Experimental Analysis on Transient Performance of SMIB System using UPFC

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ABSTRACT

The focus of this research work is on a FACTS device known as the Unified Power Flow Controller (UPFC), which can provide simultaneous control of basic power system parameters like voltage, impedance and phase angle. In this research work, two simulation models of single machine infinite bus (SMIB) system, i.e. with & without UPFC, have been developed. These simulation models have been incorporated into MATLAB based Power System Toolbox (PST) for their transient stability analysis. These models were analysed for different types of faults at different locations, i.e. at sending end of transmission line, middle of the line and receiving end of transmission line keeping the location of UPFC fixed at the receiving end of the line. Transient stability was studied with the help of curves of fault current, active & reactive power at receiving end, shunt injected voltage & its angle, series injected voltage & its angle, excitation voltage and speed of rotor. With the addition of UPFC, the magnitude of fault current reduces, oscillations of excitation voltage also reduce and the speed of rotor remains almost constant. Series and Shunt parts of UPFC provide series and shunt injected voltage at certain different angles.

Keywords: UPFC, transient, controller,

INTRODUCTION

In the transmission area, application of power electronics consists of HVDC power transmission and FACTS. HVDC is an economical way to interconnect power systems, which are situated in different regions and separated by long distances or those which have different frequencies. HVDC involves conversion of ac to dc at one end and conversion of dc to ac at the other end. Also, there is a widespread use of microelectronics, computers and high speed communication for control & protection of present transmission system.

Many of the ideas upon which the foundation of FACTS rests evolved over a period of many decades. Nevertheless, FACTS, an integrated philosophy, is a novel concept that was brought to fruition during the 1980‘s at the Electric Power Research Institute (EPRI), the utility arm of North American utilities. FACTS looks at the ways of capitalizing on many breakthroughs taking place in the area of highvoltage and high current power electronics, aiming at increasing the control of power flows in the high voltage side of the network during both steady-state and transient conditions.

FACTS being a new technology, will play the principal role to enhance controllability and power transfer capability in an ac system. FACTS technology is not a single high power controller, but rather a collection of controllers, which can be applied individually or in coordination with others to control one or more of the interrelated system parameters. This technology has opened up new opportunities for controlling power and enhancing the usable capacity of present, as well as new and upgraded lines. Current through a line can be controlled at a reasonable cost enabling a large potential of increasing the capacity of the existing line and the use of FACTS controllers to enable the corresponding power to flow through such lines under normal and contingency conditions.

FACTS CONTROLLER

FACTS controllers are used to control the interrelated parameters that govern the operation of transmission systems including series impedance, shunt impedance, current, voltage, phase angle and damping of oscillations at various frequencies below the rated frequency. By providing added flexibility, FACTS controllers can enable a line to carry power closer to its thermal rating. Certain definitions related to FACTS are:

Flexibility of Electric Power Transmission: The ability to accommodate changes in the electric transmission system under operating conditions while maintaining sufficient steady state & transient margins.

Flexible AC Transmission System (FACTS): Alternating current transmission systems incorporating power electronics based & other static controllers to enhance controllability & increase power transfer capability.

FACTS Controller: Power electronics based system & other static equipments that provide control of one or more ac transmission system parameters.

TYPES OF FACTS CONTROLLER

FACTS controller can be classified into four categories:

(a) Series Controller
(b) Shunt Controller
(c) Combined Series – Series Controller
(d) Combined Series – Shunt Controller

Depending on the power electronic devices used in the control, the FACTS controllers can be classified as :

(A) Variable impedance type

(B) Voltage Source Converter (VSC) – based.

The variable impedance type controllers include:

General symbol for a FACTS controller is shown in fig. 1. It consists of a thyristor inside a box.

Fig 1: General symbol for a FACTS controller

(a) Series Controller: The series controller could be variable impedance such as capacitor, reactor etc., or power electronics based variable source of power frequency, sub synchronous & harmonic frequencies (or a combination) to serve the desired need. In principle, all series controllers inject voltage in series with the line. Even a variable impedance multiplied by current flow through it, represents an injected series voltage in the line. As long as voltage is in phase quadrature with the line current, the series controller only supplies or consumes variable reactive power. Any other phase relationship will involve handling of real power as well. Types of series controller are static synchronous series compensator (SSSC) and thyristor controlled series capacitor (TCSC). Series controller is shown in fig. 2.

