Transient Stability Enhancement of SMIB (Single Machine Infinite Bus) System using UPFC

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Abstract---The focus of this paper is to improve transient stability of Single Machine Infinite Bus (SMIB) system with the help of Unified Power Flow Controller (UPFC). UPFC has a capability to control simultaneously real and reactive power flows in a transmission line and also to regulate voltage at the bus where it is connected. A proportional integral (PI) controller has been used for the Unified Power Flow Controller (UPFC). In this paper, two simulation models of Single Machine Infinite Bus (SMIB) system with and without Unified Power Flow Controller (UPFC) have been developed. The Flexible Alternating Current Transmission (FACTS) devices such as UPFC are the most important in suppressing power system oscillations and improving damping. We can study the transient stability using the waveform of fault current, real power, reactive power at receiving end, shunt injected voltage and its angle, series injected voltage and its angle and excitation voltage. Therefore we can conclude that transient stability of Single Machine Infinite Bus (SMIB) system is improved with the use of Unified Power Flow Controller (UPFC).

I. INTRODUCTION

There are two generations for realization of power electronic based FACTS controllers: the first generation includes conventional thyristor-switched capacitors and reactors (TSC and TSR), and Quadrature tap-changing transformers, which is variable impedance type FACTS controllers, and the second generation includes gate turn – off (GTO) thyristor - switched converter as voltage source converter (VSCs), which is VSC based FACTS controllers. The first generation has resulted in the Static VAR Compensator (SVC) (shunt connected), the Thyristor-Controlled Series Capacitor or Compensator (TCSC) (series connected), and the Thyristor-Controlled Phase Shifting Transformer (TCPST) or Static PST (combined shunt and series). The second generation has produced the Static Synchronous Compensator (STATCOM) (shunt connected), the Static Synchronous Series Compensator (SSSC) (series connected), the Unified Power Flow Controller (UPFC) (combined shunt-series), and the Interline Power Flow Controller (IPFC) (combined shunt-series) [5]. The two groups of FACTS controllers have distinctly different operations and performance characteristics. FACTS devices have been mainly used for solving various power system steady state control problems such as voltage regulation, power flow control, and transfer capability enhancement. As supplementary functions, damping the inter area modes and enhancing power system stability using FACTS controllers have been extensively studied and investigated.

The UPFC is the most versatile of the FACTS devices. UPFC can control the flow of real and reactive power by injection of a voltage in series with the transmission line. Both the magnitude and the phase angle of the voltage can be changed independently. Real and reactive power flow control can allow for power flow in prescribed routes, loading of transmission lines closer to their thermal limits and can be utilized for improving transient and small signal stability of the power system. The schematic of the UPFC is shown in Figure 1.

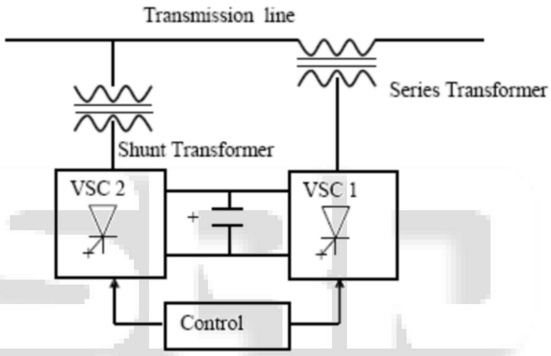

Fig. 1: Schematic arrangement of UPFC

The UPFC consists of two branches. The series branch consists of a voltage source converter (VSC), which injects a voltage in series through a transformer. The inverter at the input end of the UPFC is connected in shunt to the AC power system and the inverter at the input end of the UPFC is connected in series with the AC transmission circuit. Since the series branch of the UPFC can inject a voltage with variable magnitude and phase angle it can exchange real power with the transmission line. However the UPFC as a whole cannot supply or absorb real power in steady state (except for the power drawn to compensate for the losses) unless it has a power source at its DC terminals.

