ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 10, October 2013

HARMONICS REDUCTION ANALYSIS BY USING THREE-PHASE VOLTAGE SOURCE PWM RECTIFIER

Nooka Pavan Kumar Reddy [1], Puthireddy Umapathi Reddy [2]

Assistant professor, Department of Electrical and Electronics Engineering, Sree Vidyanikethan Engineering College, Tirupati, Andrapradesh, India[1].

Professor, Department of Electrical and Electronics Engineering, Sree Vidyanikethan Engineering College, Tirupati, Andrapradesh, India[2].

ABSTRACT: This paper deals about the planning and simulation for harmonic reduction by three phase voltage source of a pulse width modulation (PWM) rectifier with three-phase load. Support the mathematical model of PWM rectifier, the dual-close-loop engineering approach with decoupled feed-forward management is applied within the 3-phase voltage source rectifier. The goal to be reached is to identify with unity power factor issue at the input ac mains and regulate output voltage. The paper presents the MATLAB/SIMULINK simulation model and the results make sure the legitimacy of the model and its management technique.

Keywords: PWM rectifier, unity power factor, decoupled feed-forward control, MATLAB simulation.

I. INTRODUCTION

Modern electric devices are usually fed by diode or thyristors front-ends. Such equipment generates higher harmonics into a grid. Now days those problems are going more and more serious. Grids disturbances may result in malfunction or damage of electrical devices [1]-[3]. Therefore, currently many methods for elimination of harmonic pollution in the power system are developed and investigated. Restrictions on current and voltage harmonics maintained in many countries are associated with the popular idea of "clean power [4]- [5].The PWM rectifier advantages are Bi-directional power flow, Nearly sinusoidal input current, Regulation of input power factor to unity, Low harmonic distortion of line current (THD below 5%), Adjustment and stabilization of DC-link voltage (or Current), Reduced capacitor (or inductor) size due to the continuous current [6]-[7]. In actual implementations, the DC management theme is wide adopted. varied management methods are projected standard of the input ac current in DC control theme [8]. The normal management methods establish 2 loops: a line current inner loop of power issue compensation associate degreed an output voltage outer loop for voltage regulation. During this paper, the planning technique [9] and controller model supported DC control square measure analyzed [10]. Achieving strength to load variations isn't a straightforward management drawback as a result of whenever load varies the amplitude of the road current should modification to a brand new price to stay dc voltage regulation, however keeping the management objective over the road current[11]. It's troublesome to treat this drawback as a trailing drawback while not activity the load since the road current reference depends on that. a strong controller for rectifier

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 10, October 2013

exploitation the International Development Association approach and GSSA modeling is planned in [12]. It is same that the tactic rework the nonstandard trailing management drawback into a regulation one. Identical resolution by the IDA-PBC is conferred in Work [8]. But it's price to more study to prove the practicable ness in actual implementations [13].This paper briefly reviews the principles of 3-phase PWM rectifier, gives a dual close-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

The three-phase voltage source rectifier structure is shows in figure 1. The circuit diagram is in order to setup 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 U_a U_b an U_c are the phase voltages of three phase balanced voltage source, and i_a , i_b and i_c are phase currents, V_{dc} is the DC output voltage, R_1 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 i_L is load current.

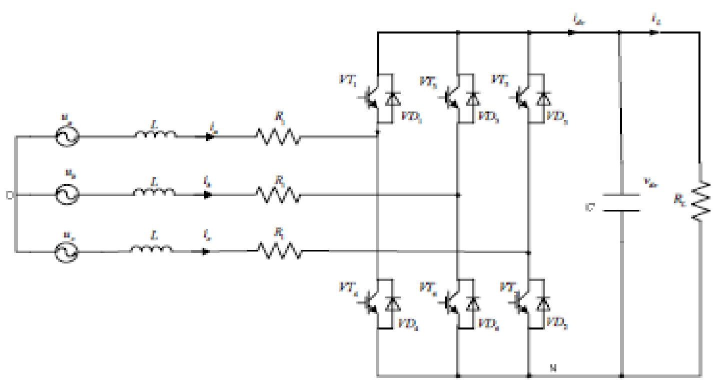


Figure 1. Circuit schematic of three-phase two-level boost-type rectifier

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

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

Where, $U_{rd} = S_d V_{dc}$, $U_{rq} = S_q V_{dc}$, U_{rd} , U_{rq} and S_d ,S_q are input voltage of rectifier, switch function in synchronous rotating d-q coordinate, respectively. U_d, U_q and i_d,i_q are voltage source, current in synchronous rotating d-q

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 10, October 2013

coordinate, respectively. ω is angular frequency.

