IMPROVING THE DPFC PERFORMANCE DURING SERIES CONVERTER FAILURES USING FUZZY LOGIC

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ABSTRACT

A Distributed Power Flow Controller (DPFC), introduced in as a new FACTS device, is used to mitigate voltage and current waveform deviation and improve power quality in a matter of seconds. The DPFC structure is derived from the UPFC structure that is included one shunt converter and several small independent series converters. The DPFC has same capability as UPFC to balance the line parameters, i.e., line impedance, transmission angle and bus voltage magnitude. Fuzzy logic controller is designed to achieve the constant load voltage, load current such that it maintains a flat voltage profile. All the results thus obtained, were verified and were utilized in framing of fuzzy rule base in order to achieve better reactive power compensation. Based on observed results for load voltage variations for different values of load resistance, inductance and capacitance a fuzzy controller is designed which controls the firing angle of shunt converter, series converter in order to automatically maintain the receiving end voltage constant.

Keyword:- *DPFC, POWER QUALITY, FACTS, FUZZY LOGIC*

1 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 (STATCOM) are used to alleviate the disturbance and improve the power system quality and reliability.

In this thesis, a Distributed Power Flow Controller (DPFC), introduced in as a new FACTS device, is used to mitigate voltage and current waveform deviation and improve power quality in a matter of seconds. The DPFC structure is derived from the UPFC structure that is included one shunt converter and several small independent series converters, as shown in Fig.1 The DPFC has same capability as UPFC to balance the line parameters, i.e., line impedance, transmission angle, and bus voltage magnitude. The receiving end voltage fluctuations were observed for different loads. Inorder to maintain the receiving voltage and current constant.

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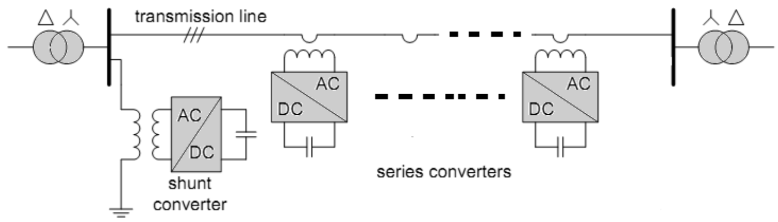


Fig.1: The DPFC Structure

Fuzzy logic controller is designed to achieve the constant load voltage, load current such that it maintains a flat voltage profile. All the results thus obtained, were verified and were utilized in framing of fuzzy rule base in order to achieve better reactive power compensation. Based on observed results for load voltage variations for different values of load resistance, inductance and capacitance a fuzzy controller is designed which controls the firing angle of shunt converter, series converter in order to automatically maintain the receiving end voltage constant.

2 DPFC (Distributed power Flow controller)

The UPFC is the combination of a Static Synchronous Compensator (STATCOM) and a Static Synchronous Series Compensator (SSSC), which are coupled via a common dc link, to allow bidirectional flow of active power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM. The converter in series with the line provides the main function of the UPFC by injecting a four-quadrant voltage with controllable magnitude and phase. The injected voltage essentially acts as a synchronous ac-voltage source, which is used to vary the transmission angle and line impedance, thereby independently controlling the active and reactive power flow through the line. The series voltage results in active and reactive power injection or absorption between the series converter and the transmission line. This reactive power is generated internally by the series converter and the active power is supplied by the shunt converter that is back-to-back connected. The shunt converter controls the voltage of the dc capacitor by absorbing or generating active power from the bus; therefore, it acts as a synchronous source in parallel with the system. Similar to the STATCOM, the shunt converter can also provide reactive compensation for the bus. The components of the UPFC handle the voltages and currents with high rating; therefore, the total cost of the system is high. Due to the common dc-link interconnection, a failure that happens at one converter will influence the whole system. To achieve the required reliability for power systems, bypass circuits and redundant backups (backup transformer, etc.) are needed, which on other hand, increase the cost. Accordingly, the UPFC has not been commercially used, even though; it has the most advanced control capabilities.

There are several possible solutions to voltage sag problems. Generally, the least expensive approach is to purchase controls and other electronic equipment designed with a greater tolerance to voltage sags. Information on these tolerances should be included in the equipment's specifications. Another inexpensive and simple solution is to adjust the trip thresholds of sensitive equipment. If you identify a relay that is inadvertently tripping during voltage sag, you can change its settings—either the voltage threshold or the trip delay. However, you can only do this if the trip settings were set too conservatively, so it is important to understand what they were designed to protect. Another option is to install a coil hold-in device. These devices are designed to mitigate the effects of voltage sags on individual relays and contactors. Coil hold-in devices are installed between the relay or contactor coil connection terminals and the incoming alternating current (AC) control line. They allow a relay or contactor to remain engaged until the voltage drops to about 25 percent of nominal, significantly improving its voltage sag tolerance without interfering with emergency shutoff functions. The best application for this type of device is to support relays and contactors in an emergency off circuit, master control relay, or motor control circuit. The next level of potential solutions in terms of cost is to consider modifying the power supplied to the sensitive equipment. For example, it may be possible to substitute a direct current (DC)–operated power supply for an AC supply. This would allow you to use simple capacitors or batteries to help support the DC bus. This is the approach that high-reliability telecommunications systems commonly use. (For other relatively simple and low-cost solutions of this type, please refer to Power Standards Testing Lab, “How to Increase Voltage Sag Immunity”.

There are several technologies that serve as quick acting voltage regulators on the AC power supply. One of the most common of these is an uninterruptible power supply (UPS). UPSs have the disadvantage of relying on a battery, which has a limited life, generates hydrogen gas (requiring ventilation), and becomes hazardous waste when it is disposed of at the end of its useful life. On the plus side, UPSs can help the equipment plugged into them ride through sags, momentary interruptions, and even extended interruptions up to the limit of the battery—10 minutes or more. A UPS can be installed off-line, which is cheaper, or on-line, which doubles the cost but adds the ability to filter out all types of voltage disturbances, including spikes and harmonic distortions.

2.1 DPFC Control during Shunt Converter Failure

Distributed Power Flow Controller (DPFC) is a new device within the family of FACTS. The DPFC has the same control capability as the UPFC, however at much lower cost and with a higher reliability. The reliability of the DPFC is given by the redundancy of multiple series converters. The shunt converter is the bottleneck for remaining reliability, because there is only one shunt converter in a DPFC system. During the shunt converter failure, the DPFC continues to work as controlled impedance, and only control the active power flow through the line.

