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Power Quality Improvement By Using Hybrid Seven Level H-Bridge Inverter Based Power Flow Controller In Distribution System

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Abstract: As indicated by advancement of electricity demand and upgraded the numerous quantities of non-linear loads in power grids requiring an adroit electrical power. In this article, enhancement of power quality in distribution systems utilizing hybrid seven level H-bridge inverter (HSLHBI) structure based distributed power flow controller (DPFC) is developed. A DPFC is one of the contemporary FACTS device and its structure is like the unified power flow controller (UPFC). Regardless of UPFC, in DPFC the normal DC-interface capacitor between the shunt and series converters is disposed of and the three-stage serial converter is isolated to many single-phase series distributed converters through transmission line. This at last empowers the DPFC to completely control all power system parameters. DPFC builds the dependability of the device and lessens its expense all the while. The HSLHBI is goes about as voltage source converter (VSC). The MLIs are utilized for high power and high voltage applications. The HSLHBI output voltage delivers a staircase output waveform, this waveform resemble a sinusoidal waveform prompts decrease in Harmonics. The fuzzy logic controller (FLC), proportional integral (PI) controller and multi-carrier sinusoidal PWM method are intended for DPFC to controlling its parameters. The execution of the designed DPFC for distribution system is verified by translating the MATLAB/Simulink model. The outcomes are exhibited to demonstrate the execution of the structured DPFC in distribution system with FLC.

Index Terms - FACTS, Power Quality, Multi Level Inverters, Intelligent Controller, Distributed Power Flow Controller**.**

1. INTRODUCTION

An electrical fault in a power system network is practically difficult to keep away from and it causes the electrical power quality issue has been the fundamental concern of the power organizations [1]. main causes of power quality disturbances might be because of insulation failure, tree falling, fledgling's contact, lightning or a fault on a contiguous feeder [2]. The power quality unsettling influences might be as voltage sag, swells, voltage imbalances, transients, interruptions and harmonics, which can influence the execution of electrical apparatus to the industry [3-4].

These custom power devices are classified as the Distribution Static Compensator (DSTATCOM), Dynamic Voltage Restorer (DVR) and Distributed Power flow controller (DPFC). A DVR is utilized in medium-to-low voltage levels to improve client power quality [12]. The DSTATCOM is a shunt connected device, which deals with the power quality issues in the currents [15]. It comprises of a DC capacitor, three-stage inverter (IGBT, thyristor) module, AC filter, coupling transformer and a control system [16-17]. Inverter circuit is the core of DSTATCOM and different inverter topologies can be used in uses of DSTATCOM, for example, cascaded H-bridge, neutral point braced and flying capacitor [18]. Specifically, among these topologies, cascaded H-bridge inverters are as a rule generally utilized as a result of their moderately and simplicity [19]. Different modulation methods can be connected to cascaded H-bridge inverters. Cascaded H-bridge inverters can also the quantity of yield voltage levels effectively by expanding the quantity of H-bridges. Fuzzy logic controller (FLC) for speed controller of induction motor drive through A.C chopper has been accounted for [20]. From the article, the execution of the motor parameter with FLC has well. Sliding mode controller (SMC), proportional integral(PI) controller, and SMC in addition to FLC for Luo-Converters has been introduced [21-23]. Among these controllers, SMC in addition to PI controller has performed well for converters.

From the above pointed out issues are tackled by structured hybrid seven level H-bridge inverter (HSLHBI) based DPFC in distribution system with FLC. Accordingly, in this article is to propose a HSLHBI based DPFC in distribution system with FLC. The execution of the planned is approved at various working conditions utilizing MATLAB/Simulink programming platform

2. DPFC PRINCIPLE AND MODELLING

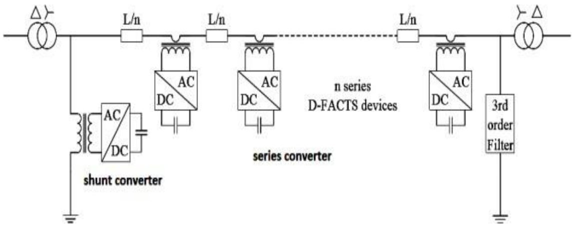


Fig. 1 Distributed power flow controller

The few individual converters are joined together to shape the structure of DPFC is delineating in Fig. 1 [6]. The converters connected in arrangement to transmission line are known as series converters.

