



INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X

Impact factor: 4.295

(Volume 4, Issue 3)

Available online at: www.ijariit.com

Unity power factor correction based on ripple cancellation with predictive controller and fuzzy controller

Athira Babu

athirakottara@gmail.com

Thangal Kunju Musaliar College of Engineering,
Kollam, Kerala

Muhammedali Shafeeque. K

kshafeeque007@gmail.com

Thangal Kunju Musaliar College of Engineering,
Kollam, Kerala

ABSTRACT

This thesis proposes a control of single-phase power factor correction. This control is capable for obtaining a unity power factor. In this paper, first a ripple estimation circuit is used to eliminate the double line frequency component of sampled output voltage. Then the result of ripple estimation is controlled by predictive controller and fuzzy logic controller. Here boost converter is used as PFC converter. The duty cycle is calculated based on reference current, inductor current, input voltage and reference output voltage. By the use of this proposed control technique, reduce THD in the input current with the output voltage (v_o) regulation. This strategy achieves a fast dynamic response and near unity PF.

Keywords— Power factor correction (Pfc), Total harmonic distortion (Thd), Power factor (Pf)

1. INTRODUCTION

The switched mode AC to DC converter produce low power factor with high harmonic content in the input current. This led to the improving of power quality. Here boost converter is used for improving the power factor. Boost converter produce an output dc voltage which is higher than input voltage. The boost converter produce regulated dc output voltage and reduce total harmonic distortion of the input current. This improving the power factor. To get the power factor much better, a ripple cancellation circuit with control techniques are used for boost converter. The boost converter is analyzed by using multiplier approach. Multiplier approach consists of two control loops outer voltage control loop and inner current control loop. This multiplier circuit is used for regulating the output voltage. This multiplier controls the amplitude of input current reference signal accordance with the output voltage error.

In power electronics applications Conventional PI controllers are widely used. For intelligent controllers, fuzzy logic controllers (FLC) are adopted. Here fuzzy logic controllers are implemented in the voltage control loop. The predictive controller strategy is used for predicts the input

error at the beginning of each modulation period. The predicted voltage is used for pulse generation at the next switching instant and hence minimizing the error. By the use of this techniques an accurate output response can be produced.

Due to the pulsating nature of the input power, the output voltage of the load is ripple. In estimation / cancellation circuit, an estimated reproduction of a sampled output ripple is generated by using this additional circuit. Ripple estimator consists of amplitude tuner and phase shifter that reproduce a sampled output voltage ripple by the adjusting of amplitude and phase of template signal. Thus ripple estimation/cancellation with control techniques are capable of maintaining a near unity power factor and fast dynamics response.

2. BOOST CONVERTER BASED AC TO DC CONVERTER

Here a single-phase diode bridge is used to rectify the AC input voltage. For reducing the output voltage ripple, a capacitor is connected in parallel to the load resistor. In this circuit, the boost inductor (L) is connected in series. The boost converter operates in two modes, ON mode and OFF mode. In ON mode, the diode is reverse biased and switch S is ON state. In this ON mode the current flow through inductor L, Diode Bridge and switch S. Here the current in the inductor L increases. In OFF mode, the diode is forward biased and switch 'S' is OFF state and the current flow through inductor L, diode D and capacitor C. Here the inductor current L decreases and output voltage increases more than V_{dc} .

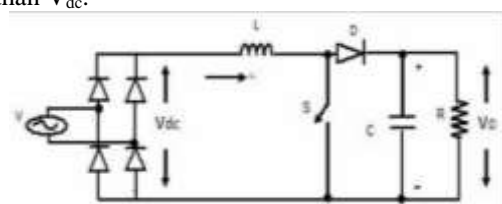


Fig. 1: Boost converter

3. PROPOSED SYSTEM OF RIPPLE ESTIMATION WITH PREDICTIVE AND FUZZY CONTROLLER

The block diagram of the proposed system is shown in figure (2).Ripple estimation/cancellation circuit is basically used to produce a ripple free signal .By the only use of the ripple estimation/cancellation circuit with boost converter a power factor of 0.93 is obtained. To obtain a near unity power factor, controllers are included with ripple estimation/cancellation circuit. In this circuit predictive control for inner current control loop and fuzzy logic controller for outer voltage control loop

