

## **Analysis and assessment of STATCOM's effectiveness in improving transient stability for power system**

Le Ngoc Giang and Liu Kaipei

*School of Electrical Engineering, Wuhan University*

*Luo-jia-shan Wuchang, Wuhan, Hubei Province, P.R.China, post code: 430072*

*lengocgianglinh@gmail.com*

### **Abstract**

*Many of papers refers to study of application for FACTS. Especially for using reactive compensators for 500KV power system in order to increase the static voltage stability margin and transient stability enhancement have considered. However the selection of suitable Var source (STATCOM or SVC) also need to be considered. The purpose of this paper is to solve the above problems in order to suggest a solution of the appropriate shunt compensator for a reality 500KV power system. All the simulations for the above work have been carried out using MATLAB-SIMULINK environment.*

**Keywords:** *FACTS, SVC, STATCOM, Transient Stability of Power System*

### **1. Introduction**

Power systems components mainly consist of generators, transmission lines, transformers, switches, active or passive compensators and loads. Power system networks are complex systems that are nonlinear, non-stationary, prone to disturbances and faults.

In recent years, the electrical power system is continuously expanding in size and growing complexity all over the world. The electricity industry has undergone several changes due to privatization all over the world which has affected power system management and energy markets [1]. The power system which are heavily loaded, faulted and having shortage of reactive power are the main reason for voltage collapse [2]. As the voltage collapse problem is closely related to reactive power planning including the contingency analysis, as these should be considered for the secure operation of the power system [3]. During the outage conditions of some critical lines, the generators are capable of supplying limited reactive power even sometimes the supplied reactive power cannot be used to fulfill the requirement of the network because the location is far from the generator point. Further, more the real powers of the generators are reduced to supply the reactive power demand of the system. Hence, the reactive power compensators are used to maintain the voltage profile and there by improving the performances of the system [4].

Flexible Alternating Current Transmission Systems (FACTS) devices are becoming very popular for improving overall performance of power systems. FACTS devices are the solid state converters having capability of improving power transmission capacity, voltage profile, enhancing power system stability and security [5].

FACTS based equipment, provide proven technical solutions to voltage stability problems. Especially, due to the increasing need for fast response for power quality and voltage stability, the shunt dynamic Var compensators such as Static Var Compensators (SVC) and Static Synchronous Compensators (STATCOM) have become feasible alternatives to a fixed reactive source, and therefore have received intensive interests [6, 7].

This paper focuses on the placement and selection of suitable Var source (STATCOM or SVC), for improving the voltage profile and reducing the real power losses for a reality 500KV power system. SVC and STATCOM is shunt FACTS devices which is designed to maintain the voltage profile in a power system under normal and contingency conditions. In practical power systems, all buses have different sensitivity to the power system security and stability. If SVC and STATCOM is allocated at more sensitive buses, it will effectively improve the voltage profiles and stability.

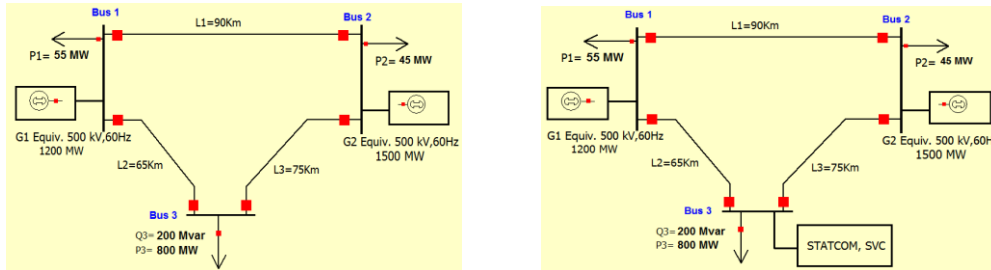
## 2. Facts Devices

SVC and STATCOM are the shunt devices of the FACTS family using power electronics to control power flow and improve transient stability on power grids [8, 9] to regulate voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, they generate reactive power (capacitive). When system voltage is high, it absorbs reactive power (inductive).

## 3. Results and Analysis

### 3.1. Circuit Description

Figure 1a shows the 3-Bus system used in the study. The power grid consists of two voltage sources 500kV, frequency 60Hz (1200 MVA and 1500 MVA respectively ) connected by transmission lines: L1=90km, L2=65km, L3=75km. Load 1: Three-Phase Load P1=55 MW. Load 2: Three-Phase Load P2= 45 MW. Load 3: Three-Phase Load P3= 800 MW, Q3 = 200MVar.

