

## Comparative Simulative Study of Power Factor Improvement by Employing Extinction Angle Control in AC-AC Voltage Converter

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### Abstract

The paper deals with comparative analysis of proposed single phase induction motor (SPIM) drive with Extinction Angle Control (EAC) technique and conventional TRIAC controller with Phase Angle Control (PAC) technique motor for fan load application. The important feature of presented scheme is leading and high power factor with smooth control. In this paper, the performance evaluation of presented scheme with EAC and conventional scheme with PAC has been illustrated in MATLAB Simulink for Static RL load. The simulated waveform of load voltage, load current, input voltage and input current for SPIM drive is also presented.

### Keywords

Efficiency; Extinction Angle; Power Factor; Induction Motor; Phase Angle; THD

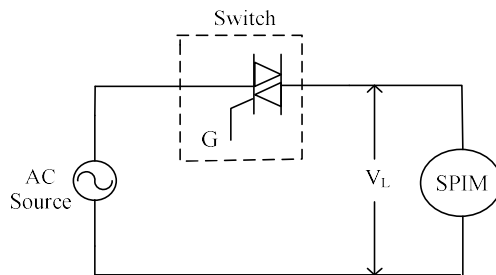
### Introduction

Single phase induction motor has been widely used for fan, blower load applications in various industries and also for low power residential applications. The control technique used for speed control of SPIM for such application is phase angle control technique with TRIAC as controllable switch. [1]-[3] However they have some disadvantages as low input power factor at large firing angle, lower efficiency and temperature rise in motor. The power flow is also discontinuous at both input and output side with PAC technique.[4] Moreover the efficiency of motor at light load is quite inefficient since the phase angle between stator voltage and stator current is lagging which makes power factor poor. [5]

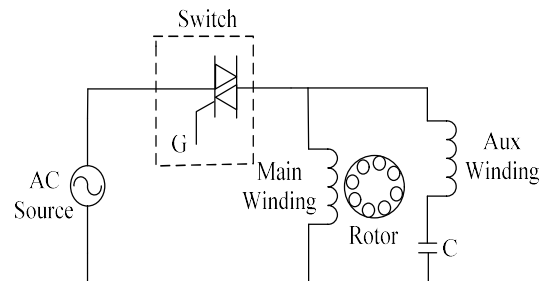
The present paper introduces a simple scheme to get direct AC to AC voltage for smooth speed control of induction motor with improved input power factor. The disadvantages discussed above with PAC technique can be overcome by employing EAC technique to the proposed scheme. The presented scheme consist of main switch which controls the speed of induction motor and freewheeling switch to freewheel the motor current when main switch is OFF. The speed of induction motor can be control by varying the duty ratio of main switch while during turnoff of switch, the circulation of current through the motor is maintained in same direction using freewheeling scheme. [6] The switching technique used to drive motor is such that the motor draws leading and high power factor current in entire controllable speed range.

### Circuit Description

The schematic diagram of conventional AC to AC voltage controller with phase angle control technique is shown in fig 1. The TRIAC is inserted in ac mains in series with main winding as shown in fig 2.

