ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 1, January 2016

Transient Stability Enhancement of SMIB System with Fuzzy Based PSS Controller and UPFC Using MATLAB Simulink

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ABSTRACT: Unified Power Flow Controller (UPFC) is the greatest multipurpose Flexible AC Transmission System (FACTS) scheme due to its capacity to control real and reactive power on transmission lines and adjusting the voltage of the bus to which it is attached. It is compulsory to analyze its effect of UPFC on power system network when the fault occurs in the power system and therefore whole system goes to severe transients. By using PSS and AVR we can simply stabilize the system. FACTS devices like TCSC, SVC, STATCOM, and UPFC are important device to suppress the power system oscillations under faults occurrence and enhance the damping of the system. The power electronic devicetermed as UPFC which efficiently control the active and reactive power. To carry out small signal stability analysis with the proposed method, a SMIB linear model of Philip- Heffron model, a recognized model for synchronous generator has been employed. Recent past has witnessed the advancements of Power System Stabilizers (PSS) and their variants for enhancing the stability of power system. But the added advantages of FACTS based design outperformed PSS in terms of performance and implementation perspective. The simulation results show that PSS and FL based PSS improves the stability of the SMIB scheme and power system fluctuations are successfully damped out. The unified power flow controller (UPFC) has various applications together with loop flow control, power flow control load sharing among parallel passages, modification of system oscillations, and voltage (reactive power) regulation and development of transient stability. In this thesis, MATLAB simulation package is employed to simulate the UPFC model. A fuzzy logic controller as power system stabilizer is used Power system stabilizers (PSSs) is additional to excitation scheme or controller loop of the generating unit to improve the damping through low frequency oscillations. A three phase fault is considered. The studies are carried out with and without fault consideration in SMIB system. SMIB system with and without UPFC controller is proposed and comparisons are made to show the effectiveness of UPFC controller for the enhancement of transient stability of SMIB system

KEYWORDS:MATLAB/SIMULINK, modelling and simulation, power system stability, single-machine infinite-bus power system, Power System Stabilizer, Fuzzy Logic Power System Stabilizer.

I. INTRODUCTION

Force systems in general are interconnected for economic, security and reliability regions.Exchange of contracted amounts of real power has been in vogue for a long time for economicand security reason.To check the power flow on tie lines connecting consoles areas, power flowcontrol equipment such as phase shifters are installed.They direct real power between controlareas. The interchange of real power is usually done on an hourly basis.Mastery of the electric power system can be realized by planning the FACTS control,where the new fashions as Artificial Intelligence can be functional to this case to boost theCharacteristics of controller presentation.The parameters of CPSS(convectional power systemstabilizer) are calculated Based on the linearized model of the powersystem[1]. The application ofCPSS for the advance of small signal oscillation and the dynamic stability of a power system hasbeen excused in the literature [2].Dissimilar types of arrangement of lag-lead compensator basedPSS are discussed in details [3].

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II.SINGLE MACHINE INFINITE BUS SYSTEM

Conduct the small signal stability studies of Single Machine Infinite Bus (SMIB) linear modelof Philip-Heffron, which is a well-known model for synchronous generators, is considered. It isquite accurate for the small signal stabilitystudies of power systems. It has operatedsuccessfully for the designing and tuning of conventional power system stabilizers.

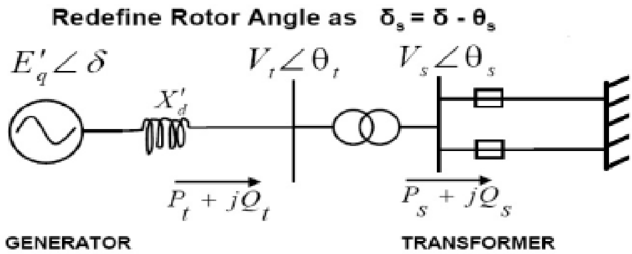

Fig. 1 Single Machine Infinite Bus System

A dynamic model of synchronous machine is considered. To do this, focus on those elements of the machine that store energy in electromagnetic or kinetic form and look at the time evolution of energy stored in those elements. The synchronous generator is represented by model 1, i.e. with field circuit and one equivalent damper winding on q-axis. The non-linear equations of machine are given by [4].

