A HYSTERESIS CURRENT CONTROLLER BASED POWER FACTOR CORRECTION CONTROL FOR COMPENSATING LED LOAD

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ABSTRACT

This paper introduces a new technique to achieve the unity power factor at the source side of the AC supply for LED lamp load consider as a non-linear load. LEDs have many superior characteristics and effective applications in background lighting, displays, street lighting. LEDs can operate from a low voltage DC supply. Therefore, an AC-DC converter is needed to drive a LED lamp. It introduces distortions to input current and draws inrush current from the supply. Due to this line current becomes non-sinusoidal and the power factor becomes poor. In this paper, the hysteresis current controlled technique proposed for achieving the unity power factor at the input side of the AC supply. This control technique provides isolation between power circuit and the control circuit. This techniques achieves less harmonic contents in the source side, a nearer to the unity power factor and a sinusoidal current waveform. Simulation and the experimental results show the function of the overall system and provide the effective solution for the power quality problems caused by led lamp.

Keywords: Hysteresis current controlled technique, Power factor control, LED lamp.

I INTRODUCTION

Currently, lighting is the most essential part in our life. However, conventional methods (incandescent lamp, fluorescent lamp and compact fluorescent lamps (CFL)) of lighting are highly inefficient. This type of lighting it produces the various power quality issues[1]. Knowledge has yielded amazing new lighting source which is LED lamps that are poles apart from the conventional lamps such as incandescent lamps, fluorescent lamps and CFL, which use the filaments for generating heat and using gaseous discharging. LED lamps present an effective solution to replace the conventional lamps due to their advantages [2-4].LEDs have grander features and several applications such as background lighting, displays, street lighting and so on. LEDs are also available in multi colours. While driving the led lamps from the AC supply, it producing power quality issues similar to conventional lamps [5]. LEDs are operated from a DC supply. For the lighting applications, the LED lamps have to operate from the universal AC input. Hence, an AC-DC converter is needed to drive the LED lamp [6]. The brightness of LED is intensely depending on its current. Therefore an efficient control is needed to regulate the LED current. The efficient driver not only performsunity PF, but also regulates LED current [7]. Utmost of the applications that need AC-DC power conversion needs the output DC voltage to be well regulated with good steady state and transient performances. The rectifier with a filter capacitor is cost effective, but it harshly destroys the quality of the supply. A large electrolytic capacitor suppresses the ripple from the output voltage; it presents the input current distortions and draws inrush current from the supply [8]. This introduces following problemssuch as the line current becomes non-sinusoidal which increases THD and increases the losses. This results in poor power quality, voltage distortion and poor power factor at the input AC mains. For all lighting products and the input power higher than 25W, AC-DC LED drivers must comply with the line current harmonic limit set by IEC61000-3-2 class C [9]. While using single phase PFC, it is an active research topic in power electronics because of the high power quality requirement and significant efforts have been made on the development of PFC converters [10]. In the proposed work, the simple single switch topologies like boost converter is used. The inductor is assumed to enter the continuous conduction mode (CCM) operation which is implemented using hysteresis current control method.In this paper, a boost PFC converter is being used along with the hysteresis current control in the proposed technique. The proposed PFC control is done byPIC controller. According to the output pulse of the PIC controller, the boost PFC converter is performed. In classic PFC techniques, it is necessary for sensing input and output voltage, and the input current. When using these sensors, it is most problematic and expensive of the sensors because it generates power loss and it also produces heat.The simplicity of the circuit is, it does not have regeneration back to the power supply is and the power switches non-floating, so it is easy to design the driver circuit. In this paper, there is no current sensor used, which can help to reduce the total cost. It is the main novelty of this paper. The two ADCs are used to sensinginput current, input and output voltages.According to that reason, the proposed technique is simpler and most reliable when compared with other techniques.The proposed technique is most accurate by using the zero crossing detector.

II POWER FACTOR CONTROL FOR LED LAMP

The hysteresis current control based Boost PFC converter is illustrate in the Fig. From the Fig, the supply voltage is step downed by using the step down transformer. The step downed voltage is passing through the diode bridge rectifier for converting AC supply into DC supply. The converted DC supply is fed to the boost converter for producing constant input voltage to the LED lamp. The output voltage of the boost converter is fed into the input voltage of LED lamp. The output voltage of LED lamp is sensed by using the analog to digital converter. That output voltage signal from the analog to digital converter is compared with reference voltage signal. The error signal from the comparator is passing through the PI controller. The output signal from the PI controller is send to the multiplier.