II. PRINCIPLE OPERATION OF UPFC

The Unified Power Flow Controller (UPFC) was proposed' for real turn-off time control and dynamic compensation of ac transmission systems, providing the necessary functional flexibility required to solve many of the problems facing the utility industry. The Unified Power Flow Controller (UPFC) consists of two switching converters, which in the implementations considered are voltage sourced inverters using gate thyristors valves, as illustrated in Fig. These inverters, labelled "Inverter1" and "Inverter 2" in the figure, are operated from a common dc link provided by a dc storage capacitor. This arrangement works as an ideal auto ac power converter in which the real power can freely flow in either direction between the ac terminals of the two inverters and each inverter can independently generate (or absorb) reactive power at its own ac output terminal since the series branch of the UPFC can inject a voltage with variable magnitude and phase angle it can exchange real power with the transmission line. However a UPFC as a whole cannot supply or absorb real power in steady state (except for the power drawn to compensate for the losses) unless, it has a power source at its DC terminals. Thus the shunt branch is required to compensate from the system for any real power drawn/supplied by the series branch and the losses. if the power balance is not maintained, the capacitor cannot remain at a constant voltage. Shunt branch can independently exchange reactive power with the system

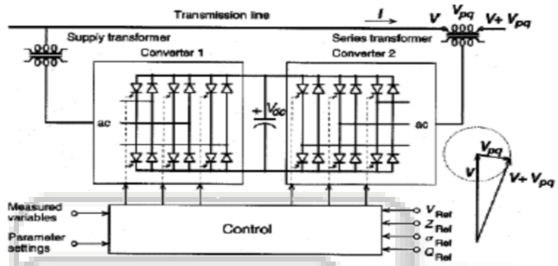

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Fig. 2: Basic circuit arrangement of the UPFC

The basic function of Inverter 1 is to supply or absorb the real power demanded by Inverter 2 at the common dc link. This dc link power is converted back to ac and coupled to the transmission line via a shunt-connected transformer. Inverter 1 can also generate or absorb controllable .reactive power, if it is desired, and thereby it can provide independent shunt reactive compensation for the line. It is important to note that whereas there is a closed "direct" path for the real power negotiated by the action of series voltage injection through Inverters 1 and 2 back to the line, the corresponding reactive power exchanged is supplied or absorbed locally by Inverter 2 and therefore it does not flow through the line. Thus, Inverter 1 can be operated at a unity power factor or be controlled to have a reactive power exchange with the line independently of the reactive power exchanged by Inverter 2. This means that there is no continuous reactive power flow through the UPFC.

A. Basic UPFC Control Function

Viewing the operation of the Unified Power Flow Controller from the stand point of conventional power transmission based on reactive shunt compensation, series compensation, and phase shifting, the UPFC can fulfil all these functions and thereby meet multiple control objectives by adding the injected voltage Vpq, with appropriate amplitude and phase angle, to the terminal voltage Vo, Using phasor representation, the basic UPFC power flow control functions are illustrated in Fig.3.2. Terminal voltage regulation, similar to that obtainable with a transformer tap-changer having infinitely small steps, is shown at (a) where $V_m = \Delta V$ (boldface letters represent phasors) is injected in-phase (or anti-phase) with V_o. Series capacitive compensation is shown at (b) where $V_{pq} = V_c$ is injected in quadrature with the line current I. Transmission angle regulation (Phase shifting) is shown at (c) where V_{pq}=V. σ is injected with an angular relationship with respect to Vo that achieves the desired σ phase shift (advance or retard) without any change in magnitude. Multi power flow control, executed by simultaneous terminal voltage regulation, series capacitance line compensation, and phase shifting, is shown a $V_{pq} = \Delta V + V_c + V_\sigma$.

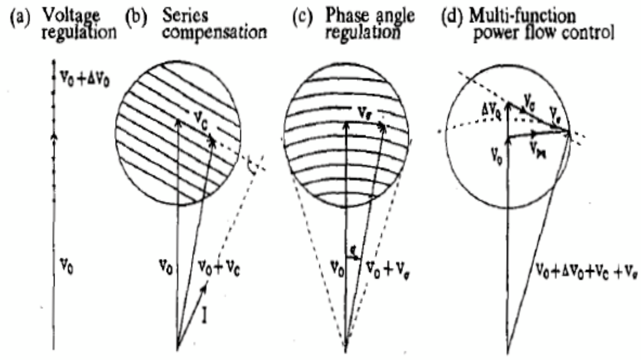

Fig. 3: Basic UPFC control function.
(a)Voltage Regulation
(b) Series compensation
(c) Angle regulation
(d) Multifunction power flow controller

