Implementation of VSI based Single-Phase to Three-Phase Drive System

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ABSTRACT: *In this paper we proposed better solution for single phase to three phase drive system by employing 2 parallel single phase rectifier stages, a3-phase inverter stage and also we require 3-phase induction motor. In this proposed topology greatly reduces rectifier switching currents and also total harmonic distortion at the side of input converter and this paper gives fault tolerance characteristics improvements, where the added advantage of the proposed system by incorporating more number of switches total energy loss present in the conventional system is reduced to more extent. The main objective of this paper is to reduce the circulating currents. Finally with developed fuzzy logic controller strategy, pulse width modulation (PWM) the total harmonic distortion and elimination of error in the voltage are decreased. We also simulated results with Matlab Simulink and three phase drive system performance.*

Index Terms: *Ac-dc-ac power converter, drive system, fault identification,Control strategy*

INTRODUCTION

In present days there is need of 3-phase AC to DC converter while it is mostly employed in power electronic related systems like UPS, DCbattery chargers and also need id in most motor drives. As we know there is need of ac-dc conversion with attachment of dc-ac conversion in UPS stages. Traditional they used to have thyristor to have variable dc voltage at the cost of non-linearity loads. Now voltage drop in line inductor because of harmonic currents that are going to disturb or dis torts Ac main voltage at the same time the other loads that were connected to AC mains also fed with adequate distortion voltage.Nowadays[1]-[5] we use three phase AC to DC converter in power electronic systems like UPS, DC battery chargers and also Dc motor drives where single phase grid used in commercial, domestic and rural areas while in three phase we require variable speed drives at the same time we require single phase to three phase conversion that uses full bridge topology that have ten power switches as depicted in fig.1, where it is coined as conventional topology.On the other hand PWMconverters as well as inverter are embedded to form a cascade topology that handles same job as PWM converter does so we adopt new concept that reduces overall components as compared to conventional type topologies. As shown in fig.2 proposed system further reduces the switching currents, total harmonic distortion present in the grid, and to further increases fault tolerance currents. Moreover as compared to conventional systems losses in proposed are greatly reduced to have an efficient topology.

I. SYSTEM MODEL

The Conventional system single-phase to three phase system and the proposed system single phase to three phase systems are labeled as fig 1 and fig 2 respectively as shown below:

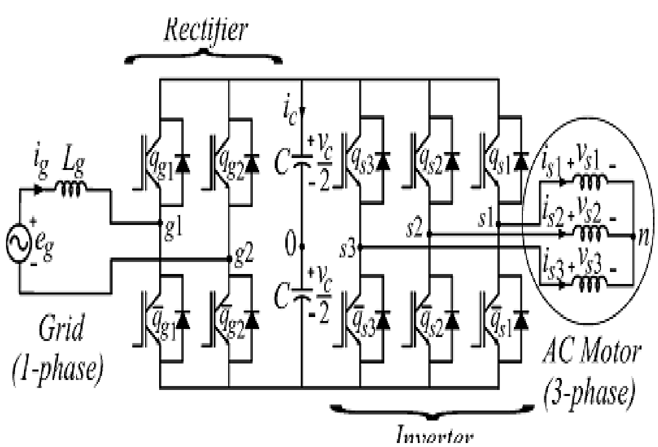

Fig.1 Conventional single-phase to three-phase system

The system is composed of ac supply, input inductors (L_a, L'_a, L_b, L'_b).The Rectifiers Aand B capacitor bank at the dc-link, inverter, and also induction machine.

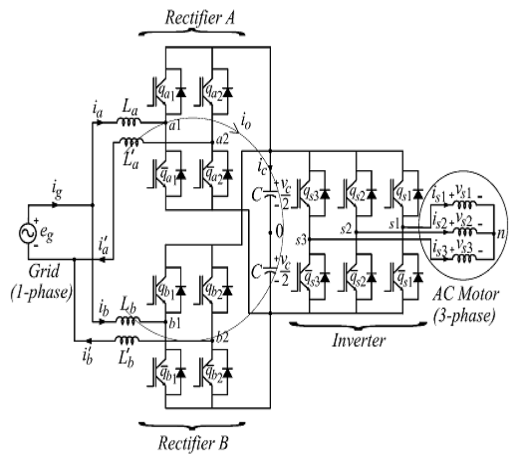

Fig 2 Modified (proposed)single-phase to 3-phase drive topology

Rectifiers A and B are consists of switches $q_{a1}, \bar{q}_{a1}, q_{a2}$ and $\bar{q}_{a2}$ and $q_{b1}, \bar{q}_{b1}, q_{b2}$ and $\bar{q}_{b2}$respectively. The inverter contains of many switches *namely* $q_{s1}, \bar{q}_{s1}, q_{s2}, \bar{q}_{s2}, q_{s3}$ and$\bar{q}_{s3}$.

