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Pigeon Inspired Optimized PI-controller based Direct Power Control of 2-level PWM Rectifier

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***Abstract*—This paper presents Pigeon inspired optimization (PIO) based direct power control of Bidirectional 2-level pulse width modulated (PWM) rectifier. Instead of the traditional PI controller, PIO optimized controller is used in this paper to reduce the peak overshoot and ripple in active power. The Switching table based PIO algorithm optimized controller for the direct power control (DPC) is simulated in this paper. And the results indicate that the proposed optimized controller achieves excellent transient performance under unity power factor operation without abnormal instantaneous reactive power fluctuations. The total harmonic distortion (THD) in the source current obtained by the PIO is also less than the THD obtained by the conventional table-based PI controller.**

***Index Terms*—Direct power control(DPC), PWM Rectifier, Hysteresis controller, Pigeon Inspired Optimization(PIO).**

I. Introduction

In present industrial applications, Bidirectional 2-level PWM Rectifiers are playing a major role. Conventional table based PI-DPC giving more THD so in this paper PIO optimized PI-DPC is proposed to reduce the THD. The PIO optimized controllers gives the desired outputs and improve the transient response, the principle of pigeon inspired optimization controllers is given in [1]. The applications of pigeon inspired optimization controllers in power electronics and drives and battery charging explained in [1], [2], [3], [4].

In [5], [6], [7] Instantaneous power control methods for direct power control and Conventional table based PI-DPC 2-level PWM rectifier and hysteresis controller methods are given. Different types of DPC methods are in [9], [10], [11].

This paper proposes Pigeon Inspired Optimized PI controller Direct Power Control to control 2-Level Bidirectional AC/DC converter, this method is high robust in nature against load changes and it is superior in performance. It has good transient ripple free response to load variations compared to conventional DPC controller. This method satisfy all the basic properties of PWM rectifier. Simulation results of MATLAB/Simulink and comparison of both methods briefed in results section.

Rest of the paper is partitioned as follows. Section II describes PWM Rectifier model. Section III describes conventional table-based DPC with proportional integral (PI) controllers. Section IV presents the simulation results and discussions of the proposed PIO optimized PI-DPC and conventional PI-DPC. Finally, Section V concludes this paper.

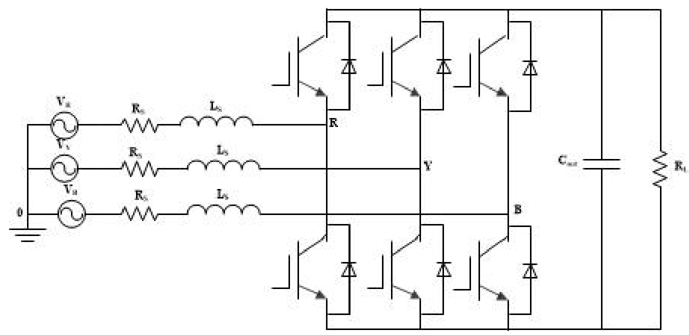


Fig. 1: Conventional topology of a 2-level PWM Rectifier.

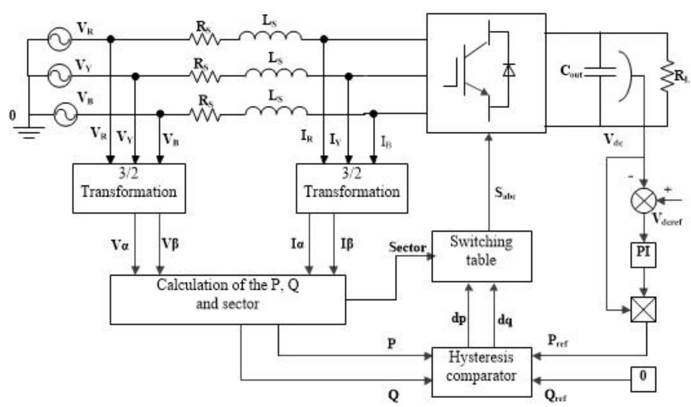


Fig. 2: Control diagram of PI-DPC PWM Rectifier.

