# PSO Based Optimal Random PWM for Three Phase Induction Motor Drives

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***Abstract*** :

*The paper proposes an endeavour to optimize the time values of the triangular carrier in the case of Random Pulse Width Modulation (RPWM). The generated pulses obtained by RPWM are used for driving the Insulated Gate Bipolar Transistors (IGBT's) of Voltage Source Inverter (VSI). The output of VSI is fed to the three phase Induction Motor. Total Harmonic Distortion (THD) is employed as the objective function for the optimization problem. Particle Swarm Optimization (PSO) is used to find the best optimal time series values of the triangular carrier in RPWM. Simulation results prove excellent performance on reducing THD of output voltage. PSO optimized random PWM is found to be superior, compared with conventional PWM techniques.*

**Keywords** — *RPWM, PSO, THD, HSF, VSI*

## I. INTRODUCTION

Various PWM techniques have been increasingly employed for VSI fed three phase Induction Motor drives. Among various PWM strategies, RPWM has gained popularity for power electronic converter applications, especially in the case of three phase inverters. The pulse width modulation (PWM) is one of the key techniques in the power converter and has gained extensive research and application [1-3]. RPWM techniques are developed with an aim to reduce the noise and vibration characteristics of electric drives in Adjustable Speed Drives (ASDs). RPWM can be employed in situations, where the problems are caused not only by acoustic noise, but also by electromagnetic noise [4]. As the overall pulse pattern varies from cycle to cycle, power spectra acquires a continuous part with reduced harmonic power [5].An optimal SVPWM method considering the switching sub cycles as optimization variables is proposed in [6].

Various heuristic approaches such as genetic algorithm (GA), Particle swarm optimization (PSO), and artificial neural network (ANN) for optimizing the switching angles of the PWM are proposed in [7]-[12].A harmonic reduction approach for a PWM AC-AC converters using Bee Colony Optimization for optimizing the switching angles is proposed in [13].

The paper is organized as follows. Section 2 gives the detailed schematic of the proposed system and briefly describes the swarm based optimization algorithm such as Particle Swarm Optimization Algorithm. Section 3 presents the simulation results. Conclusion is given in Section 4.

## II. PROPOSED SYSTEM

### A. *Problem Formulation*

The problem is formulated to optimize the time series values of triangular carrier RPWM. The objective function is given by

$$THD = \frac{1}{C_1}\sqrt{\sum_{i=2}^{N} C_i^2}$$

Where,

$$C_i = \sqrt{A_i^2 + B_i^2}$$

$$A_i = \frac{2}{T_0}\int T_0 U_{ab}(t)\cos n\omega_0 t dt$$

$$B_i = \frac{2}{T_0}\int T_0 U_{ab}(t)\sin n\omega_0 t dt$$

$\omega_0$ is the fundamental frequency

$$T_0 = \frac{2\pi}{\omega_0}$$

$$U_{ab}(t) = A_0 + \sum_{i=1}^{N}[A_i\cos(i\omega_0 t) + B_i\sin(i\omega_0 t)]\,(V)$$

### B. *Block Diagram of the Proposed System*

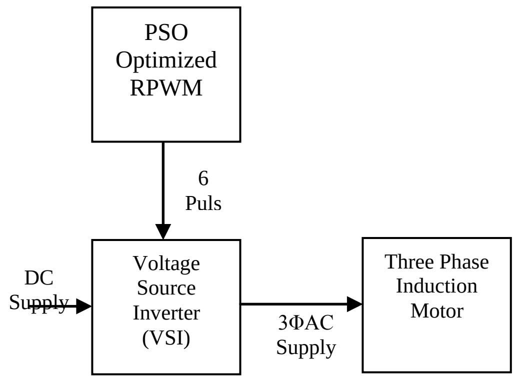


**Fig. 1 Block Diagram of the Proposed System**

Fig. 1 shows the block diagram of the proposed system. Direct Current (DC) supply is fed to the VSI. The time series values of carrier in RPWM are optimized by using PSO and the resulting six pulses are fed to the IGBT's of VSI. The output of VSI is used to drive a three phase Induction Motor.