$$\frac{H}{\pi f_o}\frac{d^2\delta}{dt^2} = \mathrm{P_m} - \mathrm{P_e} = P_a \quad (1)$$

$$\frac{d^2\delta}{dt^2} = \frac{\pi f_0}{H}(\mathrm{P_m} - \mathrm{P_e}) \quad (2)$$

$$\frac{d\delta}{dt} = \omega\mathrm{B}\,(\mathrm{S_m} - \mathrm{S_{mo}}) \quad (3)$$

$$\frac{dS_m}{dt} = \frac{1}{2\mathrm{H}}[-D(S_m - \mathrm{S_{mo}}) + \mathrm{T_m} - \mathrm{T_e}] \quad (4)$$

$$\frac{dE'_q}{dt} = \frac{1}{\mathrm{T'_{do}}}[-E'_q + (\mathrm{x_d} - \mathrm{x'_d})\,\mathrm{i_d} + \mathrm{E_{fd}}] \quad (5)$$

$$\frac{dE'_d}{dt} = \frac{1}{\mathrm{T'_{qo}}}[-E'_d + (\mathrm{x_q} - \mathrm{x'_q})\,\mathrm{i_q}] \quad (6)$$

The electrical torque *Te*is expressed in terms of variables *E' d*, *E' q* , *id* and *iq*as:

$$T_e = \mathrm{E'_d\, i_d} + \mathrm{E'_q\, i_q} + (\mathrm{x'_d} - \mathrm{x'_q})\,\mathrm{i_d}\, i_q \quad (7)$$

For a lossless network, the stator algebraic equations and the network equations are expressed as:

$$E'_q + \mathrm{x'_d\, i_d} = \mathrm{v_q} \quad (8)$$

$$E'_d - \mathrm{x'_q\, i_q} = \mathrm{v_d} \quad (9)$$

$$v_q = -\mathrm{x_e\, i_d} + \mathrm{E_b}\cos\delta \quad (10)$$

$$v_d = \mathrm{x_e\, i_q} - \mathrm{E_b}\sin\delta \quad (11)$$

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Solving the above equations, the variables *id* and *iq*can be obtained as:

$$i_d = \frac{E_b \cos\delta - E'_q}{x_e + x'_d} \tag{12}$$

$$i_q = \frac{E_b \sin\delta - E'_q}{x_e + x'_q} \tag{13}$$

The above notation for the variables and parameters described are standard and defined in the nomenclature.

III.UNIFIED POWER FLOW CONTROLLER

UPFC is a device positioned between two buses referred to as the UPFC sending bus and theUPFC receiving the bus.It consists of two voltage-source converters, as illustrated in Figure 2.The back-to-back converters, labeled “shunt converter” and “series converter” in the flesh,are operated from a common DC link provided by a DC storage capacitor.The shunt converter isutilized applied to apply the active power demand of the series converter through the commonDC link.Shunt converter can also generate or absorb reactive power, if it is required, and therebyit provides independent shunt reactive compensation for the military ascendancy.Series converterprovides the main portion of the UPFC by injecting a voltage with controllable magnitude andphase angle in series with the cable.For the fundamental frequency model, the VSCs are replacedby two controlled voltage sources[5].

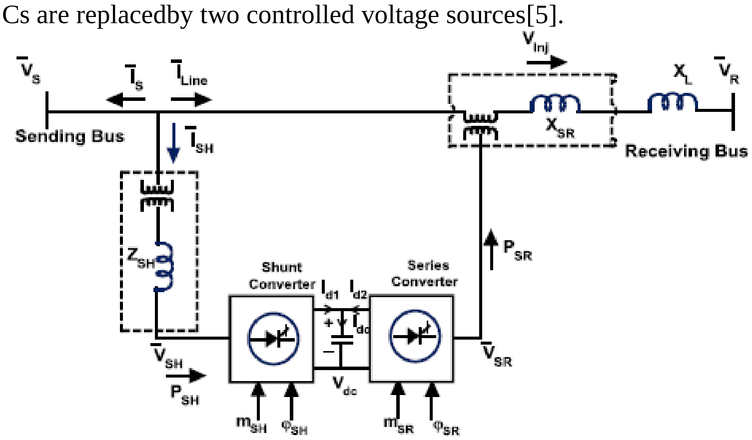

Fig. 2 Basic Circuit Configuration of the UPFC

Operation of the UPFC from the standpoint of conventional power transmission based onreactive shunt compensation, series compensation, and phase shifting, the UPFC can fulfill thesefunctions and therebymeet multiple control objectives by adding the injected voltage.