Then the input voltage is also sensed by using the analog to digital converter. The output signal from the analog to digital converter is send to the zero crossing detector. A zero crossing detector is used to produce a sync pulse associated to the AC voltage phase angle. The output of the zero crossing detector is sending to the sine wave look up table block. The output waveform from the sine wave look up table is sending to the multiplier. In the multiplier block, these two signals were multiplied. The output signal from the multiplier is passing to the hysteresis comparator.The digital signals from the input and the output voltage is compared by using the comparator. The error signal from the comparator and the inductor value is divided by using the divider. The output signal from the divider is used to drive the switch. And also the signals from the zero crossing detector and the output signals from the hysteresis comparator is used to drive the switch. According to the switching operations the integrator and the hysteresis comparator will be work. By using the output signal, PWM generator generates pulses to the MOSFET switches.

III PROPOSED SYSTEM

In this paper, a boost PFC converter is being used in theproposed technique. The simplicity of the circuit configuration and the control structure mean that no regeneration back to the power supply is necessary. Besides, the input inductor can suppress the surging input current, and the power switch is non-floating, so it is easy to design the driver circuit. The main novelty of the proposed technique is that, there is no current sensor used, which can help to reduce the total cost. The input current is estimated using two ADCs for sensing input and output voltages, which makes this proposed technique simpler and more reliable than other techniques. Also, a zero-crossing detector is used to make the proposed technique more accurate than other techniques, especially in transient operations, and when using distorted supply voltage, the input current has a sinusoidal waveform.

The boost PFC converter-based on hysteresis current mode control is illustrated in Fig 1. At first the AC supply is converted into DC supply by using the diode bridge rectifier.The output signal from the diode bride rectifier is passing to the power factor correction boost converter. In which the increased amount of voltage will be obtained on the output side. The output voltage from the boost converter is given to the LED Lamp.The source voltage, rectified voltage and the output voltage is sensed. And the sensed voltages are sending to the hysteresis current controller. In which the hysteresis comparator is employed. In this hysteresis comparator, the inductor current and the line current were compared. After the comparison, it will produces the output in the form of the pulse. The output pulse from the hysteresis comparator, is going to control the operation of switch which is placed in the power factor correction boost converter. According to the operation of switch, the output voltage from the boost converter is regulated. Thus the load voltage and the load current were regulated. Finally the source side power quality issues were eliminated and the power factor is maintained.The following circuit diagram in Fig.2 explains the circuit configuration of the proposed system.