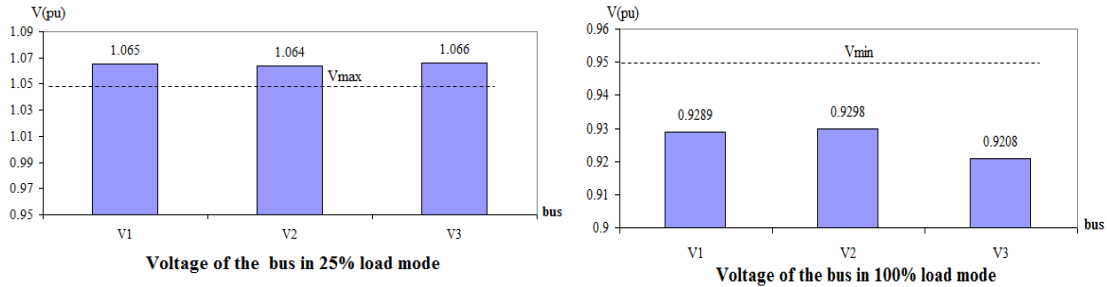


**Figure 1. a. MODEL of Power Transmission System, b. MODEL of Power Transmission System with STATCOM, SVC**

The load 3 the active power and the reactive power are 800MW and 200MVAR respectively. The percentages of load 3 are 25%, 50%, 75% and 100% in the operation. load 3 in 25% mode: P325= 200 MW, Q325 = 50MVAR. load 3 in 50% mode: P350= 400 MW, Q350 = 100MVAR. load 3 in 75% mode: P375= 600 MW, Q375 = 150MVAR. load 3 in 100% mode: P3=800 MW, Q3 = 200MVAR.

**Table 1. Voltages on the Bus of the Power System**

V1(pu)				V2(pu)				V3(pu)			
25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%
<b>1.065</b>	1.021	0.9747	<b>0.9289</b>	<b>1.064</b>	1.021	0.975	<b>0.9298</b>	<b>1.066</b>	1.018	0.9692	<b>0.9208</b>



**Figure 2. Voltage of the Bus in 25% and 100% Load Mode**

When STATCOM and SVC are not operation, load 3 in 25% mode and 100% mode, V of the 3 bus are outside the specified limits [95%, 105%]. Especially in bus 3 the load voltage are 1.066pu and 0.9208pu in proportion to 25% and 100% load respectively.

To analyze and compare the efficiency of SVC and STATCOM for the enhancement of the power system stability, we consider SVC and STATCOM on the transmission line of power system, shown in Figure 1b.

The figure 1b shown above is model of the transmission line with STATCOM installed in bus B3, and has a rating of +/- 100MVA. This STATCOM has a DC link nominal voltage of 40 kV with an equivalent capacitance of 375 uF. On the AC side, its total equivalent impedance is 0.22 pu on 100 MVA. This impedance represents the transformer leakage reactance and the phase reactor of the IGBT bridge of an actual PWM STATCOM.

### 3.2. The Obtained Results

The obtained results with and without the compensation of the reactive power were tabulated in Table 2, 3 and 4. When STATCOM and SVC are connected, the load Voltage has increased.

**Table 2. Comparison of Voltage Regulation when SVC and STATCOM are Connected**

V	V1				V2				V3			
	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%
Without	<b>1.065</b>	1.021	0.9747	<b>0.9289</b>	<b>1.064</b>	1.021	0.975	<b>0.9298</b>	<b>1.066</b>	1.018	0.9692	<b>0.9208</b>
SVC	1.031	1.011	0.9887	0.957	1.031	1.011	0.9898	0.9597	<b>1.027</b>	1.008	0.9863	<b>0.9536</b>
Statcom	1.021	1.001	0.9897	0.9589	1.021	1.001	0.9898	0.9591	<b>1.022</b>	1.003	0.9868	<b>0.955</b>

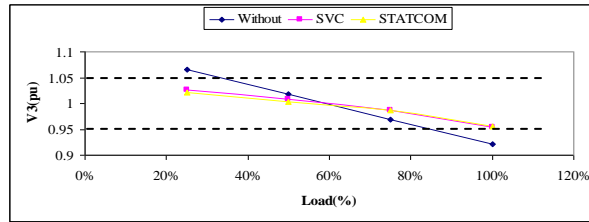
**Table 3. Comparison of Real Power Transferred when SVC and STATCOM are Connected**