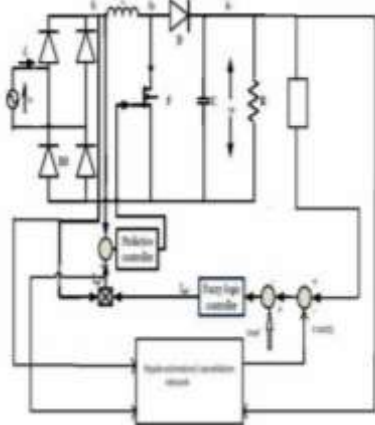


Fig 2. Proposed ripple estimation with the predictive controller and fuzzy controller.

A. Ripple Estimation Circuit

The proposed ripple estimation circuit consists of the following three stages.

- Ripple Template Generation
- Amplitude Tuner
- Phase Shifter

(i) **Ripple Template Generation:** In ripple template generator, a ripple template is produced from the sampled rectified line voltage $K_m V_{in}(t)$ and inductor current reference $i_{Lref}(t)$.

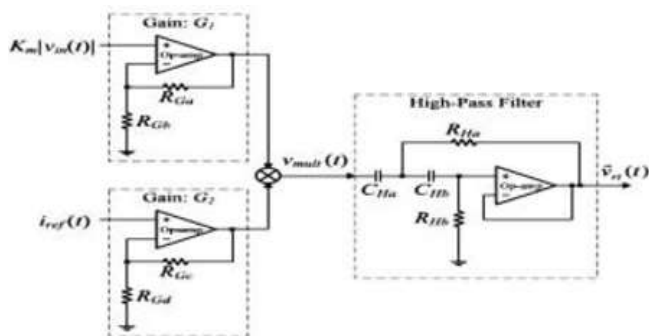


Fig 3. Block diagram of the proposed ripple template generator

The desired ripple template $V \sim_{rt}(t)$ is generated by multiplying $K_m V_{in}(t)$ and $i_{Lref}(t)$ followed by high pass filter .The high pass filter can be used to remove the dc component.

Since, assuming unity power factor,

$$V_{in}(t) = V_p \sin(\omega_{line}(t))$$

$$I_{ref}(t) = I_p \sin(\omega_{line}(t)) R_z$$

$$K_m |V_{in}(t)| |I_{ref}(t)| = K_m V_p \sin(\omega_{line}(t)) * I_p \sin(\omega_{line}(t))$$

$$V_{rt} = P_{in} K_m R_s G_1 G_2$$

$$V_{mul}(t) = [G_1 K_m |V_{in}(t)| G_2 I_{ref}(t)]$$

$$V_{mul}(t) = V_{rt} (1 \cos(2 \omega_{line}(t)))$$

HPF

$$V \sim_{rt}(t) = -V_{rt} \cos(2 \omega_{line}(t))$$

(ii) **Amplitude Tuner:** In Amplitude tuner, desired ripple template $V \sim_{rt}(t)$ and sampled output voltage ripple $\alpha V \sim_o(t)$ is fed to the input of the amplitude tuner. Here equalizing the amplitude of sampled output voltage ripple with that of ripple template $V \sim_{rt}(t)$.

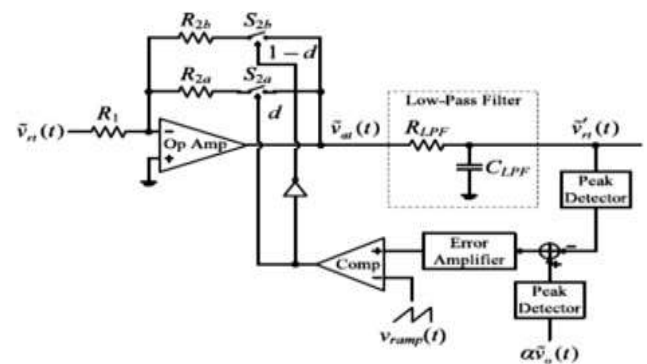


Fig. 4: Schematic diagram of the proposed amplitude tuner.

The schematic diagram is shown in figure (3). It mainly consist of an inverting amplifier, two feedback resistors (R_{2a} and R_{2b}) each connected in series with a switch having a turn-on time of dT_s and $(1-d)T_s$ respectively, where $1/T_s$ is the switching frequency. Here d is the duty cycle. Here a switching frequency of 20 KHz is chosen. According to error amplifier, from the pulse width modulator the duty cycle d is derived.