B. ONE LINE DIAGRAM FOR Case study (SMIB)

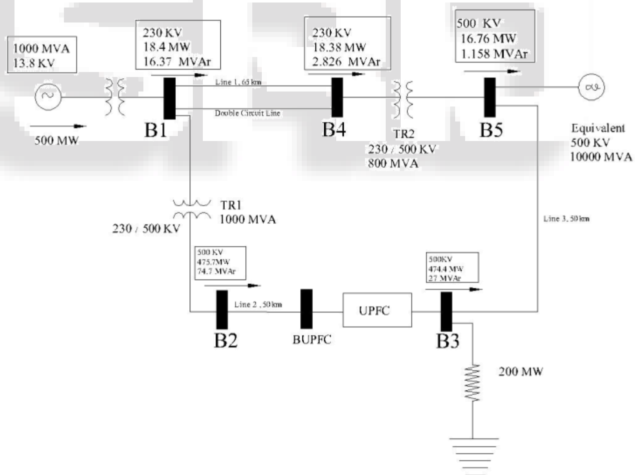

Fig. 4 Case Study (Diagram of SMIB)

C. Circuit Description

UPFC is used to control the power flow in a 500 kV/230 kV transmission systems. The system, connected in a loop configuration, consists essentially of five buses (B_1 to B_5) interconnected through transmission lines (L_1, L_2, L_3) and two 500 kV/230 kV transformer banks Tr_1 and Tr_2 are connected. Tr_1 is connected between B_1 and B_2 while Tr_2 is connected between B_4 and B_5. One power plants located on the 230-kV system generate 500 MW which is transmitted to a 500-kV 10000-MVA equivalent and to a 200-MW load connected at bus B_3. The plant models include a speed regulator, an excitation system as well as a power system stabilizer (PSS). The three 400-MVA transformers connected between buses B_4 and B_5. For this circuit we are considering a contingency case where only two transformers out of three are available (Tr_2= 2*400 MVA = 800 MVA).

Using the load flow option of the powergui Block, the model has been initialized with plants #1 generating respectively 500 MW and the UPFC out of service (Bypass breaker closed). The resulting power flow obtained at buses B_1 to B_5 is indicated by numbers on the circuit diagram.

The load flow shows that most of the power generated by plant # 1 is transmitted through the 1000 MVA transformer bank (339.7 MW out of 500 MW), the rest (160.3MW), circulating in the loop. The circuit will illustrate how the UPFC can relieve this power congestion.

The UPFC located at the right end of Line 2 is used to control the real and reactive powers at the 500 kV bus B_3, as well as the voltage at Bus B_UPFC. It consists of a phasor model of two 100 MVA, IGBT-based, converters (one connected in shunt and other is connected in series and both are interconnected through a DC bus on the DC side and to the AC power system, through coupling reactors and transformers). Parameters of the UPFC power components are given in dialog box. The series converter can inject a maximum of 10% of nominal line –to-ground voltage in series with L2. The b numbers shows on the diagram show the power flow with the UPFC in service and controlling the B3 real and reactive powers respectively at 474.4 MW and -27 Mvar.

D. *Matlab File without UPFC*

Figure 5 shows the simulation model of Single Machine Infinite Bus System without UPFC.

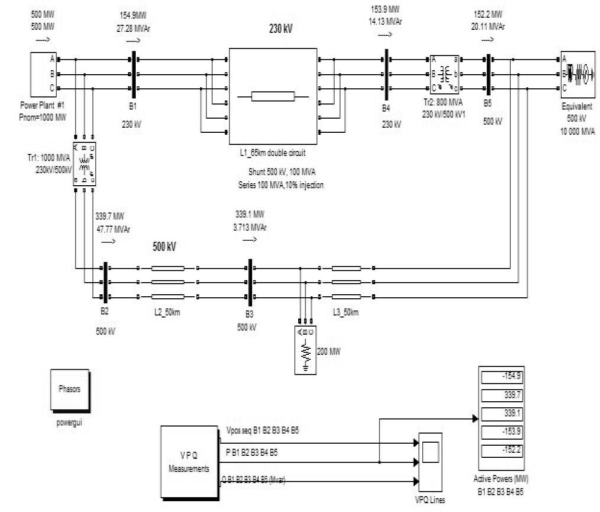

Fig. 5: Matlab Model without UPFC

Figure 6, 7 and 8 shows the Subsystem under Power Plant # 1, Regulator M1 and V P Q measurement respectively.