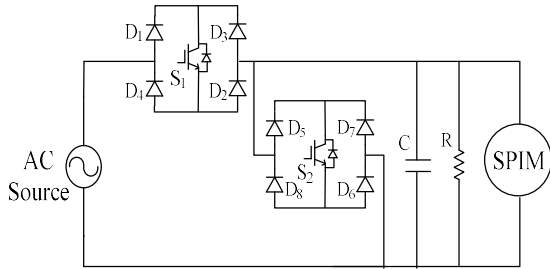


**Fig. 1: Power Circuit Diagram of Conventional Voltage Controller**

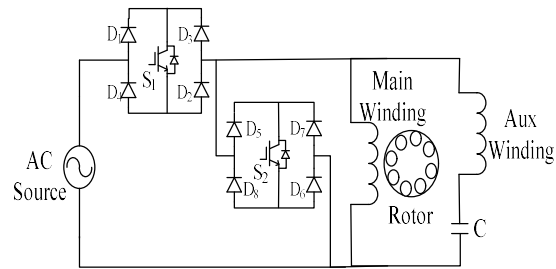


**Fig. 2: Detailed Circuit Diagram**

The variable voltage for variable speed control is achieved by adjusting the firing angle of TRIAC switch at every zero instant of input supply. [7] The circuit configuration of proposed scheme is shown in fig 3. The proposed scheme consists of two power semiconductor switches with two diode bridge rectifier. In general, one switch  $S_1$  is connected in series with the motor and other switch  $S_2$  is connected parallel with motor as shown in fig 4. The series connected main switch  $S_1$  regulates the power flow to motor and parallel freewheel switch provides the freewheeling path to discharge the stored energy in motor inductance to run motor itself. [7-8]



**Fig. 3: Power Circuit Diagram of Proposed Scheme.**



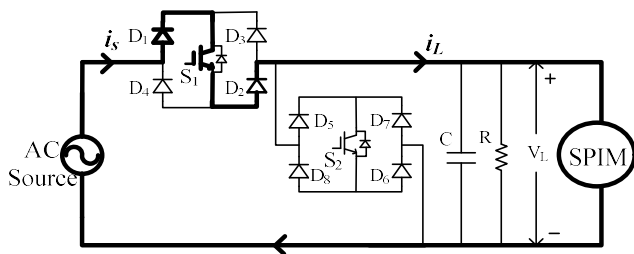
**Fig. 4: Detailed Circuit Diagram of Proposed Scheme.**

The PAC technique is employed on TRIAC based SPIM drive. The EAC technique is employed on proposed scheme to run SPIM drive. In phase angle control technique, the conduction of switch starts at  $\omega t = \alpha$  and continued till current reaches zero value while in EAC technique main switch  $S_1$  is turned on at every zero crossing instant of ac supply and forced commutated at  $\omega t = \pi - \beta$  where,  $\alpha$  and  $\beta$  are firing and extinction angle respectively. Freewheeling switch  $S_2$  is turned on just after turned off of main switch  $S_1$  with small deadband. [9]

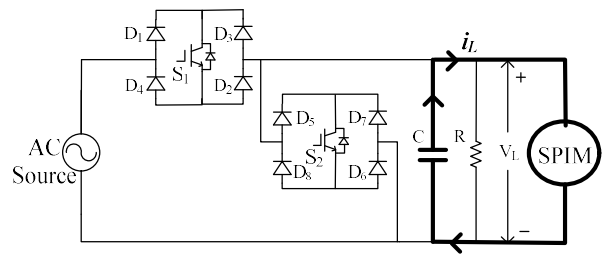
A small value of capacitor is connected across motor terminals so that during deadband mode motor current flows through capacitor and current through motor remains continuous during deadband mode.

**Modes of Operation**

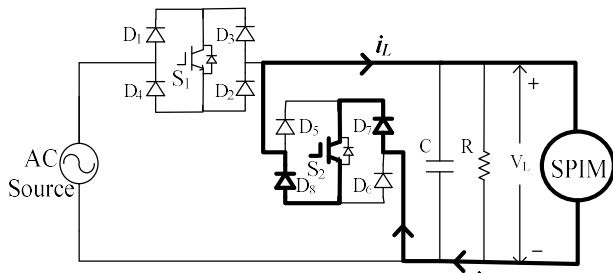
The modes of operation is divided in six modes and illustrated in fig 5(a)-(f)