$$v_{a10} - v_{a20} = e_g - (r_a + l_a p)i_a - (r'_a + l'_a p)i'_a \quad \text{----------------------} \quad (1)$$

$$v_{b10} - v_{b20} = e_g - (r_b + l_b p)i_b - (r'_b + l'_b p)i'_b \quad \text{-------------------------} \quad (2)$$

$$v_{a10} - v_{b10} = (r_b + l_b p)i_b - (r_a + l_a p)i_a \quad \text{---------------------} \quad (3)$$

$$v_{a20} - v_{b20} = (r'_a + l'_a p)i'_a - (r'_b + l'_b p)i'_b \quad \text{--------------} \quad (4)$$

$$i_g = i_a + i_b = i'_a + i'_b \quad \text{--------------} \quad (5)$$

Where $p = d/dt$and symbols like r and l represent the resistances and inductances of the input inductorsL_a, L'_a, L_b, L'_b.

The circulating current i_0 can be defined from$i_a, i'_a i_b, i'_b$.

$$i_0 = i_a - i'_a = -i_b + i'_b \quad \text{----------} \quad (6)$$

Introducing $i_0$and adding (3) and (4), relations (1)–(4) become

$$v_a = e_g - [(r_a + r'_a) + (l_a + l'_a)p]i_a + (r'_a + l'_a p)i_0 \quad \text{-----------------------} \quad (7)$$

$$v_b = e_g - [(r_b + r'_b) + (l_b + l'_b)p]i_b + (r'_b + l'_b p)i_0 \quad \text{-----------------------------} \quad (8)$$

$$v_0 = -[(r'_a + r'_b) + (l_b + l'_b)p]i_0 - [(r_a - r'_a) + (l_a - l'_a)p]i_a + [(r_b - r'_b) + (l_b + l'_b)p]i_b \text{------------} \quad (9)$$

Where$v_a = v_{a10} - v_{a20}$ ---------------- (10)

$$v_b = v_{b10} - v_{b20} \text{-------------------} \quad (11)$$

$$v_a = v_{a10} + v_{a20} - v_{b10} - v_{b20} \text{--------------} \quad (12)$$

Relations (7)–(9) and (5) constitute the front-end rectifier dynamic model. Therefore, v_a(rectifier A), v_b(rectifier B), and v_0(rectifiers A and B) are used to regulate currents i_a, i_b, i_0 respectively. Reference currents $i_a^*$and $i_b^*$are chosen equal to $i_g^*/2$ and the reference circulating current $i_0^*$is chosen equal to 0.

In order to both facilitate the control and share equally current, voltage, and power between the rectifiers, the four inductors should be equal, i.e.$r'_g = r_a = r'_a = r_b = r'_b$and $l'_g = l_a = l'_a = l_b = l'_b$. In this case, the model (7)–(9) can be simplified to the model given by

$$v_a + \frac{v_0}{2} = e_g - 2(r'_g + l'_g p)i_a \text{------------} 13)$$

$$v_b - \frac{v_0}{2} = e_g - 2(r'_g + l'_g p)i_b \quad \text{------} \ (14)$$

$$v_0 = -2(r'_g + l'_g p)i_0 \text{-------}(15)$$

Additionally, the equations fori_g, i'_a and i'_bcan be written as

$$v_{ab} = \frac{v_a + v_b}{2} = e_g - (r'_g + l'_g p)i_g \quad \text{------------} \ (16)$$

$v_a - \frac{v_0}{2} = e_g - 2(r'_g + l'_g p)i'_a$ ---- (17)

$v_b + \frac{v_0}{2} = e_g - 2(r'_g + l'_g p)i'_b$ …….. (18)

In this ideal case (four identical inductors), the circulating current can be reduced to zero imposing.

