Study of FACTS Device Applications for the 220kV Southwest Region of the Vietnam Power System

Bon Nhan Nguyen, Lam Thanh Le, Quyen Cao Le, Thai Hong Pham, Chiem Tan Nguyen, Hoang Trong Nguyen

Abstract - ***This paper presents a study of FACTS devices applications, in particularly choice of adequate shunt compensators (type of FACTS devices, location) in order to improve voltage and transient angle stability. The study is carried out for the 500kV Southern Vietnam power system in 2020 with a high load scenario. The load flow calculation, P-V curve analysis and transient stability study are examined by using the PSS/E-33 software. The obtained results show that with the application of FACTS devices, voltage stability and transient angle stability of this power system are considerably improved.***

Keywords – ***Voltage stability, Transient stability, reactive power allocation, FACTS, PSS/E***

I. INTRODUCTION

Power system plays an important role as the major infrastructure in any country. However, with the increases in economic and environment pressure, the power system now become large-scales, more complex and operating closer to their stability limit. Some power system blackouts that occurred throughout the world in recent years are consequence of that situation. Generally, network blackouts related to voltage collapse caused by lack of reactive power support in heavy conditions, or by faults.

Flexible Alternative Current Transmission System (FACTS) controllers have been proposed to enhance the transient or dynamic stability of power systems. The recent development and use of FACTS controllers in power transmission system have led to many applications not only to improve the voltage and transient angle stability of the existing power networks but also to provide operation flexibility of power systems as presented in [3, 4]. Especially, due to the fast response to provide reactive powers, the shunt dynamic VAR compensators such as Static VAR Compensators (SVC) and Static Synchronous Compensators (STATCOM) have become feasible alternatives of reactive compensation, and therefore they have received intensive interests. Reactive power planning analysis or Var planning category is considered to find optimal allocation to cover normal as well as contingency conditions. It is necessary to use dynamic analysis in time domain simulations to determine the type of Var source such as dynamic Var source or static

Var source and the response of these devices in fault conditions [1].

The Vietnam power system is separated into three regions: the Northern, the Southern and the Central regions. In 2015, outside of existing lines, several new circuits of 500 kVtransmission lines will be constructed. In this period, the peak load demands in Vietnam will be about 37500 MW. The risk of voltage instability and transient angle stability is evident due to the sizable length of the Southern-Northern transmission lines (about 1500 km), the resulting considerable amount of power transmitted through these lines, the fast increase of load demands and the specific configuration of the Vietnam power system (500 kV system).

In order to improve voltage collapse on the Vietnam power system, FACTS device applications are studied by using several indices for voltage collapse such as P-V curve analysis and dynamic voltage stability analysis. In order to demonstrate the advantages of FACTS applications to improve transient angle stability in this power system, the time domain simulation with the help of the PSS/E program is carried out. After the study, an adequate location and type of FACTS devices are determined

II. VOLTAGE STABILITY ANALYSIS

In [2], voltage instability is mainly associated with the lack of reactive power. The loadability of a bus in the power system depends on the reactive power support that the bus can receive from the system. When the system approaches the maximum loading point or voltage collapse point, both real and reactive power losses increase rapidly. Therefore, the reactive power supports are necessary to avoid voltage collapse.

There are two types of voltage stability studies: static and dynamic analysis. Static analysis involves only the solution of algebraic equations and therefore it is computationally less extensive than dynamic analysis. Static voltage stability is used to determine voltage stability limit for many contingencies.

Voltage collapse makes the system voltage decay to a level from which they are unable to recover. This phenomenon can be seen by the plot of the transferred power versus the voltage at receiving end. The plots are popularly referred to as P-V curve or "Nose" curve. In normal condition, when the power transfer increases, the voltage at

*Research supported by HCMUTE.

Bon Nhan Nguyen is with the Electrical and Electronics Engineering Faculty, Ho chi Minh University of Technology and Education (e-mail: bonnn@hcmute.edu.vn).

Lam Thanh Le is with the Electrical and Electronics Engineering Faculty, Ho chi Minh University of Technology and Education (e-mail: lamlethanh@hcmute.edu.vn).

LE CAO Quyen is with the Power Engineering Consulting Company 4 (PECC4), Electricity of Vietnam (EVN), (email: lecaoquyen@gmail.com)

Pham Hong Thai is with the Ho chi Minh Power Company (e-mail: thaiqb.qp@gmail.com).