While there is no D.C link capacitor connecting the shunt and the series converter, the real power is supplanted by harmonics and through the ac network. The principle is relied upon term of real power, which is result of the normal estimations of the voltage and the current. In the meantime, these voltage and current contains fundamental and harmonics. As the integrals of whole cross product of terms with different frequencies are null, the real power can be composed as condition (1)[6]

$$P = \sum_{n=1}^{\infty} VnIncos\O n \quad (1)$$

Where Ø $_n$=phase angle between the voltage and the current of n^{th} harmonics.

Equation (1) explains the real power at various frequencies is separated from each other and its voltage and current in one frequency has no influence on other frequency components.

3. STEADY STATE ANALYSIS

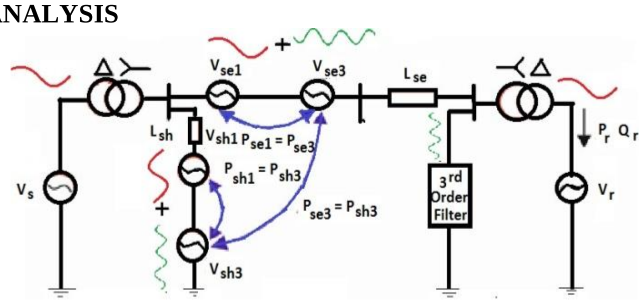


Fig.2 Simplified equivalent circuit of DPFC in two bus power system

Each converter is supplanted with control the voltage sources in series with impedance and produces the voltage at two different frequencies. From fig.2 ,the DPFC is situated in two bus power system with the sending end and receiving end voltages Vs,Vr correspondingly.

The transmission line is represented with inductance L and line current I. The injected voltage of series converters are Vse1 and Vse3 at major and third order harmonic frequency components correspondingly. The shunt converter is associated with the sending end bus via inductor Lsh and makes the voltages of Vsh1 and Vsh3 and also the injected current of shunt converter is represented by Ish.The Pr and Qr are represented by real and reactive power flow and it can be written as

$$P_r + jQ_r = V_r * I_r^* = V_r\left(\frac{Vs-Vr-Vse1}{jX1}\right)^* \quad (2)$$

Where,

X1 = ω1L – indicates the line impedance at the fundamental frequency.

The power flow without DPFC compensation Pro and Qro can be written as

$$P_{ro} + jQ_{ro} = Vr\left(\frac{Vs-Vr}{jX1}\right)^* \quad (3)$$

The power flow control range of the designed facts device can be written as

$$P_{rc} + jQ_{rc} = v_r * \frac{Vse1^*}{jX_1}$$

Where Prc and Qrc indicates the real and reactive power limit ranges of designed DPFC

DPFC power flow control range is directly proportional to the peak voltage of the series converter at fixed voltage Using equations (2) and (3), the control ability of the DPFC is expressed as

$$P_r - P_{ro} + j(Q_r - Q_{ro})^2 = \left(\frac{|V_{se1}|}{X_1}\right)^2 \quad (5)$$