IV.PROBLEAM FORMULATION

STRUCTURE OF PSS: An economic and satisfactory resolution to the unstable oscillations a power system produces isto provide additional damping (to rotor windings) for the generator rotor. This is done viaConventional PSS which gives additional controllers to the excitation system [6]. The Power System Stabilizer implemented consists, as shownin Figure 3, of three main functional blocks:

- The washout gain
- The washout circuit
- The lead-leg compensator

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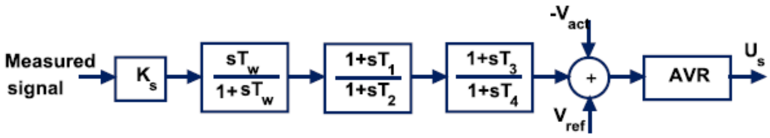

Fig. 3 Conventional PSS

Excitation System with PSS: The simplified IEEE type-ST1A excitation system is considered in this thesis. The diagram ofthe IEEE Type- ST1A excitation system is shown in figure 6. The inputs to the excitationsystem are the terminal voltage VT and reference voltage VR [7]. The gain and time constants of theexcitation system are represented by KA and TA, respectively.

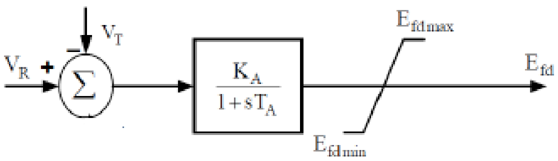

Fig. 6 IEEE type ST1A excitation systems

Models for different types of excitation systems in practice are described in [8]. It characterizes a bus-fed thyristor excitationsystem (IEEE type STIA) with an automatic voltage regulator (AVR) and a power systemstabilizer (PSS).

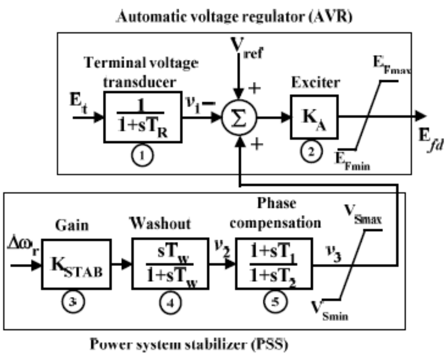

Fig. 7 Thyristor excitation system with AVR and PSS

The AVR regulator model (block 1) shown in figure 7 has been simplified to contain onlythose elements that are considered necessary for representing a specific system. ParameterTRrepresents the terminal voltage transducer time constant. A high exciter gain (block 2),without transient gain reduction or derivate feedback, is recycled. The nonlinearity related withthe model is that due to the ceiling on the exciter output voltage denoted by (EFmax, EFmin)andPSS output voltage (VSmax, VSmin*).*

Fuzzy Logic Controller Based PSS: In parliamentary law to providing stabilizer signal, the output of obtained model reference ofpower system is compared with output of the actual power system and the error signal is fed to afuzzy controller. The Fuzzy controller provides stabilizer signal in order to damping systemoscillations. Fig.8. Present the block diagram of proposed Fuzzy logic controller. In factFuzzy logic controller is one of the most effective operations of fuzzy set theory; its keycharacteristics are the usage of linguistic variables relatively than numerical variables.

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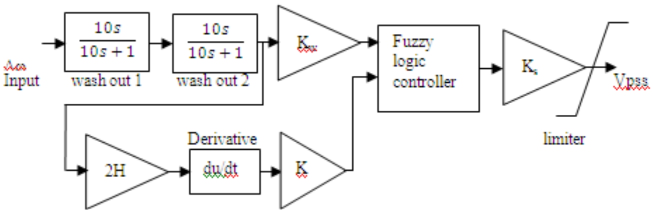

Fig. 8 Fuzzy Controller and FLPSS model

Fig. 8 shows that FLPSS consists of blocks, those are wash-out, gain (KW, KP, KS),and limiter. Each component is explained as follows:

1. Wash out This block consists of two wash-out filters with time constant 10second.
2. Gain [KW, KP and KS] Gain is needed to normalize the input and output of fuzzy logiccontroller.
3. The Fuzzy Logic Controller has a function to produce control signal as an outputappropriate with the input.
4. Limiter [Vsmin, Vsmax] Limiter gives limitation of the PSS output.