Hoang Trong Nguyen is with Ho chi Minh University of Technology and Education (e-mail: hoang.elec@gmail.com).

the receiving end decreases. Eventually, for an operation state near to the critical (nose) point, the increase in active power transfer will lead to very rapid decrease in voltage magnitude. Before reaching the critical point, the large voltage drop due to heavy reactive power losses can be observed. One way to save the system from voltage collapse is to reduce the reactive power load or add additional reactive power

The most effective way for utilities to improve voltage stability of the system is to introduce the sources of reactive power, such as shunt capacitors and/or FACTS controllers at the appropriate location.

Many analytical methodologies have been proposed for studying this problem such as P-V and V-Q curve analysis, Continuation Power Flow (CPF), optimization methods (OPF), modal analysis, saddle node bifurcation analysis (for static analysis) and Hopfbifurcation analysis, time-domain simulation (for dynamic analysis) [2]-[5].

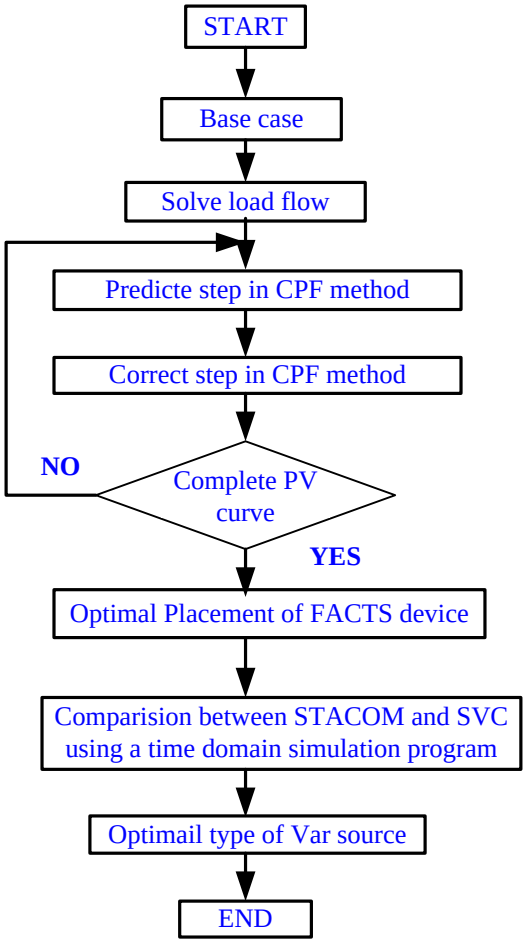


Figure 1. *Algorithm for choosing placement and type of FACTS devices*

In this part of the paper, an algorithm for choosing adequate placement and the type of FACTS devices is proposed. This approach is based on the Continuation Power Flow (CPF). A dynamic simulation is carried out in order to validate the choice of type of FACTS device. The algorithm is described as below (Fig. 1):

III. FACTS DEVICE MODELLING

This section explains briefly the modelling of SVC and STATCOM [3, 4]:

Static Var Compensator (SVC): A shunt-connected static var generator or absorber whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific parameters of the electrical power system (typically bus voltage).

Figs. 2 and 3 show schematic diagram and V-I characteristic of a static var compensator. The compensator normally includes a thyristor controlled reactor (TR), thyristor-switched capacitors (TSCs) and harmonic filters. It might also include mechanically switched shunt capacitors (MSCs), and then the term static var system is used. The harmonic filters (for the TCR-produced harmonics) are capacitive at fundamental frequency. The TCR is typically larger than the TSC blocks so that continuous control is realized. Other possibilities are fixed capacitors (FCs), and thyristor switched reactors (TSRs). Usually a dedicated transformer is used, with the compensator equipment at medium voltage. The transmission side voltage is controlled, and the Mvar ratings are referred to the transmission side.