II. PWM rectifier model

The 2-level PWM Rectifier shown in Fig.1 is taken as single line equivalent since it is balanced system.

$$V_s = I_l * R_s + I_l * jI_l * X_l + V_c \tag{1}$$

Here V_s , I_l , V_c , R_s and X_l are the source voltage, line current, converter voltage, line resistance and line reactance.

Voltages (V_R,V_Y,V_B)and Currents (I_R,I_Y,I_B) sensed from the line and then converted to α and β to calculate the insantaneous Active and Reactive power. 3/2 transformation is as follows

TABLE I: System parameters

parameter	Value
Load resistance	62 Ω
DC bus voltage	550 V
DC bus capacitor	5.2454e-3 F
Source Frequency	50 Hz
Sampling Frequency	20 kHz
Line inductance	14.8923 mH
Line resistance	0.44 Ω
AC Line voltage	220 V

$$V_\alpha = \sqrt{2/3} * [V_a - (1/2)V_b - (1/2)V_c] \quad (2)$$

$$V_\beta = \sqrt{2/3} * [(\sqrt{3}/2)V_b - (\sqrt{3}/2)V_c] \quad (3)$$

Instantaneous active and reactive power of the source is given by the .

$$P = Re[u * i^*] = u_\alpha * i_\alpha + u_\beta * i_\beta \quad (4)$$

$$Q = Im[u * i^*] = u_\beta * i_\alpha - u_\alpha * i_\beta \quad (5)$$

Here '*' is conjugate of a complex vector.

This powers given to the hysteresis controllers to compare with the hysteresis band followed by switching table given to the PWM Rectifier gates. We need to calculate the angle to identify the sector by using the following formula.

$$\varnothing = a\ tan2[u(2)/u(1)] \quad (6)$$

After calculating sector, dp and dq we give these values to switching table to generate gate pulses.

III. PROPOSED TABLE BASED PIO OPTIMIZED PI-DPC

Fig. 4 shows that the flow chart of the Pigeon Inspired Optimization process,which is similar to swarm optimization. This algorithm is developed by Duan and Qiao since it has great homing behavior.Due to this special ability this method implemented in World War II for communication purpose. The pigeons can track the way back to home with the help of the landmarks in the way, the magnetic field of earth and the sun. This behavior of pigeons has modeled as an algorithm, to find the optimized solutions.

The main operator used in PIO are the landmark operator and compass operator and the map. In d-dimensional space,pigeons generated with some velocity and the position initially. Then for all pigeons fitness function is calculated and finally the best of all is called global best(G_{best}). All other pigeons adjusts their own compass and map operators. The velocity function of this PIO method is given by,

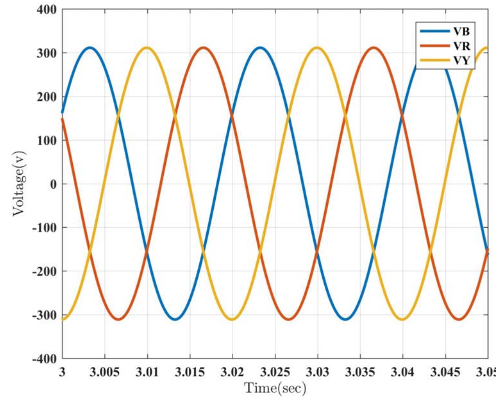
$$v(i,j) = v(i,j) * exp(-R * iter) + rand * (Lg(j) - L(i,j)) \quad (7)$$

The objective function used to find the optimized PI values for PI controller is given by

$$P(i) = (max(Vdc1)) - 550 \quad (8)$$

the constraints are

$$if\ P(i) < 0;\ P(i) = Pmax \quad (9)$$



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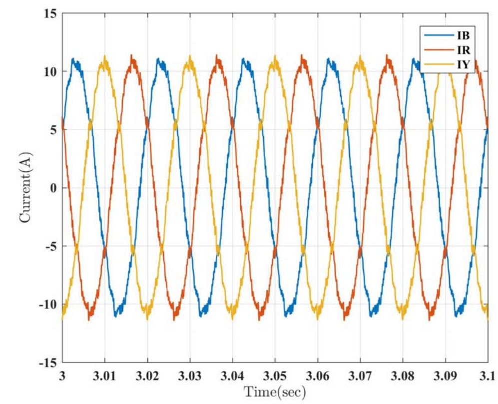

