

Transient stability improvement of Single Machine Infinite Bus (SMIB) system Using Distributed Power Flow Controller (DPFC)

G V Chiranjeevi Adari¹

Department of Electrical and Electronics
Engineering,
Vignan's Institute of Information Technology,
Visakhapatnam

¹chiranjeevi210@gmail.com, +919440218797

Abstract

Transmission of power is the most important and transmission system increasing continuously to meet the demand. The Active, Reactive powers play very important role in maintaining the system voltage and stability under faulty conditions. Especially, transient stability affects most in those cases and means must be provided to cope up with it. For this purpose most widely used device in FACTS devices is Unified Power Flow Controller (UPFC). But it is having its own drawbacks in terms of cost, size etc. so, in this work Distributed Power Flow Controller (DPFC) in combination with fuzzy controller is taken for improving the transient stability of Single Machine Infinite Bus (SMIB) system.

Keywords

Unified Power flow controller (UPFC),
Distributed Power Flow Controller (DPFC),
Single Machine Infinite Bus (SMIB) system,
Flexible AC Transmission System (FACTS),
Fuzzy Logic.

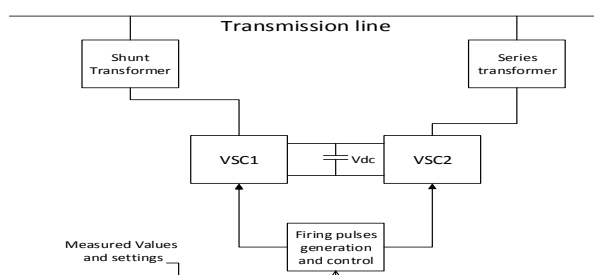
The ability of a system to recover from small and large disturbances, and settle to atolerable level of dynamics is referred to as stability in general. Unpredictable load changes, generator tripping faults and mismatches in reference values for regulating controllers, are some examples of disturbances. Importance of power electronics based Power flow control devices are increasing with time for active and reactive power control in modern power system topologies. Use of UPFC is avoidable in many cases due to its high cost and low reliability because of complexity. So, there is a need for new device which has same control capability as UPFC with low price and highly reliability. .

With the advances and feasibility in Distributed generation, Single Machine Infinite Bus system found its versatile applications in power system operation. And its mathematical model was presented in [4] controlled by Genetic Algorithms. The main concept of DPFC is elimination of common DC link used in UPFC device. The development of its mathematical and simulation model was presented in [2] and [6]. The fuzzy controller for DPFC is presented in a better manner in [7]. The system dynamics and Transient Analysis is described in [5], [1] and [9,10]. In the present paper, DPFC device is designed and implemented for SMIB for its Transient stability enhancement. Later it is combined with Fuzzy Logic Controller for better results.

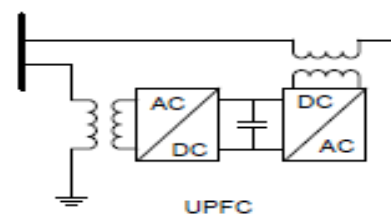
At the present work, UPFC and DPFC models were introduced first followed by the Single machine Infinite bus system. Then the corresponding models were developed with DPFC, and using fuzzy control along with DPFC. The models were simulated using MATLAB R2009b software.

UPFC vs. DPFC Models

UPFC consists of two switching converters-Voltage Source Converters (VSCs) operated from a common DC link equipped with DC storage capacitor. Real power can flow in either direction between Ac terminals of two converters or each VSC can generate reactive power at its terminal. Commonly, for Voltage compensation, Power balance and for stability improvement, the UPFC is used.



Or



In the DPFC the common DC link is eliminated and the single series converter is being distributed as number of series converters resulting in the configuration or model as shown in below.

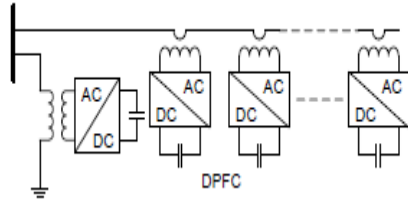


Fig. 2. DPFC model Eliminating DC link and Distributing Series Converters.

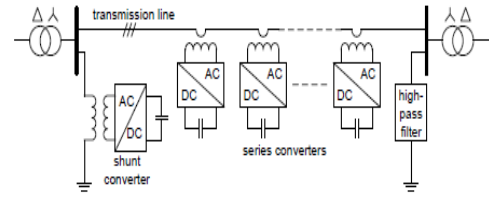


Fig. 3. DPFC model considering high pass filter at receiving end.