$v_0 = v_{a10} + v_{a20} - v_{b10} - v_{b20} = 0.$ …….. (19)

When i_0=0 ($i_a = i'_a, i_b = i'_b$) the system model (7)–(9) is reduced to

$v_a = e_g - 2(r'_g + l'_g p)i_a$ ……… (20)

$v_b = e_g - 2(r'_g + l'_g p)i_b$ …. (21)

II. PWM STRATEGY

The PWM strategy for the rectifier will be presented. Here we use voltage source inverter strategy [6]. The rectifier pole voltages $v_{a10}, v_{a20}, v_{b10}$ and v_{b20} depend on the conduction states of the power switches, i.e.

$v_{j0} = (2s_{qj} - 1)\frac{v_c}{2}$, for j=a1 to b2 ………….. (22)

Where v_c is the total dc-link voltage. Considering that v_a^*, v_b^* and v_0^* denote the reference voltages determined by the current controllers.

$v_a^* = v_{a10}^* - v_{a20}^*$ ………. (23)

$v_b^* = v_{b10}^* - v_{b20}^*$ ……… (24)

$v_0^* = v_{a10}^* + v_{a20}^* - v_{b10}^* - v_{b20}^*$ ………. (25)

Here gating signals are directly calculated from the reference pole voltages $v_{a10}^*, v_{a20}^*, v_{b10}^*$ and v_{b20}^*. However, (23)–(25) are inadequate to determine the 4 pole voltages uniquely from v_a^*, v_b^* and v_0^*. Introducing an auxiliary variable $v_x^* = v_{a20}^*$, that equation plus the three equations (23)–(25) constitute a four independent equations system with 4 variables ($v_{a10}^*, v_{a20}^*, v_{b10}^*$ and v_{b20}^*). Now solving this system of equations, we get

$v_{a10}^* = v_a^* + v_x^*$ ……… (26)

$v_{a20}^* = v_x^*$ ……….. (27)

$v_{b10}^* = \frac{v_a^*}{2} + \frac{v_b^*}{2} - \frac{v_0^*}{2} + v_x^*$ …… (28)

$v_{b20}^* = \frac{v_a^*}{2} - \frac{v_b^*}{2} - \frac{v_0^*}{2} + v_x^*$ ………… (29)

From these equations, it can be seen that, besides v_a^*, v_b^* and v_0^*, the pole voltages depend on also of v_x^*. The limit values of the variable v_x^* can be calculated by taking into account the maximum $v_c^*/2$ and minimum $-v_c^*/2$ value of the pole voltages.

$v_{xmax}^* = \frac{v_c^*}{2} - v_{max}^*$ ……… (30)

$v_{xmin}^* = \frac{v_c^*}{2} - v_{min}^*$ ……… (31)

Where v_c^* is the reference dc-link voltages, v_{max}^*= max ϑ and v_{min}^* = min ϑ, with ϑ= $\{v_a^*, 0, v_a^*/2 + v_b^*/2 - v_0^*/2, v_a^*/2 - v_b^*/2 - v_0^*/2\}$.Introducing a parameter μ ($0 \le \mu \le 1$), the variable v_x^* can be written as

$v_x^* = \mu v_{xmax}^* + (1-\mu)v_{xmin}^*$……. (32)

When μ = 0, μ = 0.5, and μ = 1 the auxiliary variable v_x^* has the following values $v_x^* = v_{xmin}^*$, $v_x^* = v_{xave}^* = (v_{xmin}^* + v_{xmax}^*)/2$ and $v_x^* = v_{xmax}^*$, respectively. When $v_x^* = v_{xmax}^*$ or $v_x^* = v_{xmin}^*$ then the leg of converter works with certainly zero switching frequency.

III. CONTROLSTRATEGY

As shown in above fig .3 the control used for controlling dc-link voltage that establishes grid power factor that closeness to unity.

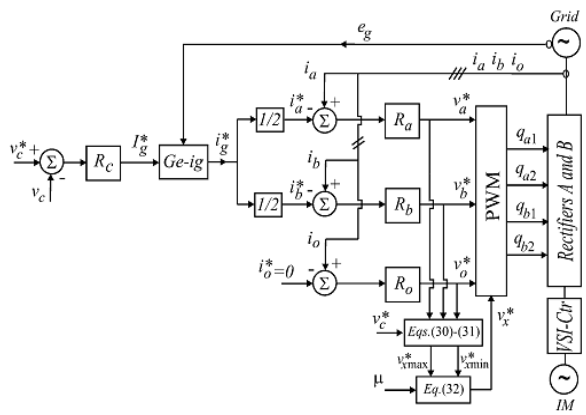

Fig. 3. Control block diagram.