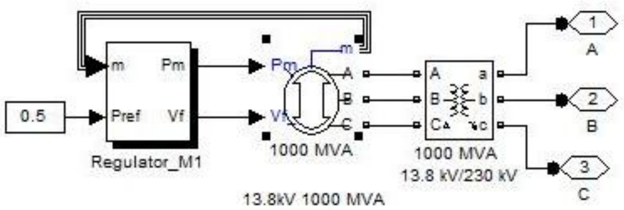

Fig. 6: Subsystem under the Power Plant # 1

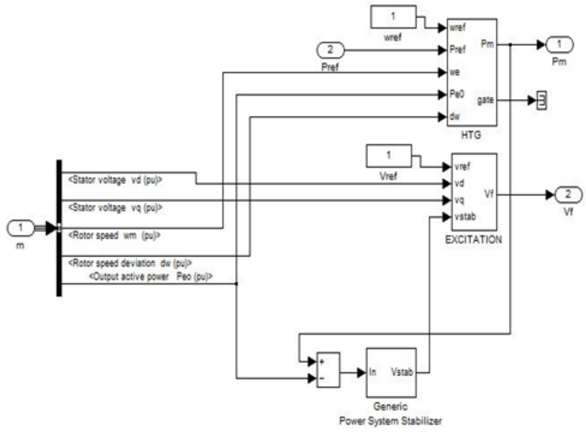

Fig. 7: Subsystem under the Regulator M1

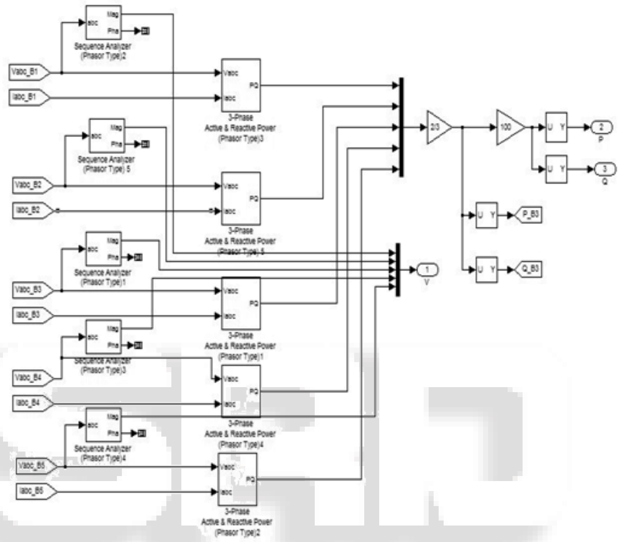

Fig. 8: Subsystem under V P Q measurement

E. *Simulation Result (without UPFC)*

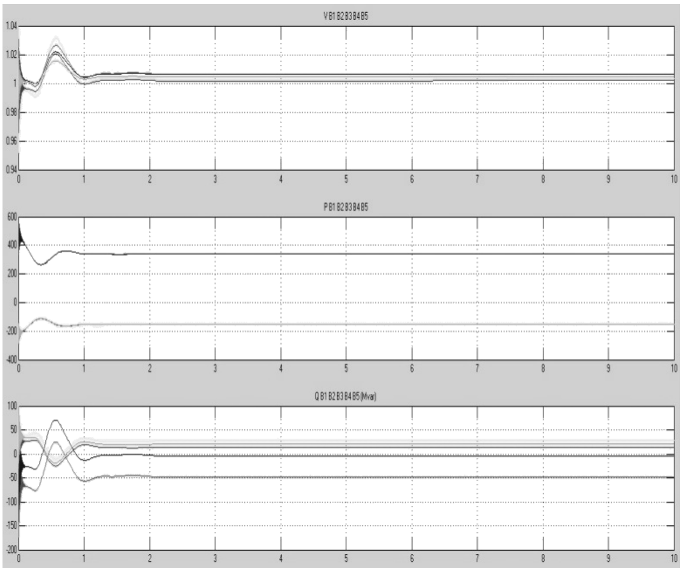

Fig. 9: Simulation Result of Active Power, Reactive Power & Voltage Result (without UPFC)

F. *Matlab File With UPFC*

Figure 9 shows the simulation model of Single Machine Infinite Bus System with UPFC.