This paper presents a control of the DPFC, which keeps the DPFC system stable during the shunt converter failure. Adapted control schemes are employed to every series converters, which can automatically switch the series converter between the full control mode and limited-control mode. With the adapted control, the reliability of the whole DFPC system is further improved. The adapted control scheme is verified both by simulation and experiment.

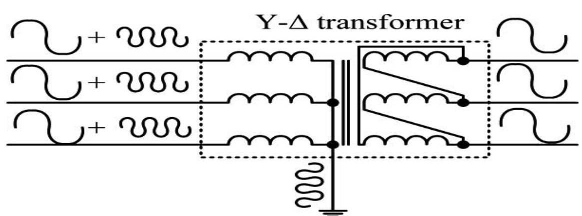


Fig.2 Utilize grounded Y–Δ transformer to provide the path for the zero sequence third harmonic.

Due to the unique characters of third-harmonic frequency components, the third harmonic is selected to exchange the active power in the DPFC. In a three-phase system, the third harmonic in each phase is identical, which is referred to as “zero-sequence.” The zero-sequence harmonic can be naturally blocked by Y–Δ transformers, which are widely used in power system to change voltage level. Therefore, there is no extra filter required to prevent the harmonic leakage to the rest of the network. In addition, by using the third harmonic, the costly high-pass filter, can be replaced by a cable that is connected between the neutral point of the Y–Δ transformer on the right side in Fig.2 and the ground. Because the Δ winding appears open circuit to the third-harmonic current, all harmonic current will flow through the Y-winding and concentrate to the grounding cable, as shown in Fig. 3 Therefore, the large-size high-pass filter is eliminated.

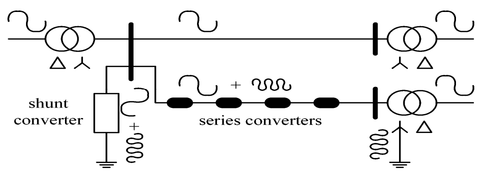


Fig.3 Route the harmonic current by using the grounding status of the Y–Δ transformer.

Another advantage of using third harmonic to exchange active power is that the way of grounding of Y–Δ transformers can be used to route the harmonic current in a meshed network. If the branch requires the harmonic current to flow through, the neutral point of the Y–Δ transformer at the other side in that branch will be grounded and vice versa. Fig.3 demonstrates a simple example of routing the harmonic current by using a grounding Y–Δ transformer. Because the transformer of the line without the series converter is floating, it is open circuit for third-harmonic components. Therefore, no third-harmonic current will flow through this line.

Theoretically, the third-, sixth-, and ninth-harmonic frequencies are all zero-sequence, and all can be used to exchange active power in the DPFC. As it is well known, the capacity of a transmission line to deliver power depends on its impedance. Since the transmission-line impedance is inductive and proportional to the frequency, high-transmission frequencies will cause high impedance. Consequently, the zero-sequence harmonic with the lowest frequency—third harmonic is selected.

2.2 Distributed Series Converter

The D-FACTS is a solution for the series-connected FACTS, which can dramatically reduce the total cost and increase the reliability of the series FACTS device.

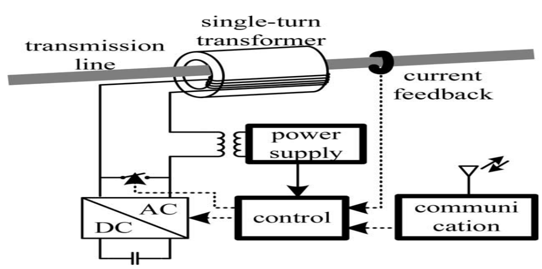


Fig.4 D-FACTS unit configuration

The idea of the D-FACTS is to use a large number of controllers with low rating instead of one large rated controller. The small controller is a single-phase converter attached to transmission lines by a single-turn transformer. The converters are hanging on the line so that no costly high-voltage isolation is required.

The single-turn transformer uses the transmission line as the secondary winding, inserting controllable impedance into the line directly. Each D-FACTS module is self-powered from the line and controlled remotely by wireless or power-line communication.

The structure of the D-FACTS results in low cost and high reliability. As D-FACTS units are single-phase devices floating on lines, high-voltage isolations between phases are avoided. The unit can easily be applied at any transmission-voltage level, because it does not require supporting phase-ground isolation. The power and voltage rating of each unit is relatively small. Further, the units are clamped on transmission lines, and therefore, no land is required. The redundancy of the D-FACTS provides an uninterrupted operation during a single module failure, thereby giving a much higher reliability than other FACTS devices.

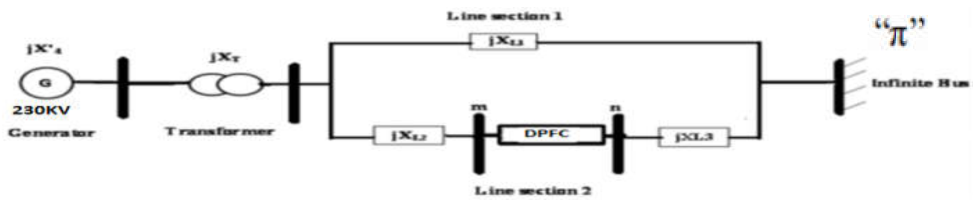


Fig.5 Single line diagram of DPFC with parallel transmission lines

An infinite bus is a source of constant frequency and voltage either in magnitude or angle. Single Machine Infinite Bus System (SMIB) equipped with a DPFC is connected to the remote system through a transformer and a parallel transmission line having section models as shown in Fig.5 A UPFC is placed in the transmission line at point m (between middle of two line sections m-n) to improve the dynamic behavior of the system. The UPFC consists of shunt and series converters controlled by sinusoidal pulse width modulation (SPWM) controller.

It is presents an adapted control scheme for the DPFC system which aims to keep the system stable during shunt converter failure. The adapted control scheme is applied to every series converters, and automatically switches the series converters between the full-control mode and limited-control mode. The control signal for this switch is the magnitude of the 3rd harmonic current through the line. During the shunt converter failure, there is no 3rd harmonic current through line, and the series converters are switched to the limited-control mode which is using the active component at the fundamental frequency to stable the dc voltage. Both the simulation and practical experiment are done to verify the adapted control for the DPFC, and proved that the adapted control can successfully switch the DPFC between the two control modes thereby increasing the whole DPFC system reliability.