INPUT MEMBERSHIP FUNCTION: Each of input variables are classified by Input membership function consists of trapezoidalmembership function and triangular membership function, described in Fig.9 and 10.

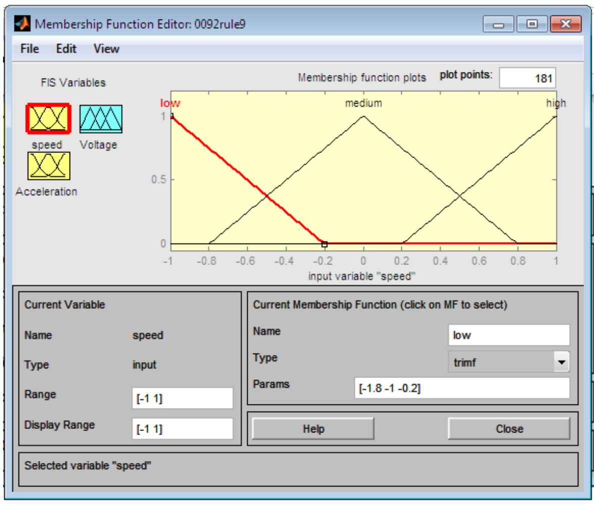

Fig. 9 Speed membership function FLPSS model

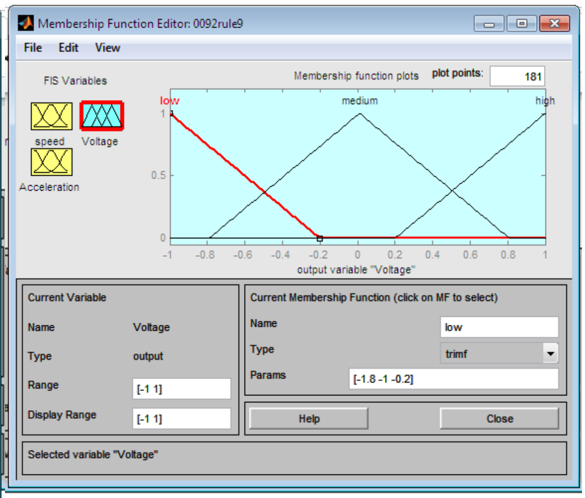

Fig. 10 Voltage membership function FLPSS model

OUTPUT MEMBERSHIP FUNCTION AND RULES: The output membership function also consists of triangular membership function and rules described in Fig.11 and 12.

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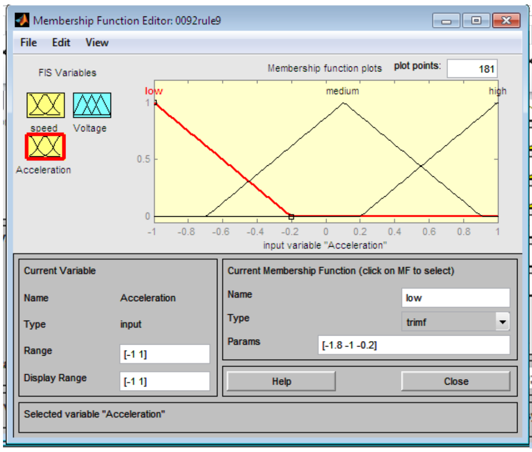