Active power exchange with eliminated DC link

Within the DPFC, the transmission line establishes a connection between the AC ports of the shunt and the series converters. Therefore, active power through the AC ports can be exchanged. The method is based on Fourier analysis based power theory of non-sinusoidal components. Thus active power can be defined as the mean value of the product of voltage and current.

$$P = \sum_{i=1}^{\infty} V_i I_i \cos \phi_i$$

Where V_i and I_i are the voltage and current at the i_{th} harmonic frequency respectively, and ϕ_i is the corresponding angle between the voltage and current

The high-pass filter allows the harmonic components to pass, and acts as a return path for the harmonic components. The shunt and series converters, the high pass filter and the ground form a closed loop for the harmonic current. Then different frequency active powers differ from each other and there will be no dependence between them. giving a possibility for converter to generate active power without any power source and absorb it at different frequency. By this concept, the shunt converter absorbs active power from the line at the fundamental frequency and series converters inject the power back at a harmonic frequency. This active power due to harmonics flows through a transmission line equipped with series converters. The DPFC series converters generate a voltage at the harmonic frequency according to the amount of required active power at the fundamental frequency, thereby absorbing the active power from harmonic components. This can be better explained with the simple diagram shown below.

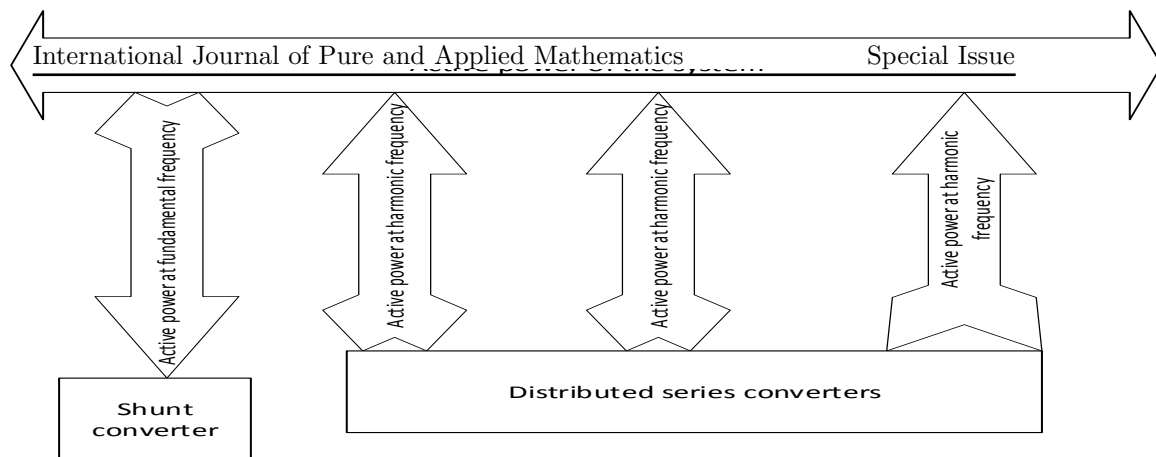


Fig. 4 Active power flow through DPFC

Advantages and Drawbacks of DPFC

The DPFC operation is based on D-FACTS concept and exchange of power through the 3rd harmonic and inherits all UPFC's advantages:

- Since DPFC can be able to simultaneously control all parameters in the network like impedance, transmission angle, bus voltage etc., it is highly Controllable.
- The distributed series converters and independency of series and shunt converters give high reliability.
- Since , no phase –phase isolation is required among series converters, it is of Low cost
- Low power vrating.
- The power rating of each converter is also low.
- It is easy to upgrade the system to DPFC,if the system already employs STATCOM.

However, there is a drawback of using the DPFC:

- Since the same transmission line is used for power exchange between the converters, there is a chance for arise of extra currents due to 3rd harmonics.

SMIB and its stability

An SMIB system is a very simple model to understand the importance of large or sustained angular disturbance stability problem. It is simply a single generator connected to a large power system represented by infinite bus having fixed voltage and constant frequency. The generator itself acts as a Constant magnitude Voltage source behind its reactance.