### *C. Flow Chart of PSO Based Optimal RPWM*

Particle swarm optimization (PSO) is a swarm based optimization technique developed by Eberhart and Kennedy in 1995. The algorithm is inspired by social behavior of birds. The non existence of operators such as crossover and mutation reduces the parameter, as compared to GA. The potential solutions, called particles, move through the problem space by tracking the current optimum particles. Every single solution is a "bird" in the search space called as "particle". Fitness values of each particle are evaluated by the fitness function, and have velocities that direct the movement of the particles. PSO is initialized with a group of random solutions, known as particles and finally searches for optima by updating the generations. In every iteration, each particle is updated by “pbest" and “gbest” value. “pbest" is the best fitness achieved so far by the particles in the population. The “gbest” is the best value, obtained so far by any particle in the population.

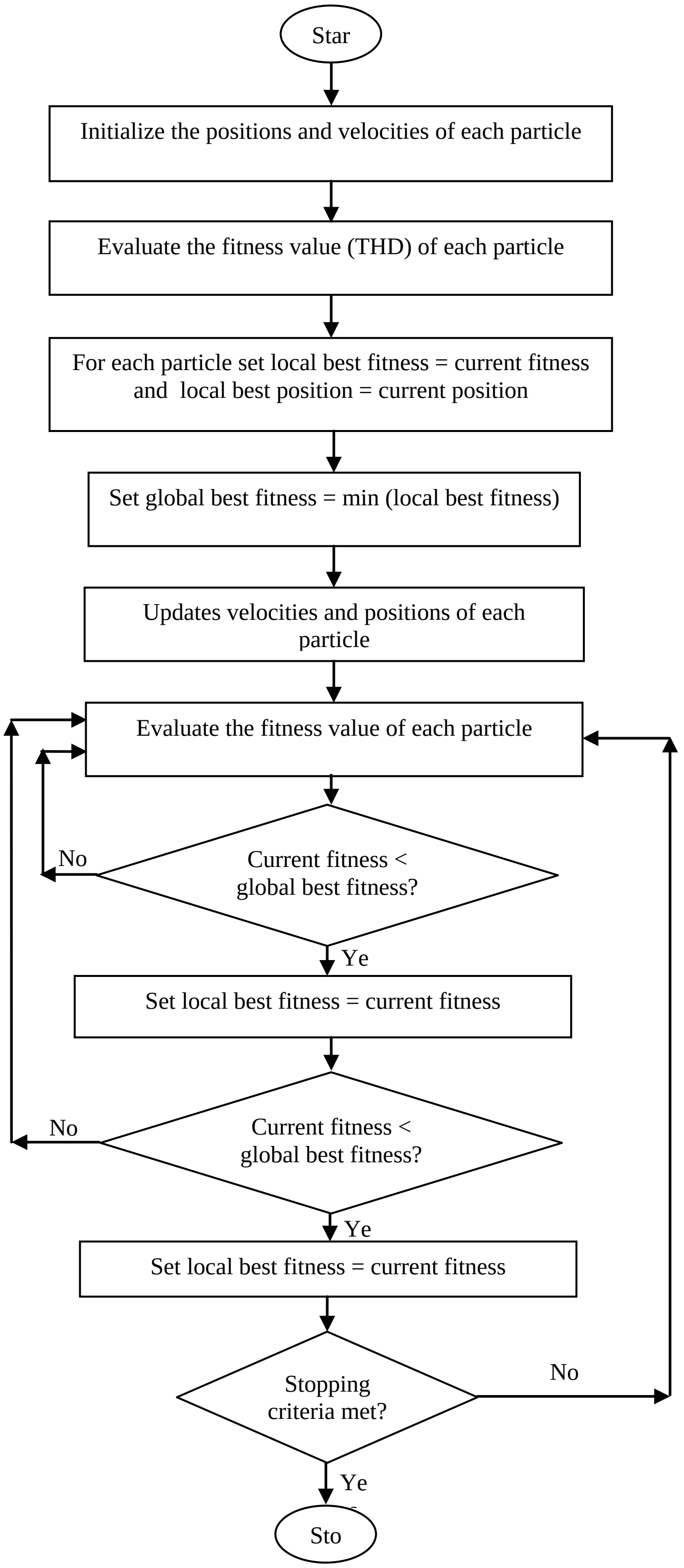


**Fig. 2 Flow Chart of PSO Based Optimal RPWM**

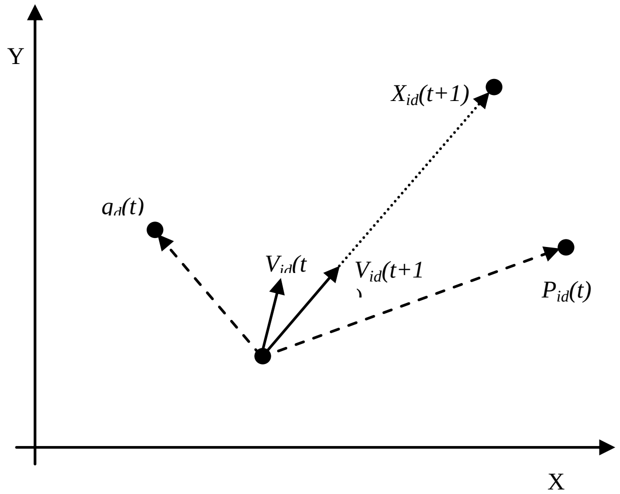


**Fig. 3 Flow Chart of PSO Based Optimal RPWM**

The position and velocity update equations are given by

$$V_{id}(t+1) = w.V_{id}(t) + c_1.r_1[P_{id}(t) - x_{id}(t)] + c_2.r_2[g_d(t) - x_{id}(t)]$$