2.3 Factor Affecting Characteristic of Voltage Sag Due to Fault in the Power System:

Faults in the power system are the most common reason for the occurrence of important power quality problem, voltage sag in the system. Due to increasing use of sensitive and sophisticated control in almost all modern devices at the industrial and residential consumer level, the Voltage sag which causes severe problems to these devices needs to be analyzed. Factors which affect the characteristics of voltage sag as a type of fault in the system, location of fault in the system, X/R ratio of transmission lines, type of transmission as single or double circuit transmission, Point on wave of sag initiation are performed. Nowadays load equipment is more sensitive to power quality variations than equipment used before, because in order to improve power system efficiency there is continuous growth in the application of devices with microprocessor and power electronics control. These devices are sensitive to power quality variations and they are the sources of power quality problems.

Out of different power quality problems, such as transients, voltage fluctuations, harmonics, inter-harmonics, voltage unbalance, waveform distortion, dc offset, noise, notches etc. voltage sag is the important. Severe voltage sag may cause tripping of equipment which will result in stopping of the process which in term leads to financial losses. Study says that voltage sags are more severe than interruptions as they are more frequent in the power system.

Voltage sags are usually associated with system faults, energizing of heavy loads or starting of a large induction motor. But faults in the system are the most frequent cause of voltage sags. These voltage sags cause the majority of equipment trips. The characteristic of sag is mainly defined by the magnitude of sag and its phase-angle. The factors which affect these characteristics of voltage sag are studied.

3 POWER QUALITY IMPROVEMENT USING DPFC METHODOLOGY

In comparison with UPFC, the main advantage offered by DPFC is eliminating the huge DC-link and instate using 3rd harmonic current to active power exchange. In the following subsections, the DPFC basic concepts are explained.

3.1 Eliminate DC Link and Power Exchange

Within the DPFC, the transmission line is used as a connection between the DC terminal of shunt converter and the AC terminal of series converters, instead of direct connection using DC-link for power exchange between converters. The product of voltage and current components provides the active power. Since the integral of some terms with different frequencies are zero, so the active power equation is as follow:

$$p = \sum_{i=1}^{\infty} V_i I_i \cos \varphi_i$$

Where V_i and I_i are the voltage and current at the i_{th} harmonic, respectively, and φ_i is the angle between the voltage and current at the same frequency. Equation (1) expresses the active power at different frequency components is independent. Based on this fact, a shunt converter in DPFC can absorb the active power in one frequency and generates output power in another frequency. Assume a DPFC is placed in a transmission line of a two-bus system, as shown in Fig.6 While the power supply generates the active power, the shunt converter has the capability to absorb power in fundamental frequency of current. Meanwhile, the third harmonic component is trapped in Y-Δ transformer. Output terminal of the shunt converter injects the third harmonic current into the neutral of Δ-Y transformer consequently, the harmonic current flows through the transmission line.

This harmonic current controls the DC voltage of series capacitors. The third harmonic is selected to exchange the active power in the DPFC and a high-pass filter is required to make a closed loop for the harmonic current. The third-harmonic current is trapped in Δ-winding of transformer. Hence, no need to use the high-pass filter at the receiving-end of the system. In other words, by using the third-harmonic, the high-pass filter can be replaced with a cable connected between Δ-winding of transformer and ground. This cable routes the harmonic current to ground.

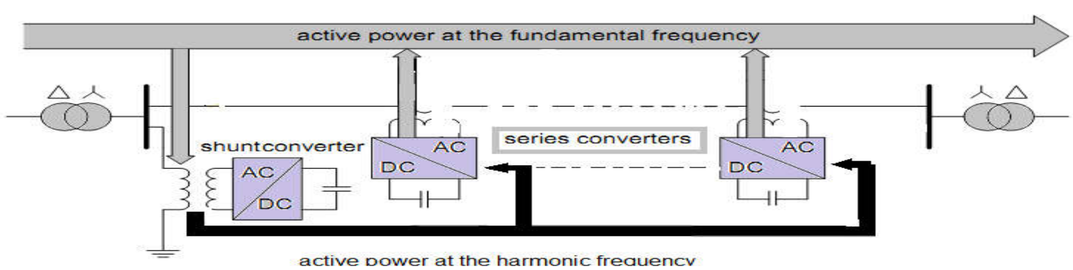


Fig.6 Active power exchange between DPFC converters

The DPFC Advantages:-

• High Control Capability

The DPFC similar to UPFC can control all parameters of transmission network, such as line impedance, transmission angle, and bus voltage magnitude.

• High Reliability

The series converters redundancy increases the DPFC reliability during converters operation. It means, if one of series converters fails, the others can continue to work.

3.2 DPFC CONTROL

The DPFC has three control strategies: central controller, series control, and shunt control, as shown in Fig.7

Central Control

The central control generates the reference signals for both the shunt and series converters of the DPFC. It is focused on the DPFC tasks at the power-system level, such as power-flow control, low-frequency power oscillation damping, and balancing of asymmetrical components. According to the system requirement, the central control gives corresponding voltage-reference signals for the series converters and reactive current signal for the shunt converter.

Series Control

The controllers used to maintain the capacitor dc voltage of its own converter by using the third-harmonic frequency components and to generate series voltage at the fundamental frequency that is prescribed by the central control. As the series converter is single phase, there will be voltage ripple at the dc side of each converter. The frequency of the ripple depends on the frequency of the current that flows through the converter. As the current contains the fundamental and third harmonic frequency component, the dc-capacitor voltage will contain 100-Hz 200-Hz and 300-Hz frequency component. There are two possible ways to reduce this ripple. One is to increase the turn ratio of the single-phase transformer of the series converter to reduce the magnitude of the current that flows into the converter. The other way is to use the dc capacitor with a larger capacitance Shown in Fig. 7

