International Journal of Research and Development in Applied Science and Engineering (IJRDASE)
ISSN: 2454-6844

An IEEE 9 BUS Power System's Transient Stability Performance Analysis Using Facts Device

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Abstract: Modern power system transmission networks are becoming increasingly complex due to growing demand and restrictions on building new lines. One of the major challenges of such modern power systems is maintaining stability following a disturbance. Transient stability control is crucial for ensuring the stable operation of power systems during faults and large disturbances. FACTS technologies have proven to be highly effective in enhancing the controllability and power transfer capability of transmission networks without compromising the desired stability margin. This paper provides a comparative performance analysis of STATCOM, SVC, and UPFC in improving the transient stability of the IEEE 9-bus power system. The Static Synchronous Compensator (STATCOM) and Static Var Compensator (SVC) are shunt devices within the Flexible AC Transmission Systems (FACTS) family. STATCOM generates reactive power when the system voltage is low and absorbs reactive power when the system voltage is high. Similarly, the SVC operates in the same manner, offering fast-acting dynamic compensation in the event of severe faults. The Unified Power Flow Controller (UPFC) is a more effective FACTS device for controlling active and reactive power flow in a transmission line and damping power oscillations by controlling its series and shunt parameters. This study analyzes the effects of STATCOM, UPFC, and SVC on the transient stability performance of the system using the MATLAB/Simulink environment for a multi-machine system. The performance of STATCOM, SVC, and UPFC are compared, with simulation results demonstrating the effectiveness and robustness of all three FACTS devices. This project aims to identify the best FACTS device for improving the transient stability of the IEEE 9-bus power system.

Key Words: FACTS, STATCOM, SVC and UPFC, Transient Stability & IEEE 9 Bus Power System

1. Introduction:

Power systems generally consist of three stages: generation, transmission, and distribution. In the first stage, electric power is generated primarily using synchronous generators. The voltage is then raised by transformers before transmission to reduce line currents, consequently reducing power transmission losses. After transmission, the voltage is stepped down using transformers for appropriate distribution. Power systems are designed to provide a continuous power supply while maintaining voltage stability. However, undesired events such as lightning, accidents, or other unpredictable occurrences can cause short circuits between the phase wires of transmission lines or between a phase wire and the ground, resulting in faults. When a fault occurs, one or more generators may be severely disturbed, causing an imbalance between generation and demand. If the fault persists and is not cleared within a specified time frame, it may cause severe damage to equipment, leading to power loss and outages. Therefore, protective equipment is installed to detect faults and isolate the faulted parts of the power system as quickly as possible before the fault energy propagates to the rest of the system. Simulink is an interactive environment for modeling and simulating a wide variety of dynamic systems. A system can be easily built using blocks, and results can be displayed quickly. Simulink is particularly useful for studying the effects of non-linearity in systems, making it an ideal research tool. Its use is rapidly growing in power system research and other areas. This paper implements a time-domain simulation method to model a multi-machine nine-bus system in MATLAB/Simulink and conduct transient stability analysis with a fault located at a bus.

2. Power System Stability:

Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact. Stability phenomenon is a single problem associated with various forms of instabilities affected on power system due to the high dimensionality and complexity of power system constructions and behaviors. For properly understood of stability, the classification is essential for significant power system stability analysis. Stability classified based on the nature of resulting system instability (voltage instability, frequency instability…), the size of the disturbance (small disturbance, large disturbance) and timeframe of stability (short term, long term). In the other hand, stability broadly classified as steady state stability and dynamic stability. Steady state stability is the ability of the system to transit from one operating point to another under the condition of small load changes. Power system dynamic stability appears in the literature as a class of rotor angle stability to describe whether the system can maintain the stable operation after various disturbances or not.