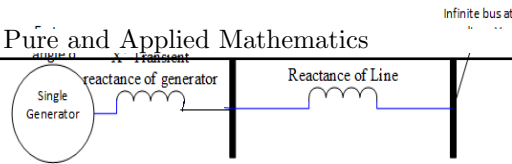


Fig. 5. SMIB model

Figure shown on left side indicates SMIB which simply consists of one Generator, its reactance, Generator bus, reactance of line and infinite bus

The phase angle of generated voltage with respect to infinite bus is given by δ . This angle will vary if relative frequency between machine and infinite bus changes. Thus, the machine angle i.e., rotor angle does not reach a steady state value after a disturbance following the swing equation after a disturbance results in losing of synchronism. This problem is commonly known as angular instability.

System parameters and the developed model

By using above information from the fundamental principles, the following models were developed for simulation. The control of DPFC can be done at individual converter levels by changing the firing angle of converters.

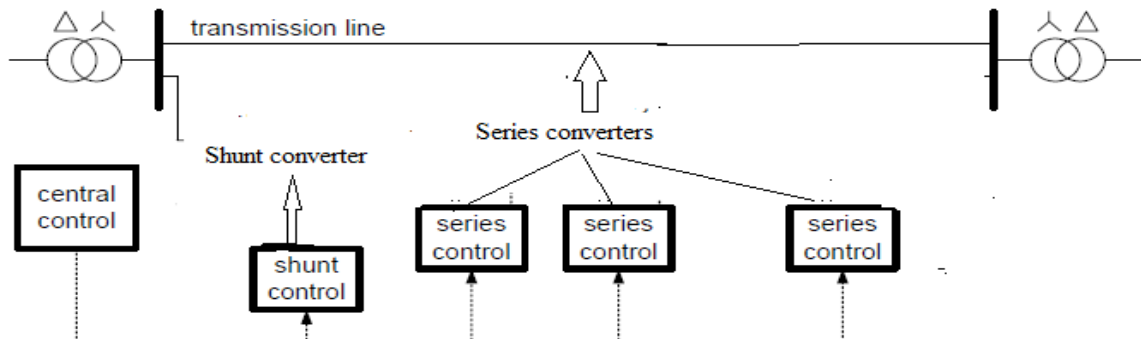
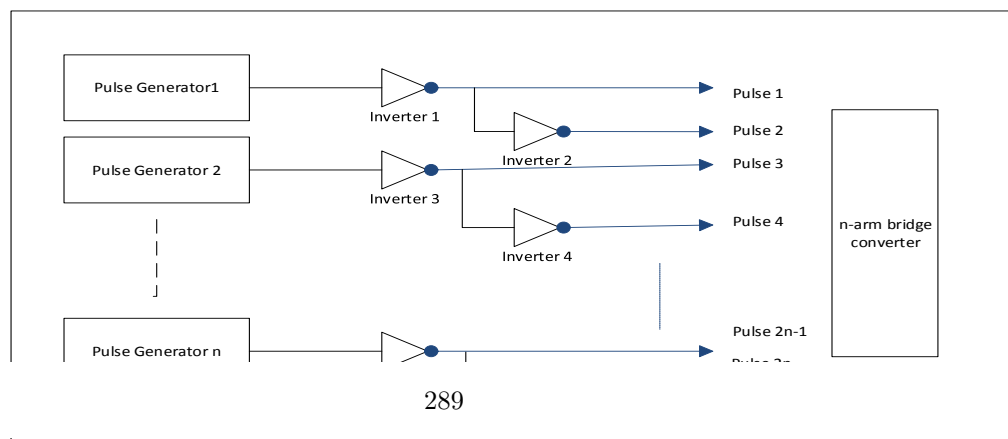


Fig 6. Control of DPFC in SMIB system

Control pulses are generated and applied to shunt converter and series converters in the following manner.



As perv the control strategy of DPFC, there will be some definite time delay from pulse generator 1 to n of shunt converter. But there is no need of that in series control pulses.