Moreover for our proposed system circulating current can be employed by the model shown below. Here we employa voltage-orientedcontrol (VOC) for obtaining 3-phase system [7] to control PF and harmonics at grid side.

IV. HARMONIC DISTORTION

As we know thatharmonic distortion of the proposed converter and its voltages had been analyzedwith the help of weighted*THD* (*WTHD*). It is solved by using

$$\mathrm{WTHD}(p) = \frac{100}{a_1}\sqrt{\sum_{i=2}^{p}\left(\frac{a_i}{i}\right)^2} \quad .... \quad (33)$$

Where a_1 is treated as amplitude of fundamental voltage and$a_i$is treated as amplitude of ith harmonic and also p may be number of harmonics in this consideration.

V. FAULT COMPENSATION

At the rectifier or inverter converter stages fault compensation can be achieved by considering power converter topology and get reconfigure it by isolating devices fast active fuses—F_j, $j = 1 \ldots, 7$) and connecting devices (back to back connected SCRs—$t1$, $t2$, $t3$), as depicted in Fig.4.

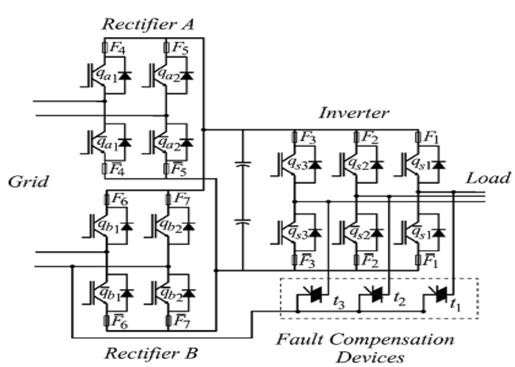

Fig.4. fault-tolerant system.

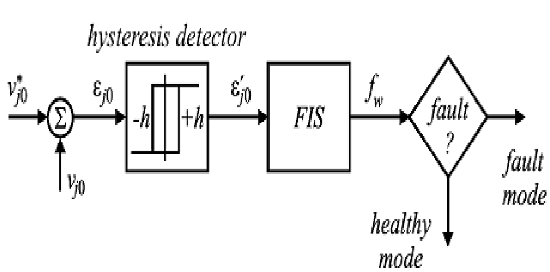

Fig. 5 fault diagnosis system.

As shown in fig.5 block diagram of fault diagnosis system consists of block fault identificationsystem (FIS) that detects and exactly locates the faulty switches in the unit,determines the leg to be isolated from the system.

VI. EXPERIMENTAL RESULTS

To study the operation of the Three-Phase Drive System, it is implemented in MATLAB/SIMULINK environment.The model is shown in Fig.6

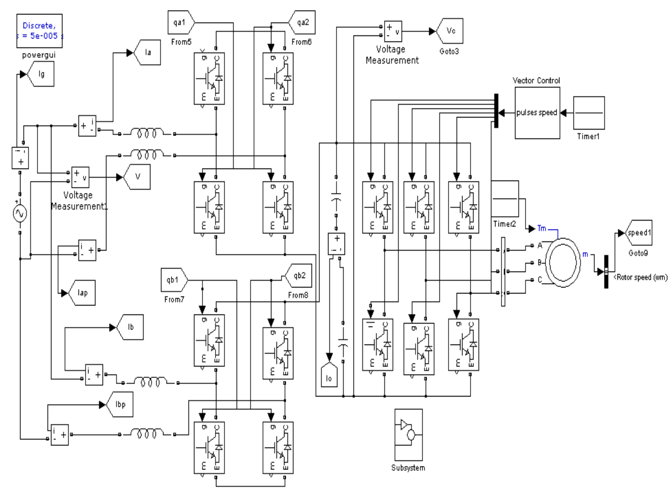

Fig. 6 Simulation Model of Single Phase to Three Phase Drive System Using Two Parallel Single Phase Rectifiers

