International Journal of Soft Computing and Engineering (IJSCE)
ISSN: 2231-2307, Volume-3, Issue-2, May 2013

A Novel Direct Power Control of 3phase Induction Multi Motor Drive with AFF

S. Elangovan, K. Thanushkodi

Abstract*— *Direct Power Control (DPC) of three phase PWM rectifiers without line voltage sensors and based on Virtual flux estimation is presented. In this paper, the compensation of neighboring nonlinear power load is proposed. The active filtering function enlarges the functionality of PWM rectifiers, which decreases the cost of additional installation of compensating equipment. It gives a chance to fulfill both shunt active power filter and PWM rectifier tasks in a multimotor drive system by one advanced PWM rectifier. The Direct Power Control Space Vector modulated (DPC-SVM) and new Synchronous Double Reference Frame Phase locked Loop (SDRF-PLL) approach, made the control system resistant to a majority of line voltage disturbances and also it allow a constant switching frequency of the converters, leading to least switching losses. This assures proper operation of the system for abnormal and failure grid conditions. Simulation results have proven excellent performance and verify the validity of the proposed system.

Index Terms*— *Active filtering function, Direct Power Control, SDRF, Space vector modulation.

I. INTRODUCTION

Harmonics related problems in utility are a result of usage equipments like a diode or thyristor rectifiers, which takes non sinusoidal currents from the grid. Several solutions to eliminate pollution problems have been developed. They are an answer for more and more restricted norms, which intend to limit the harmonic current of power electronic converters. Active power filters and PWM rectifiers are two typical examples of these methods. Both of them have basically the same circuit configuration and can operate based on the same control principle. Active filters are able to compensate not only current harmonics, but also a reactive power and unbalance of load and source. The use of virtual flux(VF) signal for power estimation leads to the following advantages of the system comparing to the conventional DPC: lower sampling frequency, simple voltage and power estimation algorithm, easy implementation of the unbalanced and distorted line voltage compensation to obtain sinusoidal line currents (low THD), excellent dynamics.

This paper explores another task of PWM rectifier –active filtering function, which intends to connect advantages of active filters and PWM rectifiers. So, the PWM rectifier supplies its load and at the same time compensates AC line current (Fig.1). The virtual flux based DPC [1],[5],[6]with Space Vector Modulator (SVM) [12] is applied to control the PWM rectifier.

Manuscript received on May,2013

S. Elangovan, Dept. of Electrical and Electronics Engineering, Akshaya College of Engineering and Technology, Coimbatore, India.

Dr.K. Thanushkodi, Director, Akshaya College of Engineering and Technology, Coimbatore, India.

For the sake of similarity of both converters (regarding topology and control algorithm), an interesting configuration for a multimotor drive system, presented in this paper, is the application of the PWM converter with small modifications, which fulfills both the SAF and PWM rectifier tasks(Fig.1). This fact can decrease the number modern ac-dc-ac converters, which fulfill existing current harmonic standards for the whole system.

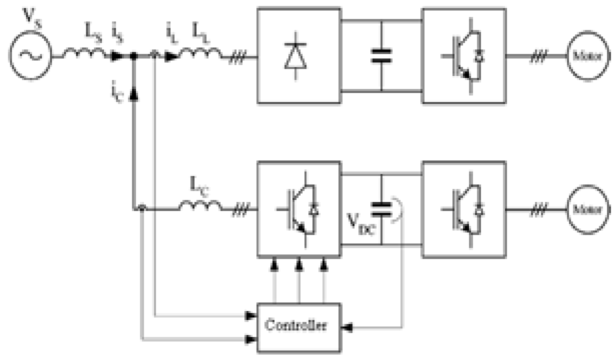

Fig.1. The proposed structure of a “clean” multimotor drive setup

II. CONTROL OF PWM RECTIFIER WITH AFF

A. DPC - SVM

The full control algorithm of the PWM rectifier with AFF is presented in Fig.2. The DPC –SVM uses closed loop power control. The commanded reactive power q_{c_ref} (set to zero for UPF operation) and active power p_{c_ref} values (derived from the outer PI dc voltage controller) are compared with the estimated p_c and q_c values respectively, where estimated powers can be described from the following formulae:

$$p_c = \omega\left(\Psi_{s\alpha} i_{c\beta} - \Psi_{s\beta} i_{c\alpha}\right) \quad (1)$$

$$q_c = \omega\left(\Psi_{s\alpha} i_{c\alpha} - \Psi_{s\beta} i_{c\beta}\right) \quad (2)$$