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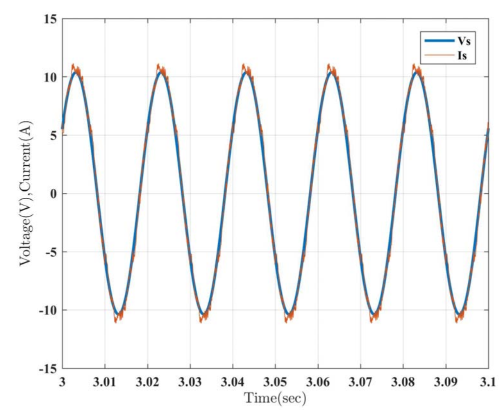


(c)

Fig. 3: Conventional PI-DPC results (a)3-ϕ supply voltages(V_{RYB}) (b)3-ϕ supply currents(I_{RYB}) (c)Phase voltage and current at load of 4750W.

$$if\ P(i) >= Pmax;\ P(i) = Pmax \quad (10)$$

$$if\ P(i) <= Pmin;\ P(i) = Pmin \quad (11)$$

The optimized PI values after running this algorithm is P=0.04281, I=0.31358. These PI values used in the simulation to get desired output.

TABLE II: Conventional switching table for direct instantaneous power control

d_p	d_q	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7	θ_8	θ_9	θ_{10}	θ_{11}	θ_{12}
1	1	7	7	0	0	7	7	0	0	7	7	0	0
1	0	6	7	1	0	2	7	0	3	7	4	0	5
0	1	1	2	2	3	3	4	4	5	5	6	6	1
0	0	6	1	1	2	2	3	3	4	4	5	5	6

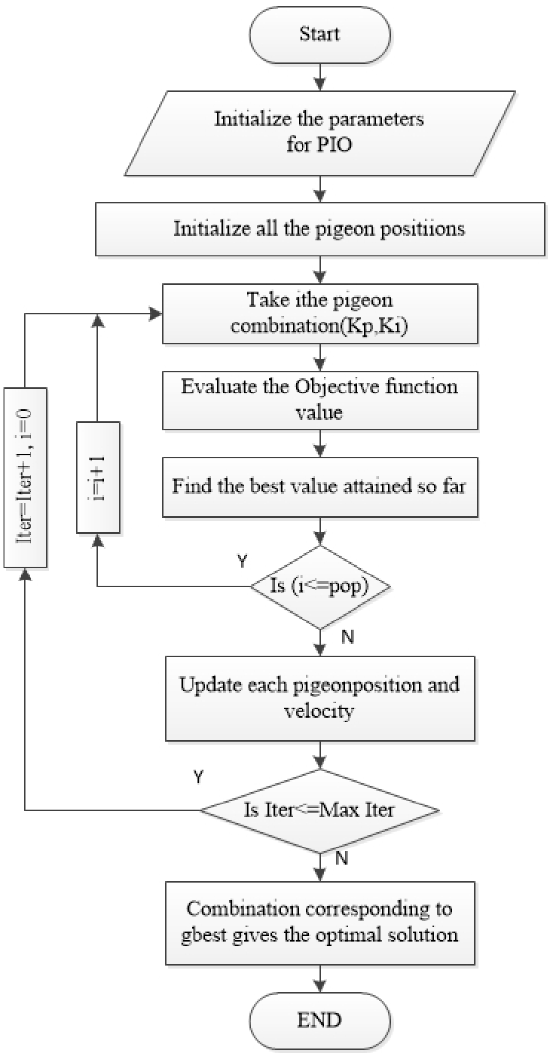


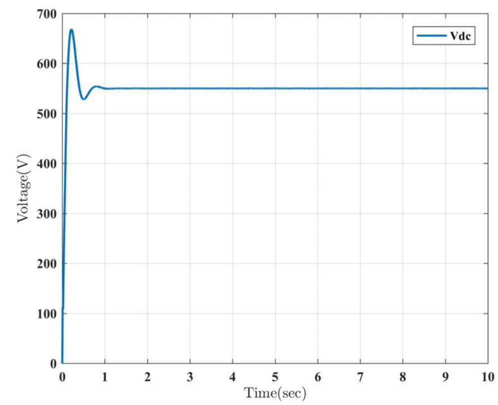
Fig. 4: Flow chart of PIO strategy.