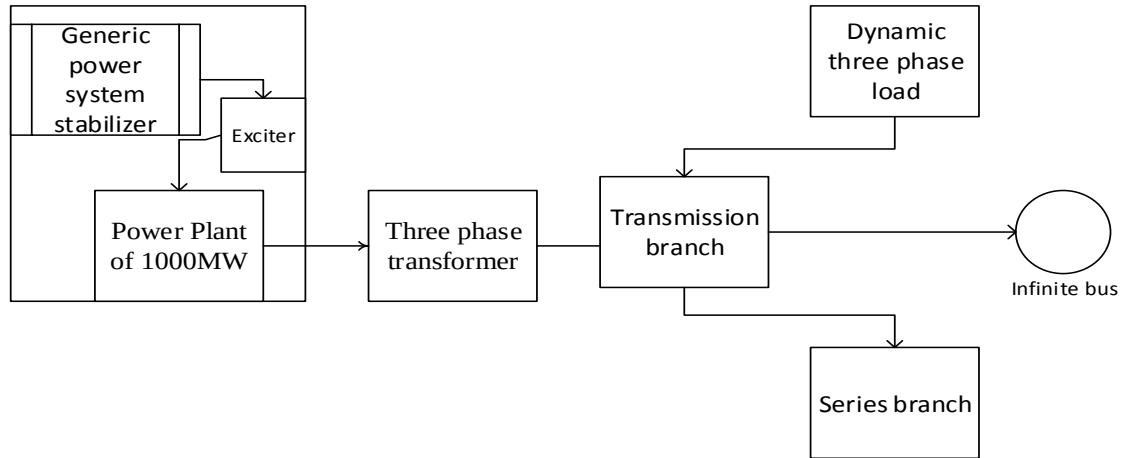


Fig 8. The developed SMIB system without any DPFC but using generic Power system Stabilizer

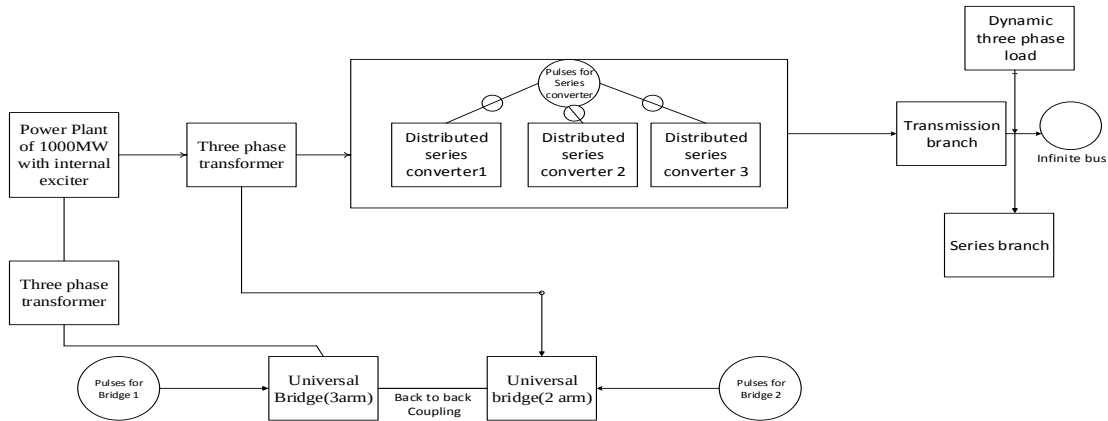


Fig 9. Developed model using DPFC

1. Fuzzy Controller Based DPFC for SMIB

Fuzzy logic acts as a one of the adaptive control method based on human previous knowledge. Here the reactive power can be better controlled by changing the excitation based on human previous knowledge in the form of linguistic rules. So, the q-axis voltage is taken as one of the input variable for fuzzy inference system. And output of it is directly applied to exciter control variable. Mamdani type Inference engine with centroid defuzzification and three triangular membership functions for both input and output variables are developed. The corresponding block diagram and simulated waveforms are presented here.

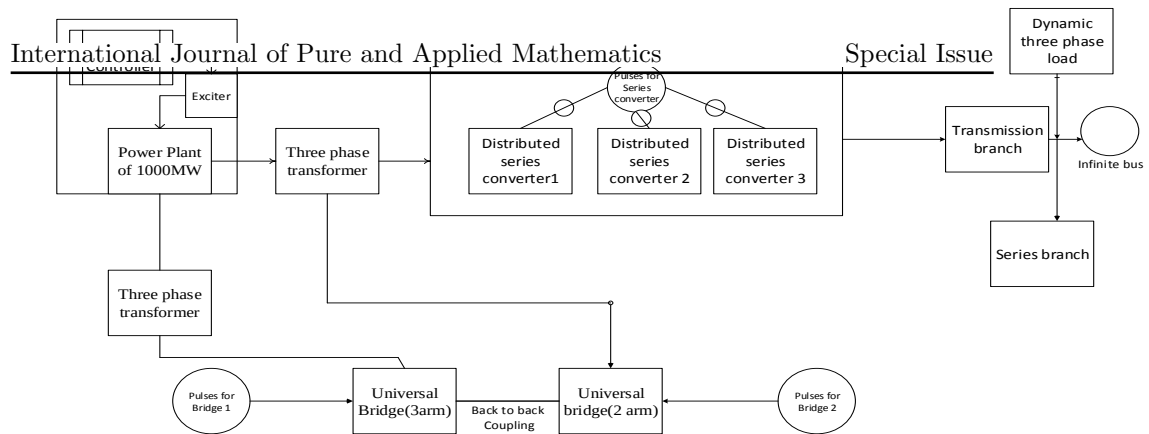


Fig 10. The developed model using DPFC with fuzzy control to excitation.