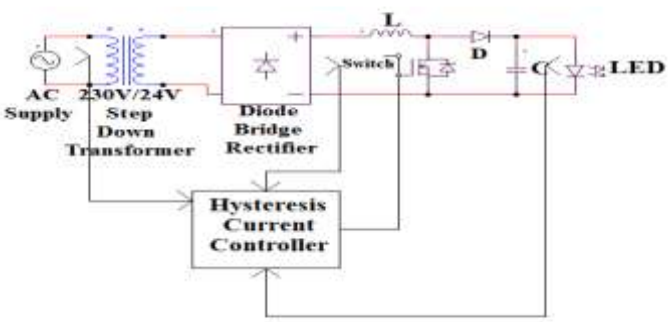


Fig.2. Circuit Diagram of Proposed System

IV HYSTERESIS CURRENT CONTROL TECHNIQUE

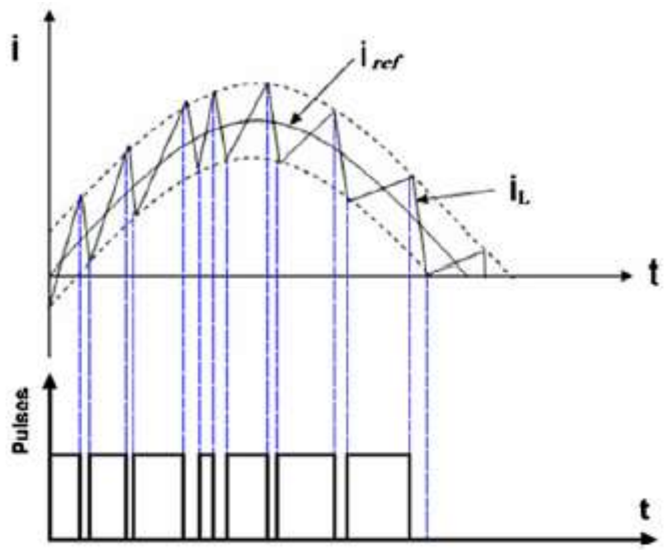


Fig. 3.Hysteresis current control technique

In the Fig 3, the inductor current is continuously compared to the reference current waveform which is obtained from the voltage control loop and the error signal is fed into a hysteresis comparator to make the inductor current always within the upper and lower band. There are two distinct states of the hysteresis comparator [11].

1. While the real inductor current (i*l*) goes beyond the reference current (iref) by the comparator hysteresis band, the current ramp goes down by varying the comparator state to make the boost converter switch off.
2. Once the real current goes lower than the reference current by the comparator hysteresis band, the current ramp goes up by changing the comparator state again to make the boost converter switch on.

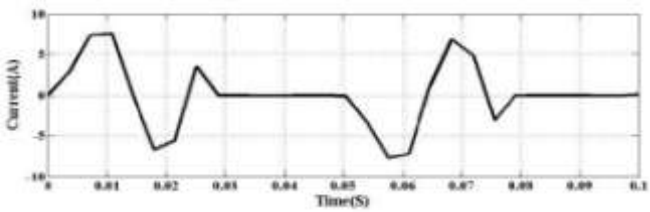
V SIMULATION RESULTS

The proposed control technique has been simulated using theMATLAB/SIMULNK software.

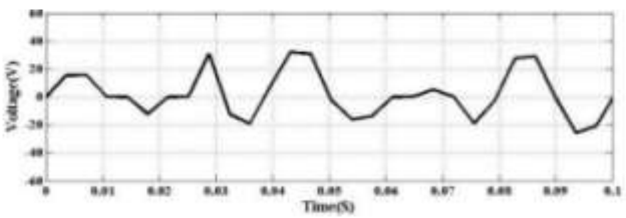
5.1 Load Compensation withoutHysteresis Current Controller

When a LED lamp is supplied with 230V ACwithout controller, the power quality issues arises. This increases the THD of the system. So, the power factor becomes poor.In the Fig4(a), the source voltage without using controller is represented. That waveform consisting of various power quality issues such as voltage sag and voltage swell. It is also contains some distortions and the waveform becomes non sinusoidal.From theFig. 4(b), it is clear that the current waveform consisting of harmonics. According to the presence of harmonics, it will create a lot of problems to the system. And this waveform is also containing distortion in its waveform. It is the main reason for poor power factor. Then by the effect of the above mentioned problems, the voltage and current waveform goes out of phase. In the Fig4(c), the 230V supply voltage can be reduced to 24V. At the starting time period of waveform, it is clear that a settling time is needed for step down to the corresponding voltage value. After the settling time period, it will step down to the respected value. This waveform is also containing power quality problems in its waveform.The simulation result of the step downed current without using controller is shown in the Fig4(d). Thus it is follows its fundamental voltage waveform. At the initial time period, it will absorbs large amount of current. After some period of time, the current will be decreased. And this current is containing harmonics and the distortion in its waveform.The simulation result of the rectified voltage without using controller is shown in theFig4(e). In which the AC supply is converted into DC supply. It is represented in that waveform.This rectified current will follows the fundamental waveform of the rectified voltage. It can be illustrated in the Fig4(f). In the Fig4(g), the waveform of load voltage without controller is represented. The load voltage is also containing some disturbances.The simulation result of the load current without using controller is shown in the Fig4(h). From that waveform, it is clear that the load current contains some harmonics and distortion in its waveform. Then for certain period of time, the current is decreased to minimum value and the peak rise will occurred in the waveform.The simulation result of the active power without using controller is shown in the Fig4(i). It will measured for the time period of 1 sec. from the above waveform, after some period of the time the active power is not maintained to the constant value.The simulation result of the reactive power without using controller is shown in the Fig4(j). In this Fig, without using the controller it is clear that, it absorbs more reactive power from the source side.The simulation result of the Total Harmonic Distortion of the source current without using controller is shown in theFig4(k). By the reference from that waveform representation, the source current contains THD of 93.33%. According to the IEEE standard, the system must contain the THD value below 5. If the control technique is implemented, the value of THD will be reduced to the standard value.

