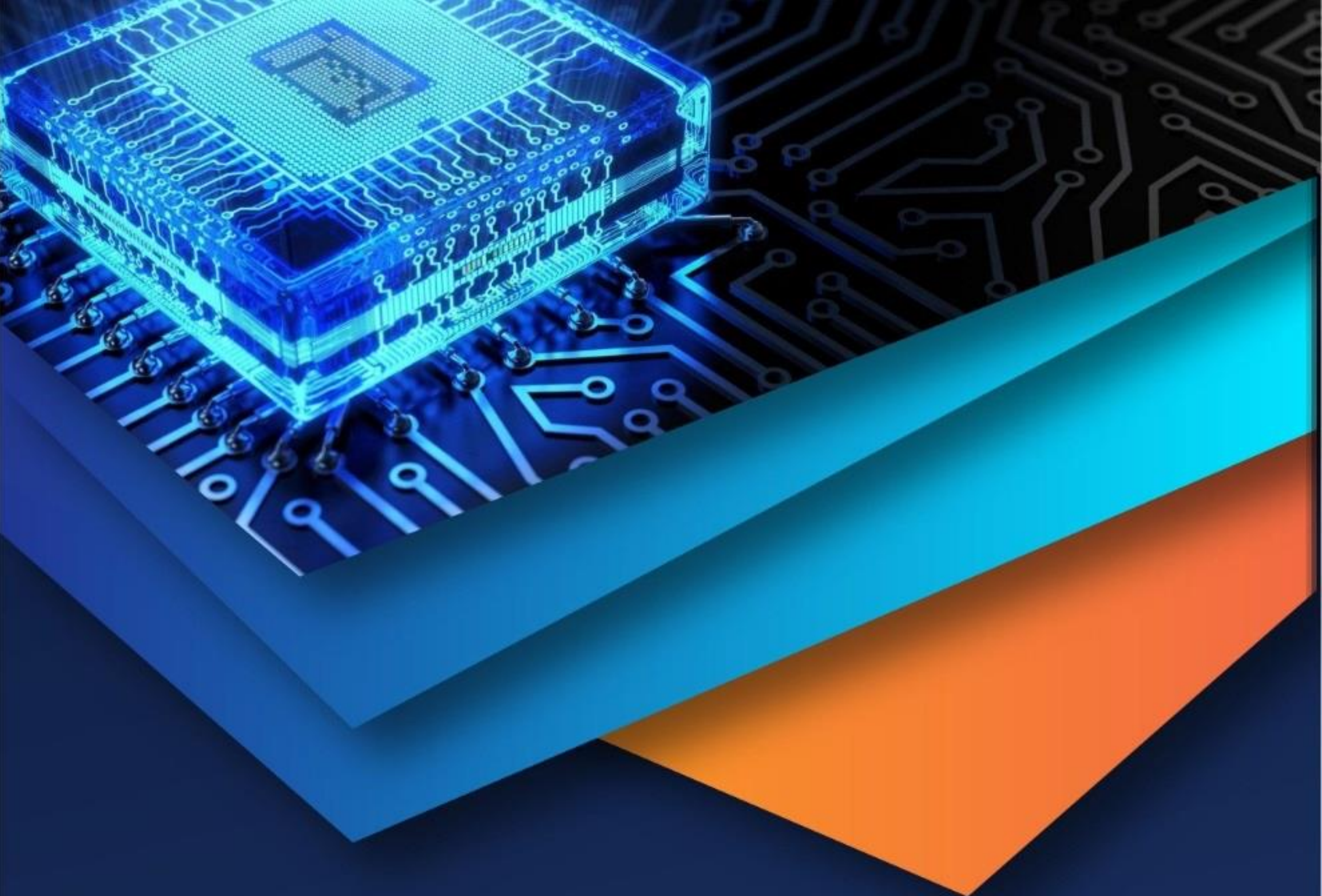
[5] C. F. Juang (2011), "A hybrid of genetic algorithm and particle swarm optimization for recurrent network design," IEEE Transactions on Power Systems, Vol. 34, No. 2, pp. 997–1006, April 2011.

[6] C. F. Juang and P. H. Chang (2010), "Designing fuzzy-rule-based systems using continuous ant-colony optimization," IEEE Transactions on Fuzzy System, Vol. 18, No. 1, pp. 138–149, February 2010.

[7] C. F. Juang and C. F. Lu (2012), "Evolutionary fuzzy control of flexible AC transmission system," Proc. Inst. Elect. Eng., Generation, Transmission, Distribution, Vol. 152, no. 4, pp. 441–448, July 2012.

[8] C. Y. Chung, K. W. Wang, C. T. Tse, X. Y. Bian, and A. K. David (2012), "Probabilistic Eigen value Sensitivity Analysis and PSS Design in Multi-machine Power Systems," IEEE Transactions on Power Systems, Vol.18, No. 4, November 2012.

[9] GuangYa Yang, GeirHovland, RajatMajumder, and Zhao Yang Dong (2007), "TCSC Allocation Based on Line Flow Based Equations Via Mixed-Integer Programming", IEEE Transactions on Power Systems, Vol. 22, No. 4, November 2007.



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