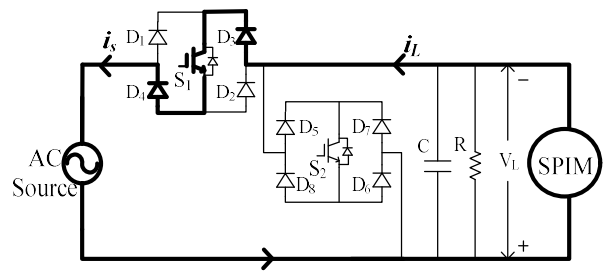
**Fig. 5(a): Mode 1**



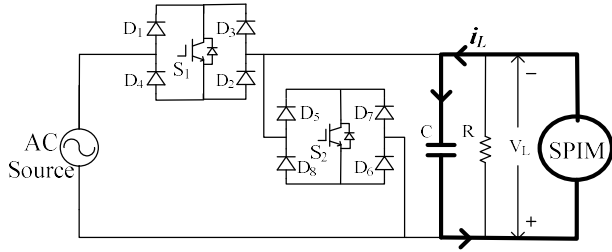
**Fig. 5(b): Mode 2**



**Fig. 5(c): Mode 3**



**Fig. 5(d): Mode 4**



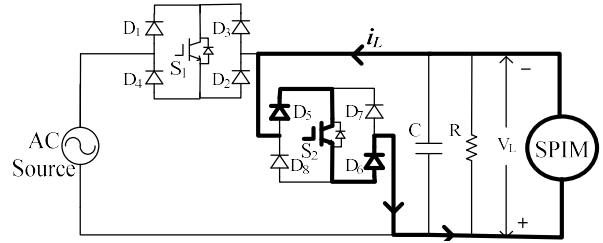
**Fig. 5(e) Mode 5**

**Mode 1:** Main switch  $S_1$  is turned ON and Switch  $S_2$  is turned OFF. This mode is called as active mode. The switch  $S_1$  is connected in series with main winding of SPIM and current flows from supply through switch  $S_1$  to the windings of motor. The motor current is positive and Load voltage is equal to  $+V_s$ .

**Mode 2:** Main switch  $S_1$  and Freewheeling switch  $S_2$  is turned off. The motor current is flowing through capacitor  $C$  connected in parallel with motor for very short duration. This mode is called as Deadband mode.

**Mode 3:** Freewheeling Switch  $S_2$  is turned on and Main switch  $S_1$  is turned off. The motor current continues to flow through motor in same direction but in decaying manner.

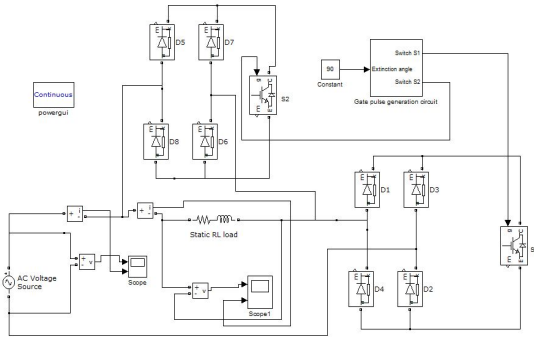
The switching conditions of main and freewheeling switches in Mode 4, Mode 5 and Mode 6 is similar to Mode 1, Mode 2 and Mode 3, but the direction of motor current and load voltage becomes reverse.



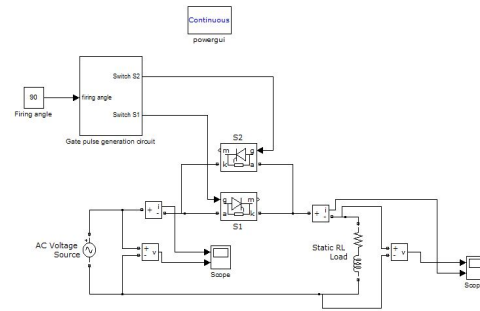
**Fig. 5(f) Mode 6**

**Simulink Model and Waveform**

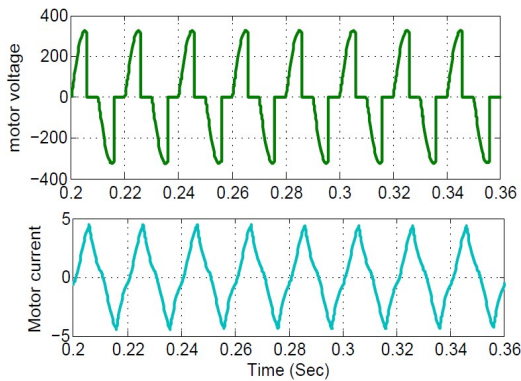
The proposed topology of direct AC to AC voltage controlled converter with EAC technique and conventional TRIAC controller with PAC technique is simulated by using MATLAB Simulink software. The Static RL load is considered for simulation with supply voltage 230V, 50Hz.