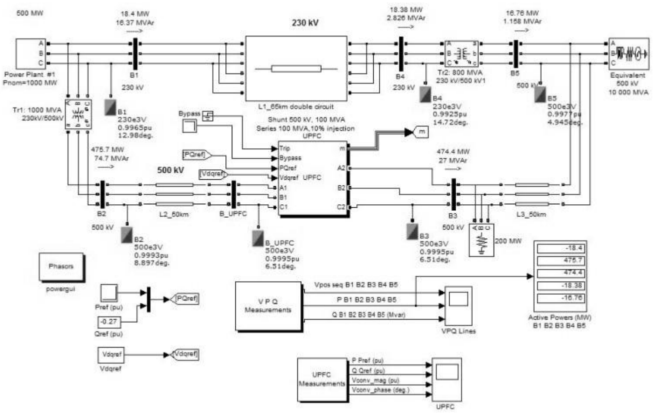

Fig. 10: Matlab Model without UPFC

G. Simulation Result (with UPFC)

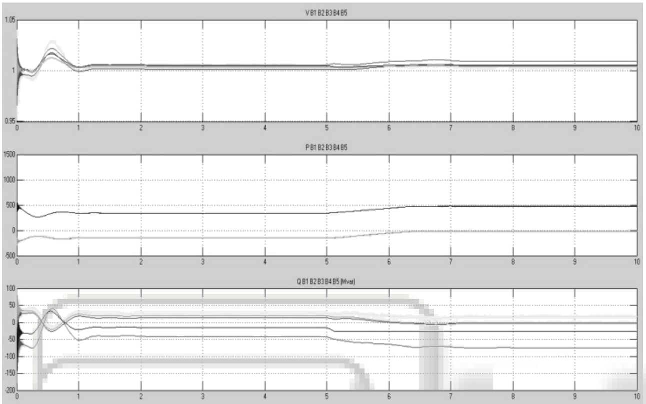

Fig. 11: Simulation Result of Active Power, Reactive Power & Voltage Result (without UPFC)

III. CONCLUSION

After the completing analysis of this paper, I conclude that Transient stability of Single Machine Infinite Bus (SMIB) System will improve by using Unified Power Flow Controller (UPFC), which is most versatile device rather than the other FACTS devices. The Dynamic response of Unified Power Flow Controller (UPFC) is better than other device. It can control the three parameters real power, reactive power and voltage of power system.

REFERENCE

[1] H. Akagi, E. Watanabe and M. Aredes, “Instantaneous Power Theory and Applications to Power Conditioning”, IEEE Press published by John Wiley & Sons, Inc., Publications.

[2] Prabha Kundur, Power System Stability and Control. New Delhi: Tata McGraw- Hill, 2006.

[3] L. Gyugyi, C.D. Schauder, S.L. Williams, T.R. Reitman, D.R. Torgerson, A. Edris, “The Unified Power Flow Controller: A New Approach to Power Transmission Control”, IEEE Transactions on Power Delivery, Volume 10, No. 2, p.p. 1085-7097, April 1995.

[4] S. Limyingcharoen, U. D. Annakkage, N. C. Pahalawaththa, “Effects of unified power flow controllers on transient stability”, IEE Proc.-Gener. Transm. Distrib. Volume 145, No. 2, March 1998, pp. 182-188.

[5] Prabha Kundur, John Paserba, Venkat Ajjarapu, Göran Andersson, Anjan Bose, Claudio Canizares, Nikos Hatziargyriou, David Hill, Alex Stankovic, Carson Taylor, Thierry Van Cutsem, and Vijay Vittal, “ Definition and Classification of Power System Stability”, IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 19, NO. 2, MAY 2004, p.p. 1387-1401.

[6] M.H. Haque, “Application of UPFC to Enhance Trasient Stability Limit”, 1-4244-1298-6/07 ©2007, pp. 1-6.

[7] Er. Ved Parkash, Er. Charan Preet Singh Gill, Dr. Ratna Dahiya, “Transient Stability Improvement of SMIB With Unified Power Flow Controller”, 2nd WSEAS Int. Conf. on CIRCUITS, SYSTEMS, SIGNAL and TELECOMMUNICATIONS (CISST'08)Acapulco, Mexico, January 25-27, 2008, ISSN: 1790-5117, ISBN: 978-960-6766-34-3, p.p. 155-159.

[8] Saidi Amara[1], Hadj Abdullah Hsan[2], “Power system stability improvement by FACTS devices: a comparison between STATCOM, SSSC and UPFC”, 2012 First International Conference on Renewable Energies and Vehicular Technology, 978-1-4673-1170-0/12©2012, pp. 360-365.

[9] Er. Tapan G. Patel[1], Jaydeep B. Sarvaiya[2], “Transient Stability of Power System Using Facts Device-UPFC”, IJSRD-International Journal for Scientific Research & Development\ Vol. 1, Issue 3, 2013\ ISSN (online): 2321-0613.