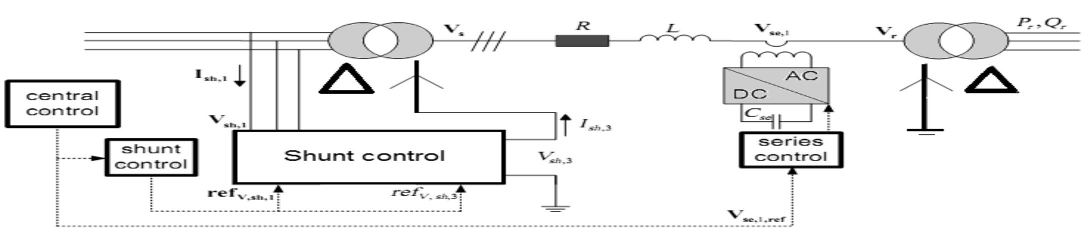


Fig. 7 DPFC control structure

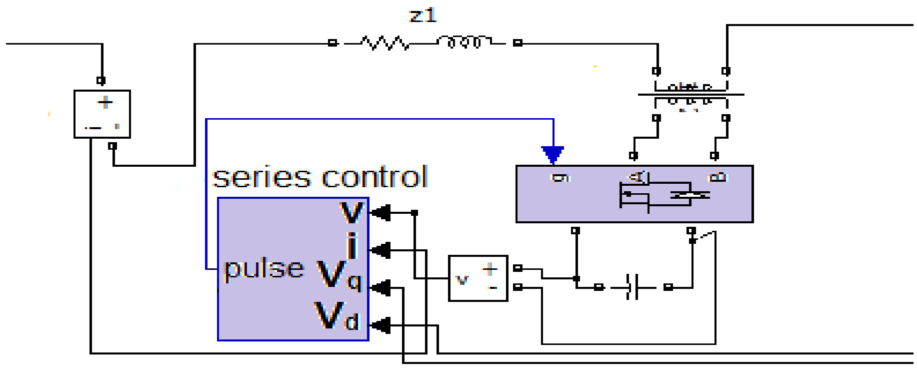
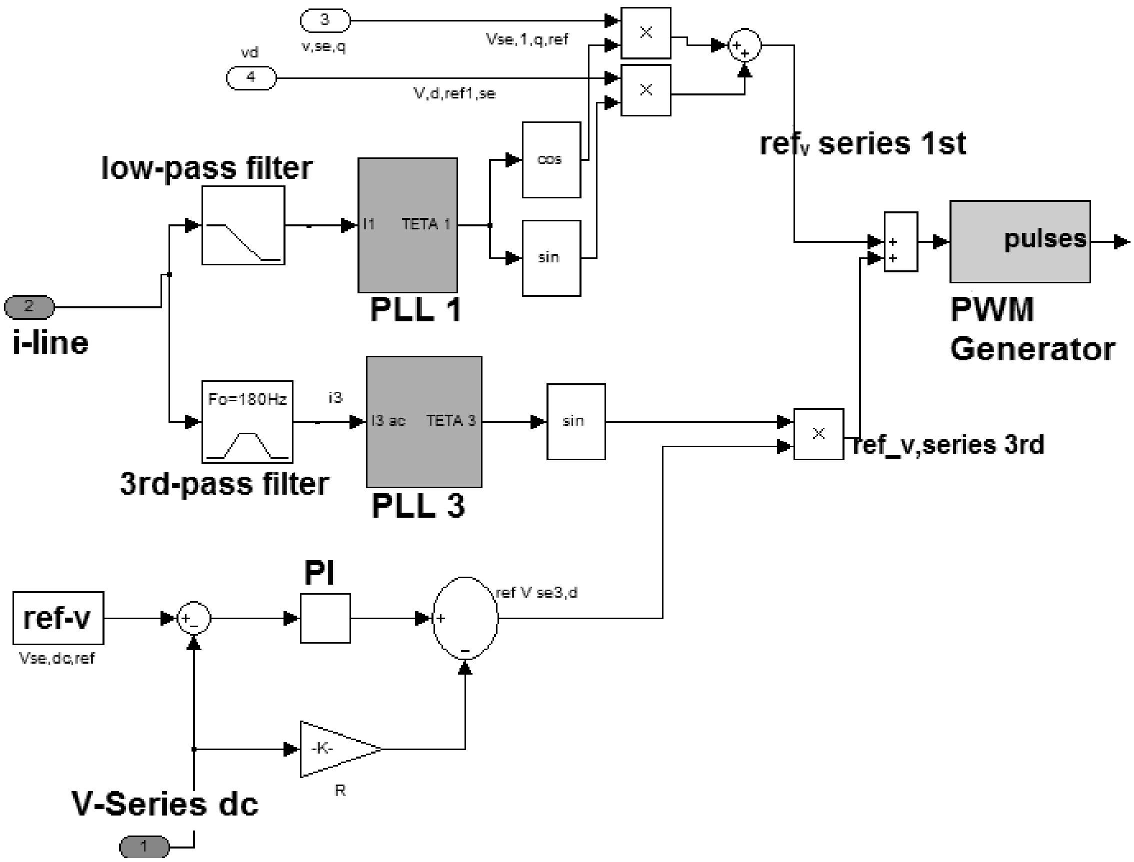