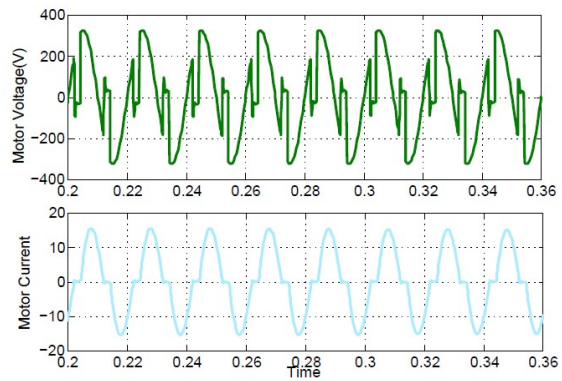
**Fig. 6: Simulink Model of Proposed Scheme with EAC Technique**



**Fig. 7: Simulink Model of Conventional TRIAC Controller with PAC Technique**



**Fig. 8: Waveform of Load Voltage or Motor Voltage and Motor Current at  $\beta=60^\circ$**



**Fig. 9: Waveform of Load Voltage or Motor Voltage and Motor Current at  $\alpha=60^\circ$**

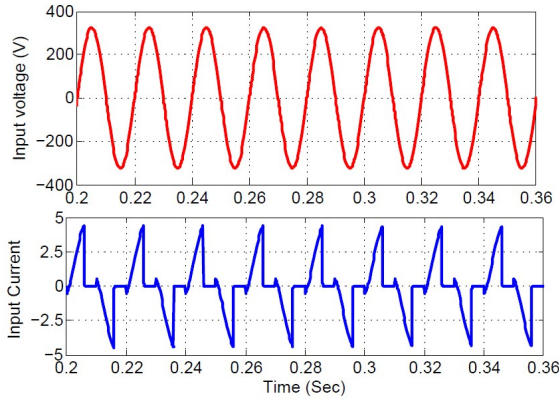


Fig. 10: Waveform of Supply Voltage and Supply Current at  $\beta=60^\circ$

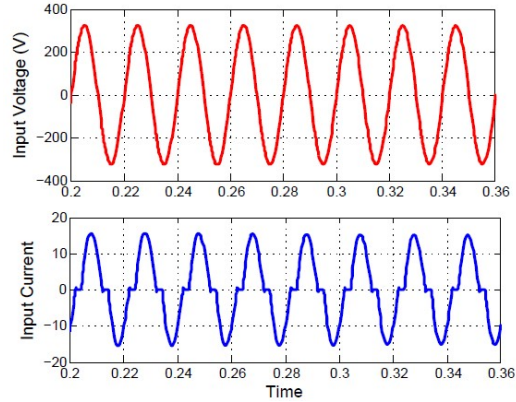


Fig. 11: Waveform of Supply Voltage and Supply Current at  $\alpha=60^\circ$

**Performance Analysis And Comparision**

This section presents the comparative and performance analysis of proposed AC-AC voltage converter and conventional converter at load angle  $\theta=45^\circ$  and  $60^\circ$ .

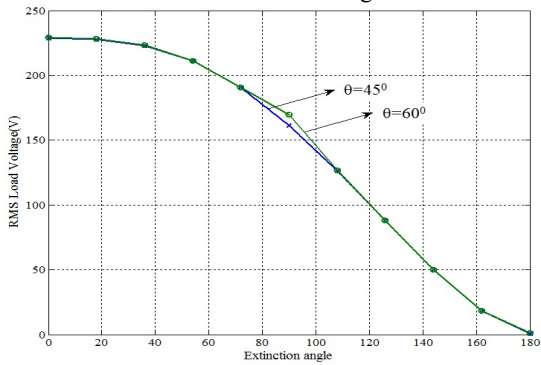


Fig. 12: Variation of RMS Load Voltage versus Extinction Angle at Load Angle  $\theta=45^\circ$  and  $\theta=60^\circ$