(a)Source voltage



(b)Source current



(c) Step downed voltage

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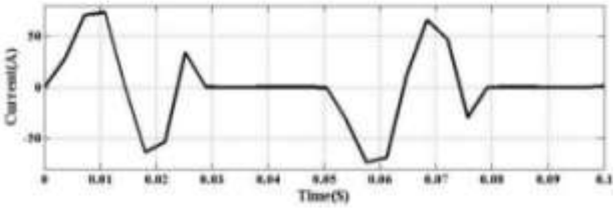
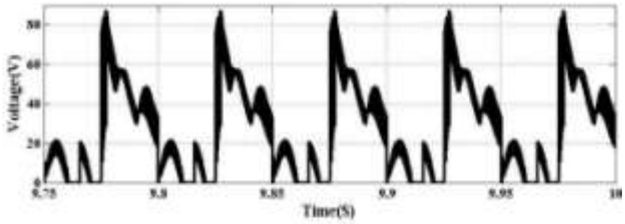
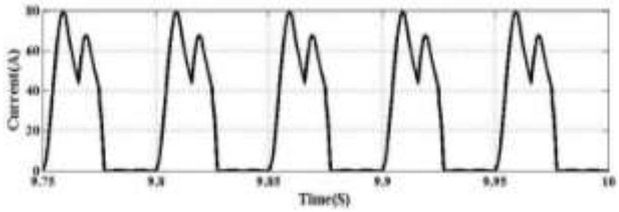