3. Transient Stability:

When a power system is under steady state, the load plus transmission loss equals to the genaration in the system. The generating units run at synchronous speed and system frequency, voltage, current and power flows are steady. When

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a large disturbance such as three phase fault, loss of load, loss of generation etc., occurs the power balance is upset and the generating units rotors experience either acceleration or deceleration. The system may come back to a steady state condition maintaining synchronism or it may break into subsystems or one or more machines may pull out of synchronism. In the former case the system is said to be stable and in the later case it is said to be unstable.

4. Facts Controllers:
FACTS are 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. Basically, FACTS controllers can be divided into four categories:

- Series Controller
- Shunt Controller
- Combined series-series Controller
- Combined series-shunt Controller

4.1 Static VAR Compensator (SVC):
SVC is an electrical device for providing the fast reactive power on high voltage transmission networks. An SVC is based on thyristor controlled reactors (TCR), thyristor switched capacitors (TSC), and/or Fixed Capacitors (FC) tuned to Filters as shown in fig1. A TCR consists of a fixed reactor in series with a bi-directional thyristor valve. TCR reactors are as a rule of air core type, glass fibre insulated, epoxy resin impregnated.

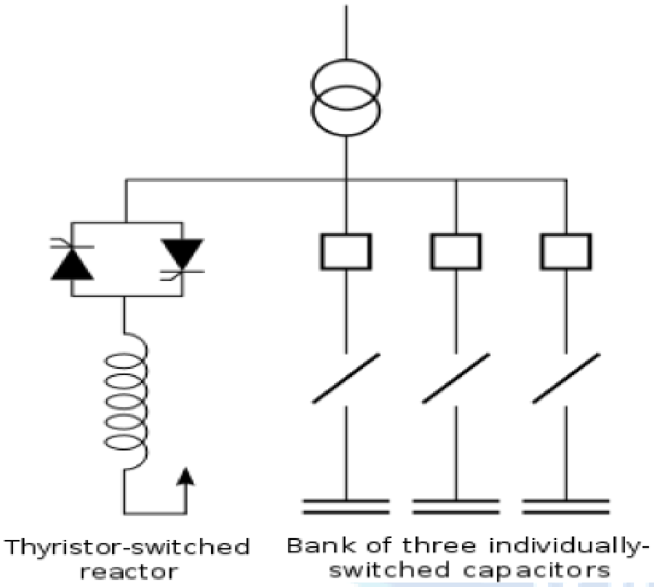

Figure 1: SVC Model

SVCs had a great advantage over simple mechanically-switched compensation schemes is their fast instantaneous response to changes in the system voltage. For this reason they are often operated at close to their zero-point in order to maximize the reactive power correction they can rapidly provide in system whenever required. They are in general cheaper, higher-capacity, faster, efficient and more reliable over dynamic compensation schemes such as synchronous condensers.

4.2 Static Synchronous Compensator (STATCOM):
A Static synchronous compensator is a shunt-connected static Var compensator whose capacitive or inductive output current can be controlled independently of the ac system voltage. STATCOM is made up of a coupling transformer, a VSC and a dc energy storage device as shown in fig2. STATCOM is capable of exchanging reactive power with the transmission line because of its small energy storage device i.e. small dc capacitor, if this dc capacitor is replaced with dc storage battery or other dc voltage source, the controller can exchange real and reactive power with the transmission system, extending its region of operation from two to four quadrants.