IV. Simulation Results and discussion

A. Simulation results

Fig. 2 represents the conventional table-based PI controller circuit diagram, this PI controller is replaced by PIO optimized PI controller in proposed topology. Table.I show the system parameters and control parameters used in simulations and control diagram.

Fig. 3 and Fig. 5 shows the results of the proposed pigeon inspired optimization PI-controller under load of 4750w. The transient responce of this DC-link volatge is improved by the proposed method. The waveforms from top to bottom are



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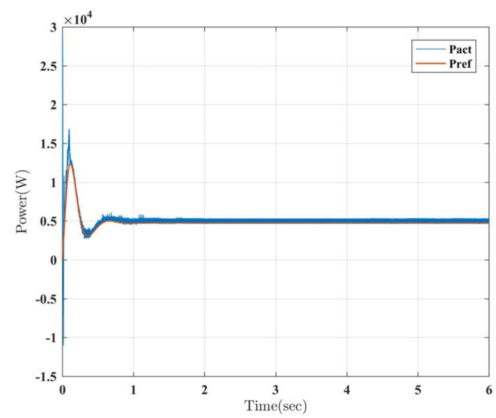

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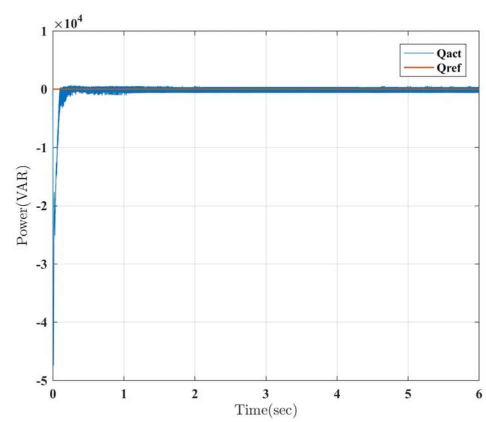

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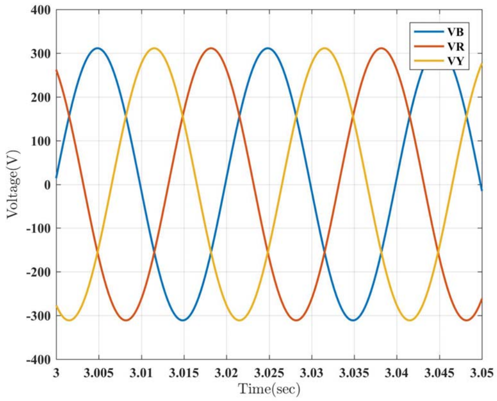
Fig. 5: Conventional PI-DPC results (a)DC-link voltage(V_{dc}) (b)Watt-full power(P) (c)Watt less power(Q) at load of 4750W.



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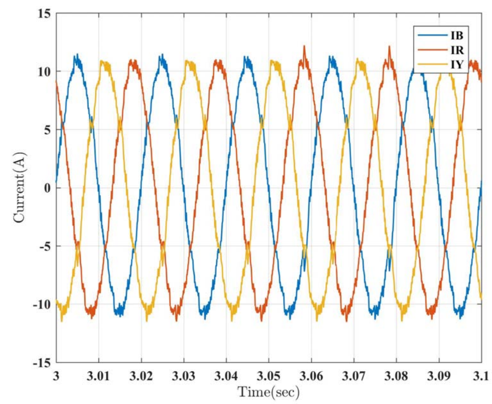

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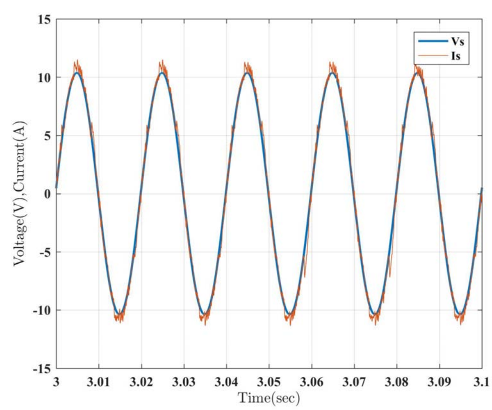

