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Power Quality Improvement by using Fuzzy PI Controlled DPFC

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ABSTRACT: The new inventions in technology lead to more power consumption by more number of nonlinear loads, which in turn affecting the quality of power transmitted. The power transmitted in a line is needed to be of high quality. The flow of power basically depends on the line impedance, sending end and receiving end voltage magnitudes. Nonlinear loads create harmonic currents which in turn creates system resonance, capacitor overloading, decrease in efficiency, voltage magnitude changes. The DPFC is a new FACTS device, employs the distributed FACTS (D-FACTS) concept, which is to use multiple small-size single-phase converters instead of the one large-size three-phase series converter in the UPFC. The large number of series converters provides redundancy, thereby increasing the system reliability. The DPFC has the same control capability as the UPFC, which comprises the adjustment of the line impedance, the transmission angle, and the bus voltage. The principle and analysis of the DPFC are presented in this research and the corresponding experimental results are shown. The proposed method introduces low cost low power rating DPFC in Single Machine Connected to infinite Bus system which improves the power quality. The addition of Fuzzy Logic with the conventional DPFC improves the quality of power. The control circuit is designed using Fuzzy Logic Control and simulated in MATLAB – SIMULINK.

KEYWORDS: Facts, D-Facts, DPFC, UPFC, Fuzzy logic.

I.INTRODUCTION

In the last decade, the electrical power quality issue has been the main concern of the power companies. Power quality is defined as the index which both the delivery and consumption of electric power affect on the performance of electrical apparatus from a customer point of view. A power quality problem can be defined as any problem is manifested on voltage, current, or frequency deviation that results in power failure. The power electronics progressive, especially in flexible alternating-current transmission system (FACTS) and custom power devices, affects power quality improvement. Generally, custom power devices, e.g., dynamic voltage restorer (DVR), are used in medium-to-low voltage levels to improve customer power quality. Most serious threats for sensitive equipment in electrical grids are voltage sags (voltage dip) and swells (over voltage). These disturbances occur due to some events, *e.g.*, short circuit in the grid, inrush currents involved with the starting of large machines, or switching operations in the grid. The FACTS devices, such as unified power flow controller (UPFC) and synchronous static compensator (STAT-COM), are used to alleviate the disturbance and improve the power system quality and reliability.

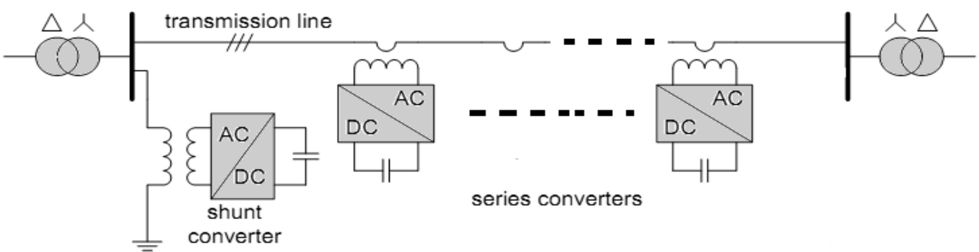

Fig.1: The DPFC Structure

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II. UNIFIED POWER FLOW CONTROLLER (UPFC)

The UPFC is a combination of a static compensator and static series compensation. It acts as a shunt compensating and a phase shifting device simultaneously.

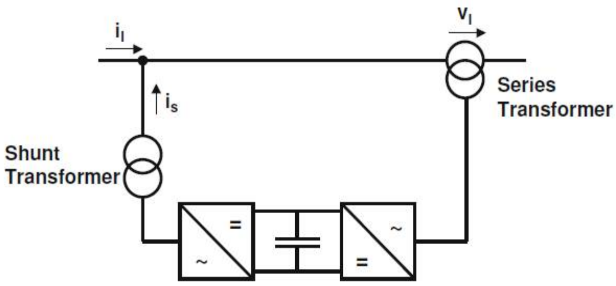

Fig.2: Principle configuration of an UPFC

The UPFC consists of a shunt and a series transformer, which are connected via two voltage source converters with a common DC-capacitor. The DC-circuit allows the active power exchange between shunt and series transformer to control the phase shift of the series voltage. This setup provides the full controllability for voltage and power flow. The series converter needs to be protected with a Thyristor bridge. Due to the high efforts for the Voltage Source Converters and the protection, an UPFC is getting quite expensive, which limits the practical applications where the voltage and power flow control is required simultaneously.