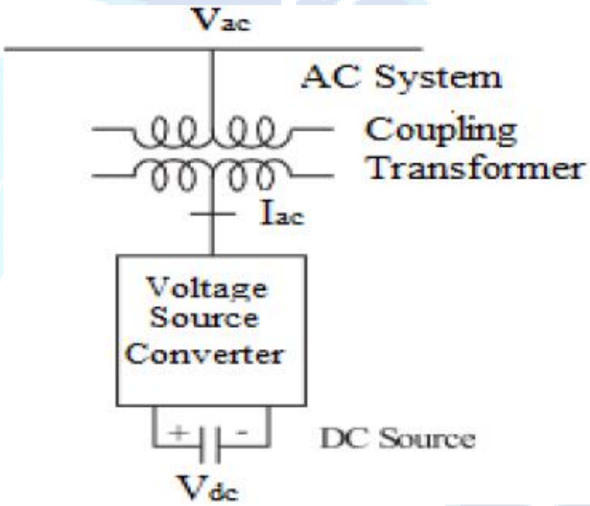

Figure 2: STATCOM Model

4.3 Unified Power Flow Controller (UPFC):
The UPFC is the most versatile FACTS controller developed so far, with all encompassing capabilities of voltage regulation, series compensation, and phase shifting. It can independently and very rapidly control both real- and reactive power flows in a transmission line. It is configured as shown in Fig.3 and comprises two VSCs coupled through common dc terminal. One VSC—converter1—is connected in shunt with the line through a coupling transformer; the other VSC—converter 2—is inserted in series with the transmission line through an interface transformer. The dc voltage for both converters is provided by a common capacitor bank. The series converter is controlled to inject a voltage phasor, Vpq, in series with the line, which can be varied from 0 to Vpq max. Moreover, the phase angle of Vpq can be independently varied from 00 to 3600. In this process, the series converter exchanges both real and reactive power with the transmission line. Although the reactive power is internally generated/ absorbed by the series converter, the real-power generation/ absorption is made feasible by the dc-energy–storage device—that is, the capacitor. The shunt-connected converter 1 is used mainly to supply the real-power demand of converter 2, which it derives from the transmission line itself. The shunt converter maintains constant voltage of the dc bus. Thus the net real power drawn from the ac system is equal to the losses of the two converters and their coupling transformers. In addition, the shunt converter functions like a

STATCOM and independently regulate the terminal voltage of the interconnected bus by generating/ absorbing a requisite amount of reactive power.

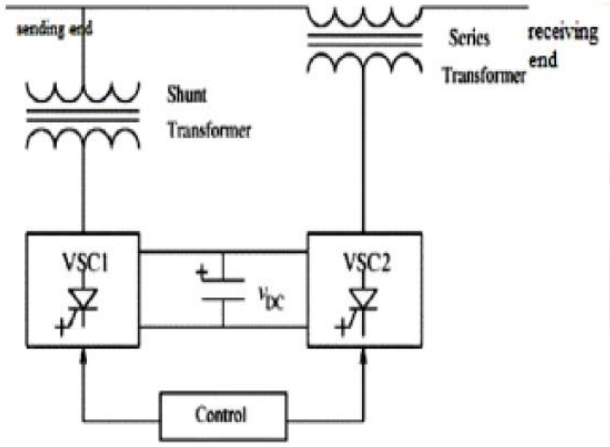

Figure 3: UPFC Model

5. Power System Stabilizers:

Power system stabilizers (PSS) have been extensively used as supplementary excitation controllers to damp out the low frequency oscillations and enhance the overall system stability. Fixed structure stabilizers have practical applications and generally provide acceptable dynamic performance. There have been arguments that these controllers, being tuned for one nominal operating condition, provide suboptimal performance when there are variations in the system load. There are two main approaches to stabilize a power system over a wide range of operating conditions, namely robust control. The block diagram for the designed conventional PSS is Shown in Fig.4.