Fig. 8 Block diagram of the series converters in Matlab/Simulink

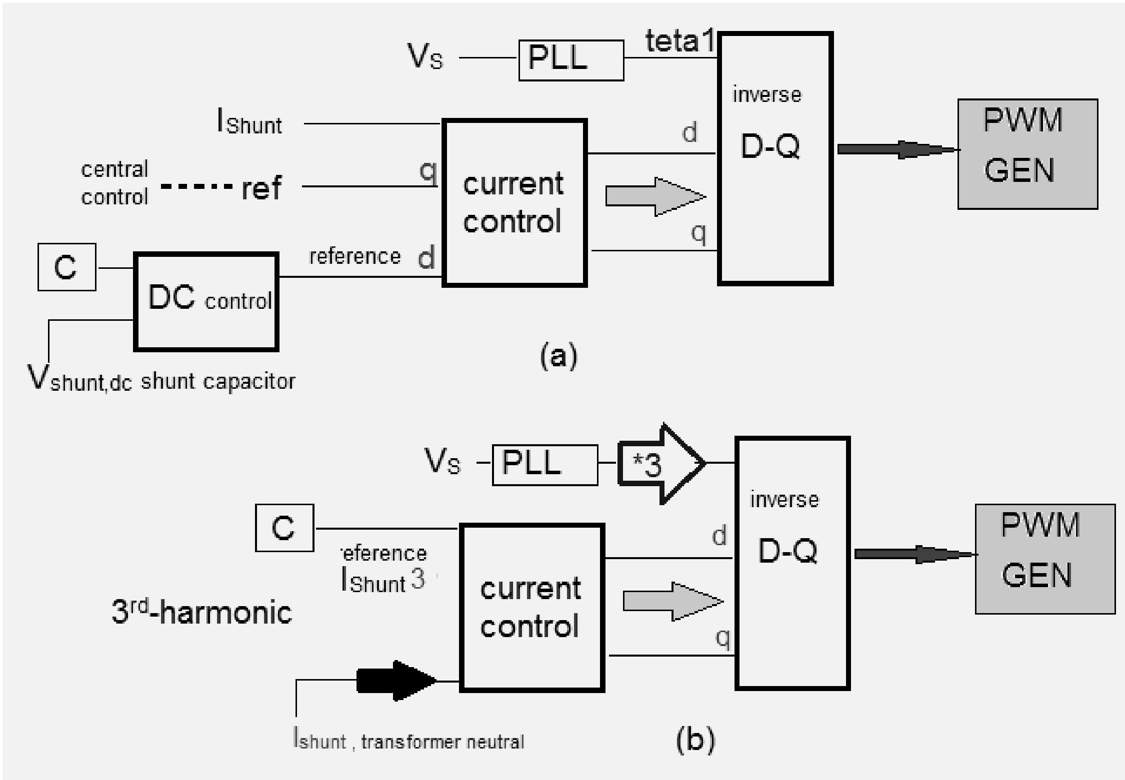
Any series controller has a low-pass and a 3rd-pass filter to create fundamental and third harmonic current, respectively. Two single-phase phase lock loop (PLL) are used to take frequency and phase information from network. The block diagram of series controller in Matlab/Simulink is shown in Fig. 8 the PWM-Generator block manages switching processes.

Shunt Control

The shunt converter includes a three-phase converter connected back-to-back to a single-phase converter. The three-phase converter absorbs active power from grid at fundamental frequency and controls the dc voltage of capacitor between this converter and single-phase one. Other task of the shunt converter is to inject constant third-harmonic current into lines through the neutral cable of Δ-Y transformer.



Each converter has its own controller at different frequency operation (fundamental and third-harmonic frequency). The shunt control structure block diagram is shown in Fig. 10



(a) For fundamental frequency (b) for third-harmonic frequency

4 Performance Analysis of Fuzzy Logic Based On DPFC

FACTS devices are used to control the power flow, to increase the transmission capacity and to optimize the stability of the power system. One of the most widely used FACTS devices is Distributed Power Flow Controller (DPFC). The controller used in the control mechanism has a significantly effects on controlling of the power flow and enhancing the system stability of DPFC. According to this, the capability of DPFC is observed by using different control mechanisms based on P, PI, PID and fuzzy logic controllers (FLC) in this study. FLC was developed by taking consideration of Takagi- Sugeno inference system in the decision process and Sugeno's weighted average method in the defuzzification process.

Case studies with different operating conditions are applied to prove the ability of DPFC on controlling the power flow and the effectiveness of controllers on the performance of DPFC.

The growth of the power systems in the future will rely on increasing the capability of existing transmission systems rather than building the new transmission lines and the power stations for an economical and an environmental reasons. The requirement of the new power flow controllers, which is capable of increasing the transmission capability and controlling the power flow through the predefined corridors, will certainly increase due to the deregulation of the electricity markets. Additionally, these new controllers must be control the voltage levels and the flow of the real/reactive power in the transmission line to use full capability of the system in some cases with no reduction in the system stability and security margins. A new technology concept known as Flexible Alternating Current Transmission Systems (FACTS) technology was presented in the late of 1980s. FACTS devices enhance the stability of the power system with its fast control characteristics and continuous compensating capability. The controlling of the power flow and increasing the transmission capacity of the existing transmission lines are the two main objectives of FACTS technology.

Thus, the utilization of the existing power system comes into optimal condition and the controllability of the power system is increased with these objectives. Gyugyi proposed the Distributed Power Flow Controller which is the new type generation of FACTS devices in 1991. Distributed Power Flow Controller (DPFC) is the member of FACTS device that has emerged for the controlling and the optimization of power flow in the electrical power transmission systems. This device formed of the combination of two other FACTS devices namely as Static Synchronous Compensator (STATCOM) and the Static Synchronous Series Compensator (SSSC). These are connected to each other by a common DC link, which is a typical storage capacitor. The all parameters of the power transmission line (impedance, voltage and phase angle) can be control simultaneously by DPFC. In addition, it can perform the control function of the transmission line real/reactive power flow, DPFC bus voltage and the shunt-reactive-power flow control.

The capability of DPFC on controlling of the power flow and the effectiveness of controllers on performance of DPFC in the power transmission line are examined in two case studies by using different control mechanisms based on PI and fuzzy controllers in this thesis. In the modeling of fuzzy controller, "Takagi-Sugeno Inference System" is used in the decision making process and "Weighted Average" method which is the special case of "Mamdani" model is used in the defuzzification process.

The desired signals are subtracted from the reference signals and the results are transformed into three phase balanced system to use in the sinusoidal-pulse-width modulation (SPWM). Thus, the firing angles of IGBTs (insulated gate bipolar transistors) are produce from the Process of SPWM technique.

5 IMPLEMENTATION OF FLC IN DPFC

FLC are formed by simple rule based on "If x and y then z". These rules are defined by taking help from person's experience and knowledge about the system behavior. The performance of the system is improved by the correct combinations of these rules. Each of the rules defines one membership which is the function of FLC. More sensitivity is provided in the control mechanism of FLC by increasing the numbers of membership functions. In this study, the inputs of the fuzzy system are assigned by using 7 membership functions and the fuzzy system to be formed in 49 rules. Hence, the sensitivity in the control mechanism is increased. The fuzzy control system is divided into three main sections. These sections are explained in the following.