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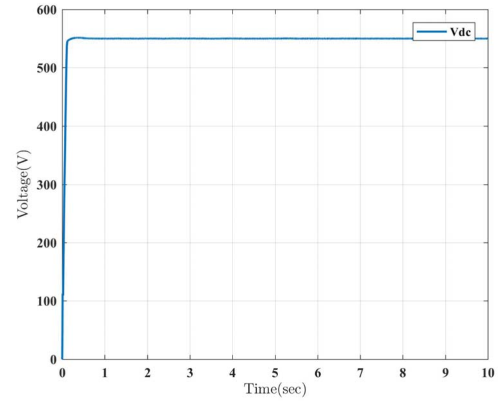
Fig. 6: Conventional PIO optimized PI-DPC results (a)3-ϕ supply voltages(V_{RYB}) (b)3-ϕ supply currents(I_{RYB}) (c)Phase voltage and current at load of 4750W.



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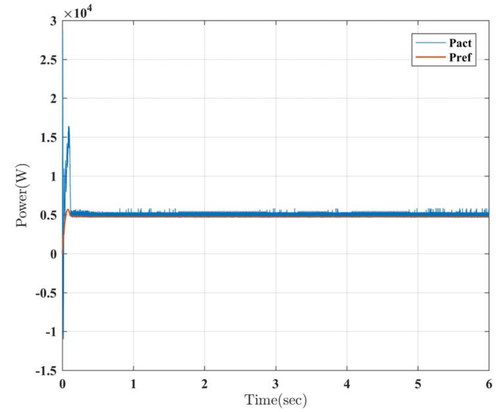

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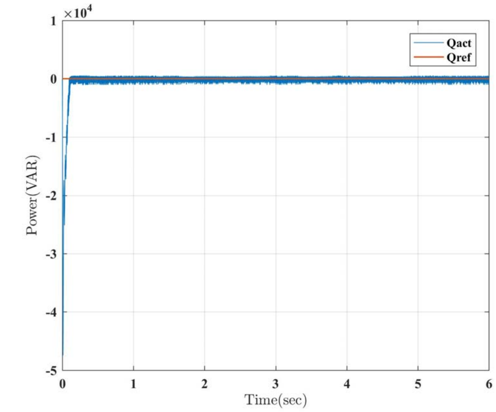

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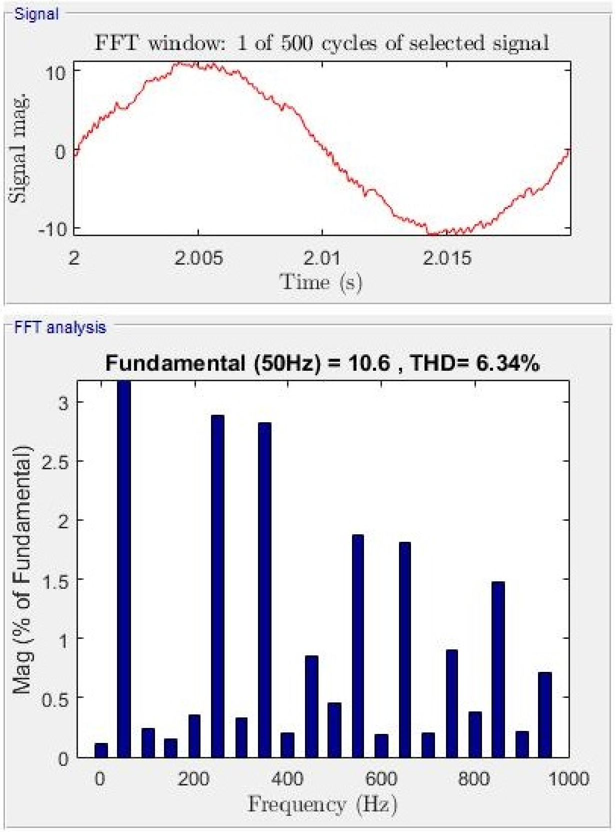
Fig. 7: Conventional PIO optimized PI-DPC results (a)DC-link voltage(V_{dc}) (b)Watt-full power(P) (c)Watt less power(Q) at load of 4750W.