System parameters for simulation

Sl . No	Device/Controller	Type	Parameter	Value
1	Synchronous Machine	Salient pole	Nominal power	1000MVA
			Line voltage	13.8KV
			Frequency	60Hz.
			Reactances	1.305 pu
			X _d	0.296pu
			X _d '	0.252pu
			X _d ''	0.474pu
			X _q	0.243pu
			X _q ''	0.18pu
			X _l	1.01s
			Time constants	0.053s
			T _d '	0.1s
			T _d ''	0.0028544pu
			T _{qo} ''	3.70s
			Stator resistance	0pu
R _s	32			
Inertia coefficient	13.8KV/230KV			
2	transformer connected Synchronous Machine to	Three phase Delta-Y grounded	Voltage	0.002pu
			R1=R2	0pu
			L1	0.12pu
			L2	500pu
			Rm	500pu
			Xm	
3	Excitation system to Synchronous Machine	IEEE type 1	Low pass filter time constant T _r	0.02s
			Gain K _a	200
			Time Constant Ta	0.001s
			Exciter gain Ke	1
			Exciter time	0s
			Initial terminal	1pu

International Journal of Pure and Applied Mathematics			voltage V_{t0}	Special Issue
			Field voltage V_{fd}	1.16938pu
4	power system stabilizer	Generic	Sensor time constant	0.03s
			Gain	20
			Wash out time constant	2
			Output limits(V_{smax} , and V_{smin})	-0.15 amnd 0.15 pu respectively
5	Three phase transmission line	RL	R	0.04pu
			L	0.001pu
6	Three phase series RLC branch	R	R	10000
7	Load	Three phase dynamic, external control of PQ	Active and reactive power(External)	0.8 and 0.28pu respectively
			Nominal L-L voltage	500KVA
			Active and reactive power at initially	50MW and 25MW
8	Bus	Infinite	Vph-ph	200
			Phase angle	-10
			Frequency	60Hz.
			Source resistance and source inductance	0.8929 and 0.01658pu respectively.
9	References for measurement of rotor speed and angle			1pu and 180° respectively.
10	Fuzzy controller	Mamdani type FIS	Input variable(stator quadratic axis voltage in pu)	(N,Z, P) range[0 1]
			Output Variable(V_{statb} input for Exciter)	(N,Z,P) range [0 1]
			Defuzzification method	Centroid
			Membership functions type	Triangular

2. Simulation Results

At first the developed model is simulated without any controller for the dynamic load whose active and reactive powers are externally controlled. The variations of Rotor angle and nu Speed are shown in the following plots whose

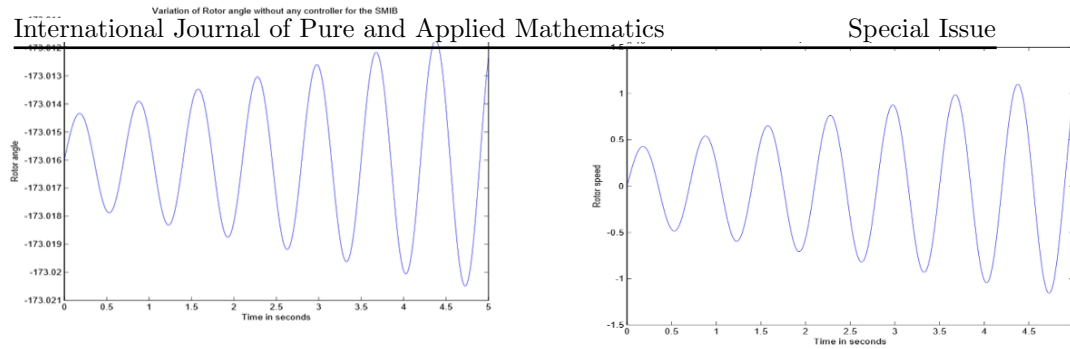


Fig 11. Simulation results for the system developed with Generic PSS

The same variations for the developed model with DPFC are shown in the following plots.