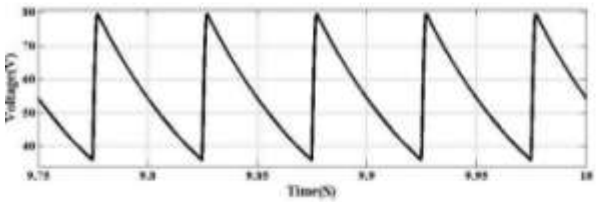
(d) Step down current



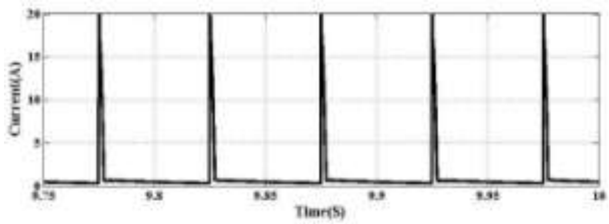
(e) Rectified voltage



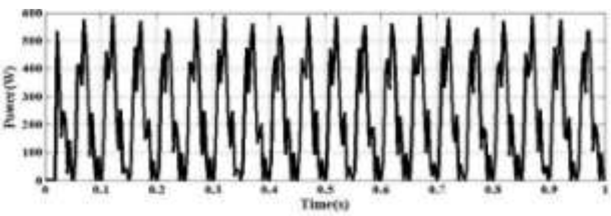
(f) Rectified current



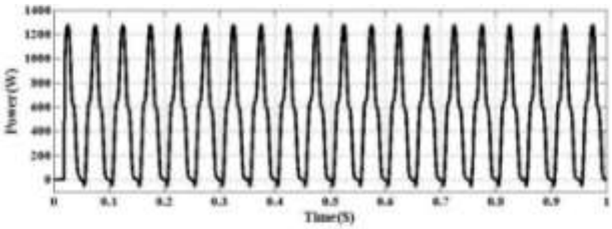
(g) Load voltage



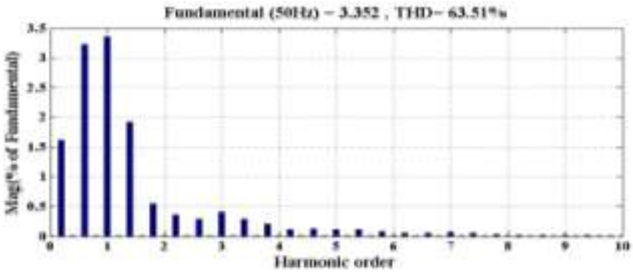
(h) Load current



(i) Active power



(j) Reactive power



(k) Harmonic spectrum

Fig. 4. Waveforms of simulation results without controller

5.2.Load Compensation with Hysteresis Current Controller

When a LED lamp is supplied with 230V AC through controller, the power quality issues are mitigated. Therefore, the THD value is reduced and so the power factor is improved.In the Fig 5(a), the simulation result of the source voltage using controller is shown in the above Fig. The power quality problems created on the source voltage such as voltage sag and voltage swell while without using controller has been eliminated. And also the sinusoidal waveform is achieved on the source voltage waveform. The simulation result of the source current using controller is shown in the Fig 5(b). The power quality problems created on the source current such as harmonics and the distortion in the waveform while without using controller has been eliminated. And also the sinusoidal waveform is achieved on the source current waveform. The simulation result of the step downed voltage using controller is shown in the Fig 5(c). According to the simulation, the 230V supply voltage can be reduced to 24V. The above mentioned power quality problems in without controller has been eliminated by using the controller. In the Fig 5(d), the simulation results of the step down current is represented. It can follows the step down voltage waveform. The simulation result of the rectified voltage using controller is shown in the Fig 5(e). In which the AC supply is converted into DC supply. It is represented in the above waveform. The problems created while without using the controller, has been eliminated.The simulation result of the rectified current using controller is shown in the Fig 5(f). This rectified current will follows the fundamental waveform of the rectified voltage. The power quality problems created without using the controller, has been eliminated. The simulation result of the load voltage using controller is shown in the Fig 5(g). While without using the controller, the load voltage is also containing some disturbances. The above mentioned power quality problem has been eliminated.The simulation result of the load current using controller is shown in the Fig. 5(h). The

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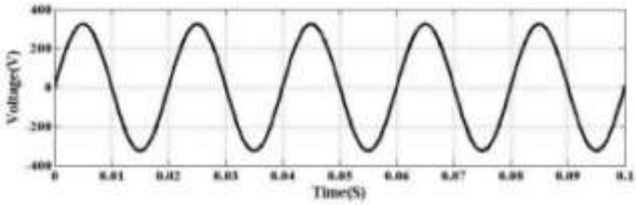
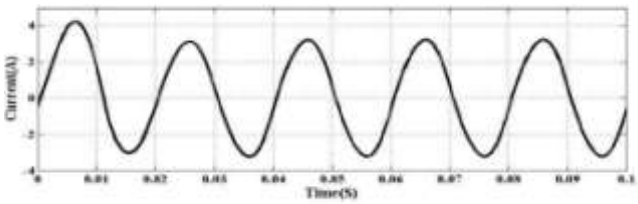
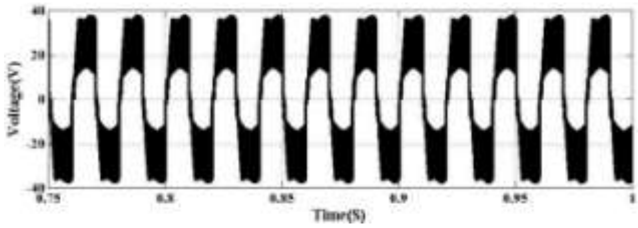
power quality issues in the without controller, can be reduced by using the controller.The simulation result of the active power using controller is shown in the Fig 5(i). It will measured for the time period of 1 sec. from the above waveform, after some certain of the time the active power is maintained to the constant value. The simulation result of the reactive power without using controller is shown in the Fig 5(j). It is clear that, using the controller it absorption of the reactive power from the source side is reduced. When implementing the corresponding control technique, the reactive power has been decreased. The simulation result of the Total Harmonic Distortion of the source current using controller is shown in the above Fig. By the reference from the above waveform representation, the source current contains THD of 3.45%.According to the IEEE standard, the system must contain the THD value below 5. The above mentioned conditions has been satisfied when using the controller.