$$x_{id}(t+1) = x_{id}(t).V_{id}(t+1)$$

$w.V_{id}(t)$ represents the inertia of the previous velocity

$c_1.r_1[P_{id}(t) - x_{id}(t)]$ is the cognition part that provides information about the personal experience of the particle,

$c_2.r_2[g_d(t) - x_{id}(t$ represents the cooperation among particles, named as the social component.

Acceleration constants (C1, C2) and Inertia weight (w) are to be defined by the user

r1& r2 are the uniformly generated random numbers in the range of [0, 1]

## III.SIMULATION RESULTS & DISCUSSION

The pulse-width series produced by standard PWM inverter is consider as the initial population. THD of PWM inverter output is taken as the fitness value of the chromosome. The simulations are carried out for a 0.75 kW, 50 Hz, 3Φ Induction Motor. The parameters (RPWM & PSO) used in the simulation are given in Table I and II respectively.

**TABLE I : Parameters of RPWM**

| Parameters | Value |
|---|---|
| Amplitude (Vp-p) of carrier wave | 2V |
| Frequency of sinusoidal wave | 50Hz |
| Modulation index | 0.2 to 1.2 |

**Table II: Parameters of PSO**

| Parameters | Value |
|---|---|
| Population size | 200 |
| Maximum number of generations | 50 |
| Acceleration Constants (C1) | 2.0 |
| Acceleration Constants (C2) | 2.0 |
| Inertia weight (w) | 0.4 |