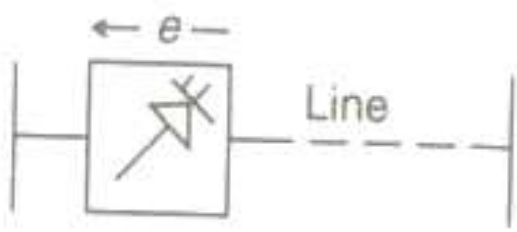

Fig. 2: Series Controller

(b) Shunt Controller: The shunt controller may be variable impedance, variable source or a combination of these as shown in fig. 1.3. In principle, all shunt controllers inject current into the system at the point of connection. Even variable shunt impedance connected to the line voltage causes a variable current flow and hence, represents injection of current into the line. As long as the injected current is in phase quadrature with the line voltage, the shunt controller only supplies or consumes variable reactive power. Any other phase relationship will involve handling of real power as well. Types of shunt controller are static synchronous compensator (STATCOM) and static var compensator (SVC).

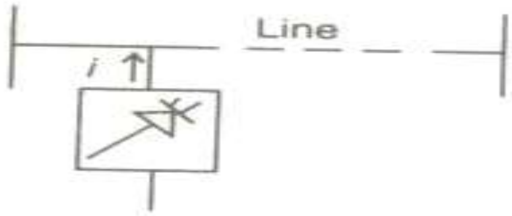

Fig. 3: Shunt Controller

(c) Combined Series-Series Controller: This could be a combination of separate series controllers, which are controlled in a coordinated manner, in a multiline transmission system as shown in fig. 4. Or it could be a unified controller, in which series controllers provide independent series reactive compensation for each line and also transfers real power among the lines via the power link. The real power transfer capability of the unified series-series controller, referred to as Interline Power Flow Controller, makes it possible to balance both real and reactive power flow in the lines and thereby maximise the utilisation of the transmission system. "Unified" means that the dc terminals of all the controller converters are connected together for real power transfer.

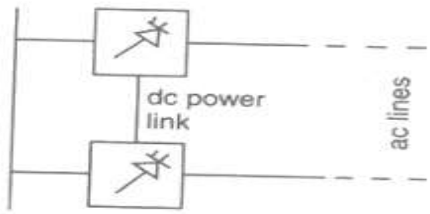

Fig 4: Unified Series-Series Controller

(d) Combined Series-Shunt Controller: This could be a combination of separate shunt and series controllers, which are controlled in a coordinated manner or a Unified Power Flow Controller with series and shunt elements. In principle, combined shunt and series controllers inject current into the system with the shunt part of the controller and voltage in series in the line with series part of the controller. However, when the shunt and series controllers are unified, there can be a real power exchange between the series and shunt controllers via the power link. Combined series- shunt controller is shown in fig. 5.

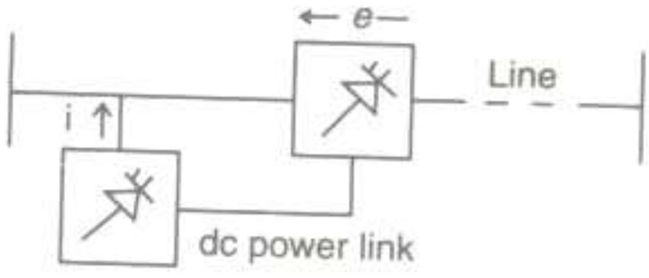

Fig 5: Unified Series-Shunt Controller

UNIFIED POWER FLOW CONTROLLER (UPFC)

It is a type of series-shunt controller i.e. a combination of static synchronous compensator (STATCOM) & a static synchronous series compensator (SSSC) which are coupled via a common dc link as represented in fig. 6. These allow bidirectional flow of real power between the series output terminals of the SSSC & the shunt output terminals of STATCOM & are controlled to provide concurrent real & reactive series line compensation without an external electric energy source. By means of angularly unconstrained series voltage injection, UPFC is able to control, concurrently or selectively, the transmission line voltage, impedance & angle or alternatively, the real & reactive power flow in the line. UPFC may also provide independently controllable shunt reactive compensation.

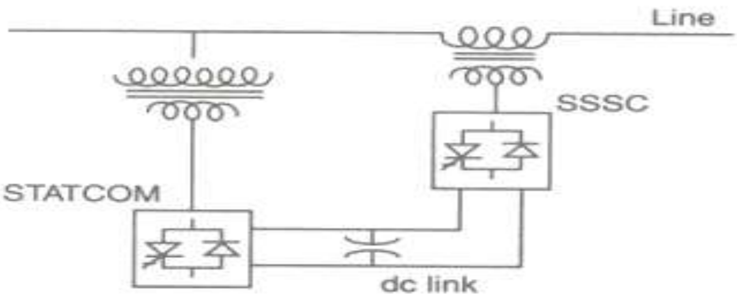

Fig 6: Unified Power Flow Controller

In UPFC, the active power for the series unit (SSSC) is obtained from the line itself via the shunt unit STATCOM. STATCOM is also used for voltage control with control of its reactive power. This is a complete controller for controlling active and reactive power through the line, as well as its line voltage control. Controlled exchange of real power with an external source, such as storage, is much more effective to control the system dynamics that modulates power transfer within a system.