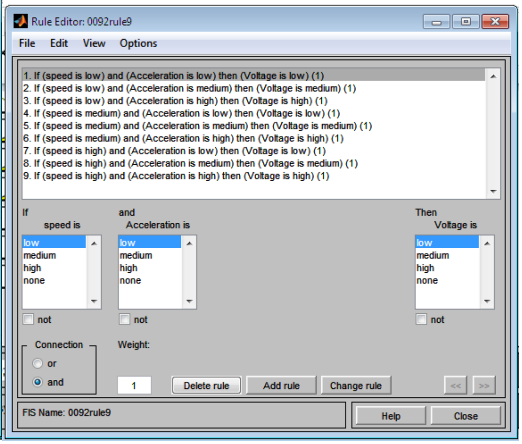


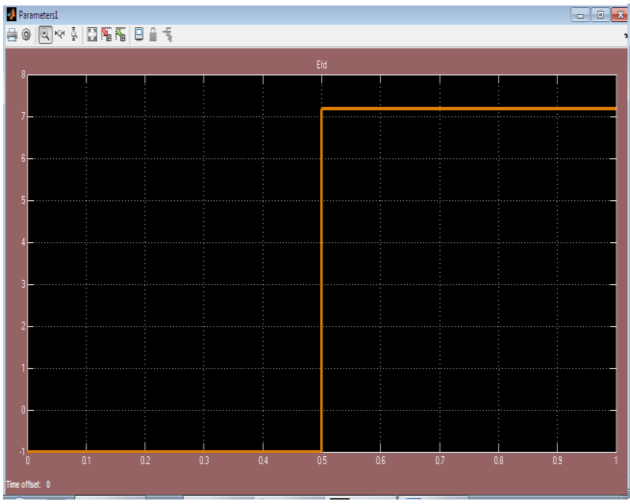
Fig. 11 Acceleration membership function FLPSS model Fig. 12 Acceleration membership function FLPSS model

V.RESULT AND DISCUSSION

Simulation model with conventional diagrams of SMIB with PSS is given in the old chapter. Result associated with them isgiven in this chapter.

SMIB with FLPSS and without UPFC Controller: In this segment, the simulation results of SMIB with PSS are discussed (i.e.Without includingUPFC controller). SMIB with PSS controller presents results under two operating conditionswhich are explained below. First term without three phase fault and second condition, with threephase fault.The three phase fault that we study here is a dead short circuit of all the three lines not involving the land.

Case 1- Without three phase fault **Case 2- With three phase fault**



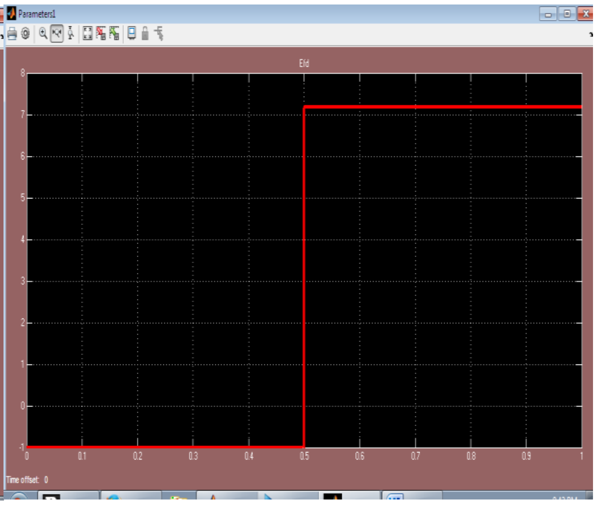


Fig. 13 Excitation voltage of SMIB with PSS without fault Fig 14 Excitation voltage of SMIB with PSS with fault

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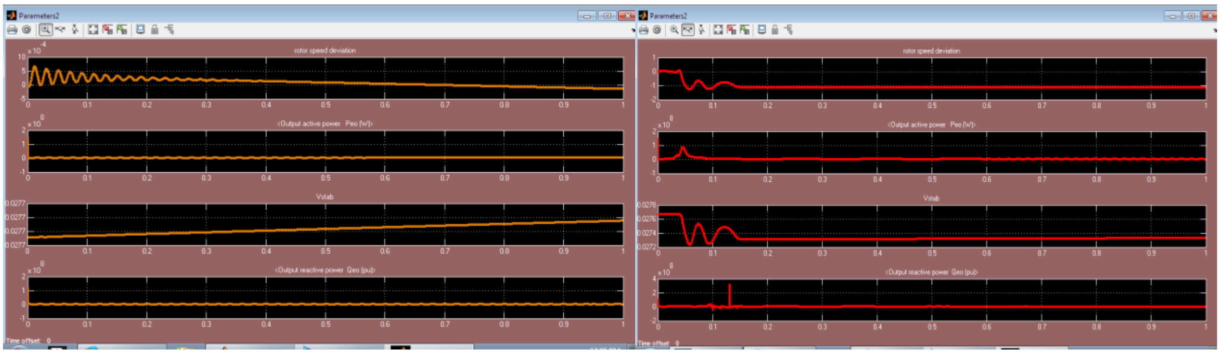

Fig. 15 (a) Rotor speed deviation (b) Output active power(c) Voltage stability (d) Output reactive power.