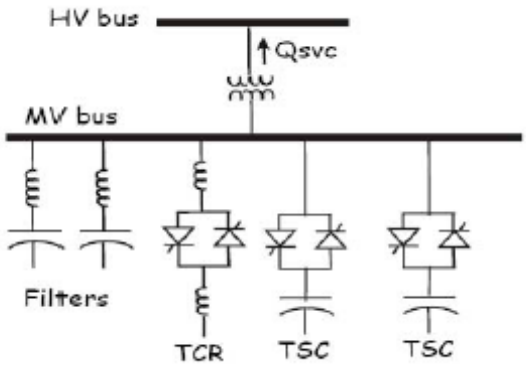


Figure 2. *Schematic diagram of a SVC*

STATCOM: A static synchronous generator operated as a shunt-connected static var compensator whose capacitive or inductive output current can be controlled independently from the AC system voltage. STATCOM is as if a controlled reactive-power source. It provides voltage support by generating or absorbing reactive power at the point of common coupling without the need of large external reactors or capacitor banks. The basic voltage-source converter scheme and V-I characteristic of the STATCOM are shown in Figs. 4 and 5.

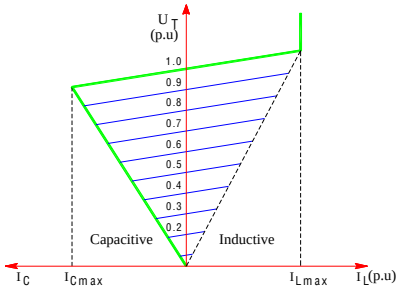


Figure 3. *V-I characteristic of the SVC*

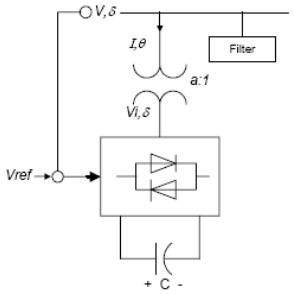


Figure 4. *Schematic diagram of a basic STACOM*

In the linear operating range the V-I characteristics (Figs. 3, 5) and functional compensation capability of the STATCOM and the SVC are similar. Concerning the non-linear operating range, the STATCOM is able to control its output current over the rated maximum capacitive.

Theoretically, the STATCOM is more effective than the SVC in providing voltage support under large system disturbances during which the voltage excursions would be well outside of the linear operating range of the compensator.