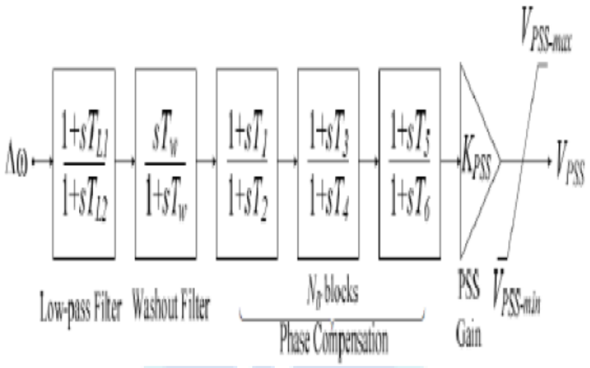

Figure 4: Power System Stabilizer Model

6. Simulation Model and Results:

The Matlab software is used to analysis of transient stability of the multi-machine, IEEE 9-bus bar power system network using ieee std 421.5 power system stabilizer. The base MVA and system frequency are considered to be 100 MVA and 50 Hz, respectively. The Here, generator G1 is connected to slack bus 1, whereas generators 2 (G2) and 3 (G3) are connected to bus bars 2 and 3, respectively. Loads A, B and C are connected in bus bars 5, 7 and 8 respectively. The transient stability analysis has been carried out by monitoring the performance of the generators (G1, G2 and G2) and different buses. The transient stability analysis of this power system network have been considered when three phase fault occurs in the network.

6.1 IEEE 9-Bus Bar Power System With Three Phase Fault:

IEEE 9-bus bar power system as shown in fig.-5 is considered in this study.

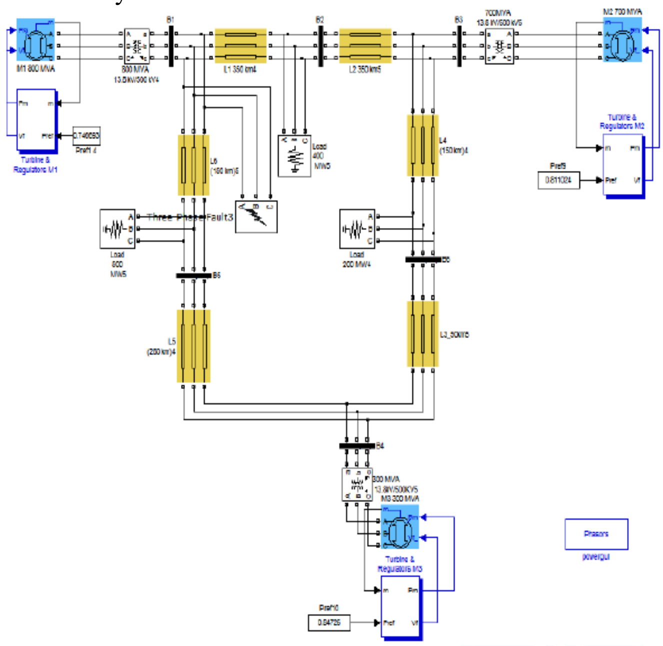

Figure 5: IEEE 9-Bus Power System during Three Phase Fault

It is considered that a 3-phase symmetrical short circuit fault of 0.1seconds occur at bus B4. The fault is cleared of 0.5 seconds. The system losses its stability. Hence the FACTS devices are used to control stability problems. The PSS also included to this MATLAB simulation.

6.2 IEEE 9-Bus Bar Power System With FACTS Device (STATCOM) and Power System Stabilizer:

IEEE 9-bus bar power system as shown in fig-6 is considered in this study.