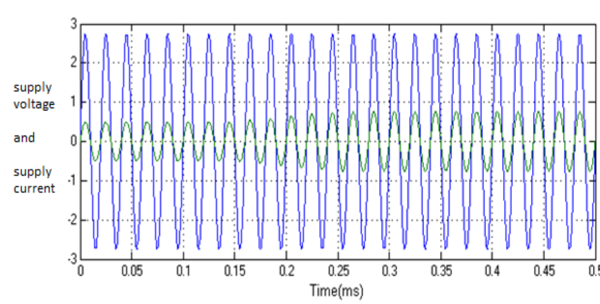

Fig. 7 (a): Supply Voltage and Current

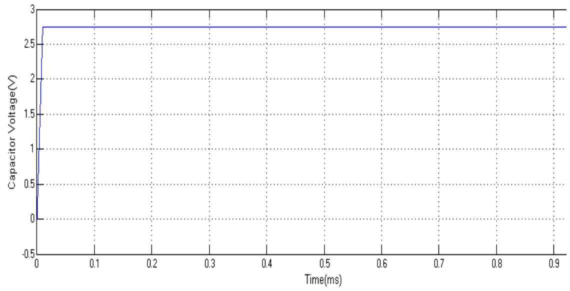

Fig. 7 (b): Capacitor Voltage

Transient means immediately after any fault (or) disturbances or abnormal conditions like 0^+, 0^- after some time it will reaches to steady state condition. Time taken of study state is 0.25 m sec in this condition we take graph between the supply voltage (volts), supply current (Amps) as a function of Time (msec).In this condition we can also check the capacitor voltage. At capacitor value is 100V.

X-axis = Time (msec), Y-axis = Capacitor voltage (volts).This graph is shown in the figure 7(b)

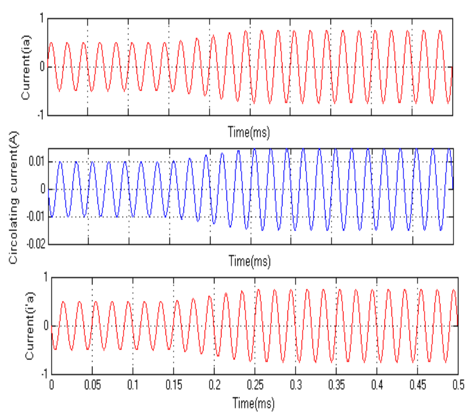

Fig.7 (c): Currents of Rectifier A (Ia and I'a) and Circulating Current

In this condition we can take rectifier A currents (Ia), (I'a) and this difference is circulating current.Rectifier A currents Ia is 4A I'a is 4A then the circulating current is ZERO.

Circulating current (io) = (Ia) - (I'a)

=4-4=0A

X-axis = Time (msec), Y-axis = Circulating current (io) current (ia) & currents (I'a). This graph is shown in the figure 7(c)

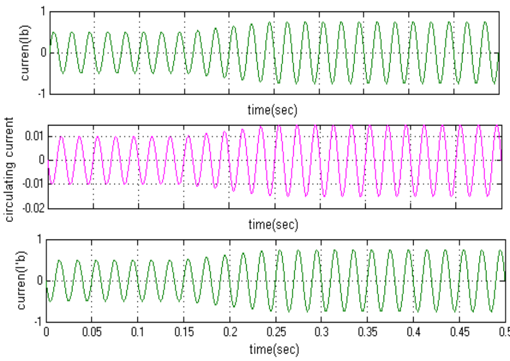

Fig.7 (d): Currents of rectifier B (Ib and I'b) and Circulating Current

In this condition we can take rectifier A currents (Ib), (I'b) and this difference is circulating current.Rrectifier B currents Ib is 1A I'b is4A then the circulating current is ZERO Circulating current (io) = (Ib) - (I'b) = 4-4 = 0A

Simulation Results for Fault at Rectifier B

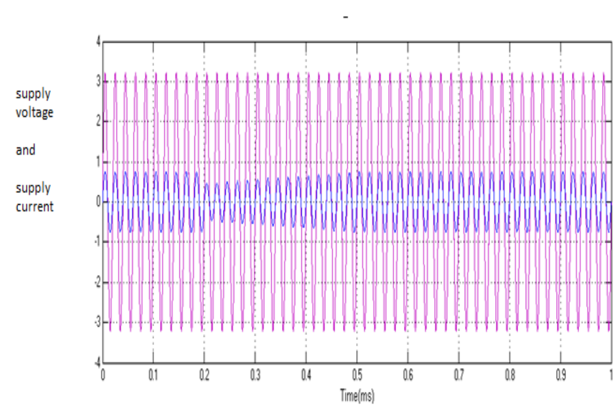

Fig. 8(a): Supply Voltage and Supply Current

Whenever a fault occurs in the rectifier B. This fault is occurs due to the misfire, because of this misfire only one time all the switches are open the it is open circuit fault all the switches are closed or short circuit fault is occurred in rectifier B .