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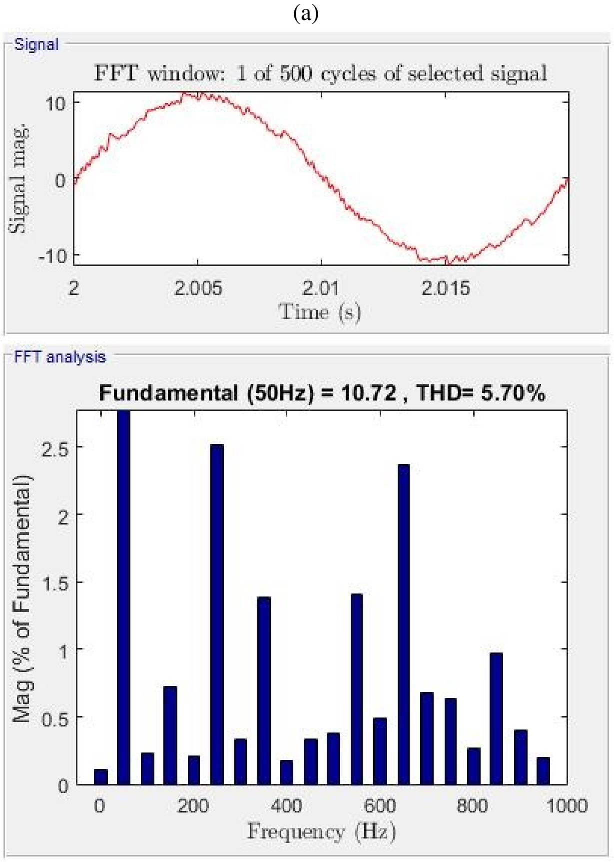

(b)

Fig. 8: Harmonic spectrum of line current Conventional table based (a)PI-DPC (b)PIO optimized PI-DPC.

line voltages, line currents, phase voltage & current, DC-link voltage, watt-full power and watt less power respectively.
Fig. 6 and Fig. 7 shows the results of the proposed PIO optimized PI-DPC PWM Rectifier under load of 4750w. The waveforms from top to bottom are line voltages, line currents, phase voltage & current, DC-link voltage, watt-full power and watt less power respectively. Switching table represented in the table.II is same for both methods and the switching frequency also same in both methods i.e 20 KHz. From the waveforms, it is clear that there is no effect on reactive power, but there is a change in active power at transient response in PIO optimized PI-controller method. In proposed PIO optimized PI controller method the transient response is very smooth, whereas in conventional PI method ripples present in DC-link voltage.

Finally Fig. 8 further shows the THD spectrum of the line current for the conventional table based PI controller-DPC and the proposed PIO optimized PI-DPC under load of 4750w. It is seen that the line current is some what more contorted and the current THD is up to 6.34% in the conventional PI-DPC. For the proposed PIO optimized PI-DPC, the current harmonic spectrum is reduced to some extent, and the current THD is 5.7% as shown in the results. The results of both the methods confirm the effectiveness of proposed controller under load of 4750w.

B. Comparisons

Both the methods are simple and more or less both are using same control circuit diagram. By observing both the results, it shows that both the methods more or less have same operation but THD is somewhat less in proposed PIO-DPC. In both the methods the power factor of source current is unity and source voltages sinusoidal in nature. In proposed method output DC-link voltage is smooth in the transient state so active power also smooth in nature in the transient state and reactive power is zero in both the cases. But in actual reactive power, some ripples present in both the methods compare with reference.

V. Conclusion

This paper PIO based DPC control method has been proposed. The results show that the smooth transient response in output DC voltage and the following requirements of PWM Rectifier is achieved.
1) Unity Power Factor in line current.
2) DC-Link voltage control is achieved.
3) Bidirectional Power flow is achieved.
4) The THD of the proposed method is less compare with conventional table-based PI-DPC.

A comparative study of the conventional table-based PI-DPC and PIO-DPC is carried out on a 2-level PWM AC/DC converter. The simulation results of MATLAB/SIMULINK confirm that the superiority of the proposed method.

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