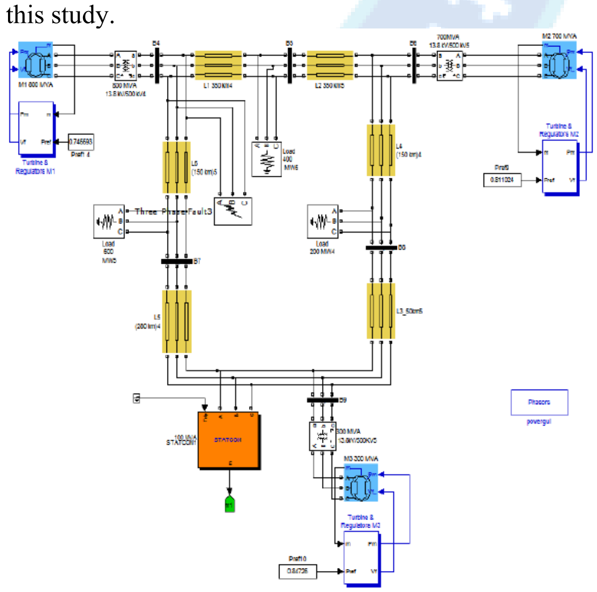

Figure 6: IEEE 9-bus power system installed with STATCOM and PSS

The system has a STATCOM installed at B7. It is considered that a 3-phase symmetrical short circuit fault of 0.1seconds occur at bus B4. Put the Generic type PSS in service by setting the command in PSS block equal to 1. Open the STATCOM block menu and change the STATCOM mode of operation to voltage regulation. fig 7: shows the relative angular positions for delt2_1, delt3_2and delt3_1 IEEE 9 bus system with STATCOM controller placed between Bus 7 and Bus 9 and fault taking place between Bus 4 and Bus 7.The total simulation
time taken is 10 sec.

7. Conclusion:

The power system stability has been compared and discussed for improvement of a 3-machine 9 bus system by STATCOM, SVC & UPFC. The dynamic behaviour of the power system is compared with the presence of STATCOM, SVC & UPFC in the system in the event of a major disturbance. Then the performance of UPFC for power system stability improvement is compared with the STATCOM and SVC. It is clear from the simulation results that there is a considerable improvement in the system performance with the use of UPFC for which settling time in post fault is found to be around 3.8 sec.

References:

[1]. Dr. Raja Singh Khela and Sandeep kaur, ―Transient Stability Using FACTS Controller‖, IJLTET, Volume 7, Issue 1, May 2016.

[2]. Shenglong Yu, Tat Kei Chau, and Tyrone Fernando, Andrey V. Savkin, and Herbert H.-C. Iu, ―Novel Quasi-Decentralized SMC-Based Frequency and Voltage Stability Enhancement Strategies using Valve Position Control and FACTS Device‖, IEEE Access, May 2016.

[3]. Bhuvan Sharma Arvind Sharma, ―Power System Stability Enhancement Using FACTS‖, IJARCSSE, Volume 5, Issue 5, May 2015.

[4]. Tingjian Liu, Youbo Liu, and Junyong Liu, Yue Yang, Gareth A. Taylor, and Zhengwen Huang, ―Multi-indicator Inference Scheme for Fuzzy Assessment of Power System Transient Stability‖, IEEE, Volume 2, Issue 3, September 2016.

[5]. Yang Liu, Q. H. Wu, and Haotian Kang, Xiaoxin Zhou, ―Switching Power System Stabilizer and Its Coordination for Enhancement of Multi-machine Power System Stability‖, IEEE, Volume 2, Issue 2, June 2016.

[6]. Divya Prakash, Er. Vinay Kumar, ―Enhancing Stability of Multi-Machine IEEE 9 Bus Power System Network Using PSS‖, IJAREEIE, Volume 4, Issue 5, May 2015.

[7]. Ben-Sheng Chen and Yuan-Yih Hsu, ―An Analytical Approach to Harmonic Analysis and Controller Design of a STATCOM‖, IEEE, Volume 22, Issue 1, January 2007.

[8]. Siwei Liu, Gengyin Li, and Ming Zhou, ―Power System Transient Stability Analysis with Integration of DFIGs Based on Center of Inertia‖ IEEE, Volume 2, Issue 2, June 2016.

[9]. P. Kundar, ―Power System Stability and Control‖. NewYork: McGraw-Hill, 1994.

[10]. Swaroop Kumar. Nallagalva, Mukesh Kumar Kirar, and Dr. Ganga Agnihotri, ―Transient Stability Analysis of the IEEE 9-Bus Electric Power System‖ IJSET, Volume 1, Issue 3, July 2012.