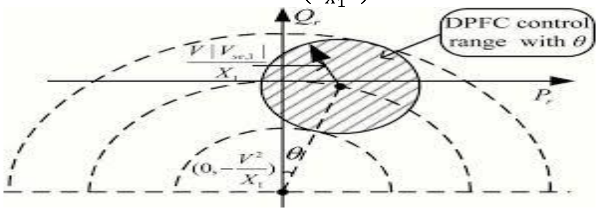


Fig 3.DPFC real and reactive power control range using transmission angle

The DPFC with its control range is represented as shown in fig.3From the above figure it is clearly focused the locus of the power flow control without presence of the DPFC compensation f(Pro,Qro)is a circle with radius of $|V^2|/|X_1|$.The Vse1 at fundamental frequency is expressed by

$$V_{se1} = \left(\frac{S_r - S_{ro}}{V_r}\right) jX1 \quad (6)$$

Where,

Sr and Sro shows the real power in compensated network and reactive power in non-compensated network. Toward infuse a 360◦ rotatable voltage, at the third harmonic frequency component by means of the transmission line, and it is expressed as (7)

$$P_{se1`} = \frac{X_1}{|V_r^2|}|S_r||S_{ro}|sin(\emptyset_{ro} - \emptyset_r) \quad (7)$$

4. CONTROL METHODOLOGY FOR DPFC

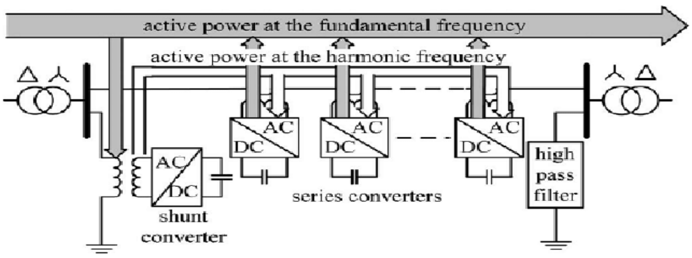


Fig.4 control methodology for DPFC

A. Central Control Central control unit (CCU) is produced reference signals furthermore; According to the system needs, the CCU makes the reference signal of Vse1ref for series control block and reference signal of q-component of Ish1qref for shunt control.

B. Series control

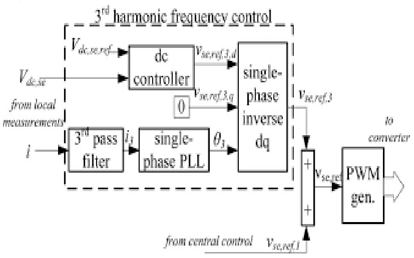


Fig .5 control block diagram of series converter

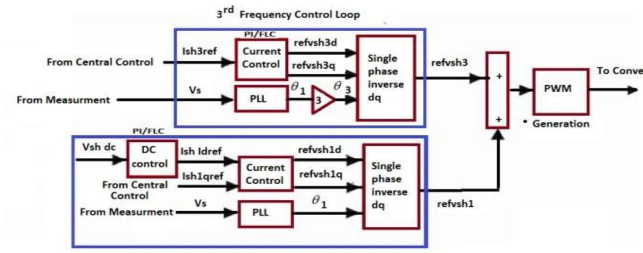


Fig .6 control block diagram of series converter

C. Shunt control: The main function of this controller and its area were at that point talked about in the valuable segments. The principle control block of shunt converter of DPFC (see Fig. 6) has two in fundamental frequency control loop (FFCL) and third order frequency control loop (3rdFCL). Again, the FFCL comprises of DC voltage control and current control. In FFCL, the bus voltage is picked as rotation reference frame. The CCU and DC control is produced by the q component current and the d part reference signal. The current control is produces the desired control to the single-stage inverter parks change utilizing PI controller and FLC. The 3rdFCL is created the third order harmonic component of shunt converter of DPFC, which is synchronized with bus voltage at fundamental frequency. A PLL is applied to follow the bus voltage frequency and the output signal which are multiplied with constant "3" to produce the decoupled double synchronous rotation reference frame for the 3rd harmonic current. The similar current control (PI control and FLC) is applied for 3rd harmonic frequency components. Both the frequency control loops are combined to offer the reference signal for shunt converter of DPFC to maintain the DC link voltage constant and constant 3rd harmonic current injected into the grid. Series converter rules and membership functions were applied for shunt converter also.