A. Design of current loop

It is seen from (1) that mutual interference exists in the d-q current control loops. The voltage de couplers 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

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

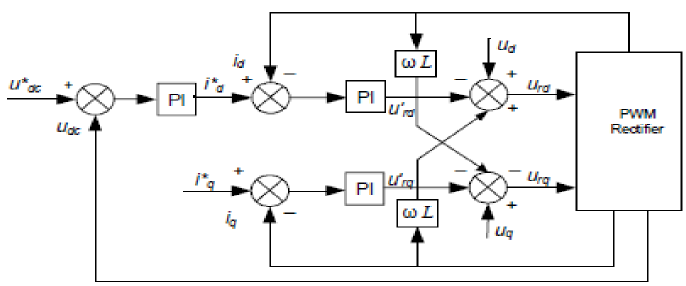


Figure 2. Control block diagram of d-q dual-close-loop controller of the rectifier

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

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

The simple proportional-integral (PI) controllers are adopted in the current regulation; u_{rd} and u_{rq} are controlled by the following expression:

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

Assume that the d–q voltage commands are not saturated for linear operation of PWM modulation and the d–q

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 10, October 2013

current control loops have been fully decoupled. For d-axis current control loop, the structure can be simplified to Figure 3.

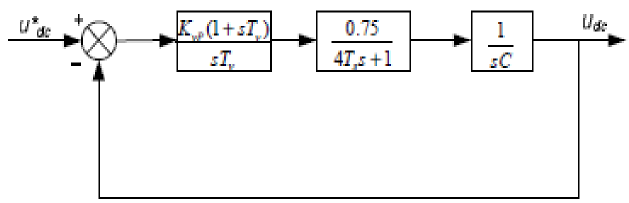


Figure 3. Equivalent control block diagram of the d–q current control loop

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

$$w_i(s) = \frac{K_{ip} K_{PWM}}{RT_i s(1.5T_s + 1)} \qquad (5)$$

The parameters of the PI controller should be chosen as

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

$$\begin{cases} K_{ip} = \dfrac{RT_i}{3T_s K_{PWM}} \\ KiI = \dfrac{Kip}{Ti} = \dfrac{R}{3T_s K_{PWM}} \end{cases} \qquad (7)$$

B. Design of voltage loop

The transfer function of voltage regulator is $G(s) = K_{vp} \frac{1+T_v}{T_{vs}}$ (8)

Where

$$K_{vi} = \frac{K_{vp}}{T_v} \qquad (9)$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 10, October 2013

A robust controller for rectifier using the interconnection and damping assignment (IDA) approach and generalised state space averaging (GSSA) modelling is proposed which transform the non-standard tracking control problem into a regulation one. The same solution by the interconnection and damping assignment passivity based control (IDA-PBC) is presented in Work. But the feasibility of these solutions in practical environment has to be proved.

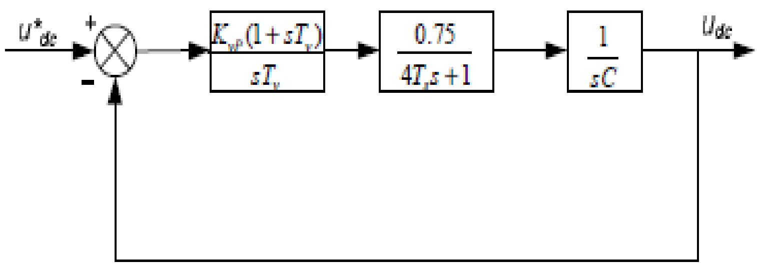


Figure 4. Equivalent control block diagram of the Voltage control loop

Figure 5. Three phase voltage sourse PWM rectifier system model

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

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

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

$$\frac{0.75K_{vp}}{CT_v} = \frac{h_v+1}{32h^2vT^2{}_s} \qquad (11)$$

Where hv=Tv/4Ts is the frequency width in the\voltage loop take hv=5 then T_v=20Ts (12)

