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Mitigation of Harmonics by Three-Phase Voltage Source PWM Rectifier

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Abstract- This paper is concerned with the design and simulation of a pulse width modulation (PWM) rectifier for three-phase Permanent Magnetic motor drive. Based on the mathematical model of PWM rectifier, the dual-close-loop engineering design with decoupled feed-forward control is applied in the 3-phase voltage source rectifier. The objective to be reached is to realize unity power factor at the input ac mains and regulate output voltage. The paper resents the MATLAB/SIMULINK simulation model. The results confirm the validity of the model and its control method.

Index Terms- PWM rectifier, unity power factor, decoupled feed-forward control

I. Introduction

Power electronics equipments become more widely used. Unfortunately, the standard diode/Thyristor bridge rectifiers at the input side cause several problems as: Low input power factor, high values of harmonic distortion of ac line currents, and harmonic pollution on the grid. In recent years, the research interest in the area of PWM rectifiers has grown rapidly [1] [2].

The PWM rectifier offers several advantages such as: control of DC bus voltage, bi-directional power flow, unity power factor, and sinusoidal line current. Many pulse-width modulation (PWM) techniques have been adopted for these rectification devices to improve the input power factor and shape the input current of the rectifier into sinusoidal waveform. The phase and amplitude control (PAC) seems to be the most simple structure and provides a good switching pattern, but the dc offset on input current of the rectifier during transient state deteriorates the control system stability. The current regulating fashion in synchronous frame has the advantages of fast dynamic current response, good accuracy, fixed switching frequency and less sensitive to parameter variations [3].

In actual implementations, the direct current control scheme is widely adopted. Various control strategies have been proposed to regulate the dc bus voltage while improving the quality of the input ac current in direct current control scheme [4]. The traditional control strategies establish two loops: a line current inner loop of power factor compensation and an output voltage outer loop for voltage regulation. In this paper, the design method and controller model based on direct current control are analyzed.

This paper briefly reviews the principles and the topologies of 3-phase PWM rectifier, gives a dualclose-loop design method of system controller. The control strategy is proved feasibility by MATLAB/SIMULINK simulation with different loads.

II. Three phase Voltage source PWM rectifier model

Figure 1 shows the circuit diagram of the three-phase voltage source rectifier structure. In order to set up math model, it is assumed that the AC voltage is a balanced three phase supply, the filter reactor is linear, IGBT is ideal switch and lossless [5]. Where ua , ub and uc are the phase voltages of three phase balanced voltage source, and ia , ib and ic are phase currents, vdc is the DC output voltage, R1 and L mean resistance and inductance of filter reactor, respectively, C is smoothing capacitor across the dc bus, RL is the DC side load, ura , urb , and urc , are the input voltages of rectifier, and iL is load current.

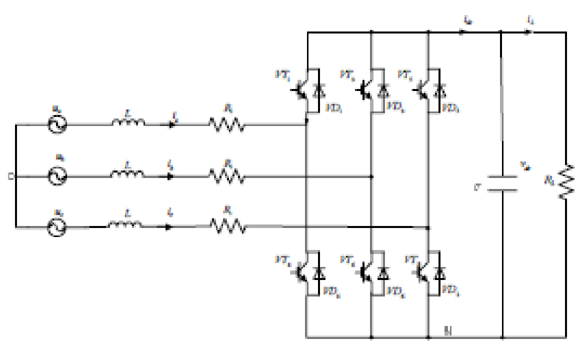

Figure 1: Circuit schematic of three-phase two-level boost-type rectifier

The following equations describe the dynamical behavior of the boost type rectifier in Park coordinated or in d-q:

$$\begin{cases} L\dfrac{di_d}{dt} = u_d - i_d R_1 + \omega L i_q - u_{rd} \\ L\dfrac{di_q}{dt} = u_q - i_q R_1 - \omega L i_d - u_{rq} \\ C\dfrac{dV_{dc}}{dt} = -\dfrac{V_{dc}}{R_L} + \dfrac{3}{2}(S_d i_d + S_q i_q) \end{cases} \qquad (1)$$

Where, urd = Sd Vdc , urq = Sq Vdc , urd , urq and Sd ,Sq are input voltage of rectifier, switch function in synchronous rotating d-q coordinate, respectively. ud ,uq and id , iq are

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voltage source, current in synchronous rotating d-q coordinate, respectively. □□is angular frequency.