III. OPERATING PRINCIPLE OF UPFC

The basic components of the UPFC are two voltage source inverters (VSIs) sharing a common dc storage capacitor, and connected to the power system through coupling transformers. One VSI is connected to in shunt to the transmission system via a shunt transformer, while the other one is connected in series through a series transformer

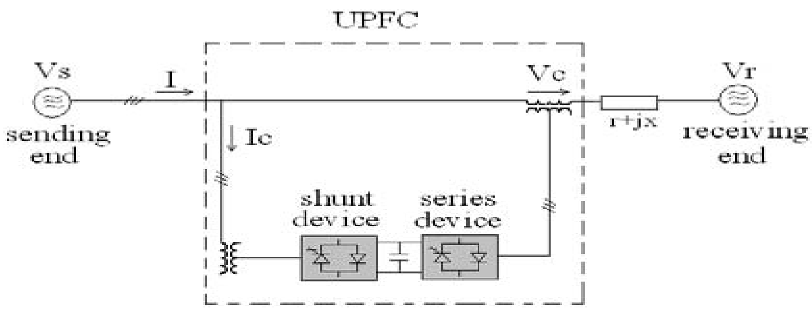

Fig.3: Functional Scheme

IV. FUZZY LOGIC CONTROLLERS (FLC)

The section of FLC is divided in three subsections. These subsections are given as summarized in the following:
Fuzzification: The numeric input-variable measurements are transformed by fuzzification part into the fuzzy linguistic variable, which is a clearly defined boundary with a crisp. These linguistic variables of error/error rate are shown in Fig.4

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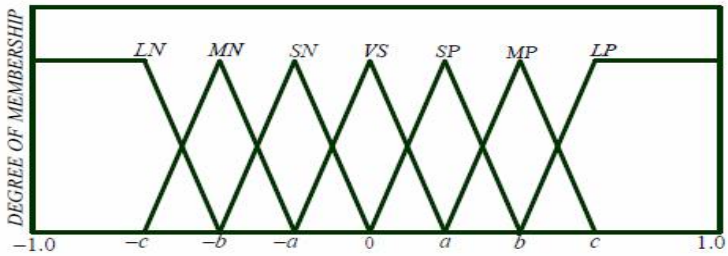

Fig.4: Error and error rate of fuzzy membership function

Decision Making: The fuzzy models are created by using "Sugeno Inference System". According to this system, the Ith rule can be calculated by using in the following equations:

$$L^{(1)} : If\ x_1\ is\ F_1^l\ and....and\ x_n\ is\ F_n^l,\ then$$

$$y^l = c_0^l + c_1^l x_1 + c_2^l x_2 + ... + c_n^l x_n$$

Where F^1_1 *denotes* fuzzy set, C^1_1 is the real coefficients, Y^1 is the output set and x1….x2 is the inputs.
The basic if-then rule is defined as "*If* (error is very small and error rate is very small) then output". The signals error and error rate are described as linguistic variables in the FLC such as large negative (LN), medium negative (MN), small negative (SN), very small (VS), small positive (SP), medium positive (MP) and large positive (LP). These are shown in Fig.6.4. In the same way, the input values of the fuzzy controller are connected to the output values by the if-then rules. The relationship between the input and the output values can be achieved easily by using Takagi-Sugeno type inference method. The output values are characterized by memberships and named as linguistic variables such as negative big (NB), negative medium (NM), negative small (NS), zero (Z), positive small (PS), positive medium (PM) and positive big (PB). The membership functions of output variables and the decision tables for FLC rules are seen in Table I.