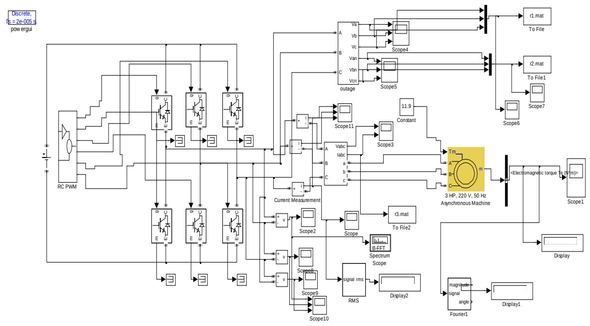

**Fig. 4 Simulink Implementation of PSO Based Optimal RPWM for VSI Fed IM drive**

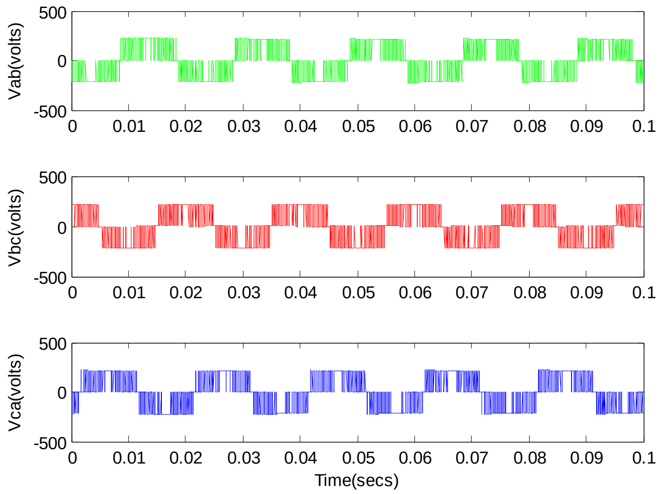


**Fig. 5 Phase-to-Phase Voltage Waveforms (PSO – RPWM)**

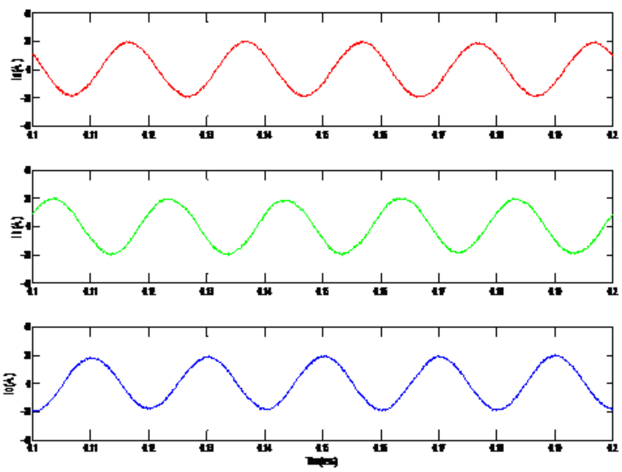

**Fig. 6 Line current Waveforms for Three Phases (PSO – RPWM)**

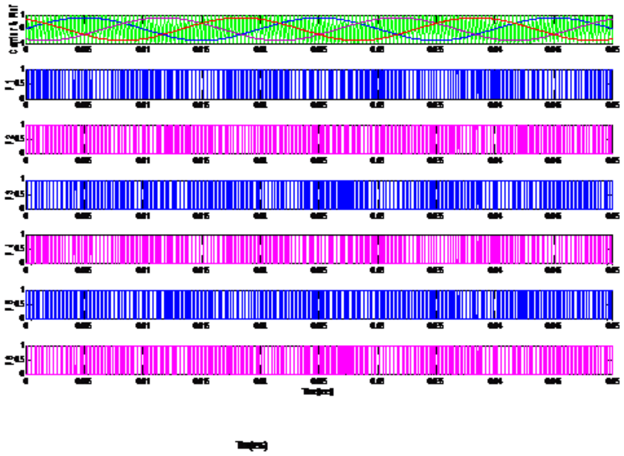

**Fig. 7 Carrier Waveforms & Outputs of Six Pulses (PSO – RPWM)**

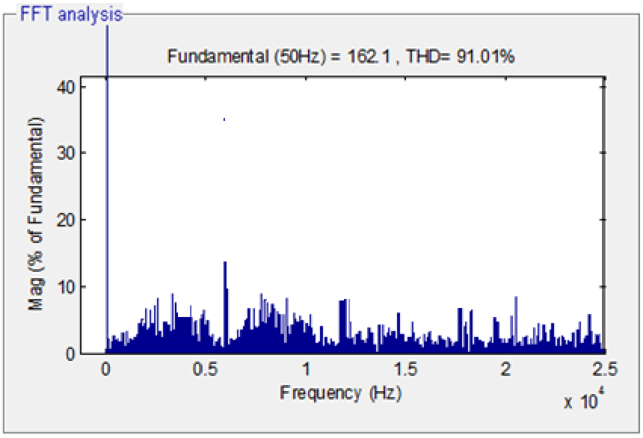


**Fig. 8 FFT Analysis**

**Table III : Results of Existing GA Based RPWN**

| | Existing GA based RPWM | | |
|---|---|---|---|
| Ma | Fundamental Component of Output Voltage | Total Harmonic Distortion | Harmonic Spread Factor |
| 0.2 | 52 | 253 | 8.1 |
| 0.4 | 89 | 162 | 6.4 |
| 0.6 | 126 | 110 | 5.9 |
| 0.8 | 161 | 91 | 5.5 |
| 1.0 | 177 | 71 | 5.3 |
| 1.2 | 224 | 67 | 4.8 |

**TABLE IV : Results of PSO RPWM**

| | PSO RPWM | | |
|---|---|---|---|
| Ma | Fundamental Component of Output Voltage | Total Harmonic Distortion | Harmonic Spread Factor |
| 0.2 | 53 | 253 | 7.9 |
| 0.4 | 91 | 162 | 5.6 |
| 0.6 | 130 | 112 | 5.4 |
| 0.8 | 162 | 91 | 5.3 |
| 1.0 | 181 | 69 | 5.1 |
| 1.2 | 231 | 64 | 4.7 |

Fig. 4. shows the MATLAB - Simulink implementation of the proposed system.