FUZZY LOGIC CONTROLLER (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

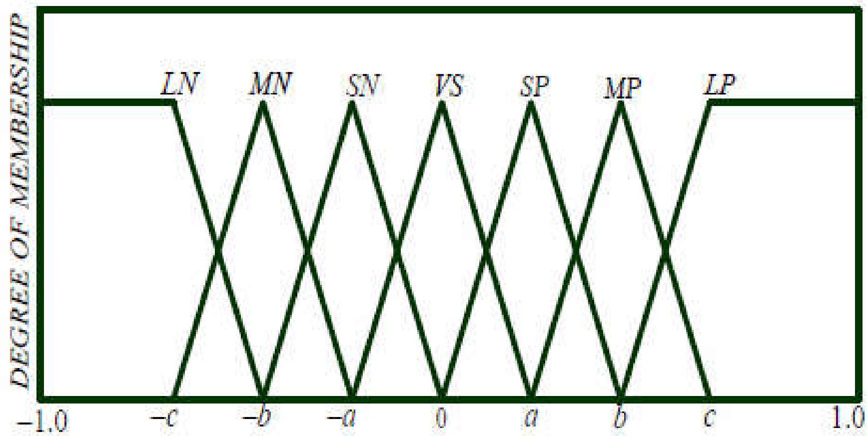


Fig. 11 Error and error rate of fuzzy membership function

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:

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

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

where $F^1{}_1$ denotes fuzzy set, $C^1{}_1$ is the real coefficients, Y^1 is the output set and $x_1 .... x_2$ 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.11. 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

Defuzzification:

In the Defuzzification process, the controller outputs represented as linguistic labels by a fuzzy set are converted to the real control (analog) signals. In the created fuzzy model, "Sugeno's Weighted Average" method which is the special case of "Mamdani Model" is selected for the defuzzification process. According to this model, the defuzzification is achieved by using following equations:

$$y = \frac{\sum_{l=1}^{M} w^l y^l}{\sum_{l=1}^{M} w^l} \qquad (2)$$

$$w^l = \prod_{i=1}^{n} M_{F_i^l}(x_i)$$

where W^1 is the overall truth value of the rule

$L^{(1)}$ is the membership function described the meaning of the linguistic $F^1{}_1$ variable

Signal Processing

The control signals are produced from the output of FLC process. They are used in the generation of switching signals for converter by comparing with carrier signal.

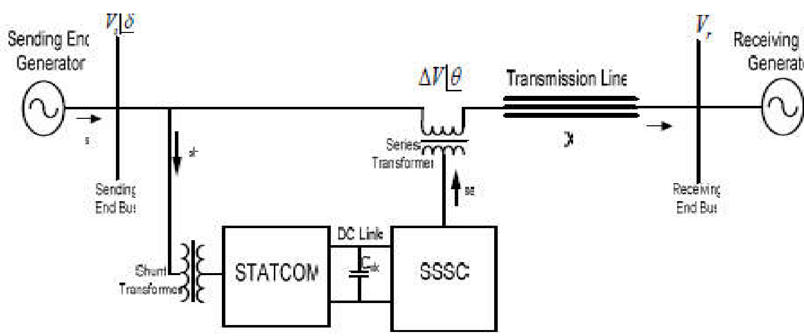


Fig. 12 Test System for Case study

In the first case study, the receiving end generator is delayed from the sending end generator according to several phase angles. The values of the real/reactive power results in the line are taken by consideration of using the different controllers in the control mechanism separately and compared as with and without DPFC in the line.

6 SIMULATION OF SINGLE MACHINE INFINITE BUS

Introduction

Matlab is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include Math and computation Algorithm development Data acquisition Modelling, simulation, and prototyping Data analysis, exploration, and visualization Scientific and engineering graphics Application development, including graphical user interface building.

Matlab is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or FORTRAN.

Matlab has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, matlab is the tool of choice for high-productivity research, development, and analysis.

Matlab features a family of add-on application-specific solutions called toolboxes. Very important to most users of mat lab, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of matlab functions (M-files) that extend the mat lab environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

SIMULINK

Simulink is a software add-on to matlab which is a mathematical tool developed by The Math worksa company based in Natick. Matlab is powered by extensive numerical analysis capability. Simulink is a tool used to visually program a dynamic system (those governed by Differential equations) and look at results. Any logic circuit, or control system for a dynamic system can be built by using standard building blocks available in Simulink Libraries.