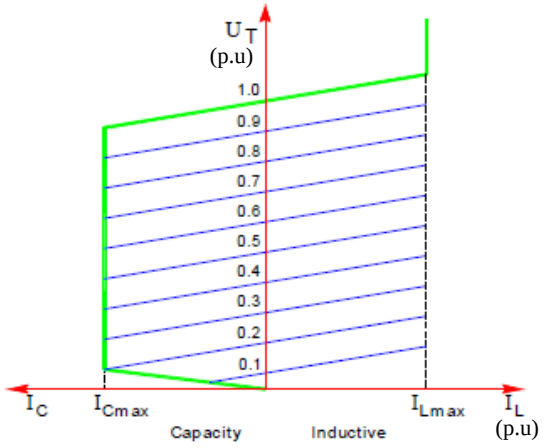


Figure 5. *Schematic diagram of a basic STATCOM*

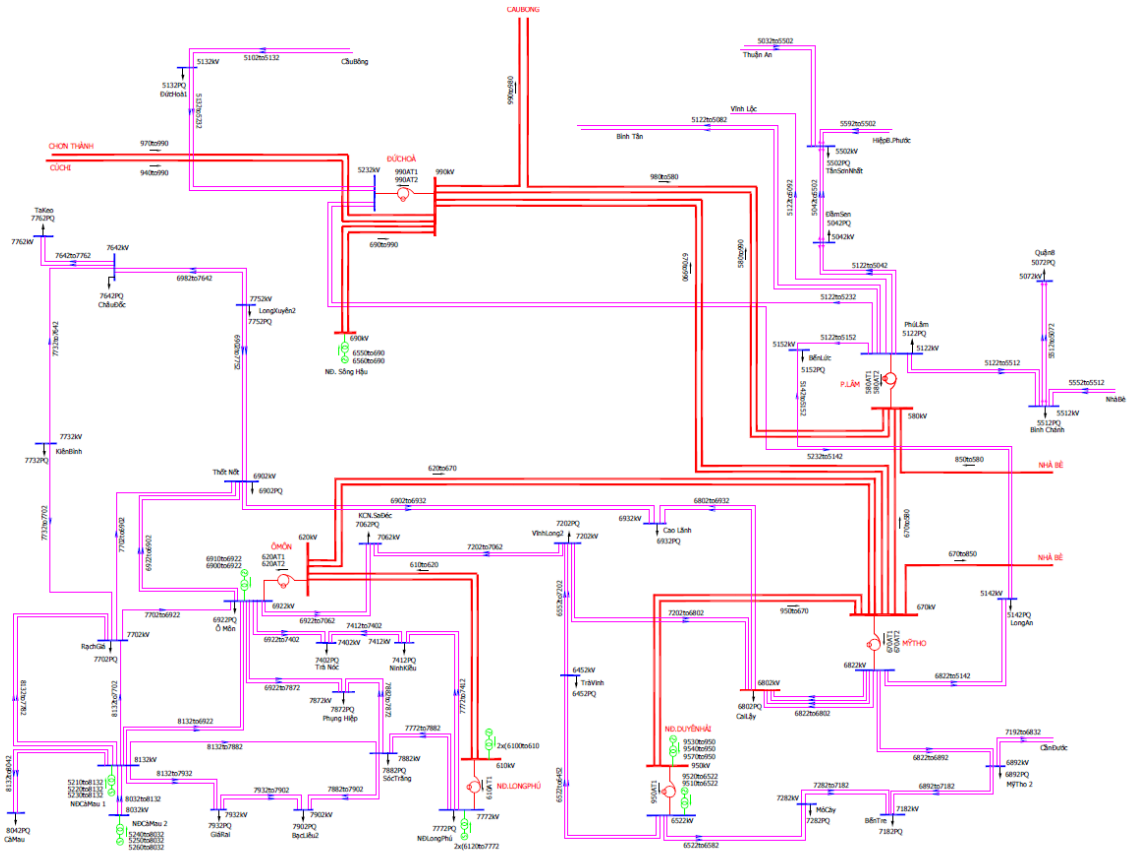


Figure 6. *Load flow analysis for the 500 kV Southern Vietnam power system in 2020*

IV. IMPROVING VOLTAGE STABILITY

Configurations of the 220kV, 500 kV Southwest region of Vietnam power system in 2020 are used to analysis. This system consists of 114 buses (29 load busses and 85 generation buses), 82 500kV transmission lines and 71 500/220 kV transformers.

The purpose of this part is to find optimal placements of shunt compensator for the 220kV, 500 kV Southwest region of Vietnam power system with the high load scenario.

The result of load flow analysis of the 220kV, 500 kV Southwest region of Vietnam power system is given in Fig. 6 with the peak load demands.

The active and reactive load at all load buses in this power system is increased in step by step and the sources in this power system are mobilized to supply for these increase.

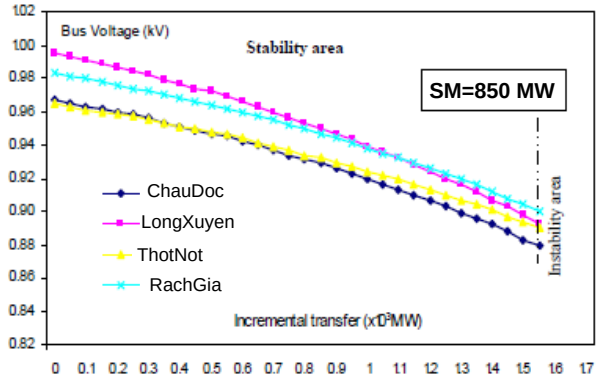


Figure 7. *PV curves of 4 selected load buses where voltages are the lowest*

The increasing of loads provides an incremental active power transferred on 500kV Omon-My Tho and My Tho-Nha Be transmission lines (Fig. 6).

Fig. 7 shows that a voltage collapse occurs when the transferred power reaches to 850MW (SM=850MW: Static voltage stability Margin). The critical case corresponds to this SM factor.

Based on the P-V curve analysis, the best location for shunt reactive power compensation in order to improve the voltage stability margin is chosen at buses where voltages are the lowest. These buses correspond to the weakest buses of the system. By introducing shunt compensation devices at these buses, this permits to improve the voltage stability (or to increase SM).

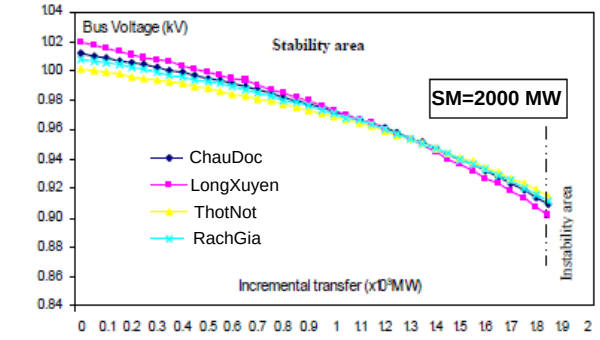


Figure 8. *PV curves of 4 selected load buses where voltages are the lowest*

In order to verify this choice, P-V curves are calculated with four shunt reactive power compensation devices placed at 220kV buses of Chau Doc, Long Xuyen, Thot Not and Rach Gia. The SM for this application is increased to 1850MW (Fig. 8).