Finally the results obtained as

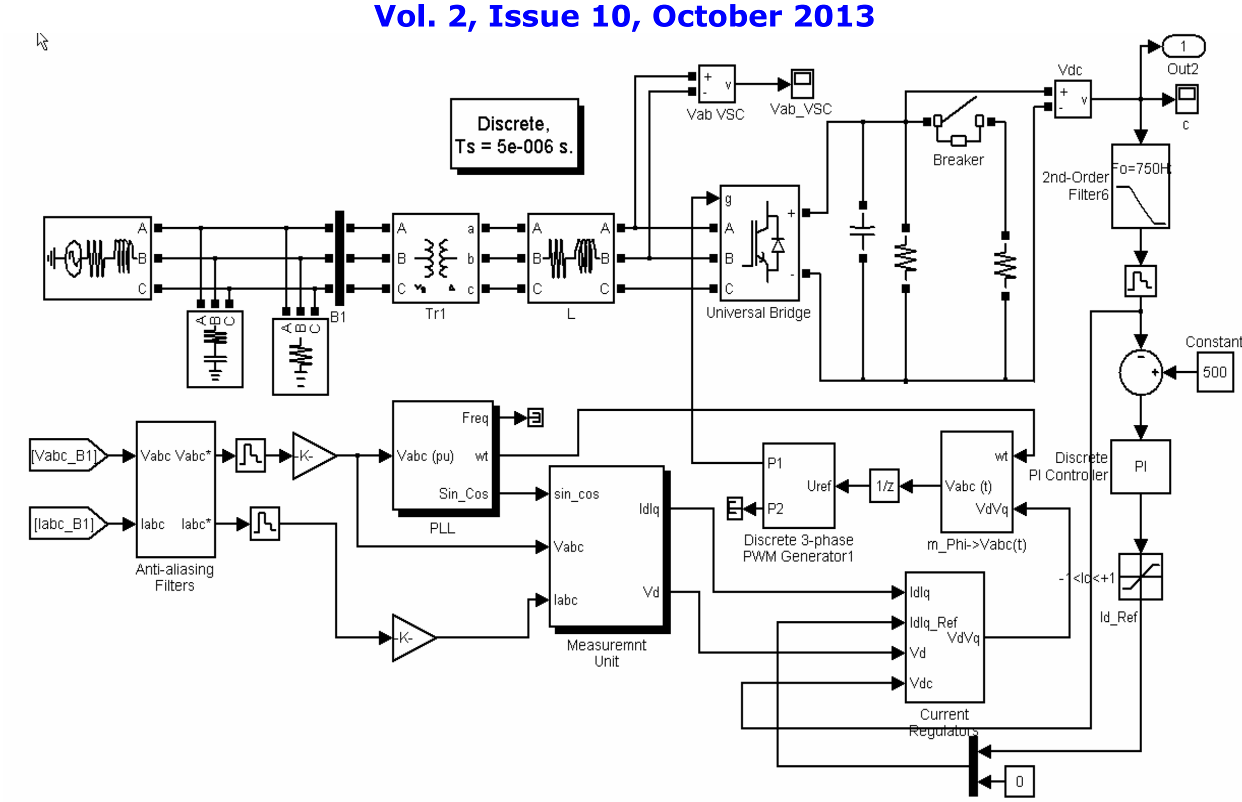
$$\begin{cases} K_{vp} = \dfrac{C}{5T_s} \\ K_{vI} = \dfrac{K_{vp}}{20T_s} \end{cases} \qquad (13)$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 10, October 2013



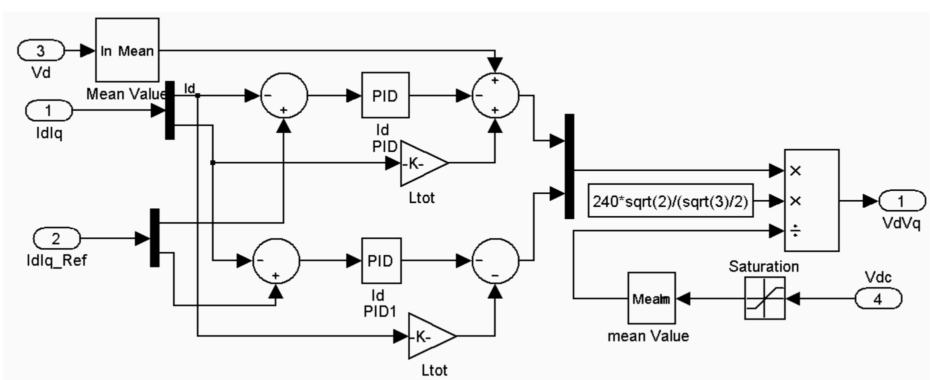


Figure 6. The current regulator unit

III. SIMULATION RESULTS

The decoupled dual-closed-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

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 10, October 2013

simulation model is shown in figure 5 and current regulator unit figure 6 respectively. The actual rectifier is shown at the top of the model in figure 1. 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 0.01Ω. 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 10 kHz.The following two figures summarize the results of the simulation. The first figure 7 shows the transient response of the output voltage during the load variation. The second figure 8 shows transient response of input current for a step load change. At t=200 ms, a 10-kW load is switched-in. By exploitation nonlinear input transformation, the traditional nonlinear models are improved to linear models. This improvement makes the look of the controller become easy [6]. The controller is designed analytically and severally with the in operation purpose.