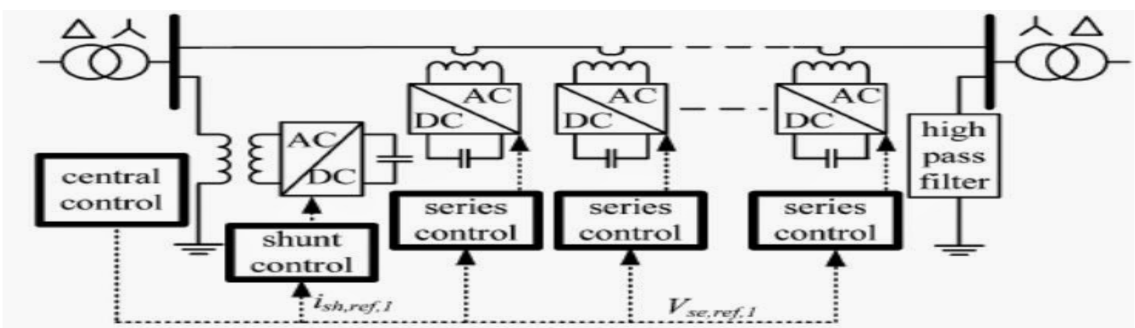


Fig.13 Block Diagram of DPFC

Simulation Diagram Without DPFC

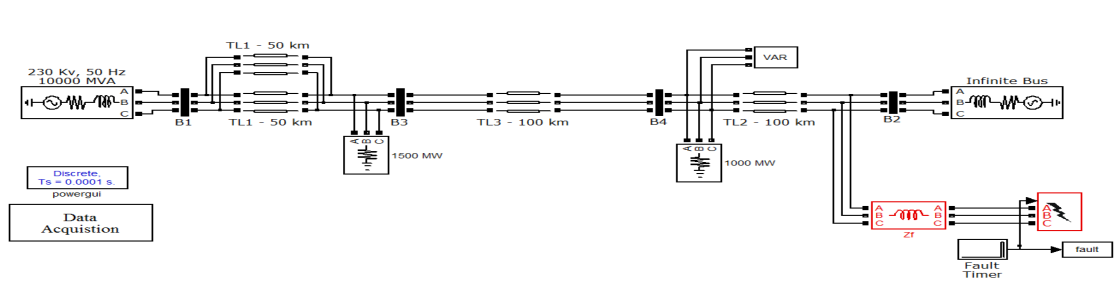


Fig. 14 simulation design in Matlab without DPFC

Simulation model Diagram with DPFC

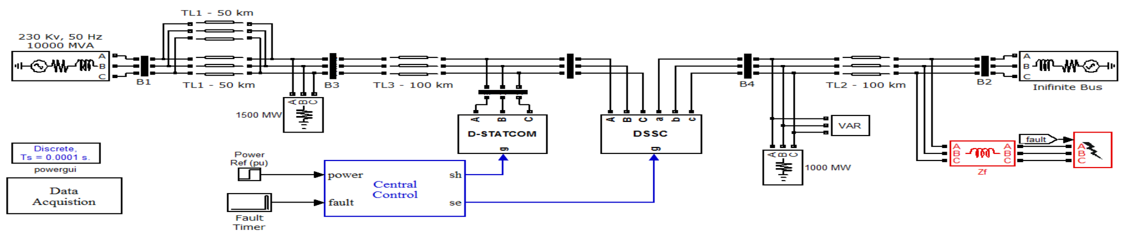


Fig. 15 Simulation model Diagram with DPFC

The whole model of system under study is shown in Fig.15 The system contains a three phase source connected to a nonlinear RLC load through parallel transmission lines (Line 1 and Line 2) with the same lengths. The DPFC is placed in transmission line, which the shunt converter is connected to the transmission line 2 in parallel through a Y-Δ three-phase transformer, and series converters is distributed through this line.

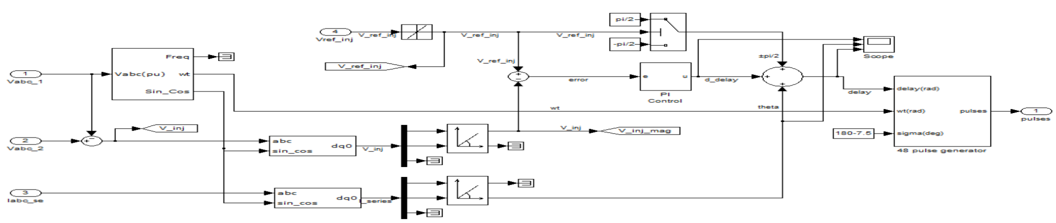


Fig. 16 Representation of series control circuit

The operation mode to “SSSC (Voltage injection)”. Make sure that the SSSC references values (3rd line of parameters) [Vinj_Initial Vinj_Final StepTime] are set to [0.0 0.08 0.3].

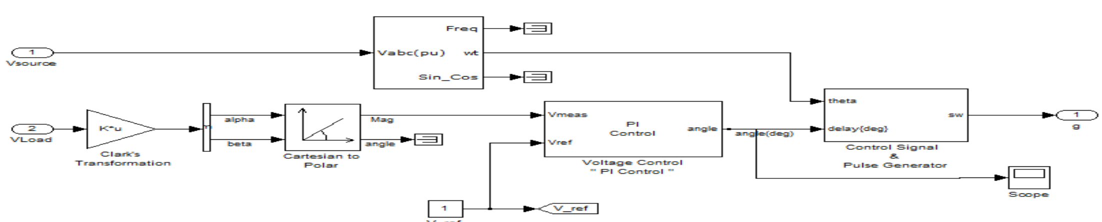


Fig. 17 Representation of shunt control circuit

SIMULATION RESULTS

At time t = 0 sec a power command of 400 MW is initiated to DPFC and the results is shown in Fig. 18 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. 19

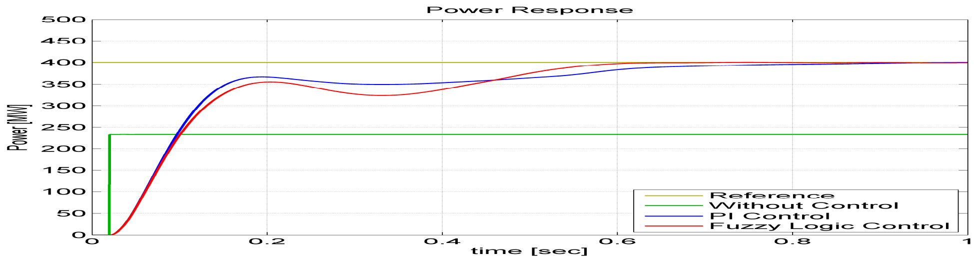


Fig. 18 Power flow from single machine to infinite bus

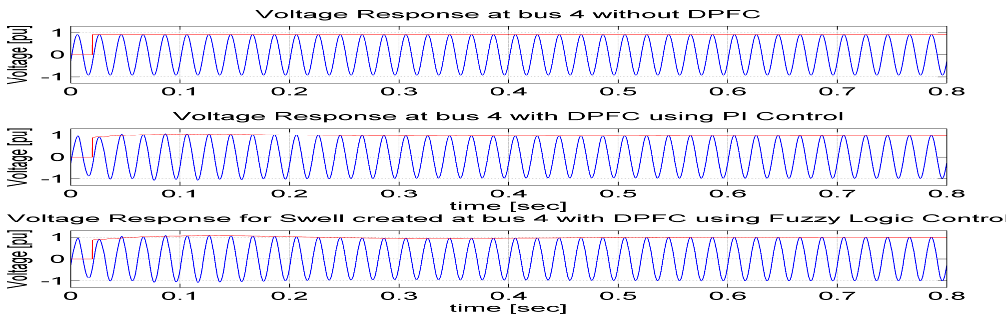


Fig. 19 Voltage Response for power command 400 MW

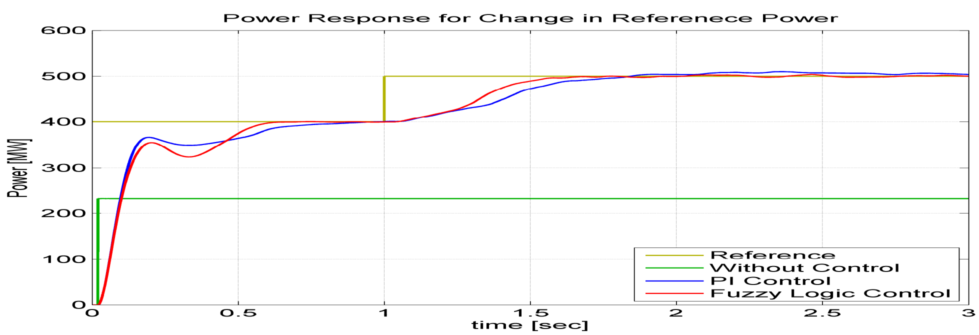


Fig. 20 Power for Change in power command from 400MW to 500MW

Fig. 19 shows the power response for increase in the power from 400 to 500MW. It show that PI Control takes 2.37 sec to settle to its reference value whereas Fuzzy control takes 1.5 sec