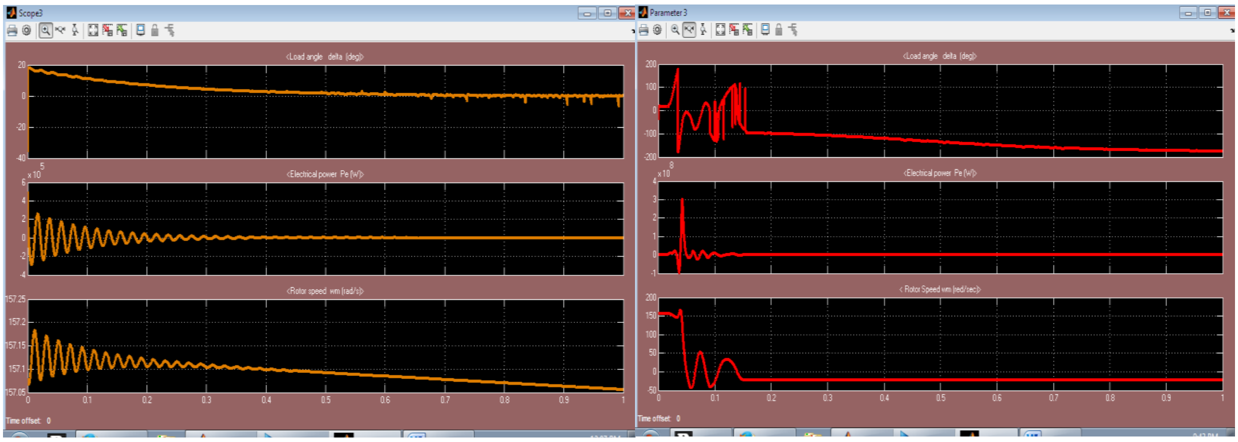

Fig. 16 SMIB with PSS (a) Load angle (b) Electrical power (c) Rotor speed

SMIB with FLPSS and with UPFC Controller: To prove the advantages of UPFC controller incorporated with PSS in SMIB power system, simulation results are carried out in this section. Same as above, SMIB with UPFC presents results under two cases i.e. with and without three phase fault.

Case 1- Without three phase fault **Case 2- With three phase fault**

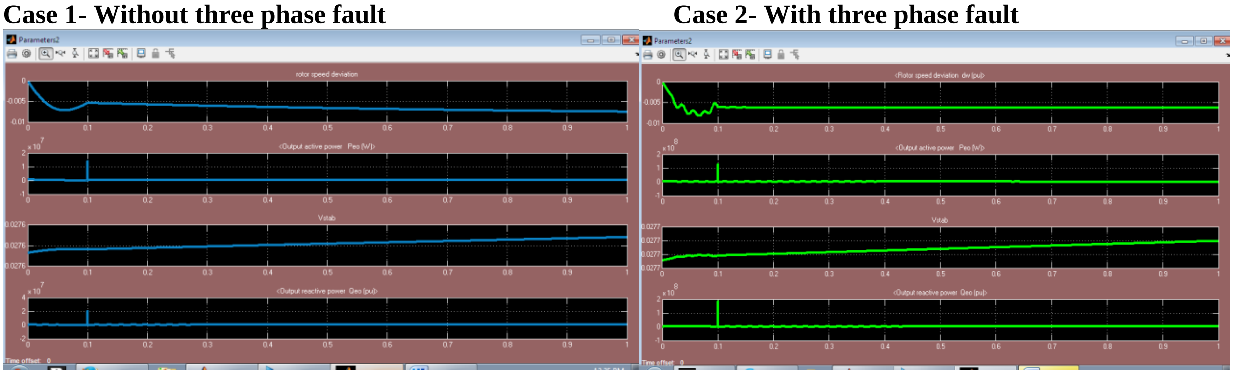

Fig. 17 SMIB with PSS- UPFC (a) Rotor speed deviation (b) Output active power
(c) Voltage stability (d) Output reactive power