From the schematic diagram R_1 is the input resistance of the amplitude tuner R_{2a} / R_1 and R_{2b} / R_1 are gains during dT_s and $(1-d)T_s$ respectively. The instantaneous output signal $V \sim_{at}(t)$ is smoothened by low pass filter. The output of the low pass filter is shifted 180° in Phase.

The amplitude of the modified ripple template is denoted as $V' \sim_{rt}(t)$. It should be equal to the amplitude of the sample output voltage ripple. But its phase should be inverted compared to $V \sim_{rt}(t)$. Here LPF cutoff frequency is lighter than the double line frequency. After the amplitude equalization,

$$V' \sim_{rt}(t) = \alpha V_r \cos(2 \omega_{line}(t))$$

Where, V_r is the ripple template amplitude.

(iii) **Phase Shifter:** After the amplitude adjustment of ripple template, $V' \sim_{rt}(t)$ is fed to the input of phase shifter. Here phase adjustment can be obtained.

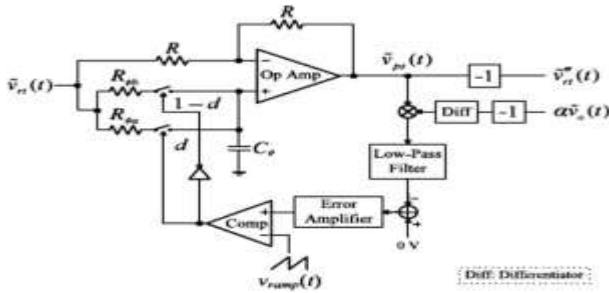


Fig. 5: Schematic diagram of the proposed phase shifter.

An input signal at frequency ω is pass through all-pass filter. This phase shift depend on frequency. Here amplitude cannot be changed. For adjusting the phase shift, two resistors R_{1a} and R_{1b} arranged to switch alternately. Here switching frequency is changed to be 20 KHz. Here d is duty cycle of switch. When d is varied from 0 to 1, the amount of phase shift will also vary from 0 to 180° .

The output of the phase shifter is $V_{rt}(t)$

$$V_{rt}(t) = -\alpha V_r(\cos(2\omega_{line}(t) + \theta_r))$$

$$V_{rt}(t) = -\alpha V_r(\cos(2\omega_{line}(t) + \theta_r))$$

$$V_{rt}(t) = \alpha V_o(t)$$

4. CONTROLLERS

A. Fuzzy Logic Controllers

Fuzzy Controller is used in the outer voltage loop. The fuzzy logic is a powerful tool to reduce the input current distortion and output voltage errors .FLC control rules can be applied to several pre-regulator topologies. According to converter parameters some scale factor must be tuned. A fuzzy control system can be explained as nonlinear control system. The analogue input for the fuzzy control system can be analysed in terms of logical variables. The three steps involved in fuzzy control are

- Fuzzification
- Rule-based
- Defuzzification

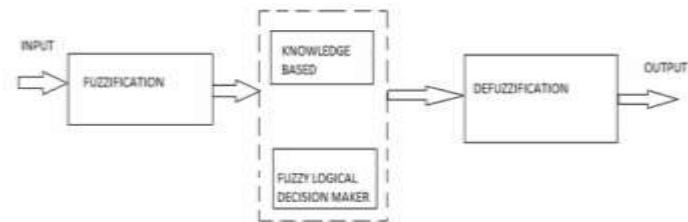


Fig. 6: Structure of fuzzy logic controller

1. Fuzzy Logic Controller for Boost converter

Figure shows the block diagram of fuzzy logic controller for boost converter.