P	P1				P2				P3			
	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%
Without	90.62	175.8	243.9	296.5	137	239.5	321	383.8	227.4	414.7	563.7	678.3
SVC	84.05	172.2	252.5	318	127.1	234.6	332.4	411.5	211	406.2	583.7	727.5
Statcom	84.31	172.2	252.6	319.3	127.5	234.7	332.5	413.2	211.6	406.3	583.8	730.4

**Table 4. Comparison of Reactive Power Transferred when SVC and STATCOM are Connected**

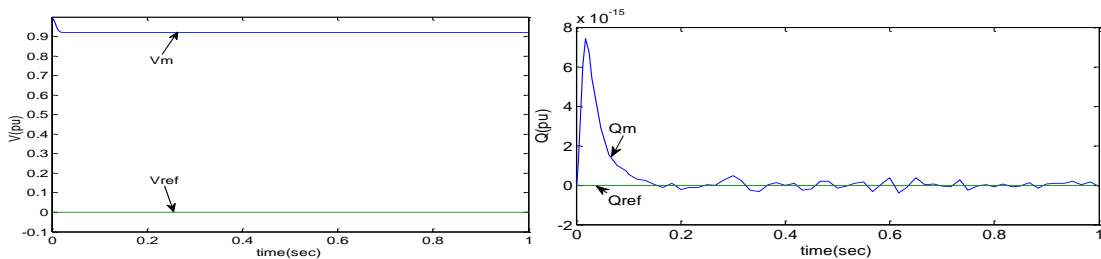
Q	Q1				Q2				Q3			
	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%
Without	-114.1	-77.87	-47.05	-18.97	-140.6	-96.68	-56.76	-21.32	56.85	103.7	140.9	169.6
SVC	-64.87	-65.72	-68.66	-60.67	-80.25	-80.57	-83.21	-72.32	145.6	127.6	100.9	90.93
Statcom	-64.9	-65.73	-68.67	-62.73	-80.28	-80.58	-83.22	-74.83	145.5	127.6	100.8	86.91

Table 2, 3, 4 and Figure 3 show that, when SVC and STATCOM devices are entered in the operation, it has regulated the voltage in the allowed limit.



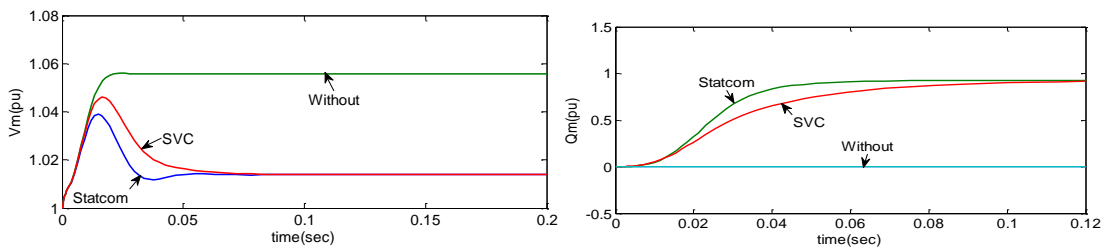
**Figure 3. Voltage Regulation with and Without the Compensation**

Figure 4 illustrate the Voltage and reactive power of 100% load without the compensation.

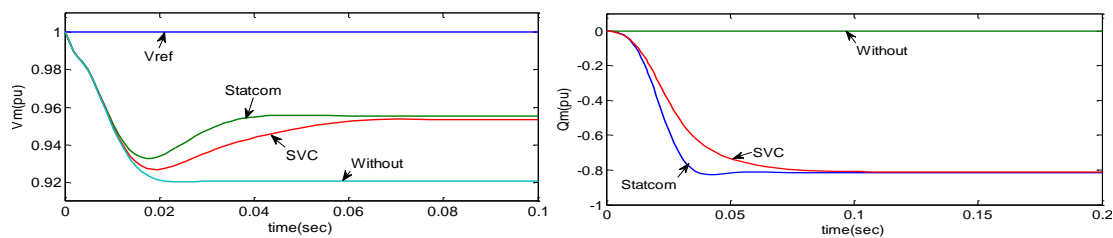


**Figure 4. Voltage & Reactive Power of 100% Load without the Compensation**

Figure 5 and 6 show that the voltage regulation and reactive power generate or absorb when STATCOM & SVC devices are connected in cases the percentage load are 25% and 100% respectively. Through which we see, voltage is controlled better when without STATCOM & SVC.