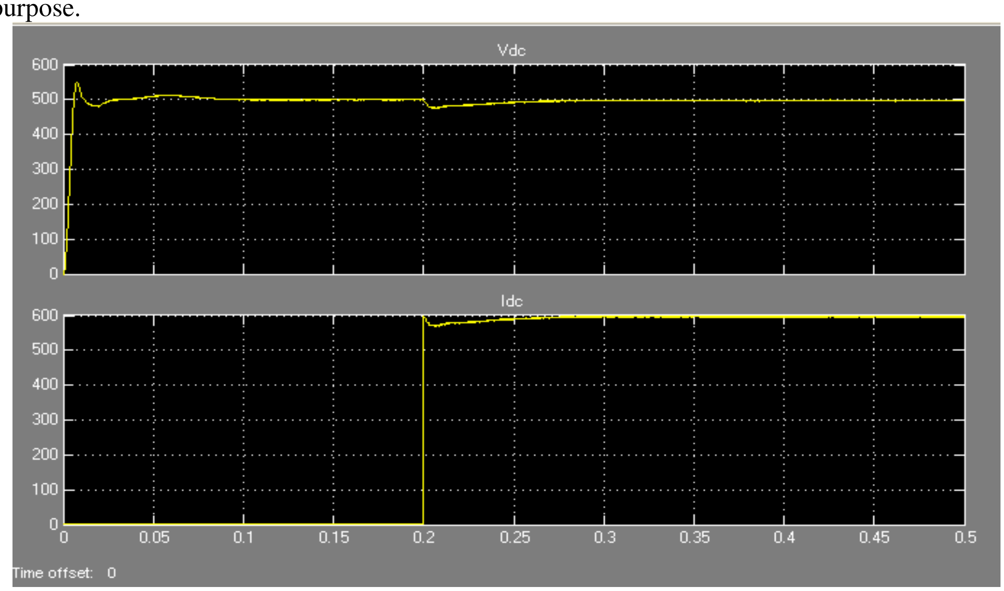


Figure 7. Simulation result for DC-link voltage

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 10, October 2013

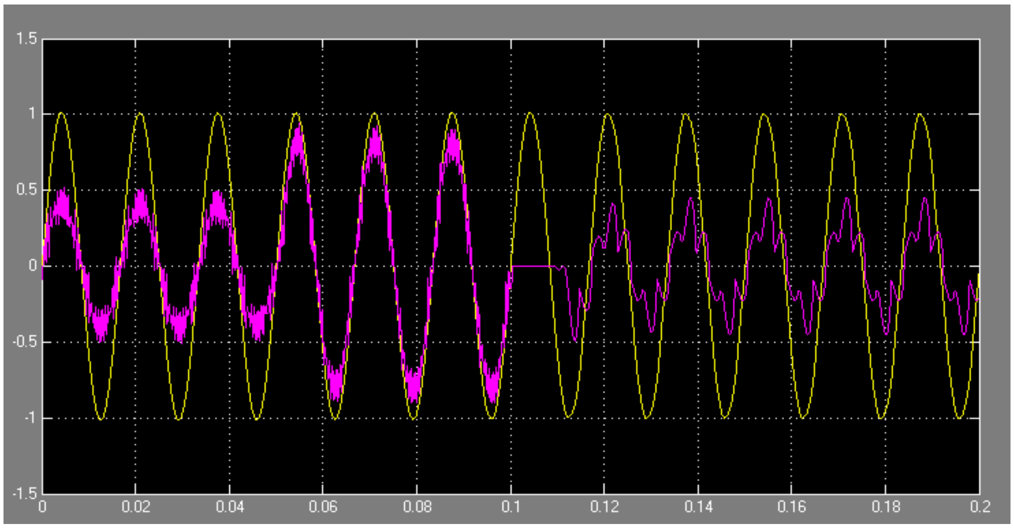


Figure 8. Simulation results for line current.