Errors are delivered to the PI controllers, which eliminate steady-state error and finally generates output signals V_{cd}, V_{cq} after transformation from a synchronous rotating dq to stationary αβ coordinate system, are used for switching signals generation by a SVM. Powers of nonlinear load p_L and q_L [1] – [4] are estimated using information about currents($i_{L\alpha}$ and $i_{L\beta}$) and VF ($\Psi_{s\alpha}$, $\Psi_{s\beta}$)[7],[9]. The calculated active power is delivered to the high pass filter (HPF) to obtain the alternate values, which finally are used as compensating components. The reactive power can be delivered to HPF or directly to the input of the PI controller (Switch S1) depending on compensation requirements or compensation of higher harmonics and reactive power at the same time, respectively.

Simulation results of PWM rectifier operation with AFF and without AFF as shown in Fig.3 at the distorted by 5% of the 5th harmonic line voltage for rectifying and regenerative mode. Under Active filtering function operation, the line current ($i_{s\alpha}$) becomes almost sinusoidal as well as in phase with line-line voltage ($V_{s\alpha}$), which gives near to unity power factor. In this case, the current of converter ($i_{c\alpha}$) is distorted to compensate current harmonics of the nonlinear load($i_{L\alpha}$). The THD is also no larger than 2%.

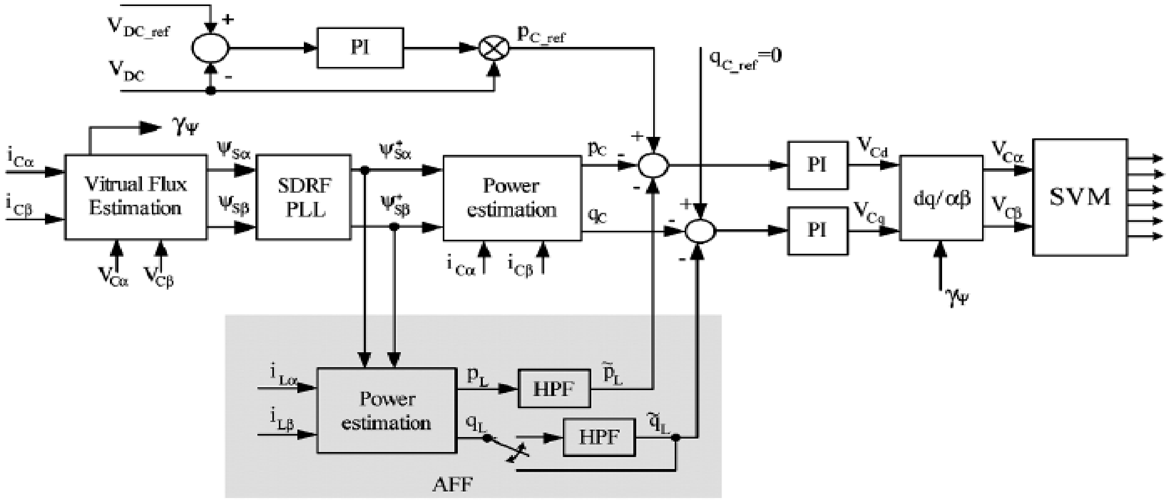

Fig.2. Control Algorithm

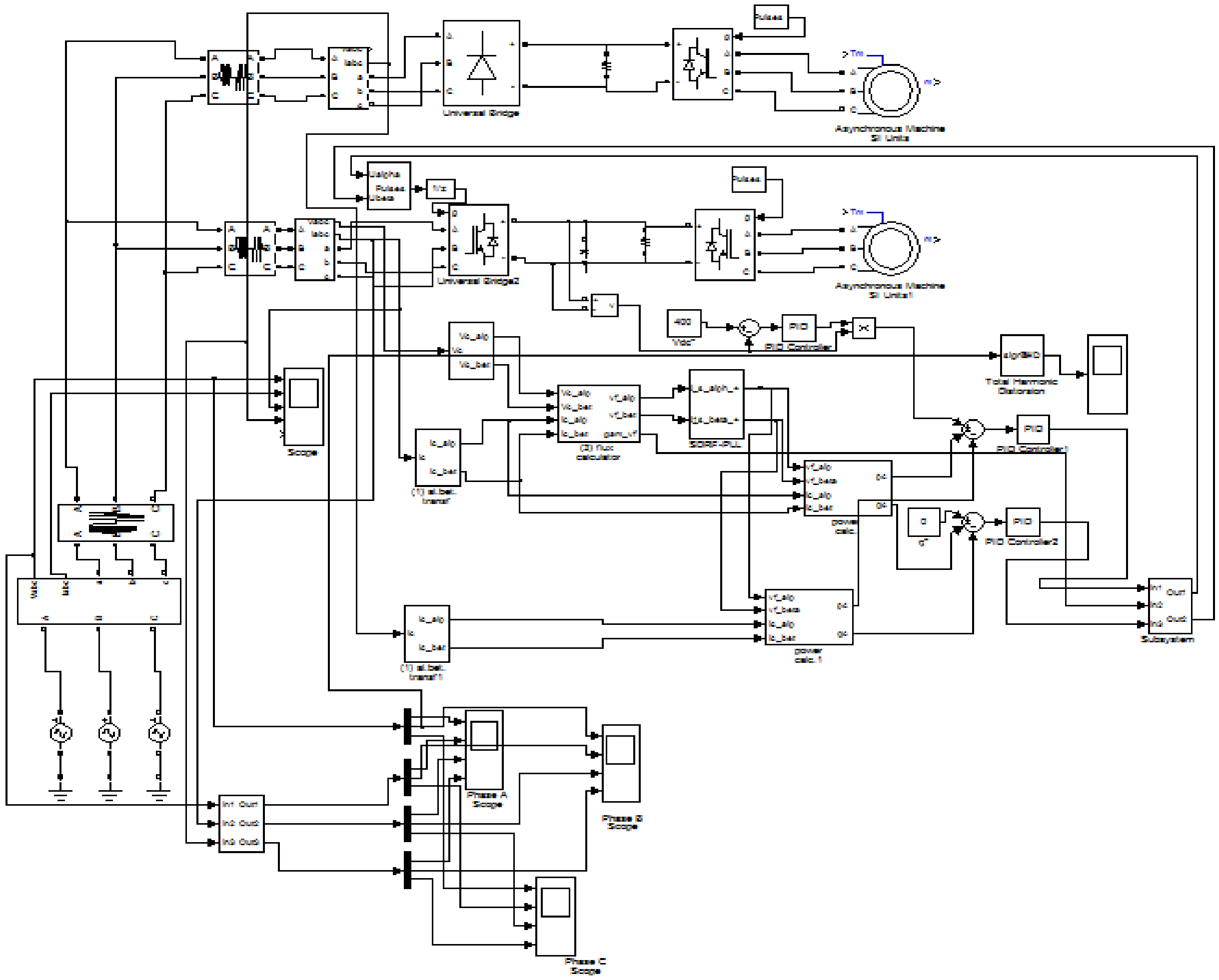

Fig.3 Simulation diagram of Active Filtering Function of PWM Rectifier

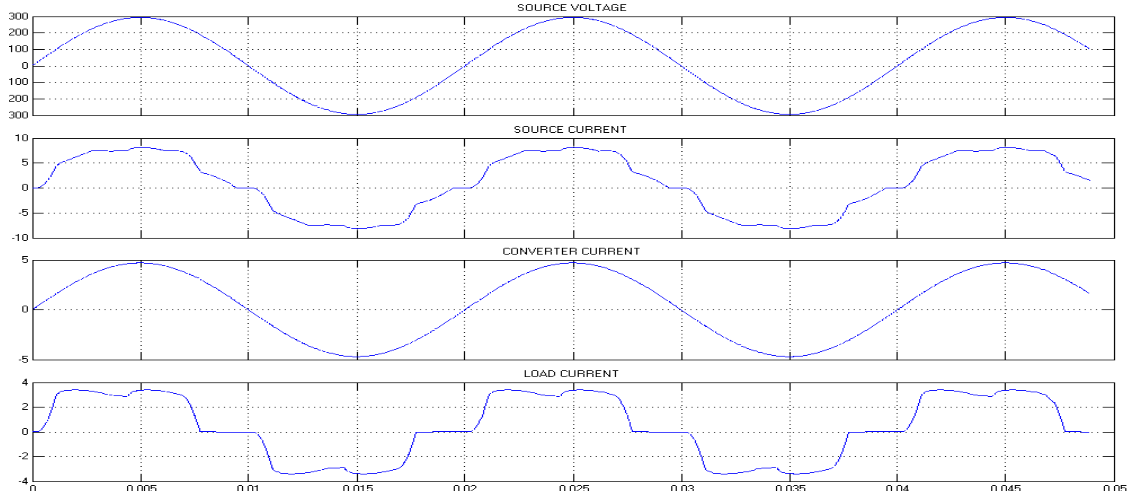

Fig. 4. Simulation results for PWM rectifier without AFF

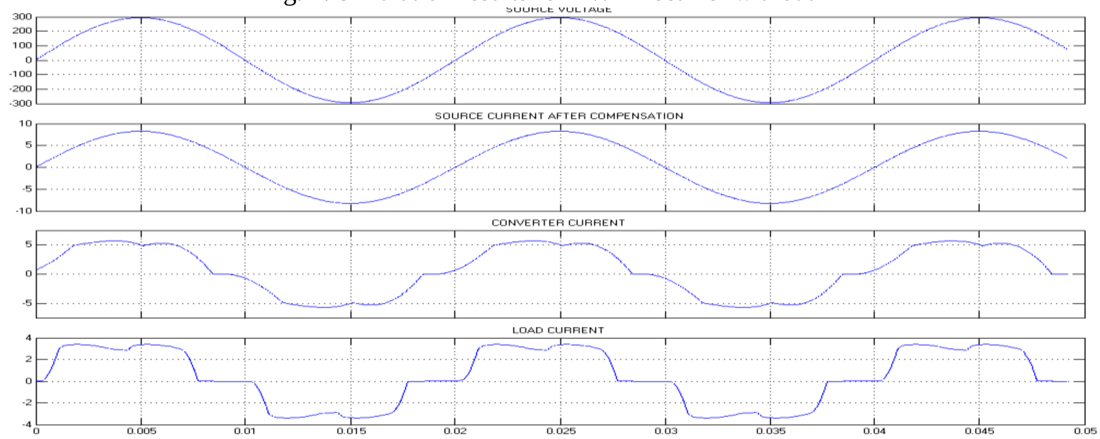

Fig. 5. Phase 'A' Scope for operation of PWM rectifier with AFF

B. SDRF – PLL

Positive sequence VF detection is a crucial matter in connection of the boost rectifier to the grid. When the utility frequency is known, the method of instantaneous symmetrical components is commonly used. In certain applications, such as wind generation, the utility frequency can change significantly. In this case, a PLL based on a SDRF – PLL is usually used. This technique is efficient when the utility voltages are present. To solve this problem, a PLL based on a synchronous double frame (SDRF – PLL) is used in this paper. When the utility voltage is unbalanced, the VF estimated can be expressed on the αβ double reference frame as in equation (2).

The virtual flux is expressed on the double reference frame shown in Fig.4.

$$\Psi^s_{\alpha\beta} = \Psi^+_s + \Psi^-_s = |\Psi^+_s| \begin{bmatrix}\cos(\gamma\Psi s)\\ \sin(\gamma\Psi s)\end{bmatrix} + |\Psi^-_s| \begin{bmatrix}\cos(\gamma\Psi s)\\ -\sin(\gamma\Psi s)\end{bmatrix} \quad (2)$$