5. HYBRID SEVEN LEVEL H-BRIDGE INVERTER

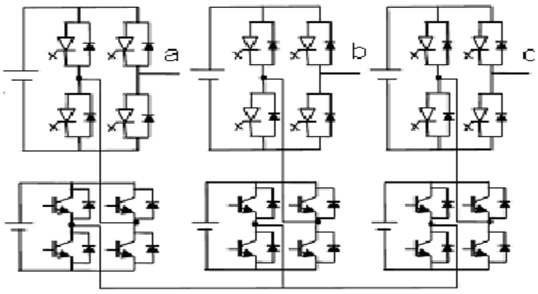


Fig. 7. Circuit diagram of Hybrid Seven Level H- Bridge Inverter.

Table 1. Switching Pattern between a and b of inverters

Command Signal (Desired Output)	GTO Inverter	IGBT Inverter
Between -400V and -300V	-300V	0 □ -100V
Between -300V and -100V	-300V	0 □ 100V
Between -100V and -0V	0.0 V	0 □ -100V
Between 0V and 100V	0.0 kV	0 □ 100V
Between 100V and 300V	300V	0 □ -100V
Between 300V and 400V	300V	0 □ 100 V

With a modular H-bridge topology [16], fear of MLIs with a hybrid approach including IGBTs and IGCTs working in synergism is feasible. hybrid MLI topologies have been reported for high power applications [17-18]. The topology tended to in [18] consolidates a Gate Turn-Off (GTO) Thyristors based inverter, and an IGBT inverter, like that Fig.1. It very well may be approved that with a blend of 300V and 100V DC bus voltages in this topology, it is reachable to deliver ventured waveforms with seven voltage levels through. -400V, - 300V, - 100V, 0, 100V, 300V, 400V at the each stage leg yield of the structured MLI. From the Fig. 1, the higher voltage levels (±300V) are integrated utilizing GTO inverters while lower voltage levels (±100V) are blended with IGBT inverters. Be that as it may, it is outstanding that switching ability of GTO Thyristors is confined at high frequencies [17]. In this way ,hybrid ,modulation strategy that consolidates stepped synthesis in blend with changeable pulses width of the successive steps is offered. The switching pattern of the designed MLI at each state is addressed in Table 1 and its comparing simulated responses are shown in Fig.2.

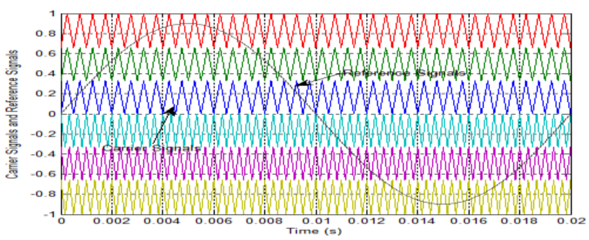


Fig. 8 Multi-carrier sinusoidal PWM technique for Hybrid Seven Level H- Bridge Inverter

6. DESIGN OF FLC:

The FLC is intended for controlling the parameters of DPFC system, for example, D.C link capacitor voltage, arrangement converter voltage and shunt current. The design of FLC is picking the right inputs and outputs and designing each of four components of the FLC shown in Fig. 3. The FLC is initiated just in the transient period and once the estimation of the dc connect voltage settles down, the controller gains are kept settled at the consistent state value[20, 23].