2.1. Design of current loop

It is seen from (1) that mutual interference exists in the d-q current control loops. The voltage decouplers are therefore designed to decouple the current control loops and suitable feed forward control components of source voltages are also added to speed up current responses. The d–q current control loop of the rectifier in the proposed system is shown in Figure 2 Where the d – q voltage commands can be expressed as

$$\begin{cases} u_{rd} = -u'_{rd} + \omega L i_q + u_d \\ u_{rq} = -u'_{rq} + \omega L i_d + u_q \end{cases} \quad (2)$$

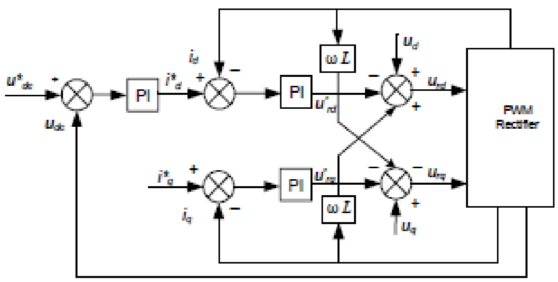

Figure 2: Control block diagram of d-q dual-close-loop controller of the rectifier

Let us take into account this assumption in (1) and get the following equations:

$$\begin{cases} L\dfrac{di_d}{dt} = -i_d R_1 + u'_{rd} \\ L\dfrac{di_q}{dt} = -i_q R_1 + u'_{rq} \end{cases} \quad (3)$$

The simple proportional-integral (PI) controllers are adopted in the current regulation; urd and urq are controlled by the following expression:

$$\begin{cases} u_{rd} = -(K_{ip} + \dfrac{K_{iI}}{s})(i^*_d - i_d) + \omega L i_q + u_d \\ u_{rq} = -(K_{ip} + \dfrac{K_{iI}}{s})(i^*_q - i_q) + \omega L i_d + u_q \end{cases} \quad (4)$$

Assume that the d–q voltage commands are not saturated for linear operation of PWM modulation and the d–q current control loops have been fully decoupled. For d-axis current control loop, the structure can be simplified to Figure 3.

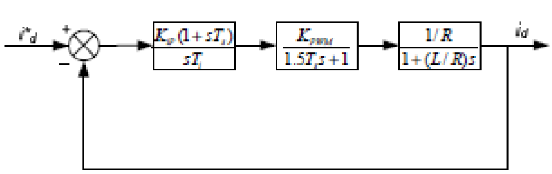

Figure 3: Equivalent control block diagram of the d–q current control loop

When the current responses speed is concerned, the current regulator can be designed as the typical Ⅰ model system. For pole-zero cancellation, take Ti = L / R . The open-loop current transfer function can be expressed as

$$W_i(s) = \frac{K_{iP} K_{PWM}}{RT_i s(1.5T_s + 1)} \quad (5)$$

The parameters of the PI controller should be chosen as

$$\frac{1.5T_s K_{iP} K_{PWM}}{RT_i} = \frac{1}{2} \quad (6)$$

$$\begin{cases} K_{iP} = \dfrac{RT_i}{3T_S K_{PWM}} \\ K_{iI} = \dfrac{K_{iP}}{T_i} = \dfrac{R}{3T_s K_{PWM}} \end{cases} \quad (7)$$

2.2. Design of voltage loop

The transfer function of voltage regulator is

$$G(s) = K_{vP}\frac{1+T_v}{T_v s} \quad (8)$$

Where $$K_{vI} = \frac{K_{vP}}{T_v} \quad (9)$$

By Figure 4, the open transfer function of system can be expressed as

$$W_{ov}(s) = \frac{0.75K_{vP}(1+sT_v)}{CT_v s^2(4T_s s+1)} \quad (10)$$

Due to the main function of voltage control loop is to keep stability of output voltage, so the noise immunity must be taken into account in the course of design voltage loop. The proper choice to this end is to adopted typical Ⅱ model system. So

$$\frac{0.75K_{vP}}{CT_v} = \frac{h_v + 1}{32h_v^2 T_s^2} \quad (11)$$

Where, $h_v = T_v / 4T_s$ is the frequency width in the voltage loop, take $h_v = 5$, then

$$T_v = 20T_s \quad (12)$$

Finally the results obtained as:

$$\begin{cases} K_{vP} = \dfrac{C}{5T_s} \\ K_{vI} = \dfrac{K_{vP}}{20T_s} \end{cases} \quad (13)$$