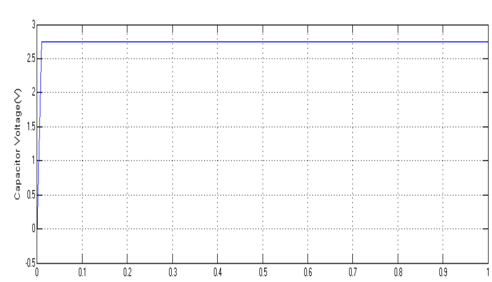

Fig .8(b): DC Link Capacitor Voltage

Here supply voltage is 110Vand supply current is 8 Amp. In that time we can take the graph between supply voltage (Volts), supply current (Amps) as a function time (msec).

In the same way fault is in the rectifier B we can also check the on DC link voltage side. Here capacitor voltage is 110V, when fault occurred rectifier b capacitor voltage decreases and again it reaches to100V.In this condition we can take rectifier A currents (ia), (i'a) and this difference is circulating current.

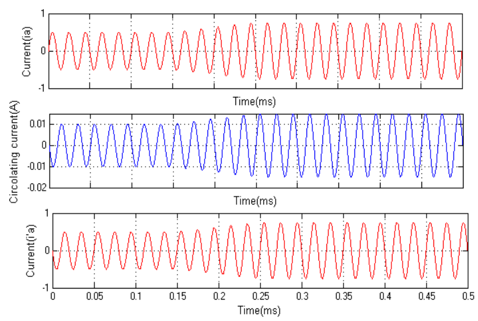

Fig 8(c): Currents of Rectifier A and Circulating Current

Rectifier A currents Ia is 4A I'a is 4A then the circulating current is ZERO

Circulating current (io) = (Ia) - (I'a)

=4-4 =0A

X-axis = Time (msec), Y-axis = Circulating current (io) current (ia) & currents (I'a). This graph is shown in the fig. 8(c)

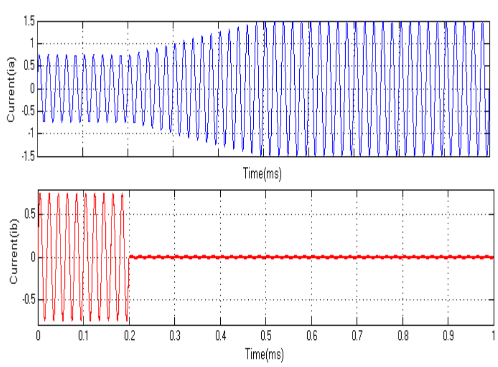

Fig 8(d): Currents of Rectifier A and B

And also check the rectifier A and rectifier B currents then here we can see the one difference of the both rectifiers, in rectifier A is continuously supply the voltage and rectifier B is not giving continuous supply because fault is occurred at rectifier B.X-axis = Time (msec), Y-axis = current of rectifier A, current of rectifier B (Amps).This graph is shown in the fig 8(d).We extended our work to have better results by adopting Fuzzy Logic Toolbox software with MATLAB technical computing software as a tool for solving problems with fuzzy logic that involves more benefits as shown in fig.9

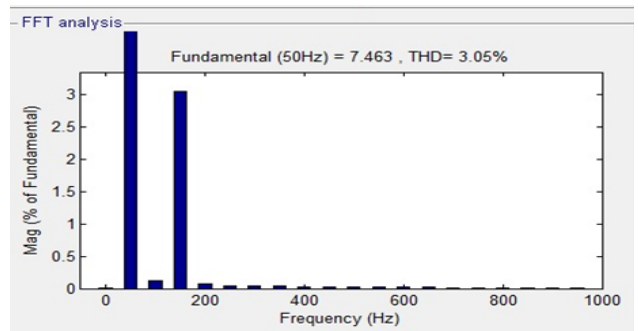

Fig.9 fuzzy based topology for optimized results

As shown in Fig.9 we observe that compared to PI controller THD has been decreased to at 3.05% as compared with pi controller.In PI controller THD was reduced to a percentail 85.2%.

VII. CONCLUSION

In our proposed scheme topology consists of combination of two rectifiers without employing transformers. From the above observations are concluded finally as follows:

i. Further reduces the switching currents,

ii. Total harmonic distortion present in the grid, and

iii. To further increases fault tolerance currents.

iv. Moreover as compared to conventional systems losses in proposed are greatly reduced to have an efficient topology.

The experimental results have proved to be systemis greatly controlled, even with transient and occurrence of faults.

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