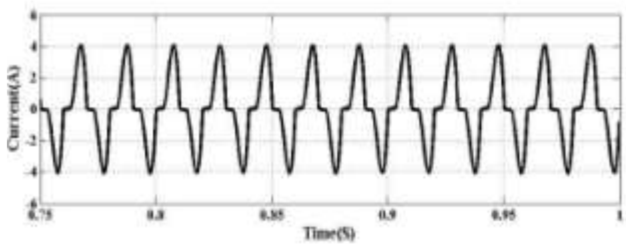
(a) Source voltage



(b) Source current



(c) Step down voltage



(d) Step down current

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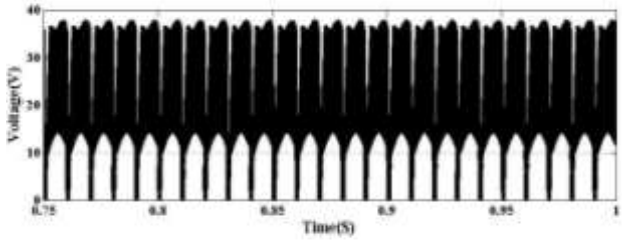
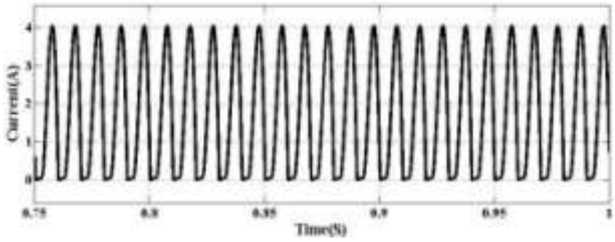
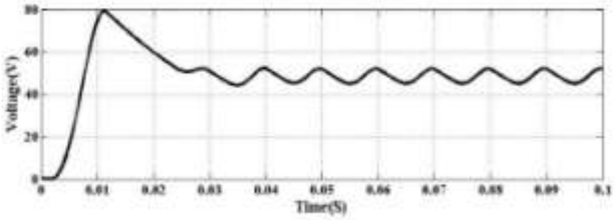


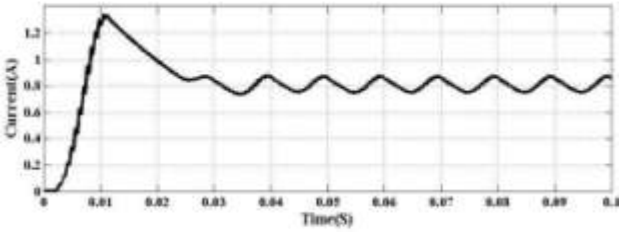
(e) Rectified voltage



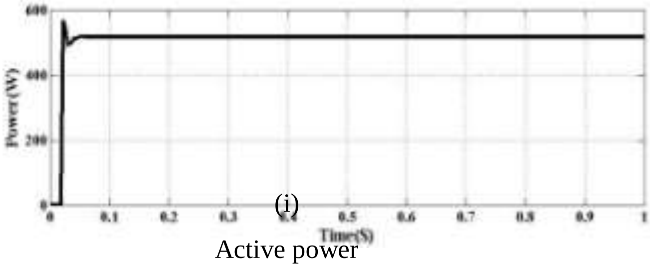
(f) Rectified current



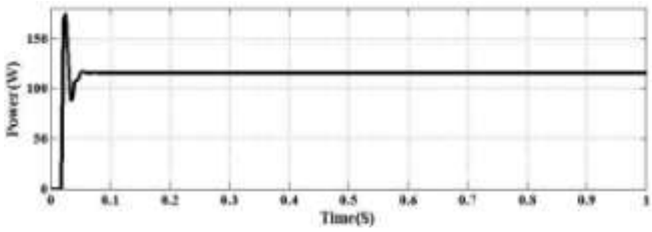
(g) Load voltage



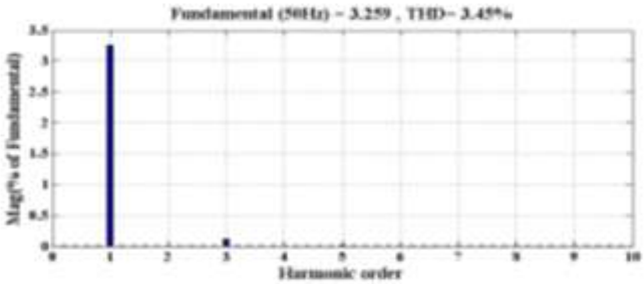
(h) Load current



(i) Active power



(j) Reactive power



(k) Harmonic spectrum

Fig. 5. Waveforms of simulation results with controller

VI CONCLUSIONS

The hysteresis current control technique can be used to mitigate the power quality issues when LED lamp is connected to 230V AC supply. As a result to the THD value is reduced and power factor is improved nearer to unity. Also the sinusoidal waveform is achieved on the source side

REFERENCES

[1]M. Rico-Secades, A.J. Calleja, J. Ribas, E.L. Corominas, J.M.Alonso, J. Cardesin, J. Garcia-Garcia, Evaluation of a low-costpermanent emergency lighting system based on high-efficiencyLEDs, IEEE Trans. Ind. Applic. 41 (5) (2005) 1386–1390.