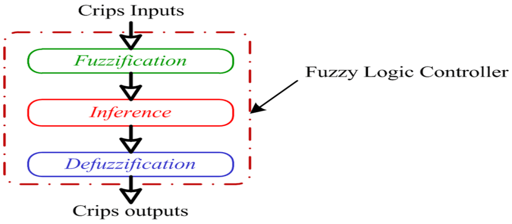


Fig.9 FLC for DPFC

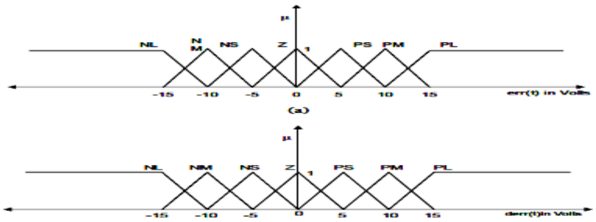
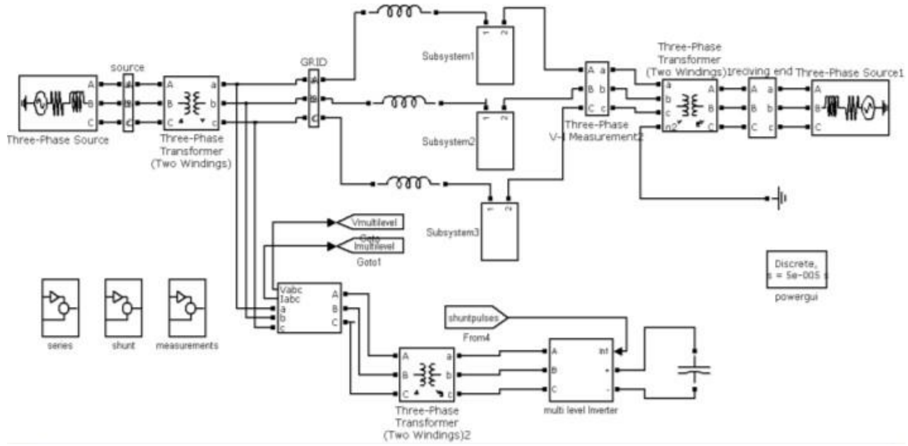


Fig 10. Membership functions for error input.

The fuzzification interface changes the inputs to a form in which they can be utilized by the inference mechanism. It takes in the crisp input signals and doles out a membership value to the membership function under whose range the input signal falls typical input membership functions are triangular trapezoidal or exponential. Seven triangular membership functions (MFs) have been picked: NL (Negative Large), NM (Negative Medium), NS (Negative Small), Z (Zero), PS (Positive Small), PM (Positive Medium) and PL (Positive Large) for both blunder (fail) and change in error (derr) . The input MFs are shown in Fig. 10. The tuning of the input MFs is done based on the system characteristics.

Inference mechanism: The two main operations of inference mechanisms are Based on the dynamic MFs in error and the adjustment in error inputs, the standards that use for the current state are calculated. Once the standards which are on are assessed, the confidence of the control exploit is ascertaining out from the membership values.

defuzzification : The inference mechanism provides us a lot of rules each with a $\mu_{premise}$. The defuzzification mechanism about these guidelines and their individual $\mu_{premise}$ values, joins their effect and comes up with a crisp, numerical output. In this way, the fuzzy control action is changed to a non fuzzy control action. The 'center of gravity' method has been connected for this DPFC. In any case, the resultant crisp output of this technique is sensitive to the entire active fuzzy outputs of the inference mechanism