**Figure 5. Voltage & Reactive Power at Load Mode 25% with and without Statcom & SVC**

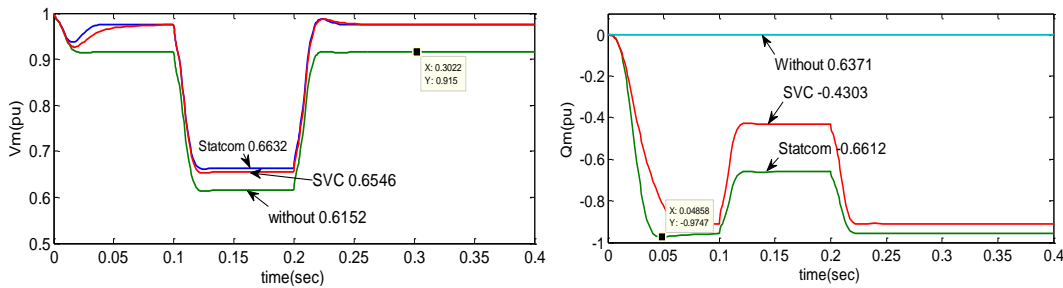


**Figure 6. Voltage & Reactive Power at Load Mode 100% with and Without Statcom&SVC**

### 3.3. The Fault Appears

When the ground fault phase A appears, if without compensation the voltage will be 0.6371pu. In contrast, if with STATCOM exists, the reactive power is -0.6612pu, at that time voltage reached to 0.6632pu. With SVC the reactive power is -0.4303pu, at that time voltage reached to 0.6546pu.

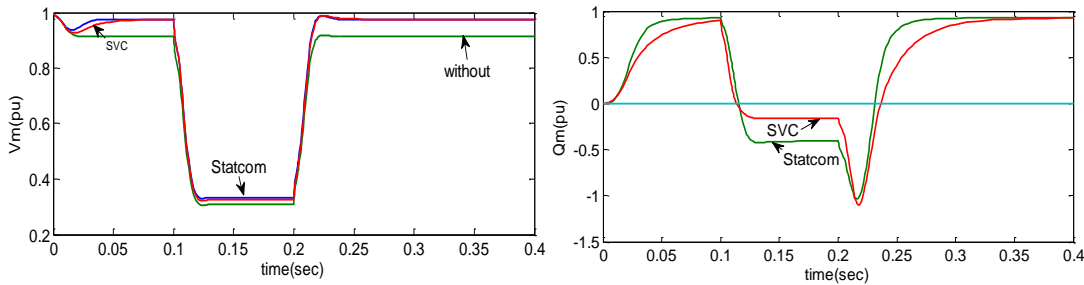
Figure 7 show the change of voltage and reactive power when ground fault phase A appear with and without the compensation.



**Figure 7. Voltage and Reactive Power when the Ground Fault Phase A appears, with and Without the Compensation**

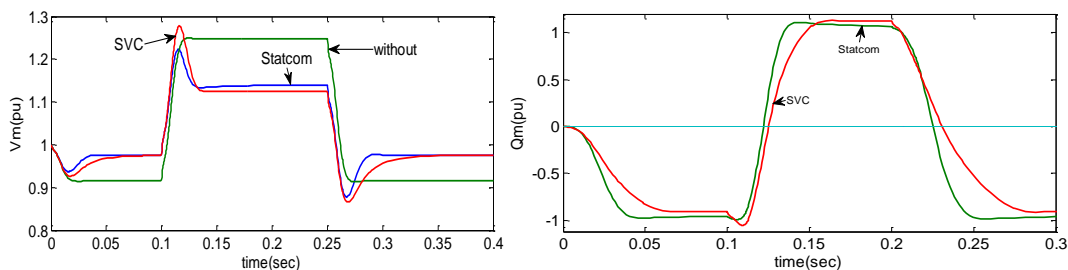
Applying the same analysis as above, when ground fault two phases A&B appear. At that time, the effects of STATCOM will be better than these of SVC.

Figure 8 show that voltage and reactive power when ground fault two phases A, B appear with and without the compensation.



**Figure 8. Voltage & Reactive Power when the Ground Fault Phase A&B appears, with and Without the Compensation**

Figure 9 compares the effects between STATCOM and SVC under the condition when the three-phase of Breaker Fault appear in  $t = 0.1s$  to  $t = 0.2s$ .