V. TRANSIENT STABILITY ASSESSMENT

Transient stability assessment of the system with shunt compensation devices including SVC and STATCOM is studied and compared in the Southern power system.

Program Power System Simulation Engineering (PSS/E) [6] is employed for transient stability analysis with block diagram of SVC (CSVGN1) and STATCOM (CSTCNT) in PSS/E library.

A three-phase fault is applied at bus 500kV Omon-My Tho and My Tho-Nha Be transmission lines is tripped at 0.7sec after fault by protection relays. Without FACTS installation, the power system is instable shown in Fig. 9.

All cases of simulation are carried out with the range for the SVCs or STATCOMs from -300 MVAr to 300 MVAr. These FACTS devices are placed at four indicated buses.

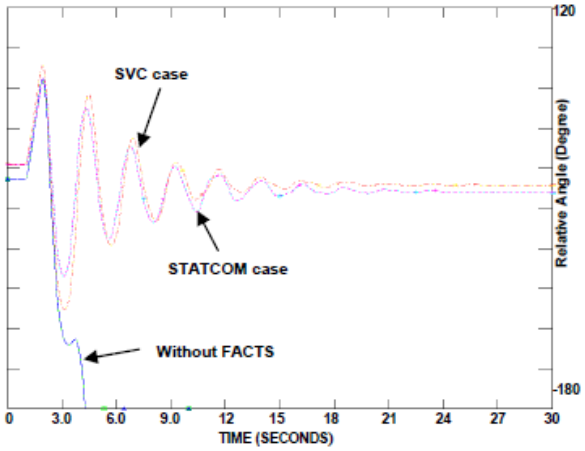


Figure 9. *Rotor angle at Duyen Hai machine with three phases fault.*

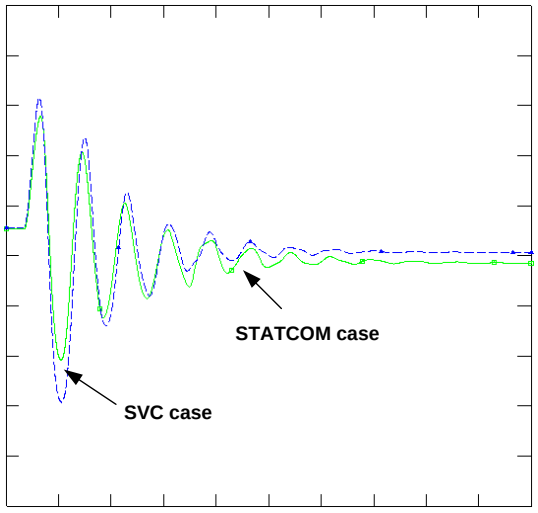


Figure 10. *Rotor angle at Duyen Hai machine with three phases fault.*

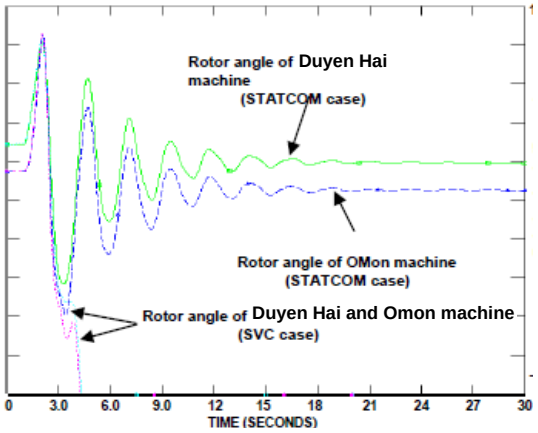


Figure 11. *Rotor angle at Duyen Hai machine with three phases fault.*

Fig. 9 and Fig. 10 show the angle variation of Duyen Hai and O Mon machines with SVC or STACOM placed at 220kV buses of Chau Doc, Long Xuyen, Thot Not and Rach Gia. (the same as the preceding part). It shows that the magnitude of rotor angles variation of Duyen Hai machine (P=1000MW) and O Mon machine (P=330MW) with SVC case is higher than in comparison with STATCOM case.