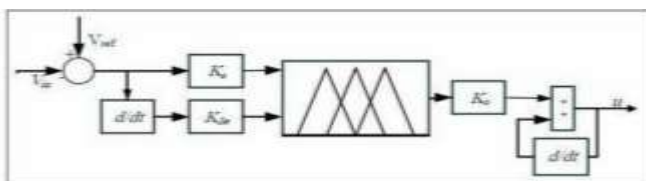


Fig. 7: Fuzzy Logic Controller

The fuzzy logic controller is for controlling the output voltage V_o . Fuzzy controller have two input variables. They are error voltage and change in error voltage. The error voltage is obtained from the difference between the output

voltage (V_o) and reference voltage (V_{ref}).The change in error de is obtained from the difference between the error voltage and previous error voltage.

$$\text{Error, } e = V_{ref} - V_o$$

$$de = e_k - e_{k-1}$$

$$dt$$

$$\Delta u = k_1 e + k_2 \frac{de}{dt}$$

2. Fuzzy logic membership function

The input error (e) and change in error (de/dt) has five membership function .Fuzzy controller compares the two input membership function and produce one output membership function

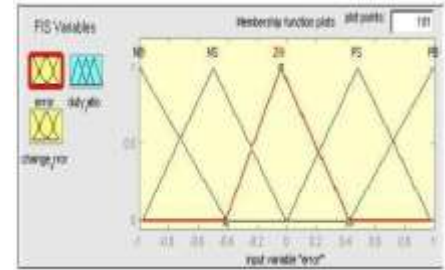


Fig. 8: Shows the membership function of input error (e)

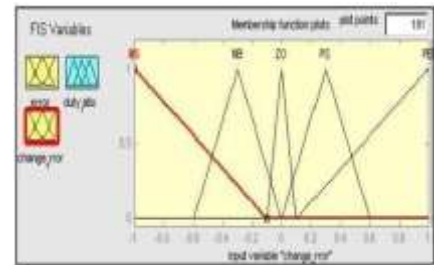


Fig. 9: Shows the membership function of change in error (de)

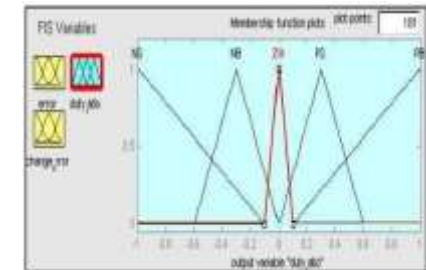


Fig. 10: Shows the membership function of output variables.

3. Fuzzy rules

The rules are collection based up on the knowledge and working of the system. The number of rules can be set as desired one. The rules-based include twenty five rules which depends on five membership function of input variable.

Table 1: shows the fuzzy rule

e/de	NB	NS	ZO	PS	PB
NB	NB	NB	NB	NS	ZO
NS	NB	NB	NS	ZO	PS
ZO	NB	NS	ZO	PS	PB
PS	NS	ZO	PS	PB	PB
PB	ZO	PS	PB	PB	PB

B. Predictive Controller

Predictive control is used for control of converter switch. If the case of converter switch 'S' is ON.

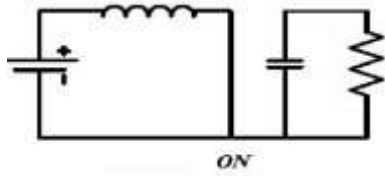


Fig 11. Shows the case of switch 'S' is ON

If the case of converter switch 'S' is OFF

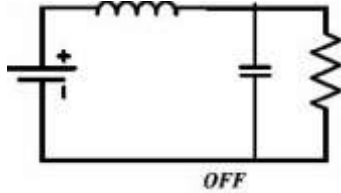


Fig. 12: Shows the case of switch 'S' is OFF

For switch 'S' is ON $\frac{di_L}{dt} = V_{in}(t)$ for $t(k) \leq t < t(k) + d(k)T_s$ (1)

$$\frac{di_L}{dt} = V_{in}(t) - V_o(t) \text{ for } t(k) + d(k)T_s \leq t < t(k+1) \quad (2)$$

Where, $t(k)$ is the started time at k^{th} switching

$t(k)$ is the started time at $k+1$ switching .

$d(k)$ is the duty cycle . T_s is the switching period

$$\frac{L i_L((t(k) + d(k)T_s) - i_L t(k))}{d(k)T_s} = V_{in}(t(k))$$

$$\frac{L i_L(t(k+1) - i_L(t(k) + d(k)T_s))}{(1 - d(k))T_s} = V_{in}(t) - V_o(t)$$

Figure (13) shows the inductor current for one switching cycle.