**Figure 9. Voltage & Reactive Power When Three-phase of Breaker Fault**

The results of Researched model indicated that STATCOM and SVC are very useful in improving the transient stability, Voltage profile & power flow, as well as in providing the system a faster & steadier state achievement. Simulation results show the effectiveness of SVC and STATCOM in controlling the real and reactive power. Besides, STATCOM reacts faster and provides good effects to stabilize electric system, especially when faults appear.

#### 4. Identify Optimal Type of Reactive Power Generating Source in Fact of Power System

Vietnam's 500kV grid system in 2015 was included in the survey of which the southern grid is considered to compensate reactive power because of large load demand which is dramatically increased. The two receiving/transmitting reactive power devices with equivalent size, which are included in the survey of stability in the domain time, are SVC and STATCOM.

In case of calculation with the capacity mobilized from the North to the South at the boundary value of 1550 MW, transmission capacity in 500kV grid connecting the Middle with the South is quite large. To evaluate the ability to improve the stability of the reactive power generating devices, the considered incident scenario is that incident is occurred on 3 permanent phases in 500kV lines from Di Ling to Tan Dinh, fault location is near Tan Dinh 500kV transformer station; main relay does not work, the preventive relays system send the turn-off delay signal with the time ranging from 0.7 sec to 0.8 sec.

The results of analysis of phase angular oscillation of 1000MW generators in Tra Vinh show that after short-circuit breaking, breaking time is 0,7 sec; amplitude of phase angle of Tra Vinh generator in case of using reactive power compensation source created by SVC is greater than that in case of using STATCOM. With large amplitude if time of short-circuit elimination is increased, the system will be unstable.

Another survey with the same incident case but with short-circuit breaking time extending to 0.8 sec is conducted. The Southern electrical system in case of reactive power compensation generated by SVC was unstable, while in case of that generated by STATCOM, the system still remains the stability.

Basing on the above calculation it can be concluded that in term of stability in the domain time, the reactive power compensation system generated by STATCOM will be controlled more quickly, flexibly and reliably than SVC.

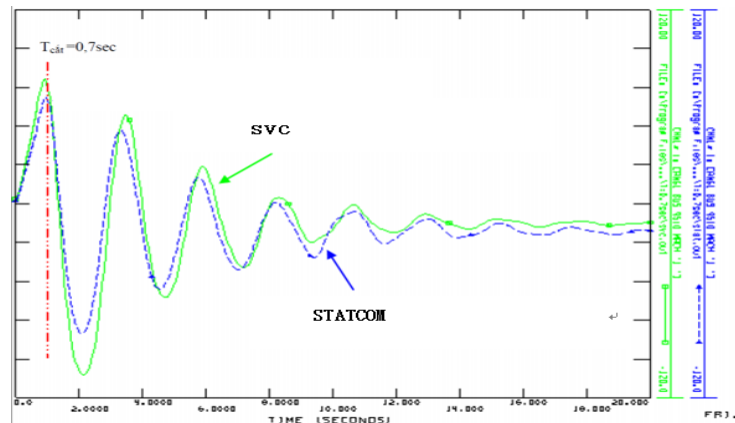
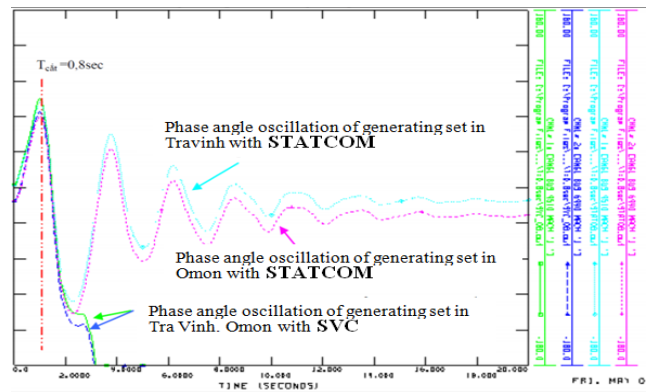
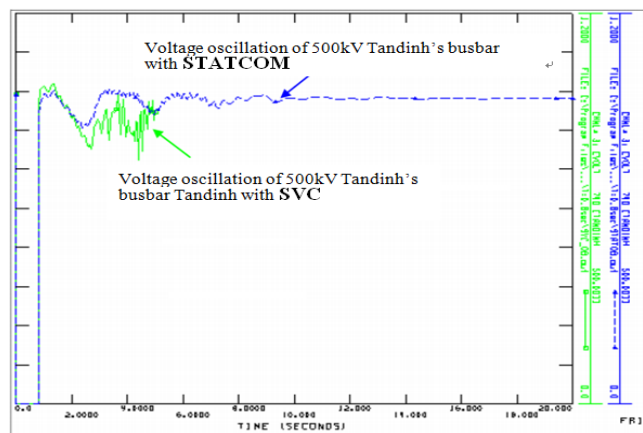