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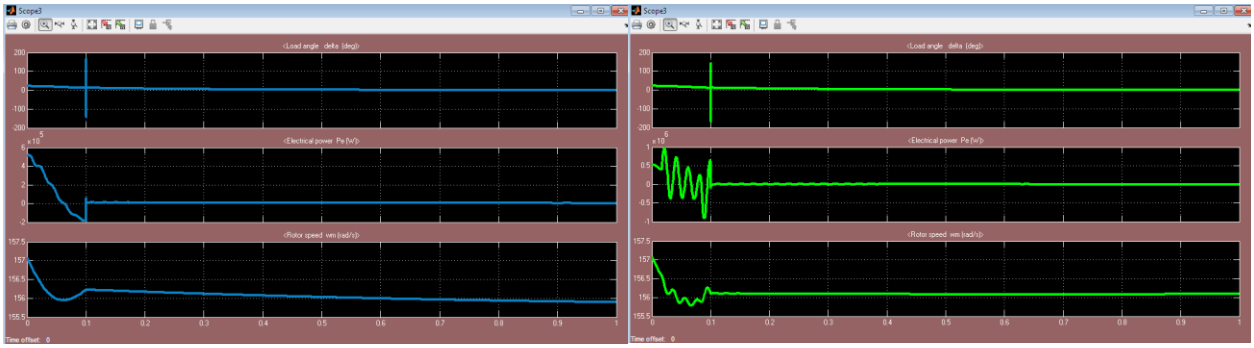

Fig. 18 SMIB with PSS-UPFC (a) Load angle (b) Electrical power (c) Rotor speed

UPFC Parameters: Fig. 19 and 20 shows the line voltage and line power with UPFC

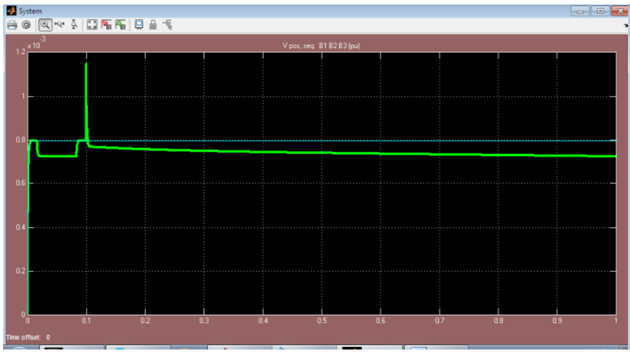

Fig. 19 Line Voltage (VLabc) with UPFC

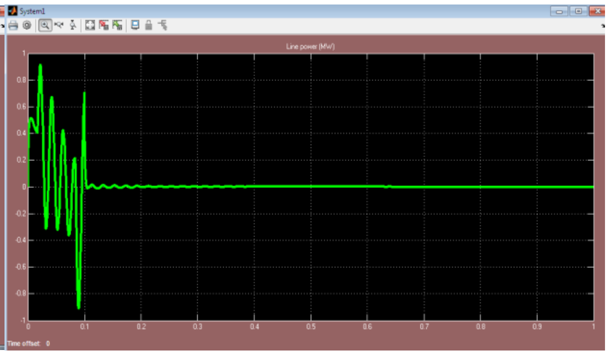

Fig. 20 Line power (MW) with UPFC

Various simulation results shown above with and without fault have been explored and results validate the superior performance of the proposed system.Final results show that SMIB with both PSS and UPFC controllers is more effective than SMIB with PSS controller only.

VI.CONCLUSION

This thesis studied related to simulation of SMIB with UPFC controller using the Fuzzy toolboxfor increasing transient stability in fault conductions.Modelling & Simulation of FuzzyController for Enhancement of Transient Stability in SMIB with UPFC Using MATLABSimulink is simulated using MATLAB software. In this dissertation modeling of modifiedPhilip-Heffron model is exercised in carrying out small signal studies on a single machineinfinite bus (SMIB) power system.Flexible AC transmission systems (FACTS) based controllersUnified Power Flow Various loading conditions are likewise taken to simulate the real worldsurroundings.From the above experimental section, followed by results and analysis of differentloading conditions indicated the superiority of the proposed method.Farther, this intelligentmethod proved to be more beneficial than existing traditional methods such as PSS.

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