RESULTS & DISCUSSIONS

Transient Stability Analysis of SMIB System

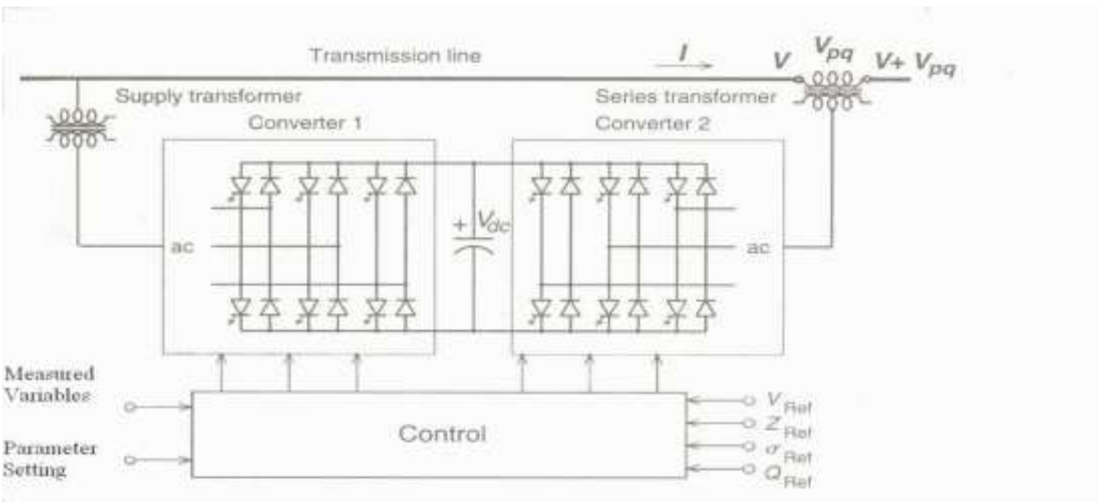

Fig 7: Implementation of UPFC by two back-to-back voltage source converters

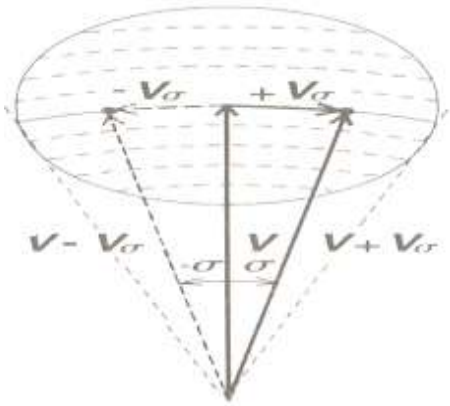

Fig 8: Conventional transmission control capabilities of UPFC (Phase Shifting)

Single Machine Infinite Bus (SMIB) System with UPFC at Receiving end

Resulting curves of the variation of speed of rotor, excitation voltage, fault current, active & reactive power at receiving end, magnitude & angle of series injected voltage and magnitude & angle of shunt injected voltage are shown in fig.5.5 to 5.10.