TABLE I
FUZZY DECISION TABLE

Error rate /Error	LP	MP	SP	VS	SN	MN	LN
LP	PB 1	PB 2	PB 3	PM 4	PM 5	PS 6	Z 7
MP	PB 8	PB 9	PM 10	PM 11	PS 12	Z 13	NS 14
SP	PB 15	PM 16	PM 17	PS 18	Z 19	NS 20	NM 21
VS	PM 22	PM 23	PS 24	Z 25	NS 26	NM 27	NM 28
SN	PM 29	PS 30	Z 31	NS 32	NM 33	NM 34	NB 35
MN	PS 36	Z 37	NS 38	NM 39	NM 40	NB 41	NB 42
LN	Z 43	NS 44	NM 45	NM 46	NB 47	NB 48	NB 49

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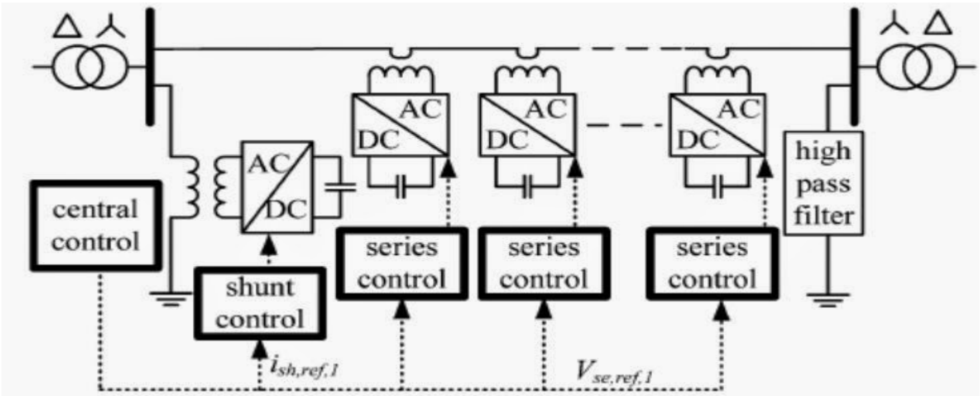
V. SIMULATION 0F SINGLE MACHINE INFINITE BUS