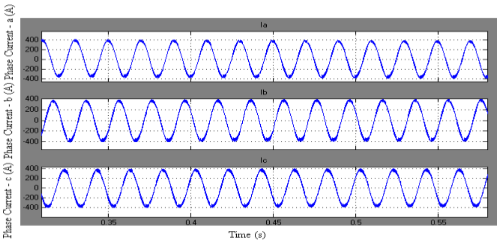


. Fig.11 MATLAB and simulink model of FLC based DPFC for distribution system

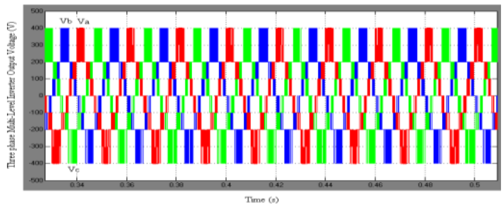
7. SIMULATION RESULTS

Table 3 Specifications of DPFC in distribution system

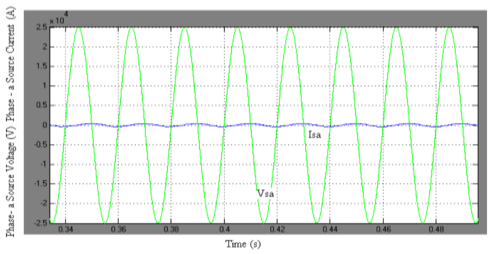
Sl. No.	Parameters Name	Values		
Shunt Converter			**Series Converter**	
1	Three Phase Shunt Transformer Details Winding 1 (star)	735KVA	Single Phase Series Transformer Details Winding 1 (delta)	1KV
2	Winding 2 (Delta)	315KVA	Winding 2 (star)	100kV
3	D.C link capacitors	3000 μF	Switching frequency	6kHz
4	D.C link voltage	300		



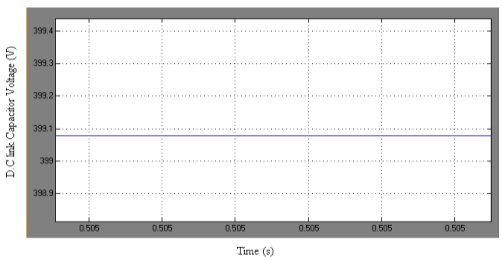
(a)



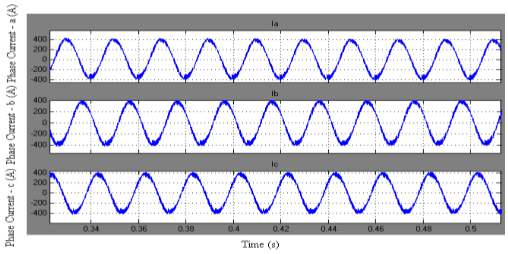
(b)



(c)



(d)



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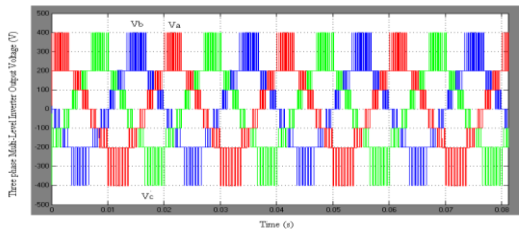

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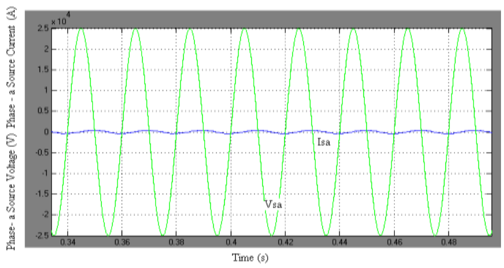

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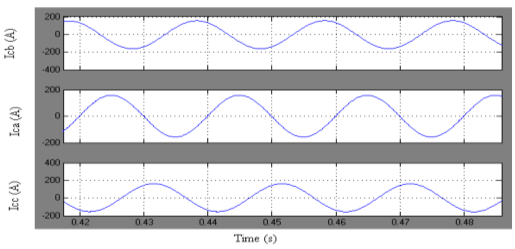

(d)

Fig. 7 Performance of the PI controller based seven level VSC DPFC Fig. 8 Performance of the FLC based seven level VSC for power system, (a). Three phase source current, (b). Three phase DPFC for power system ,(a)three phase source current Output voltage of ML VSC, (c). Source voltage and current,
(b) three phase output voltage of ML VSC, (c) source
(d) DC link capacitor voltage current (d) three phase compensation current

8. CONCLUSION

In this article FLC based HSLHBI DPFC for distribution system has been researched in MATLAB/Simulink programming stage. The designed DPFC has capably regulated active and reactive power flow in the power system. The results of source current THD value of the planned designed power system with developed DPFC have delivered extremely less. Here, the series converter of the DPFC utilizes the D-FACTS concept, which utilizes different converters rather than one large size converter. The dependability of the DPFC is incredibly expanded on account of the excess of the series converters. The complete expense of the

DPFC is likewise much lower than the UPFC, in light of the fact that no high-voltage isolation is required at the series converter part and the rating of the components are low.

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