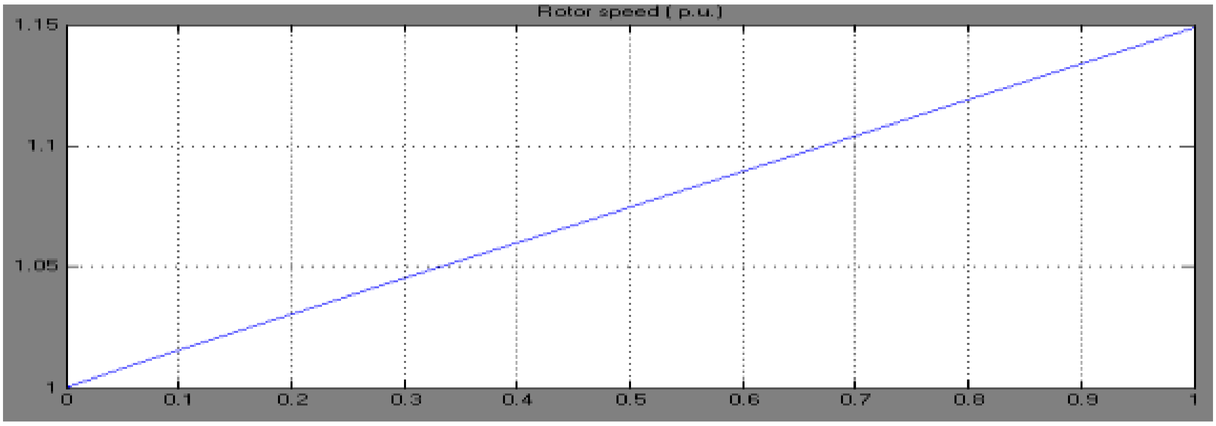

Figure 9: Variation of rotor speed Vs time

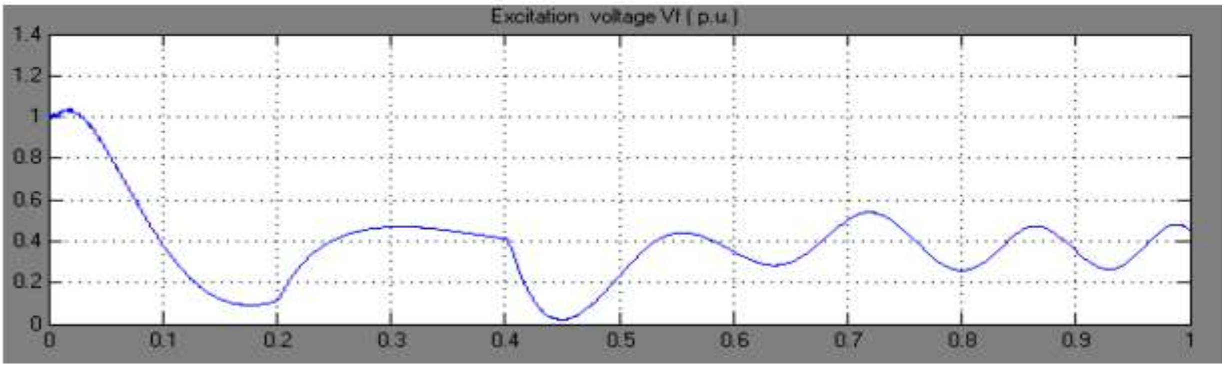

Figure 10: Variation of excitation voltage Vs time

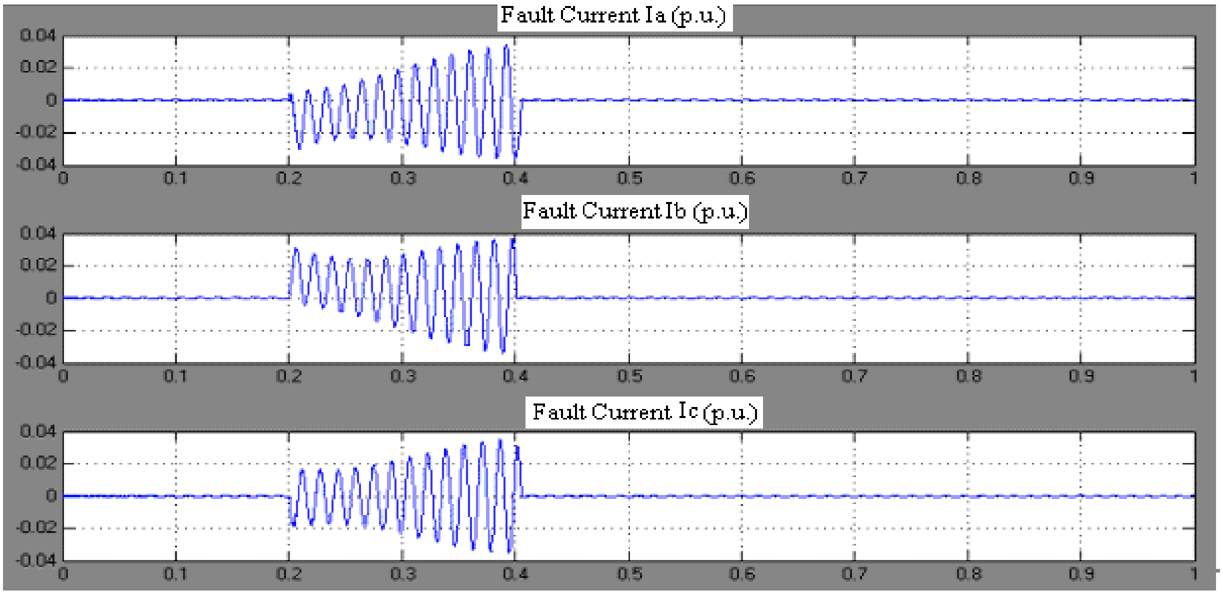

Figure 11: Variation of fault current Vs time

CONCLUSIONS

From the results & the curves presented in previous chapter, the following conclusions are drawn if UPFC is added in SMIB system:

- Fault current is reduced when fault occurs at middle of the line or receiving end of the line. But there is no change in fault current when fault occurs at sending end of the line as UPFC is kept fixed at receiving end of transmission line.
- Excitation voltage is modified with damping out of oscillations when fault occurs at middle of the line or receiving end of the line. But there is no change in excitation voltage when fault occurs at sending end of the line as UPFC is kept fixed at receiving end of transmission line.
- Speed of rotor almost remains constant irrespective of the fault location.
- On the whole, the transient stability of SMIB is improved at middle of the line & receiving end of the transmission line if UPFC is included at receiving end of the line.

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