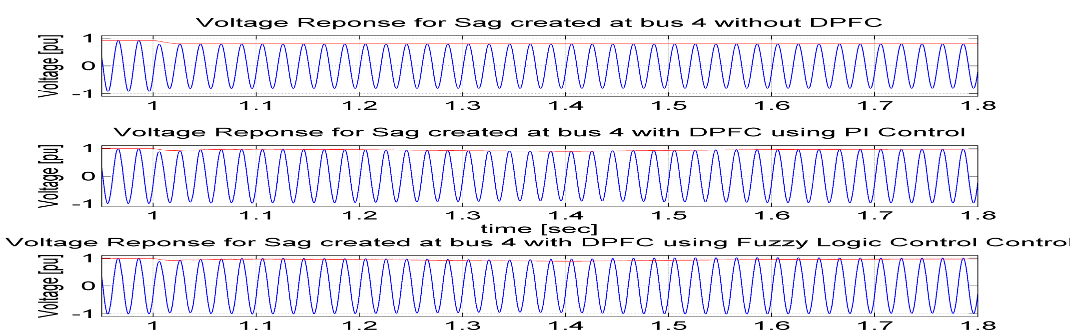


Fig. 21 Mitigation of load voltage sag with DPFC

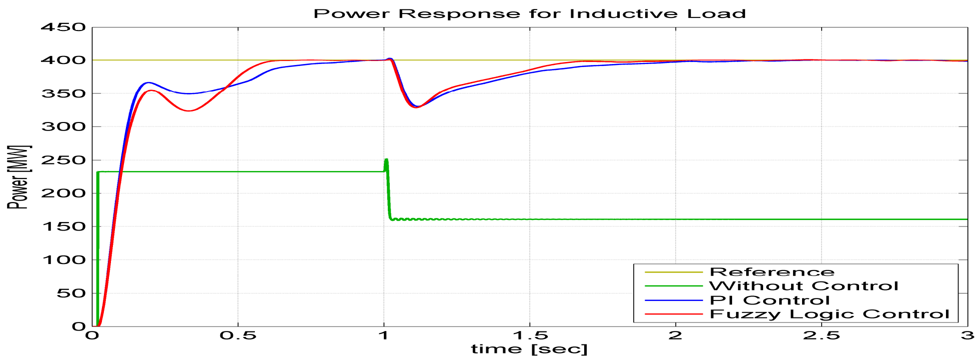


Fig. 22 Power response for Mitigation of sag with DPFC

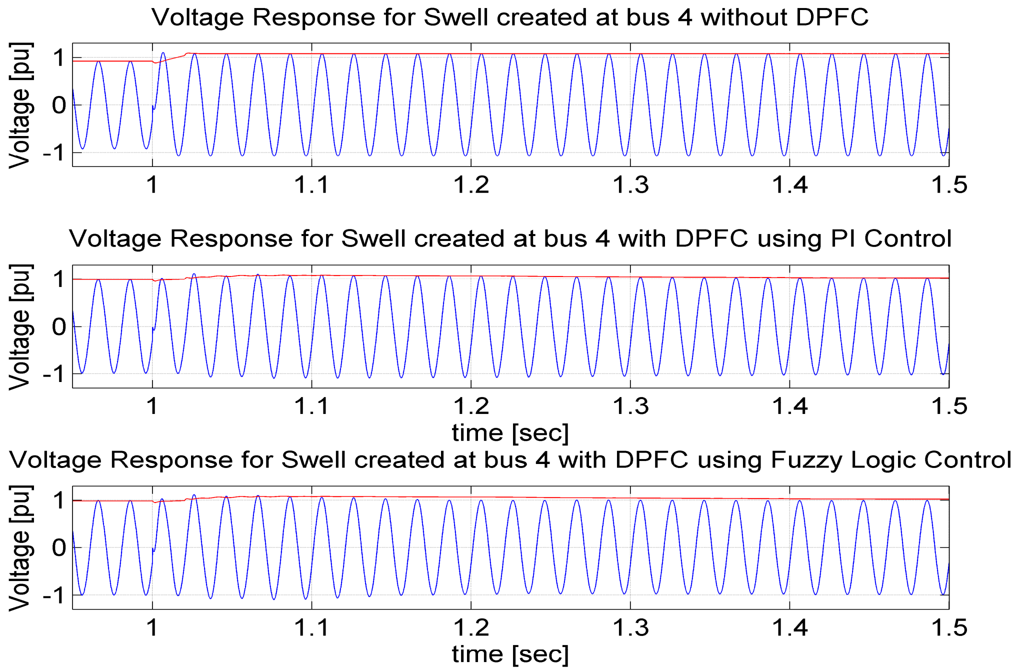


Fig. 23 Mitigation of load voltage swell with DPFC

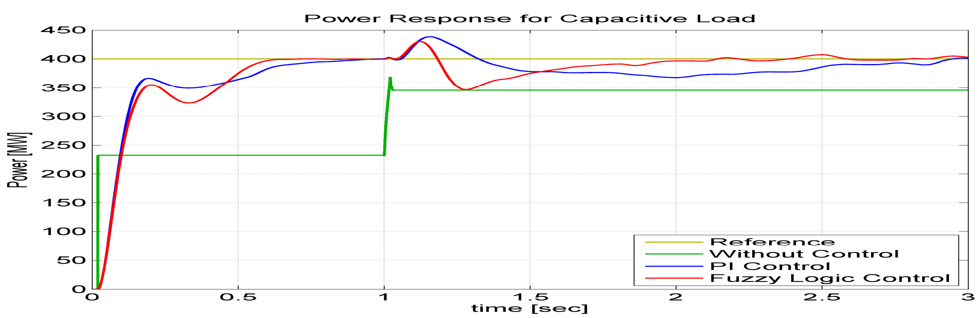


Fig. 24 Power response for Mitigation of sag with DPFC

TABLE II - 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

TABLE III - **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

7 CONCLUSION & FUTURE SCOPE

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 the 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 low cost. The DPFC is modelled and three control loops, i.e., central controller, series control, 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. The "VOLTAGE SAG AND SWELL MITIGATION USING DPFC AND FOR MULTI SYSTEM "with fuzzy has more accurate and gives the control capability than the proportional integral controller. 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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