Simulation Diagram without DPFC



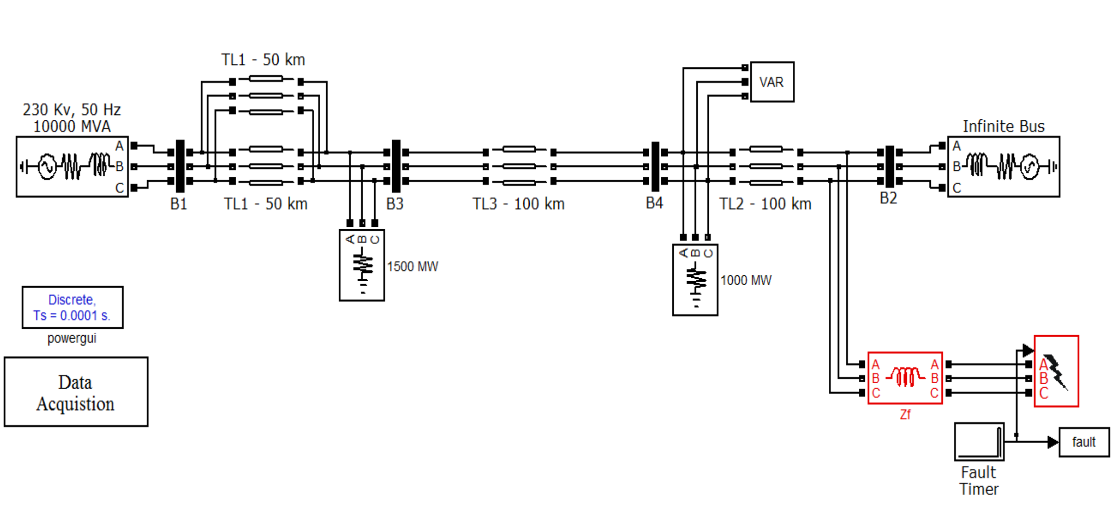


Fig.5: Simulation design in mat lab without DPFC

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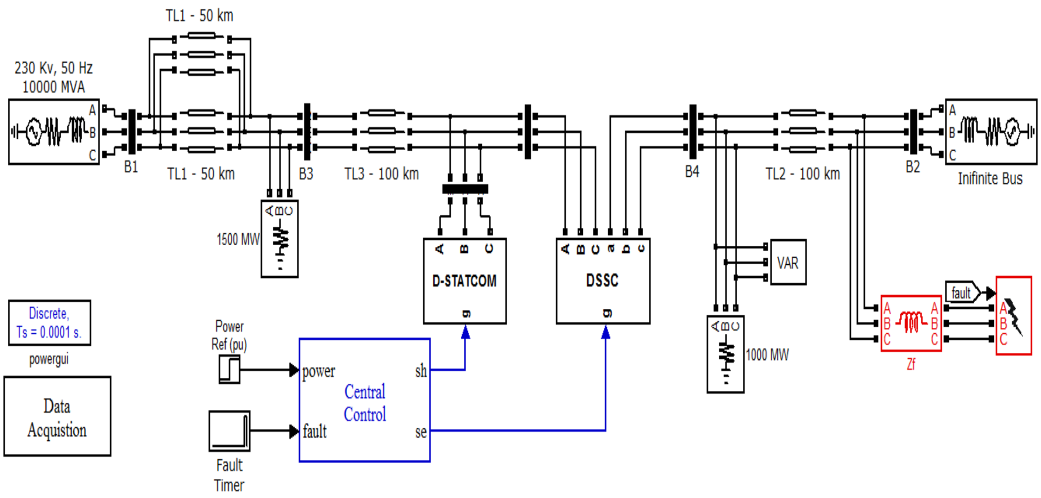

Fig.6: Simulation model Diagram with DPFC

VI. SIMULATION RESULTS

At time t = 0 sec a power command of 400 MW is initiated to DPFC and the results is shown in Fig 5.5. Below plot show that DPFC with PI Control takes 0.8 sec to reach to the reference value and DPFC with Fuzzy Logic control takes 0.6 sec. The corresponding voltage at the bus connect at DPFC is show in Fig

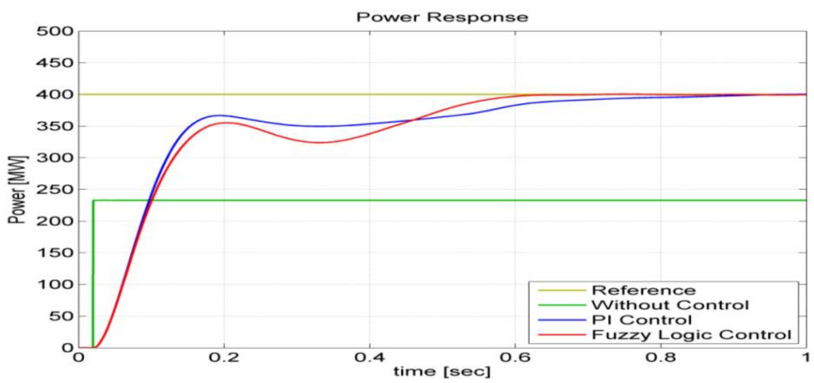

Fig.7: Power flow from single machine to infinite bus

Fig.5.5 shows the power response for single machine to infinite bus the power at 400MW. It show that PI Control takes 1 sec to settle to its reference value whereas Fuzzy control takes 0.6 sec