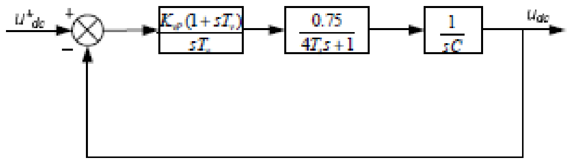

Figure 4: Equivalent control block diagram of the voltage control loop

III. SIMULATION RESULTS

The decoupled dual-close-loop controller has been simulated using MATLAB/SIMULINK to test the performance of VSC described by the proposed model. The whole system behavior is simulated as a discrete control system. The simulation model is shown in figure 5 and figure 6. The actual rectifier is shown at the top of the model in figure 5. In the circuits, the ac source is an ideal balanced three-phase voltage source with frequency of 50Hz. The phase to phase voltage is 380V. The line resistor of each phase is 0.0lΩ. The line inductance of each phase is 5mH. The output capacitor is 4700uF. In steady state, the dc voltage is set to be 500V. The switching frequency is 10kHz

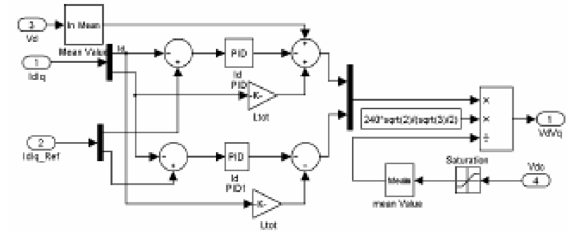

Fig 6. The current regulator unit

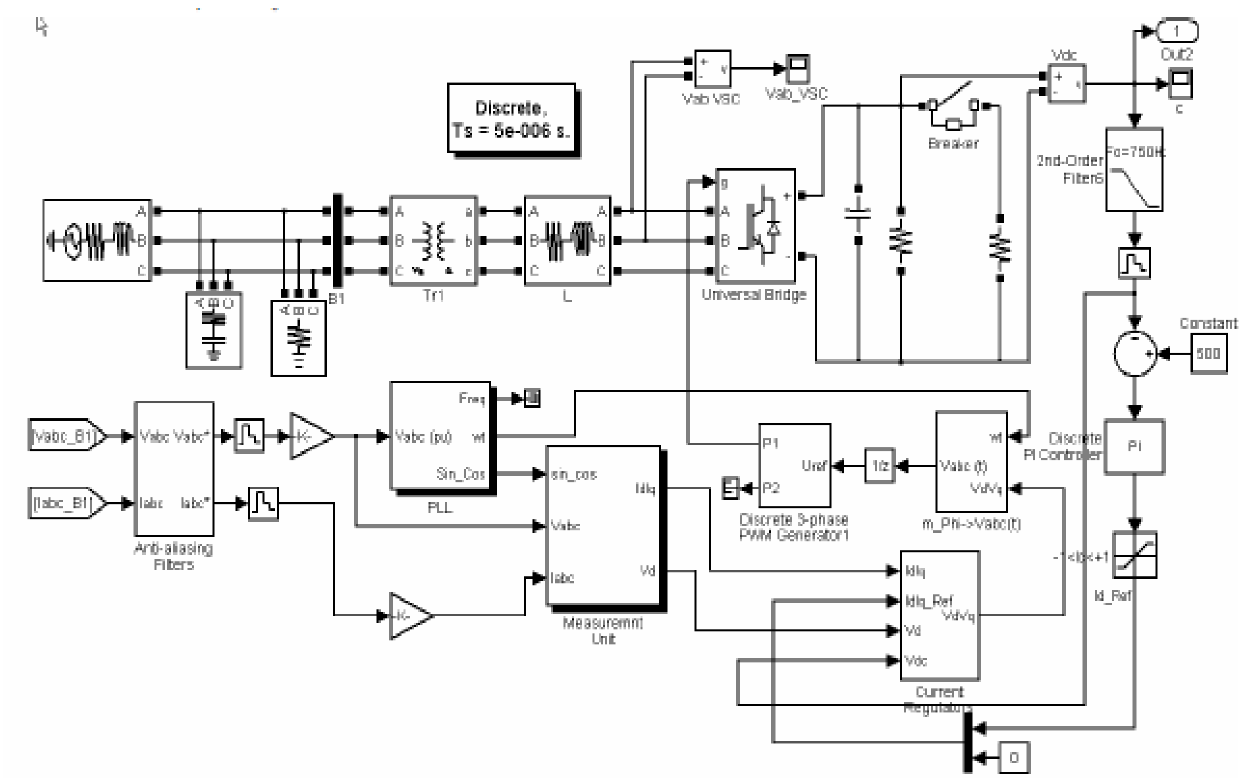

Figure 5.Three-phase voltage source PWM rectifier system model

The following two figures summarize the results of the simulation. The first figure shows the transient response of the output voltage during the load variation. The second figure shows transient response of input current for a step load change. At t=200 ms, a 10-kW load is switched-in. We can see that the dynamic response of the DC regulator to this sudden load variation (10 kW to 20 kW) is satisfactory. The DC voltage is back to 500 V within 1.5 cycles and the unity power factor on the AC side is maintained.