Figure 10. Phase Angle Oscillation of 1000MW Generating Set in Tra Vinh



**Figure 11. Phase Angle Oscillation of Generating Set in Tra Vinh, Omon**



**Figure 12. Voltage Oscillation of 500kV Tandinh's Bus Bar**

## 5. Conclusion

In this study, the power system stability enhancement via STATCOM and SVC stabilizers is presented and discussed. An effort is made to assess voltage stability and security of multi-bus power system in presence of STATCOM and SVC. A comparative study on effectiveness of STATCOM and SVC in improvement of voltage stability and security has also been presented. STATCOM is found to be more effective than SVC to ensure voltage stability and security, at the same time, it is also capable to considerably reduce reactive power line loss. The results of this work are of certain practical significance and applicable value. Based on such calculation, For Vietnam's 500kV grid, power compensation by using STATCOM will improve operation stability better than using SVC.

## References

- [1] C. A. Canizares, "Applications of Optimization to Voltage Collapse Analysis", IEEEIPES Summer Meeting, San Diego, (1998) July 14.
- [2] P. Kundur, L. Paserba, V. Ajjarapu, G. Anderson, A. Bose, C. A. Canizares, N. Hatziargyfiou, D. Hill, A. Stankovic, C. Taylor, T. Van Cutsem and V. Vittal, "Definition and Classification of Power System Instability", IEEE Trans. On Power Systems, vol. 19, no. 2, (2004) May, pp. 1387-1401.
- [3] Z. T. Faur, "Effects of FACTS Devices on Static Voltage Collapse Phenomena", M.S. dissertation, Dept. Elect. Eng., Univ. of Waterloo, (1996).

- [4] J. G. Singh, S. N. Singh and S. C. Srivastava, "An Approach for optimal Placement of Static Var Compensators Based on Reactive Power Spot Price", IEEE Trans. On Power Systems, vol. 22, no. 4, (2007) November.
- [5] I. A. Erinmez, "Static var compensators", CIGRE Working Group 38-01, Task Force No.2 on SVC, (1986).
- [6] L. M. Tolbert and T. J. King, "Power electronics strategy for transmission and distribution and for distributed energy", ORNL/TM- 2005/230, Oak Ridge National Laboratory, (2005) December.
- [7] A. Scarfone, B. Oberlin, J. Di Luca Jr., D. Hanson, C. Horwill and M. Allen, "Dynamic performance studies for a  $\pm 150$  Mvar STATCOM for Northeast utilities, Panel session on FACTS applications to improve power system dynamic performance", Proceedings of the IEEE PES T&D Conference and Exposition, Dallas, Texas, (2003) September.
- [8] A. Garg and S. Kumar Agarwal, "Voltage control and dynamic performance of power transmission system using STATCOM and it's comparison with SVC", International Journal of Advances in Engineering & Technology, (2012) January.
- [9] Y. Bai-jie, C. Qin, Y. Tie-jiang and Y. Hai-dong, "Research of STATCOM Impact on Wind Farm LVRT and Protection", TELKOMNIKA Indonesian Journal of Electrical Engineering, vol. 10, no. 8, (2012) December.

## Authors



**Le Ngoc Giang**, he was born in Hanoi, Vietnam, on July 21, 1975. Currently, he is a Ph.D Student of Wuhan University, School of Electrical Engineering, His main research interests are power system control and power system stability analysis, smart grid demand response, building automation system, and renewable energy. lengocgianglinh@gmail.com



**Liu Kaipei**, he was born in Wuhan Province, China, in 1962. He graduated from Wuhan University in Computer Application Technology. Currently, he is a Professor and Vice Dean of School of Electrical Engineering, Wuhan University. His main research interests are Non-linear control technolog, signal processing techniques in Power electronic systems, analysis and control of power quality, research on smart grid and the new energy.