Fig. 5. and 6. shows the phase to phase voltage and line current waveforms of proposed PSO-RPWM.

From the Table IV, it is inferred that PSO has almost the same total harmonic distortion. Fundamental Component of output voltage is slightly improvesd with PSO compared to GA. The Harmonic Spread Factor (HSF) is reduced by 20% in PSO based random PWM technique, for the modulation index of Ma =0.8.

## IV. CONCLUSIONS

By optimizing the time series value of the triangular carrier wave, it is inferred that the fundamental voltage is increased slightly, while the total harmonic distortion remains almost the same, compared to conventional RPWM. Harmonics Spread Factor is improved as compared to other existing evolutionary RPWM techniques. From the simulation results, it can be concluded that PSO optimized RPWM performs well than GA based RPWM technique.

## REFERENCES

[1] Ahmet M. Hava, Russel J. Kerlman, Thomas A. Lipo, 1999, "Simple Analytical and Graphical Methods for Carrier-based PWM-VSI Drives", *IEEE Transactions on Power Electronics*, vol. 14, No.1, pp.49~61.

[2] Holmes D. G., Lipo T. A., 2003, "Pulse Width Modulation for Power Converters: Principles and Practice", *IEEE Press*, USA.

[3] ZHENG Zhongjiu, LI Guofeng, WANG Ninghui, 2011, "Research on Control Strategy of Three-phase High Power Factor PWM Rectifier", *JDCTA: International Journal of Digital Content Technology and its Applications*, Vol. 5, No. 8, pp. 365 ~ 373.

[4] A.M. Stankovic, G.C. Verghese, and D.J. Perrault, "Analysis and synthesis of random modulation schemes for power converters," *in Proc. PESC93*, pp. 1068-1074.

[5] J.T. Boys, 1993, "Theoretical spectra for narrow-band random PWM waveforms". , vol. 140, no. 6, pp. 393-400.

[6] Joachim Holtz, Bernd Beyer, 1994, "Optimal Pulsewidth Modulation for AC Servos and Low-cost Industrial Drives", IEEE Transactions on Industrial Electronics, Vol.40, No.4, pp. 1039~1047.

[7] K. Sundareswaran and A. P. Kumar, 2004, "Voltage harmonic elimination in PWM A.C. chopper using genetic algorithm," in Proc. IEE Electr. Power Appl., Vol. 151, No. 1, pp. 26-31.

[8] S. S. Rao and S. N. Warangal, 2005, "Improving voltage regulation and harmonic elimination using genetic algorithm in PWM choppers," in Proc. INTELEC, pp. 449-454.

[9] M. S. A. Dahidah and M. V. C. Rao, 2007, "A hybrid genetic algorithm for selective harmonic elimination PWM AC/AC converter control," Electric Engineering, Vol. 89, No. 4, pp. 285-291.

[10] S. Kaitwanidvilai and P. Piyarungsan, 2010, "Low-cost microprocessor-based alternating current voltage controller using genetic algorithms and neural network," IET Power Electron., Vol. 3, No. 4, pp. 490-499.

[11] P. Jitta, S. Kaitwanidvilai, and A. Ngaopitakkul, 2011, "Switching angle design for pulse width modulation AC voltage controller using genetic algorithm and distributed artificial neural network," in Proc. IMECS, pp. 970-974.

[12] A. Kouzou, S. Saadi, M.O. Mahmoudi, and M. S. Boucherit, 2009, "Voltage quality enhancement of PWM AC voltage controller using particle swarm optimization," in Proc. POWERENG, pp. 309-314.

Wanchai Khamsen†, Apinan Aurasopon*, and Chanwit Boonchuay, 2014, "Optimal Switching Pattern for PWM AC-AC Converters Using Bee Colony Optimization", Journal of Power Electronics, Vol. 14, No. 2, pp. 362-368.