Decoupled feed-forward controller for 3-phase voltage supply rectifier is intended within the paper. Simulation result shows that in no time response is achieved in each dc amount and reactive power management. the answer planned during this paper needs the sensing of input voltage, line current and output voltage. usually speaking, industrial masses for this rectifier area unit variable masses, this being the most disadvantage to get easy controllers. Achieving strength to load variations isn't a straightforward management drawback as a result of whenever load varies, the amplitude of the road current should modification to a brand new price to stay dc voltage regulation, however keeping the management objective over the road current form. it's troublesome to treat this drawback as a trailing drawback while not activity the load since the road current reference depends on that. a strong controller for rectifier exploitation the International Development Association approach and GSSA modeling is planned

IV. CONCLUSION

In this paper, a serious improvement is obtained in modeling the rectifier. By exploitation nonlinear input transformation, the traditional nonlinear models are improved to linear models. The controllers are designed analytically and operate within limits. The controller for 3-phase voltage supply rectifier is intended to reduce harmonics 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. Further the use of the three phase voltage source PWM rectifier can be extended to various loads and using this method the power factor of that particular load circuit can be analysed and using various power factor correction methods the system can be made to operate at near unity power factor to optimise its performance.

REFERENCES

[1] Ricardo LuizAlves, and Ivo Barbi, "A New Hybrid High Power Factor Three-Phase Unidirectional Rectifier", IEEE International

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 10, October 2013

Symposium on Industrial Electronics, Vol. 2, pp.1046 – 1051, July 2006.

[2] Ye, Y., Kazerani, M., Quintana, V.H., “A Novel Modeling and Control Method for three-phase PWM converters”, IEEE 32nd Conference on Power Electronics Specialists, 2001, Vol. 1, pp.102 – 107, 17-21 June 2001.

[3] Jninne-ChingLiao, Sheng-NianYeh, “A Novel Instantaneous Power Control Strategy and Analytic Model for Integrated Rectifier/Inverter Systems”, IEEE Transaction on Power Electronics 2000, Vol. 15, NO. 6, pp.996- 1006,2000.

[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, pp.1390 – 1396, November 2003.

[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, pp.5582-5585, June 15-19, 2004,.

[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, pp. 609-616, March 2005.

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

[9] J. Rodriguez, S. Bernet, B. Wu, J. O. Pontt, And S. Kouro, “Multi- Level Voltage-Source-Converter Topologies For Industrial Medium-Voltage Drives,” IEEE Trans. Ind. Electron., Vol. 54, No. 6, pp. 2930–2945, 2007.

[10] S. B. Monge, J. Rocabert, P. Rodriguez, S. Alepuz, And J. Bordonau, “Multilevel Diode-Clamped Converter For Photovoltaic Generators With Independent Voltage Control Of Each Solar Array”, IEEE Trans. Ind. Electron., Vol. 55, No. 7, Pp. 2713–2723,2008.

[11] J. I. Leon, S. Vazquez, A. J. Watson, L. G. Franquelo, P. W. Wheeler, And J. M. Carrasco,“Feed-Forward Space Vector Modulation For Single-Phase Multilevel Cascaded Converters With Any Dc Voltage Ratio,” IEEE Trans. Ind. Electron., Vol. 56, No. 2, pp. 315–325,2009.

[12] R. Seyezhai and B.L. Mathur, “Design and implementation of fuel cell based Interleaved Boost Converter”, International Conference on Renewable Energy, University of Rajasthan, Jaipur, Jan 17-21, 2011.

[13] Antosh A and Shivashankar Tallada, “Simulation Of High-Efficiency AC/DC Converter For Power Factor Correction”, International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622,Vol. 2, Issue 4, pp.2043-2050, 2012..

BIOGRAPHY

Mr. N. PAVAN KUMAR REDDY received B.Tech degree and M.Tech (EPS) degree from JNTU Anantapur. Presently working as Assistant Professor in department of EEE at Sree Vidyanikethan Engineering College, Tirupathi. His research interest includes Power System Operation and Control and Power electronic devices applications in power system.

Dr. P.UMAPATHI REDDY: He received his B.E from Andra University, M.Tech., (Electrical Power Systems) from Jawaharlal Nehru Technological University, Anantapur, and did his Ph.D. from Jawaharlal Nehru Technological University Kakinada, Kakinada, India in 1998, 2004 and 2013 Respectively, Currently he is working as a professor in the department of Electrical and Electronics Engineering, Sree Vidyanikethan Engineering College, Tirupati, India. His research interest includes Power Distribution Systems, Power System Operation and Control and Power electronic devices applications in power systems. He is life member of Indian Society for Technical Education and The Indian Science Congress Association.