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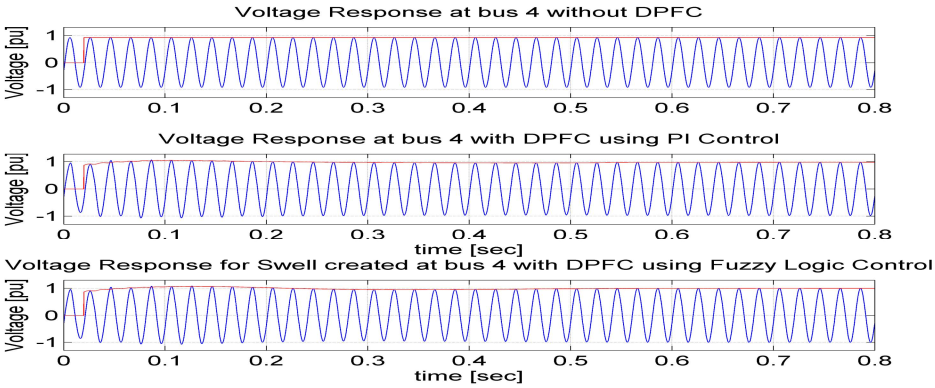

Fig.8: Voltage Response for power command 400 MW

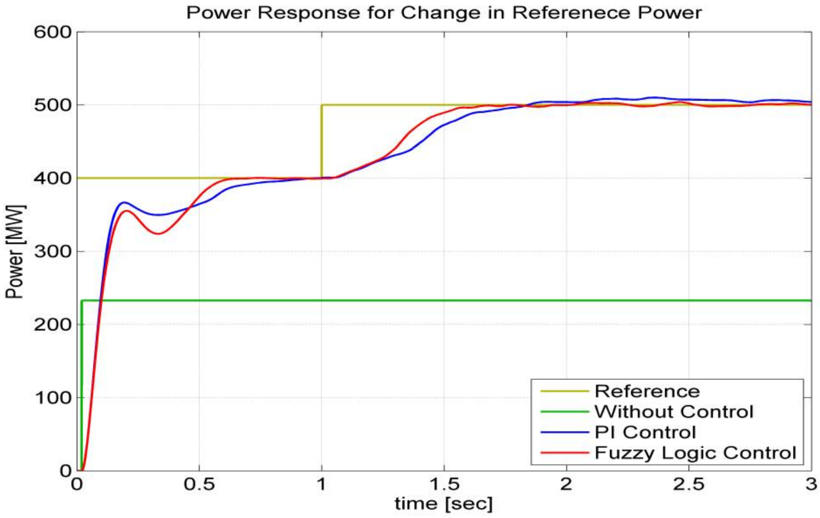

Fig.9: Power for Change in power command from 400MW to 500MW

Fig.5.7 shows the power response for increase in the power from 400 to 500MW. It shows that PI Control takes 2.37 sec to settle to its reference value whereas Fuzzy control takes 1.5 sec.

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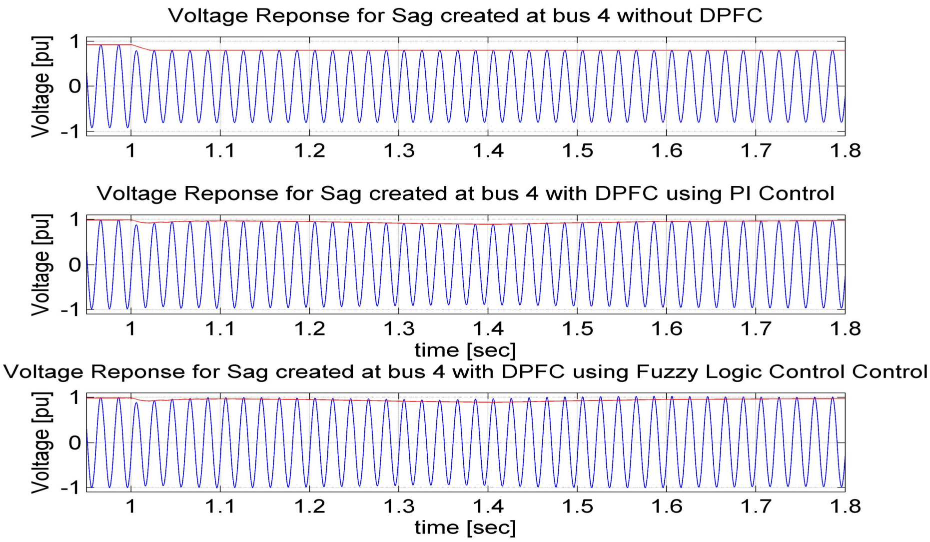

Fig.10: Mitigation of load voltage sag with DPFC

Fig.5.8 shows the power response for increase in the power from 400 to 500MW. It shows that voltage response for sag created at bus 4 without DPFC the voltage varies with different times. It will take some time to settle. The circuit will be controlled by PI controller it will take less time to settle but it is not constant. The circuit is controlled by DPFC and FLC it will settled with constant as compared to above methods it is better to control the circuit and it will give better results.