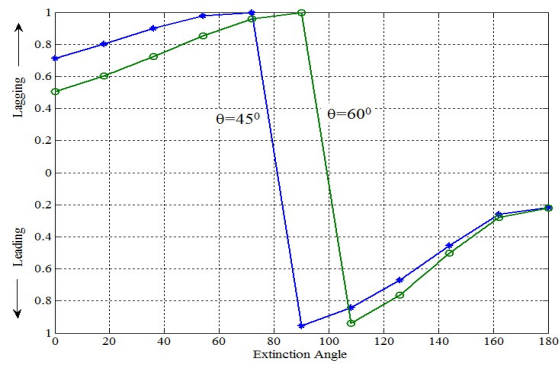


Fig.13: Variation of Input Power Factor versus Extinction Angle at Different Load Angle

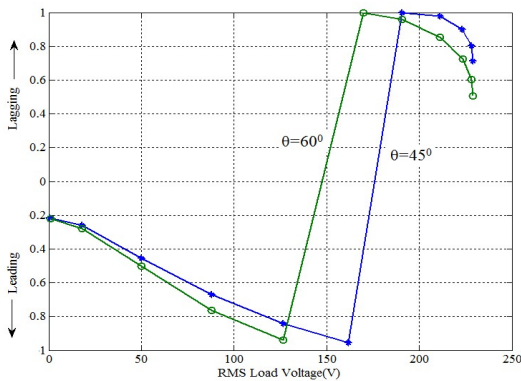


Fig.14: Variation of Input Power Factor versus RMS Load Voltage at Different Load Angle

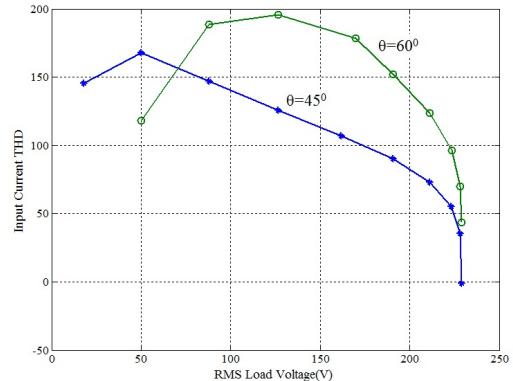
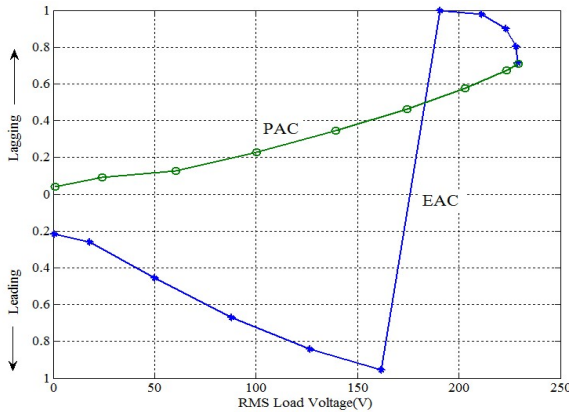
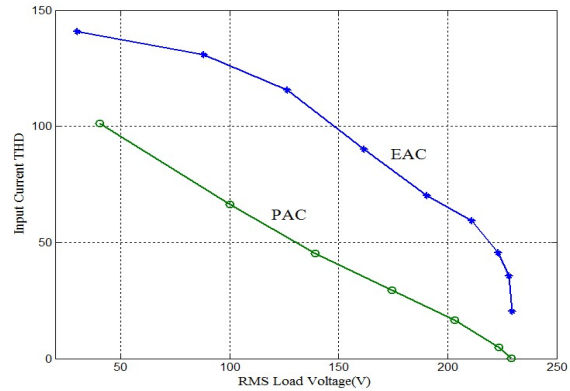


Fig. 15: Variation in Input Current THD versus RMS Load Voltage at Load Angle  $\theta=45^\circ$  and  $\theta=60^\circ$