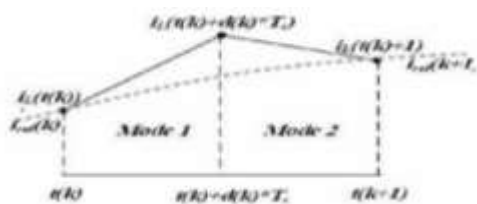


Fig. 13: Inductor current during one switching cycle

For designed boost converter, the inductor current $i_L(k+1)$ has force to track the sinusoidal reference. To calculate the duty cycle.

$$d(k) = \frac{L i_{ref}(k+1) - i_L(k)}{T_s V_{ref}(k)} + \frac{V_{ref}(k) - V_{in}(k)}{V_{ref}(k)}$$

From the above equation the reference current

$$i_{ref}(k+1) = k_{fuzzy} \cdot |\sin \omega_{line} t(k+1)|$$

k_{fuzzy} is the peak value of the reference current that given by the output of fuzzy controller.

Figure (14) shows a boost converter with predictive control and fuzzy controller.

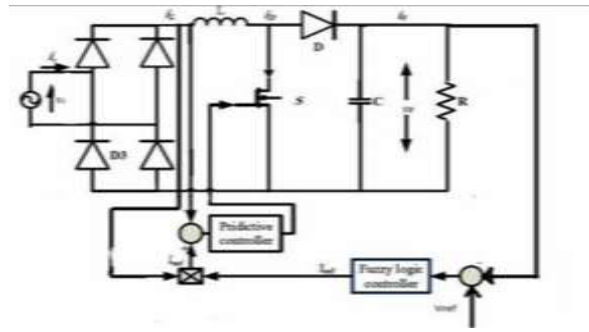


Fig. 14: Boost converter with predictive control and fuzzy controller

5. OVERALL SIMULATION

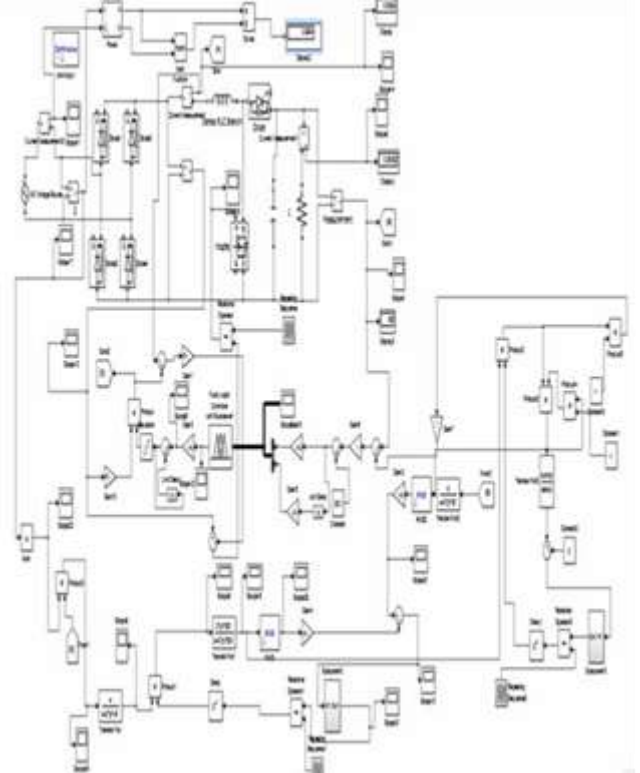


Fig. 15: Overall Simulation

The simulation results are given below:

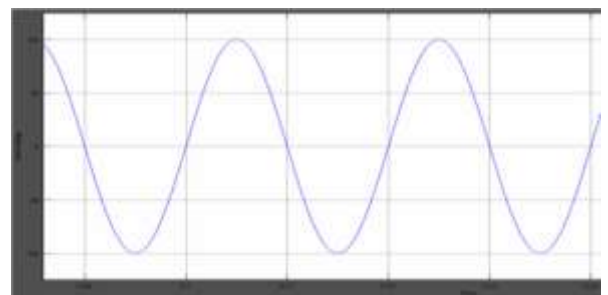


Fig. 16: Shows the input voltage waveform

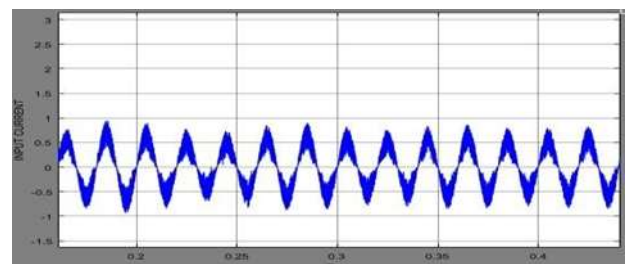


Fig. 17: Shows the input current waveform

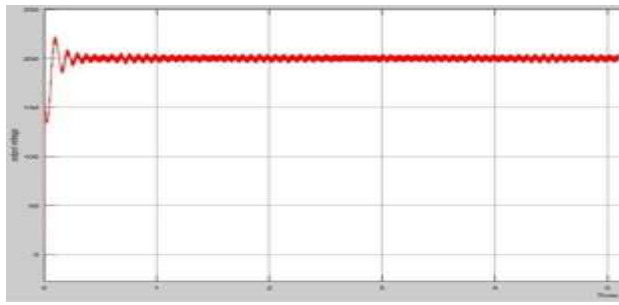


Fig. 18: Output voltage waveform



Fig. 19: Shows the output current waveform

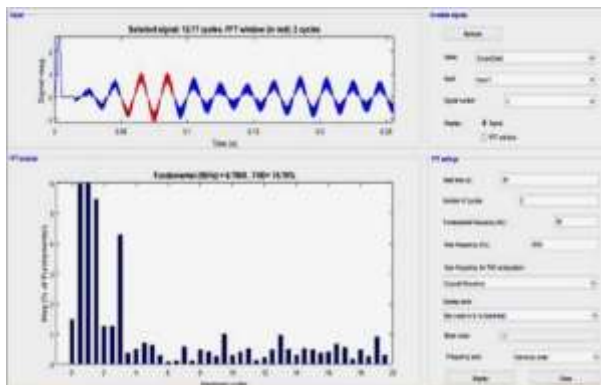


Fig. 20: Shows the harmonic spectrum of the input current

6. CONCLUSION

Simulation is performed in MATLAB. Here the closed loop performance of PFC converter based on ripple cancellation with predictive control and fuzzy controller study is discussed. Here verification of the circuit is done through the simulation model and its analysis.

By the use of this proposed control strategy, a closeness of unity power factor can be obtained. Here a power factor of 0.9815 is achieved. In this simulation, the THD of the input current is 18.78%.

7. ACKNOWLEDGMENT

I offer my sincere thanks to almighty, my guide, my parents, EEE department of TKM College of Engineering Karicode, KTU University for their immense support and for giving me an opportunity to dedicate my time and energy on this project and gather a lot of knowledge on the subject and present the same as a paper in this journal.

8. REFERENCES

- [1] R. Ghosh and G. Narayanan, "A simple method to improve the dynamic response of single-phase PWM rectifiers," *IEEE Trans. Ind. Electron.*, vol. 55, no. 10, pp. 3627–3634, Oct. 2008.
- [2] José Rodríguez, Senior Member, IEEE, Jorge Pontt, Senior Member, IEEE and Ulrich Ammann "Predictive Current Control of a Voltage Source Inverter", *IEEE transactions on industrial electronics*, vol. 54, no. 1, february 2007.
- [3] K. H. Leung, K. H. Loo, Member, IEEE, and Y. M. Lai, Senior Member, IEEE "Unity-Power-Factor Control Based on Precise Ripple Cancellation for Fast-Response PFC Preregulator", *IEEE transactions on power electronics*, vol. 31, no. 4, april 2016.
- [4] P.Kripakaran, J.Sathishkumar, R.Gopi Krishna" A Predictive Control Strategy for Power Factor Correction", *IOSR Journal of Electrical and Electronics Engineering*, Volume 8, Issue 6 Nov. Dec. 2013.
- [5] Mr.B.Sai Sreenivas, Dr.Ch.Sai Babu, Mr.D. Lenine " Design and Analysis of Predictive control using PI controller for Boost Converter with Active Power Factor Correction", *International Journal of Emerging Technology and Advanced Engineering* ,Volume 2, Issue 6, June 2012.
- [6] Abdelhalim Kessal" Combined Fuzzy and Predictive Controller for Unity Power Factor Converter", *International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering* Vol:8, No:9, 2014