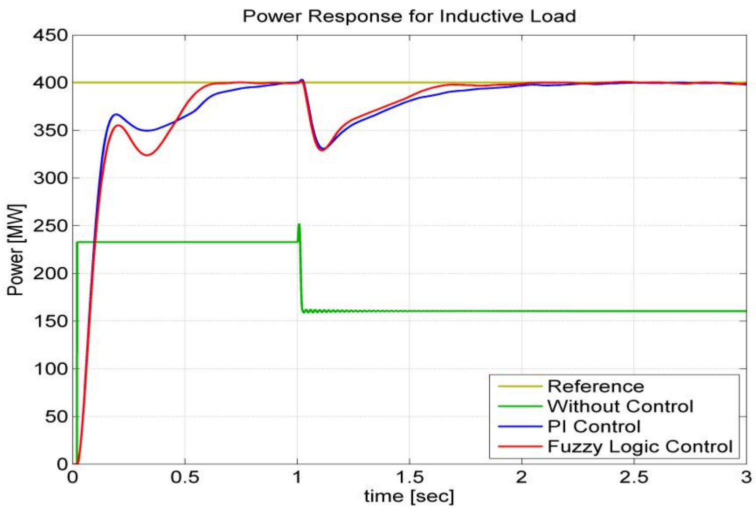

Fig.11: Power response for Mitigation of sag with DPFC

Fig.5.9 shows the power response for mitigation of sag with DPFC with Inductive Load the power at 400MW. It shows the response of sag with different controllers. We can observe that with control will give more accurate results and settle very less time. It shows that PI Control takes 2.12sec to settle to its reference value whereas Fuzzy control takes 1.56 sec.

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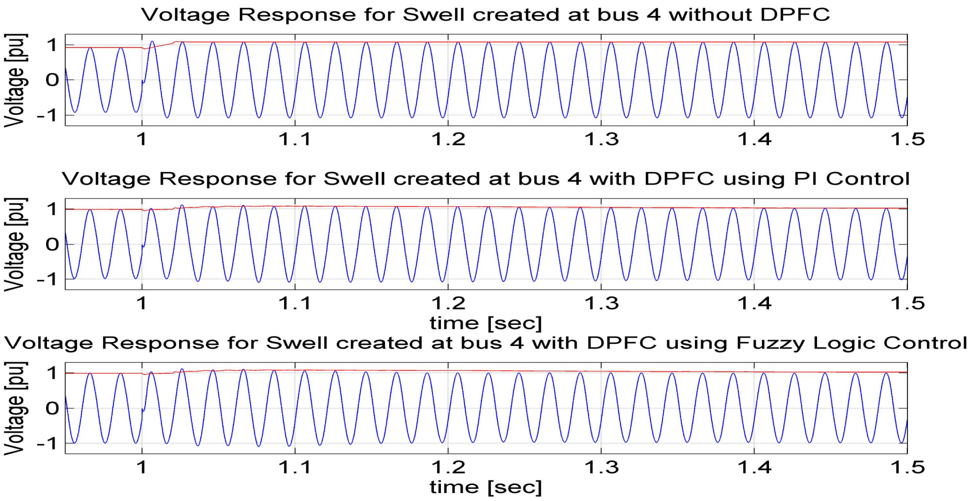