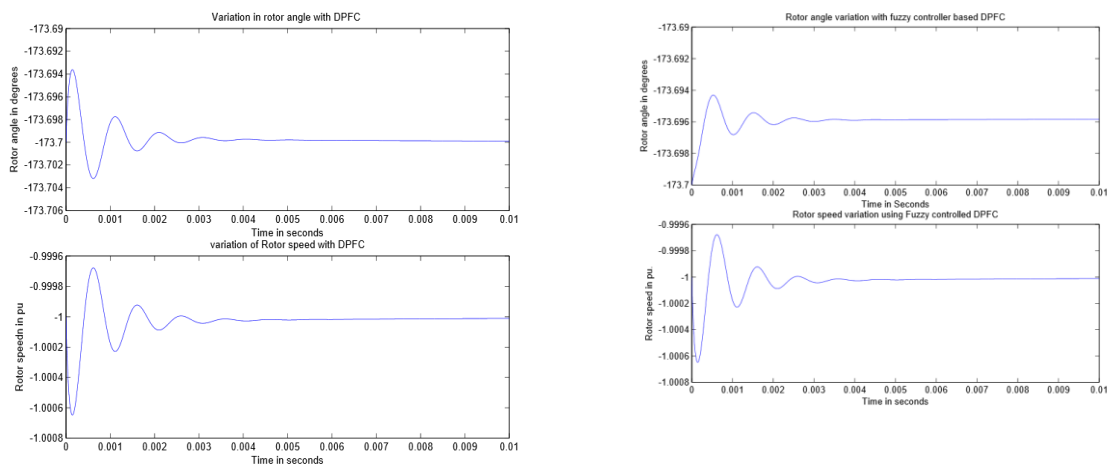
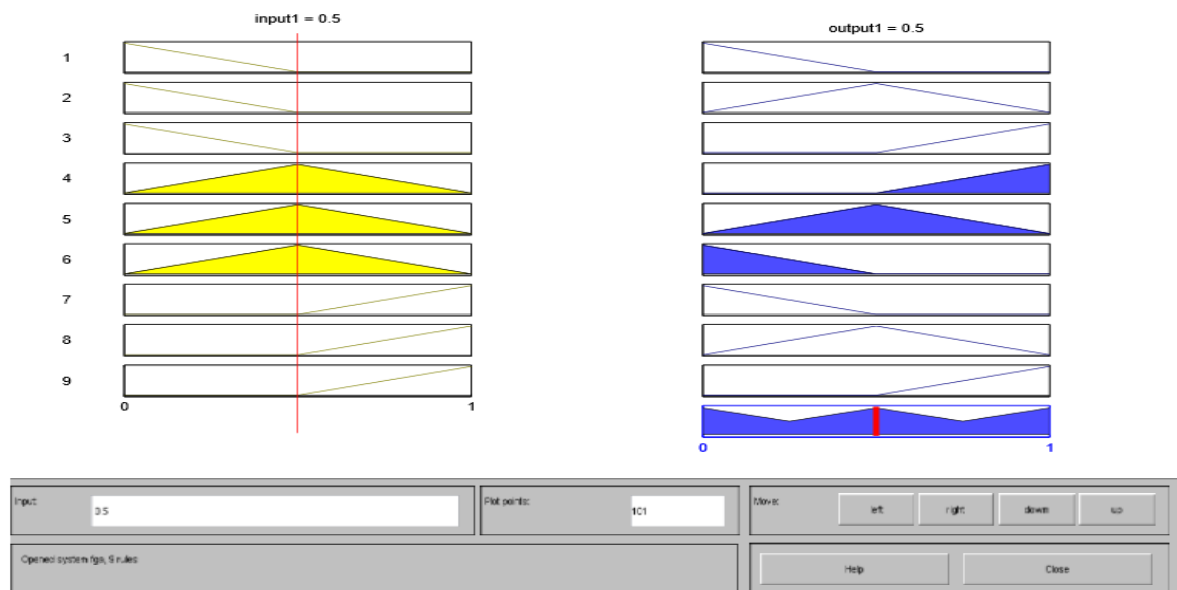


Fig 12. Simulation results with DPFC controller

And the system is simulated with fuzzy controlled DPFC using rule base formulated from previous experience. Then the above variations are as in the following.



From the developed model and simulation results it can be concluded that for the distributed generation, the proposed DPFC based SMIB results in better stable system in terms of rotor speed and rotor angle. From that it can be concluded that the transient stability in terms of system frequency is better controlled using this Concept. For adaptive control it can be combined with artificial techniques such as Fuzzy Controller. But while applying Fuzzy human previous knowledge is required for the development of rule base and membership functions.

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