**Fig.16: Variation of RMS Load Voltage versus Input Power Factor**



**Fig. 17: Variation of Input Current THD versus RMS Load Voltage at Load Angle  $\theta=45^\circ$**

Fig.12 shows the variation of RMS value of motor voltage with extinction angle  $\beta$  for load angle at  $\theta=45^\circ$  and  $\theta=60^\circ$ . It has been observed that the RMS value of motor voltage or load voltage decreases with increase in extinction angle  $\beta$ . The variation of input power factor with extinction angle for different load angle is shown in Fig 13. It has been observed that the input power factor is improved gradually from lagging PF and it becomes leading after it exceeds load angle and as extinction angle increases. In EAC technique, this feature is most important. Fig 15 shows variation of total harmonics distortion factor of current versus the RMS output voltage for different load condition. In this figure as the output voltage decreases, the extinction angle increases and hence the input THD increases. Also, as the load power factor decreases, the input THD increases.

Fig. 16 shows the variation of RMS load voltage with input power factor. As extinction angle increases the RMS load voltage decreases, the input power factor is improved from lagging power factor and becomes leading after the extinction angle exceed the load angle. However, the proposed scheme with EAC technique is better than conventional PAC technique for improving the input power factor. Fig. 17 illustrates the variation of the input current THD versus RMS output voltage.

### Conclusion

Comparative study of two techniques i.e. EAC and PAC for SPIM drive has been presented in this paper. The EAC technique was found to be better for input power factor improvement. It not only improves the supply power factor from load power factor but also it becomes leading as extinction angle exceeds load angle. The PAC technique applied to TRIAC controller is superior from input current THD point of view and provides better results than proposed technique.

### References

1. A. A. Khan, H. Cha and H. F. Ahmed, "An Improved Single-Phase Direct PWM Inverting Buck-Boost AC-AC Converter," in *IEEE Transactions on Industrial Electronics*, vol. 63, no. 9, pp. 5384-5393, Sept. 2016.
2. A. A. Khan, H. Cha, H. F. Ahmed, "High-efficiency single-phase AC-AC converters without commutation problem", *IEEE Trans. Power Electron.*, vol. 31, no. 8, pp. 5655-5665, Aug. 2016.
3. M. K. Nguyen Y. C. Lim Y. J. Kim "A modified single-phase quasi-Z-source AC-AC converter" *IEEE Trans. Power Electron.* vol. 27 no. 1 pp. 201-210 Jan. 2012
4. Ju-Sung Kang, N. A. Ahmed, Kwang-Joo Choi, Hyun Woo Lee and Mutsuo Nakaoka, "Pulse modulated AC voltage regulator using bidirectional active switches with different control strategies," *2005 International Conference on Electrical Machines and Systems*, Nanjing, 2005, pp. 1107-1111 Vol.2
5. S. Paramashivam and S. Muralidharan, "Analysis of AC/AC converter with enhanced power quality," *3rd International Conference on Electronics Computer Technology (ICECT)*, Kanyakumari, 2011, pp. 179-183
6. N. A. Ahmed and E. H. El-Zohri, "Power factor improvement of single-phase ac voltage controller employing extinction angle control technique," *46th IEEE Midwest Symposium on Circuits and Systems*, 2003, Vol. 3, pp. 1075-1080.
7. K. Ambhorkar, A. K. Rana, P. Jain and D. R. Tutakne, "Single phase AC-AC converter with improved power factor for efficient control of fan motors," *2016 7th India International Conference on Power Electronics (IICPE)*, Patiala, 2016, pp. 1-5.

8. S. Deotale and D. R. Tutakne, "Controllable Power Factor And Efficiency Improvement of Three Phase Induction Motor Using Extinction Angle Control," 2018 International Conference on Smart Electric Drives and Power System (ICSEDPS), Nagpur, 2018, pp. 351-356.
9. K. O. H. Eltayeb, M. M. Hamza and S. F. Babiker, "Displacement Power Factor Correction using Firing and Extinction Angle Control," 2018 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE), Khartoum, 2018, pp. 1-5.