[11]. S. K. Sethy, J. K. Moharana, ―Design, Analysis and Simulation of Linear Model of a STATCOM for Reactive Power Compensation with Variation of DC-link Voltage‖ IJEIT, Volume 2, Issue 5, November 2012.

[12]. Prof. P.S.R. Murthy, ―Power System Analysis‖, Hyderabad: BS Publications, 2007.

[13]. M. Srinivasa Rao, L. Murali Mohan, ―Transient Stability Performance Analysis of Power System Using Facts Devices‖ IJERA, Volume 4, Issue 2, February 2014.

[14]. Sanjiv Kumar, Dr. Narendra Kumar, ―Effectiveness of FACTS Devices for Power System Stability Enhancement‖ IJAES, Volume 1, Issue 2, April 2011.

[15]. P R Sharma, Narender Hooda, ―Transient Stability Analysis of Power System Using Matlab‖ IJESRT, Volume 1, Issue 7, September 2012.

[16]. Hingorani, N. G., &Gyugyi, L. (2000). Understanding FACTS: concepts and technology of flexible AC transmission systems (Vol. 1). M. El-Hawary (Ed.). New York: IEEE press.

[17]. Murali, D., Rajaram, D. M., &Reka, N. (2010). Comparison of FACTS devices for power system stability enhancement. International Journal of Computer Applications (0975–8887) Volume, 30-35.

[18]. Deshpande, A. S., Kadam, P. A. and Rana, V. M. (2011, May). First Swing Stability of Power System Using FACTS Device. 2011 National Conference on Recent trends in Engineering and Technology.

[19]. Rath, S., Sahu B., & Dash, P. (2012). Power System Operation and Control Using FACTS Devices. International Journal of Engineering Research and Technology. 1(5).

[20]. Murali, D., &Rajaram, M. (2010). Active and Reactive Power Flow Control using FACTS Devices. International Journal of Computer Applications. 9(8). 45-50.

[21]. Kumar, A., &Priya, G. (2012, December). Power system stability enhancement using FACTS controllers. In Emerging Trends in Electrical Engineering and Energy Management (ICETEEEM), 2012 International Conference on (pp. 84-87). IEEE.

[22]. Kodsi, S. M., &Canizares, C. A. (2003). Modeling and simulation of IEEE 14 bus system with FACTS controllers. University of Waterloo, Canada, Tech. Rep.

[23]. Haddad, S., Haddouche, A. &Bouyeda, H. (2009, April). The use of FACTS Devices in Distributed power systems-Modelling, Interface and case study. International Journal of Computer and Electrical Engineering. 1(1).

[24]. Abido, M. A. (2009). Power System Stability Enhancement Using Facts Controllers: A Review. Arabian Journal for Science & Engineering (Springer Science & Business Media BV), 34.

[25]. Somalwar, R. &Khemaria, M. (2012, March). A Review of enhancement of Transient stability using FACTS Devices. International journal of Emerging Technologies in Sciences and Engineering, 5(3).

[26]. Venkateswarlu, K. and Babu, C. S,. (2011, May). Analysis and Enhancement of Transient Stability using SHUNT Controlled FACTS Controllers. International Journal of Engineering Sciences Research. 1(2).

[27]. Overbye, T. J., & Brown, D. (1993, August). Use of FACTS devices for power system stability enhancement. In

ISSN: 2454-6844

Circuits and Systems, 1993. Proceedings of the 36th Midwest Symposium on (pp. 1019-1022). IEEE.
[28]. Mohanty, A. K., & Barik, A. K. (2011). Power System Stability Improvement Using FACTS Devices. International Journal of Modern Engineering Research, 1(2), 666-672.
[29]. ABAZARI, & EMADI. (2003). Transient stability improvement by using advanced static VAR compensators. Electric Power Components and Systems, 31(4), 321-334.
[30]. Kaur, T. and Kakran, S. (2012). Transient stability Improvement of Long Transmission Line System by Using SVC. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering. 1(4).