Fig. 11 shows the variation of angle at Duyen Hai and O Mon when the fault is cleared about 0.8sec after fault (the fault time is at t=1sec). With SVC case, the power system isinstable. Fig. 12 shows the variation of voltage at 500 kV Omon..

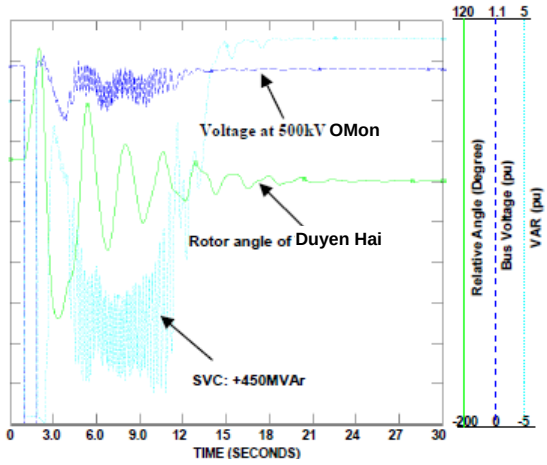


Figure 12. *Rotor angle at Duyen Hai and OMon machines with three phases fault (SVC and STATCOM cases).*

With SVC case, the maximum transient capacitive current is determined by the size of the capacitor and the amplitude of the AC system voltage. The reactive power support provided by the SVC is dependent on the AC system voltage and hence its capability is de-rated at lower voltage

The obtained results show that STATCOM application is better in order to improve the transient angle stability and voltage stability in comparison with SVC application.

In contrast, STATCOM's compensating current is notdependent on the voltage level at the connection point which means that the compensating current is not lowered when the voltage drops.

With STATCOM case, when the reactive power ofSTATCOM is reduced from 300 to 200MVAr, the obtained result shows that the power system is also stable. Whereas with SVC case, the reactive power support provided by the SVC is increased from 300 to 450MVAr to keep transient angle stability (Fig.12).

The obtained results show that with the same reactive power rating or lower, STATCOMs are more effective than SVCs for a same situation.

VI. CONCLUSION

The P-V curve method for choosing optimal placement of shunt compensation device have been used for this study.

One of the most important advantages of STATCOM in comparison with SVC is that its compensating current is not dependent on the voltage level at the connection point. This means that the compensating current is not lower when the voltage drops.

The maximum compensating current of the SVC decreases linearly with the AC system voltage and the maximum VAR output decreases with the square of the voltage. This implies that for obtaining the same dynamic performance, a higher rating SVC is required in comparison with a STATCOM.

An application of FACTS devices for the 220kV Southwest region of Vietnam power system in 2020 was studied to improve voltage stability and transient angle stability of this power system.

The obtained results show that with the application of FACTS devices, voltage stability and transient angle stability of this power system are considerably improved.

The transient angle stability simulations have shown that STATCOM gives a better solution to improve the stability in comparison with SVC devices.

REFERENCES

[1] H. G. Sarmiento, G. Pampin, J. D. de Leon, "FACTS solutions for voltage stability problems in a large metropolitan area", 2004 IEEE/PES Power Systems Conference and Exposition, vol. 1, pp. 275– 282, Oct. 2004.

[2] A. Sode-Yome, N. Mithulananthan, K.Y. Lee, "Static Voltage Stability Margin Enhancement Using STATCOM, TCSC and SSSC", Transmission and Distribution Conference and Exhibition: Asia and Pacific, 2005 IEEE/PES, pp.1-6, 2005.

[3] Isaiah G. Adebayo , Adisa A. Jimoh , Adedayo A. Yusuff , C. Subramani, " Static Voltage Stability Enhancement Using FACTS Controller ", IEEE,2016.

[4] K. Rayudu, G. Yesuratnam, K. Surendhar, A. Jayalaxmi, Voltage Stability Enhancement Based on Particle Swarm Optimization and LP Technique, IEEE,2016.

[5] Pratheeksha R. , K. M. Kavitha, " Analysis of STATCOM, SVC and UPFC FACTS Devices for Transient Stability Improvement in Power System" . International Journal of Science and Research (IJSR), Volum 5 Issue 5, May 2016.

[6] PSS/ETM 33.4 online documentation, March 2013.