In this double reference frame, the d^+ axis is synchronized with Ψ_s^+, and the d^+ axis is synchronized with Ψ_s^+. The expressions of Ψ_s on these reference frames are,

$$\Psi^+_{dq} = \begin{bmatrix}\Psi^+_{sd}\\ \Psi^+_{sq}\end{bmatrix} = [T^+_{dq}]\Psi^s_{\alpha\beta}$$

$$\Psi^-_{dq} = \begin{bmatrix}\Psi^-_{sd}\\ \Psi^-_{sq}\end{bmatrix} = [T^-_{dq}]\Psi^s_{\alpha\beta} \quad (3)$$

$$[T^+_{dq}] = \begin{bmatrix}\cos(\gamma'\Psi s) & \sin(\gamma'\Psi s)\\ -\sin(\gamma'\Psi s) & \cos(\gamma'\Psi s)\end{bmatrix} \quad (4)$$

$$[T^-_{dq}] = \begin{bmatrix}\cos(\gamma'\Psi s) & -\sin(\gamma'\Psi s)\\ \sin(\gamma'\Psi s) & \cos(\gamma'\Psi s)\end{bmatrix} \quad (5)$$

The PI controller in conventional three phase PLL is tuned, and then the flux components of (3) can be approximated as shown in (6) – (9)

$$\Psi^+_{sd} \approx |\Psi^+_s| + |\Psi^-_s|\cos(2\gamma'_{\Psi s}) \quad (6)$$

$$\Psi^+_{sq} \approx |\Psi^+_s|(\gamma_{\Psi s} - \gamma'_{\Psi s}) + |\Psi^-_s|\sin(-2\gamma'_{\Psi s}) \quad (7)$$

$$\Psi^-_{sd} \approx |\Psi^-_s| + |\Psi^+_s|\cos(-2\gamma'_{\Psi s}) \quad (8)$$

$$\Psi^-_{sq} \approx -|\Psi^-_s|(\gamma_{\Psi s} - \gamma'_{\Psi s}) - |\Psi^+_s|\sin(-2\gamma'_{\Psi s}) \quad (9)$$

Positive and negative sequence fluxes could be obtained by means of a Low pass filter (LPF), but a very low cutoff frequency would be necessary since these fluxes oscillate at twice the utility frequency. In order to achieve a precise and fast response, the amplitude detector shown in Fig.4 is proposed. As (7) shows, the input signal to the PI controller presents an oscillation at 2ω frequency and amplitude of Ψ_s. Therefore, the control loop is modified according to Fig.6 in order to eliminate this perturbation in the input of the PI controller.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Consequently, the bandwidth of the system can be enlarged and a better dynamic behavior is obtained.

Once the magnitude and the phase of the positive sequence VF vector are exactly known, its α-β components are reconstructed as shown in Fig.4.

The simulation diagram for the system with two induction motor loads connected to the same source through two different ac-dc-ac converter is shown in the Fig.3. From the simulation diagram, it is very clear that the additional shunt active filter is not used, instead, the converter used for the second drive is connected with the control circuit of Active filtering function.

Fig.3 shows the waveforms of the source voltage, source current, converter current and load current of system without implementing the Active filtering function. In this the waveform of source current is non sinusoidal due to the presence of power electronics loads. Fig.4 shows the waveforms of the system after implementing the Active filtering function. From the waveforms, it is clearly shown that, the source current is very close to the sinusoidal waveform i.e., the source current is getting compensated for all the harmonics.

By reducing the number of converter circuits the switching losses, overall cost of the system is reduced. The control system uses direct power control with Space vector modulation is used. The use of newly introduced Synchronous double reference frame PLL will enable the system performance with any kind of voltage disturbance in the source. The concept of the same is explained in the next section.

III. OPERATION UNDER LINE VOLTAGE DISTORTIONS

The power quality problems can be demonstrated as non-standard voltage and current or frequency deviation. The most common line voltage problems can be summarized as follows:

- ✓ Voltage sag
- ✓ Voltage swell
- ✓ Harmonics

The system also will show the satisfied performance with all the above mentioned line voltage distortions. The source current will be compensated even there is line voltage distortions.

IV. CONCLUSION

The PWM rectifier with filtering function is a highly attractive application in a multidrive system. The small power reserve of the PWM rectifier allows for compensation at the same time of other neighboring nonlinear loads. The presented solution posses following features and advantages:

- ✓ Ac line voltage sensor-less operation
- ✓ The noise resistant power estimation algorithm is easy to implement in DSP
- ✓ It has a lower sampling frequency
- ✓ Coordinate transformation and decoupling between active and reactive current is not required
- ✓ No current regulation loops are required
- ✓ It offers low THD
- ✓ Constant switching frequency
- ✓ Robustness to majority of the line voltage disturbances

REFERENCES

[1] T. Kataoka, Y. Fuse, D. Nakeajima, and S. Nishikata, "A three phase voltage type PWM rectifier with the function of an active power filter", Power Electron. Variable speed drives, pp.386-391, Sep.2000.