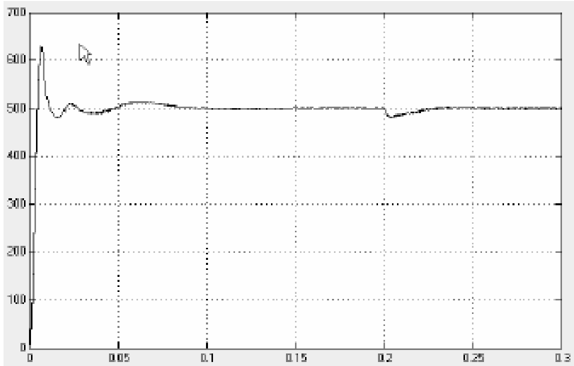

Figure 7 Simulation result for DC-Link voltage dynamics

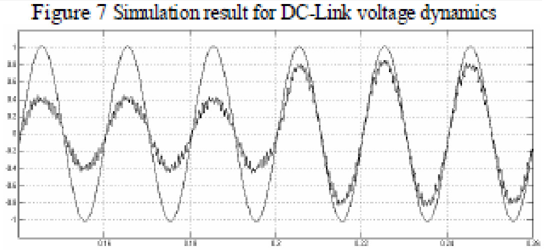

Figure 8 Simulation result for line current

IV. CONCLUSION

In this paper, a major improvement is obtained in modeling the rectifier. By using nonlinear input transformation, the conventional nonlinear models can be improved to linear models. This improvement makes the design of the controller become straightforward [6]. The controller can be designed analytically and independently with the operating point. Decoupled feed-forward controller for 3-phase voltage source rectifier is designed in the paper. Simulation result shows that very fast response can be achieved in both dc quantity and reactive power control. The solution proposed in this paper requires the sensing of input voltage, line current and output voltage. Generally speaking, industrial loads for this rectifier are variable loads, this being the main drawback to obtain simple controllers. Achieving robustness to load variations is not a simple control problem because whenever load varies, the amplitude of the line current must change to a new value to keep dc voltage regulation, but keeping the control objective over the line current shape. It is difficult to treat this problem as a tracking problem without measuring the load since the line current reference depends on it. A robust controller for rectifier using the IDA approach and GSSA modeling is proposed in [7].It is said that the method transform the nonstandard tracking control problem into a regulation one. The same solution by the IDA-PBC is presented in Work [8].But it is worth to further study to prove the feasibility in actual implementations.

REFERENCES

[1] Ricardo Luiz Alves, and Ivo Barbi,"A New Hybrid High Power Factor Three-Phase Unidirectional Rectifier",Industrial Electronics, 2006 IEEE International Symposiumon Volume 2, July 2006 pp.1046 – 1051.

[2] Ye, Y., Kazerani, M., Quintana, V.H., "A Novel Modeling and Control Method for three-pahse PWM converters", Power Electronics Specialists Conference, 2001. PESC. 2001 IEEE 32nd Annual Volume 1, 17-21 June 2001,pp.102 – 107.

[3] Jninne-ChingLiao, Sheng-NianYeh, "A Novel Insantaneous Power Control Strategy and Analytic Model for Integrated Rectifier/Inverter Systems, IEEE Transactionon Power Electronics,2000 VOL. 15, NO. 6, pp.996-1006.

[4] Mariusz Malinowski, Marian P. Kazmierkowski, Andrzej M. Trzynadlowski, "A Comparative Study of Control Techniques for PWM Rectifiers in AC Adjustable Speed Drives",IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 18, NO. 6, NOVEMBER 2003,pp.1390 – 1396.

[5] Wang Jiuhe, Yin Hongren, Zhang Jinlong, and Li Huade, "Study on Power Decoupling Control of Three Phase Voltage Source PWM Rectifiers", Power Electronics and Motion Control Conference, 2006

[6] Z. Yang, and L. Wu, "A new Passivity-Based Control Method and Simulation for DC/DC Converter", Proceedings of the 5th World Congress on Intelligent Control and Automation, Hangzhou, P. R. China, June 15-19, 2004, pp.5582-5585.

[7] C. Gaviria, E. Fossas and R. Griñó, "Robust Controller for a Full-Bridge Rectifier Using the IDA Approach and GSSA Modeling", IEEE Transactions on Circuits and Systems, Vol. 52, No. 3, March 2005, pp. 609-616.

[8] Mendez, J., Garcia, Y., Mata, M.T., "Three-Phase Power Converter Stabilization via Total Energy-Shaping", Industrial Electronics and Applications, 2006 1ST IEEE Conference on 24-26 May 2006

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