Fig.12: Mitigation of load voltage swells with DPFC

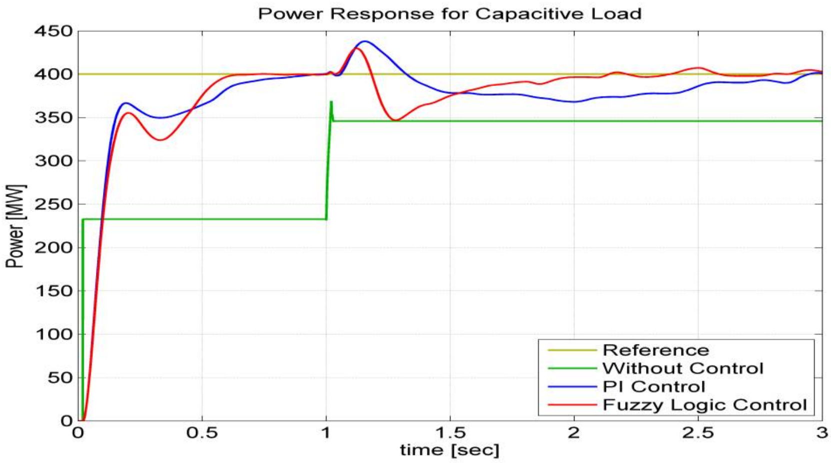

Fig.13: Power response for Mitigation of sag with DPFC

Comparison of their settling time of

DPFC with PI Control & Fuzzy Logic controller

	Initially		Change in Power Command		Voltage Sag		Voltage Swell	
	PI	Fuzzy	PI	Fuzzy	PI	Fuzzy	PI	Fuzzy
Load Voltage			2.05	1.16	2.067	1.45	1.55	1.17
Power	0.8	0.6	2.37	1.504	1.75	1.56	2.83	1.91

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Simulated system parameters

Parameters	**Values**
Three phase source	
Rated voltage	230 kV
Rated power/Frequency	100MW/60HZ
X/R	3
Short circuit capacity	11000MW
Transmission line	
Resistance	0.012 pu/km
Inductance/ Capacitance reactance	0.12/0.12pu/km
Length of transmission line	100 km
Shunt Converter 3-phase	
Nominal power	60 MVAR
DC link capacitor	600 µF
Continue of Table I :	
Coupling transformer (shunt)	
Nominal power	100 MVA
Rated voltage	230/15 kV
Series Converters	
Rated voltage	6 Kv
Nominal power	6 MVAR
Three-phase fault	
Type	ABC-G
Ground resistance	0.01ohm

VI.CONCLUSION

To improve power quality in the power transmission system, there are some effective methods. In this project, the voltage sag and swell mitigation, using a new FACTS device called distributed power flow controller (DPFC) is presented. The DPFC structure is similar to unified power flow controller (UPFC) and has a same control capability to balance line parameters, i.e., line impedance, transmission angle, and bus voltage magnitude. However, the DPFC offers some advantages, in comparison with UPFC such as high control capability, high reliability, and shunt control are design. The system under study is a single machine infinite-bus system, with and without DPFC. Over all DPFC shown improved performance than conventional controller in terms of settling time.

VII. FUTURE SCOPE

The "power quality improvement by using FUZZY PI controlled DPFC" with fuzzy has more accurate and gives the control capability than the proportional integral controller which was presented in the reference paper. This project can be implemented for single machine connected to infinite bus (SMIB) in real time application for electrical power system network in order to improve the power quality.

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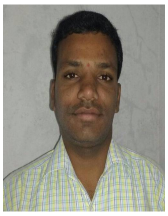
BIOGRAPHY

G. Sathish Goud, has Received his B.Tech degree in Electrical and Electronics Engineering from JNTUH, Hyderabad, India and M.Tech degree in electrical power systems from JNTU Hyderabad, India. He is life member of **Indian Society for Technical Education.** Presently He is working as Assistant Professor In Siddhartha Institute of Engineering & Technology, Hyderabad. His is doing currently research in Fuzzy logic controllers, ANN and electrical power systems, power electronic &drive



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G. Rupa, Received M.S degree in Electrical & Computer Science Engineering at State University of Newyork at Newpaltz. She is currently working as Assoc. Professor in EEE Department of Siddhartha Institute of Engineering & Technology, Hyderabad. . He is life member of **Indian Society for Technical Education** At present she is working in area of machines and power systems.