[2] M. Malinowski, M.P. Kazmierkowski, "Simple direct power control of three phase PWM rectifier using space vector modulation(DPC-SVM)", IEEE Trans. Industrial Electronics, Vol.51, No.2, Apr 2004,pp.447-454.

[3] H. Akagi, "New trends in active filters for power conditioning", IEEE Trans. Industrial Application, Vol.32, No.6, pp.1312-1332, Nov./Dec. 1996.

[4] F.Z. Peng,"Application issues of active power filters", IEEE Industrial Application magazine, Vol.4, no.5, pp.21-30, Sep/Oct.1998.

[5] F. Abrahamsen and A. David, "Adjustable speed drive with active filter capability for harmonic current compensations" in Proc.IEEE PESC'95,1995, pp.1137-1143.

[6] M. Malinowski, M.P. Kazmierkowski, S. Hansen, F. Blaabjerg and G.D. Marques,"Virtual flux based direct power control of three phase PWM rectifiers", IEEE Trans. Ind. Applications, Vol.37, no.4, pp,1019-1027, Jul/Aug.2001.

[7] M. Malinowski, G. Marques, M. Chichowlas, and M.P. Kazmierkowski, "New direct power control of three phase PWM boost rectifiers under distorted and imbalanced line voltage conditions", In proc. IEEE ISIE'03. Rio de Jeneiro, Brazil, 2003, CD ROM.

[8] A. Ghosh and A. Joshi, "a new algorithm for the generation of reference voltages of a DVR using the method of instantaneous symmetrical components", IEEE power Eng. Rev., Vol2, no.1, pp. 63-65. Jan 2002.

[9] S. Bhattacharya and D. Divan, "Active filter solutions for utility interface of industrial loads", In proc. Int. Conf. Drives and Energy Systems for Industrial growth, vol.2, Jan 8-11, 1996, pp.1078-1084.

[10] J.A. Oliver, R. Lawrence and B.B. Banerjeee, "How to specify power quality – tolerant process equipment", IEEE Ind. Appl. Mag., vol.8, no.5, pp.21-30, Sep/Oct.2002.

[11] M.P. Kazmierkowski, R. Krishnan and F. Blaabjerg, "control in power electronics. New York; Academic 2002.

[12] P. Rodriguesz, J, Bergas, and L. Sainz , "New PLL approach considering unbalanced line voltage condition" in Proc. IEEE Int. conf. Power and Energy systems, June 2002, pp.329-334.

[13] M. Cichowlas, M. Malinowski, M.P. Kazmierkowski, and F. Blaabejerg, "Direct power control for three phase PWM rectifier with active filtering function", in Proc. IEEE APEC'03, Miami beach, FL, Feb.9-13,2003, CD ROM.

[14] S. Chung, "A phase tracking system for three phase utility interface inverters", IEEE Trans. Power Electronics, Vol15, no.3, pp.431-438. May 2000.

S. Elangovan born in 1978 at Panruti, Tamilnadu. He received his B.E. degree from University of Madras in 1999 and M.E. degree from Government College of Technology, Coimbatore in 2006 and currently he is doing his Ph.D. at Anna University.

He is an Associate Professor in the department of electrical and electronics engineering at Akshaya College of Engineering and Technology, Coimbatore, Tamilnadu, India. His research area includes Direct torque control, Direct power control, shunt active filter, control of electrical drives, modern controllers, digital controllers for electrical machines etc.,

Dr.K. Thanushkodi received his B.E. degree in Electrical and Electronics Engineering from College of Engineering, Guindy in the year1972. He has received M.Sc. (Engg.) degree from PSG College of Technology, Coimbatore in the year1974. He has received PhD degree in Power Electronics from Bharathiyar University in the year 1991. Presently he is the Director of Akshaya College of Engineering and Technology, Coimbatore and he is a former Syndicate Member, Anna University of Technology, Coimbatore. His research interests are Power Electronics Drives, Electrical Machines, Power Systems, and Soft Computing techniques, Computer Networks, Image Processing and Virtual Instrumentation.