[2]M. Ali, M. Orabi, M.E. Ahmed, A.E. Aroudi, A single stageSEPIC PFC converter for street lighting applications, in: IEEEInternational Conference on Power and Energy (PECon),Selangor, Malaysia, 2010, pp. 501–506.

[3]L. Torok, S. Beczkowski, S. Munk-Nielsen, J. Gadegaard, T.Kori, K. Pedersen, High output LED-based profile lightingfixture, in: 37th Annual Conference on IEEE Industrial Electronics Society (IECON 2011), Melbourne, Australia,2011, pp. 2941–2946.

[4]Shu Wang, Xinbo Ruan, Kai Yao, Siew-Chong Tan, YangYang, Zhihong Ye, A flicker-free electrolytic capacitor-less AC–DC LED driver, IEEE Trans. Power Electron. 27 (11) (2012) 4540–4548.

[5]H.J. Chiu, Y.K. Lo, A high-efficiency dimmable LED driver for low power lighting applications, IEEE Trans. Industr. Electron. 57 (2) (2010) 735–743.

[6]W.Y. Choi, J.M. Kwon, B.H. Kwon, Efficient LED back-lightpower supply for liquid-crystal-display, IET Electr. PowerApplic. 1 (2) (2007) 133–142.

[7] A. Shrivastova, B. Singh, A universal input single-stage frontend power factor corrector for HB-LED lighting applications,in: India Conference (INDICON), 2012 Annual IEEE, Roorkee, India, 2012, pp. 1095–1099.

[8]Y.M. Liu, L.K. Chang, Single-stage soft-switching AC–DC converter with input current shaping for universal line applications, IEEE Trans. Ind. Electron. 56 (2) (2009) 467–479.

[9]Compliance Testing to the IEC 1000-3-2 (EN 61000-3-2) andIEC 1000-3-3 (EN 61000- -3) Standards, Application Note 1273, Hewlett Packard Co., December 1995.

[10]Ying-chun Chuang, Yu-Lungke, Hung-Shiany Chuang, Chia-Chieh Hu,Single-stage power factor correction circuit with fly back converter to drive LEDs for lighting applications, in: Annual Meeting of the IEEE Industry Applications Society (IAS), Texas, USA, 2010, pp. 1–9.

[11]B. Mather, D. Maksimovic, A simple digital power-factorcorrection rectifier controller, IEEE Trans. Power Electron. 26 (1) (2011) 9–19.

[12]A.P. Finazzi, L.C. de Freitas, J.B. Vieira Jr., E.A.A. Coelho, V.J. Farias, L.C.G. Freitas, Current-sensor less PFC boost converter with preprogrammed control strategy, in: IEEE International symposium on Industrial Electronics (ISIE),Gdansk, Poland, 2011, pp. 182–187.

[13]K. Hwu, H. Chen, Y. Yau, Fully digitalized implementation of PFC rectifier in CCM without ADC, IEEE Trans. Power Electron. 27 (9) (2012) 4021–4029.

[14]Francisco J. Azcondo, Angel De Castro, F. Javier Diaz, Oscar Garcia, Power factor correction without current sensor based on digital current rebuilding, IEEE Trans. Power Electron. 25 (6) (2010) 1527–1536.

[15]Jonathan W. Kimball, Philip T. Krein, A current-sensorlessdigital controller for active power factor correction control based on Kalman filters, in: Applied Power Electronics Conference and Exposition (APEC), Twenty-Third Annual IEEE, Austin, Texas, USA, 2008, pp. 1328–1333.

[16]Ray-Lee Lin, Yi-Fan Chen,Equivalent Circuit Model of Light-Emitting-Diode for System Analyses ofLighting Drivers, IEEE Trans.(2009).

[17]Dheepanchakkravarthy, A., Venkatraman, K., Selvan, M.P., Moorthi, S. and Venkatakirthiga, M., “Capability Evaluation of Four-leg DSTATCOM for Compensating Multifarious Loads”, **Australian Journal of Electrical and Electronics Engineering** (Taylor & Francis), Vol. 13, No. 04, 2016, pp. 229-243, **Scopus Indexed** ISSN 1448-837X