e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:02/February-2022 Impact Factor- 6.752 www.irjmets.com

PULSE WIDTH MODULATION BY PARTICLE SWARM OPTIMMIZATION FOR THREE – PHASE RECTIFIERS

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ABSTRACT

Pulse-width modulated three-phase rectifiers are widely used in power supply distribution systems such as in small turbines, wind power, gas electromagnetics, etc. Controlled and non-controlled rectifiers are normally non-linear. Therefore, it causes high harmonic content in current, power factor reduction, low efficiency, voltage distortion, etc. To overcome these disadvantages, power converter needs to apply techniques control technique. The spatial space vector pulse width modulation (SVPWM) method used for rectification control has given certain results. Besides, pulse width modulation technique applying swarm optimization algorithm (PSO) has been widely applied in engineering field due to its simplicity and high efficiency compared to other algorithms. This paper presents a pulse width modulated rectifier by PSO to find optimal parameters for PID controller simulated on Matlab software, which has controlled output voltage exactly according to preset parameters, good response time, fast setup time and small overshoot (TDH).

Keywords: DC Motor Control, PWM, PID Controller, PSO, SVPWM, TDH, Three-Phase Rectifiers.

I. INTRODUCTION

DC power supply with high power quality, low harmonics, and power factor that can be adjusted according to operating requirements is one of the practical requirements in today's electrical engineering industry. Active rectification has many advantages when it comes to power quality and the harmonic distortion that can be achieved is very low. Currently, many rectification control methods have been studied and applied, such as sine pulse width modulation (SPWM) [1], [2] and space vector pulse width modulation (SVPWM) [3], [4], [5], [6], [7].

The PID controller requires complex calibration and by many experimental results. To solve this problem, the PSO algorithm is applied to detect the parameters K_p, K_i for the PID controller [8], [9], [10], [11], [12]. The research on pulse width modulation (PWM) rectifier control methods has been carried out more and more, the most successful one is the spatial vector PWM method (SVPWM).

This paper focuses on research on pulse width modulation by space vector method (SVPWM) using swarm optimization algorithm (PSO) to find optimal parameters for PID controller. This is a promising solution with the advantages of this structure: improved harmonics of the current for many nonlinear loads; improved power factor in case of high load application; Improved power supply current alignment. The results obtained from this study show that the system has fast response, overshoot and low harmonic distortion.

II. RESEARCH METHOD

2.1 Mathematical model of the PWM rectifier:

The three-phase rectifier circuit uses a three-phase source with a neutral point with the schematic diagram as shown in Figure 1. The circuit consists of six independently controlled K-locks. Each K-lock consists of an IGBT and a diode in parallel for bidirectional conduction. Capacitor C is used to filter the output voltage flat. The coil L and the resistor R are two components of the source filter boost inductor. Control the switching of the keys K so that the output DC voltage reaches the desired set value. Control law: do not close two locks on the same phase to avoid output short circuit, (State of the lock $\overline{K_a}, \overline{K_b}, \overline{K_c}$ is not concurrent with the lock state K_a, K_b, K_c).

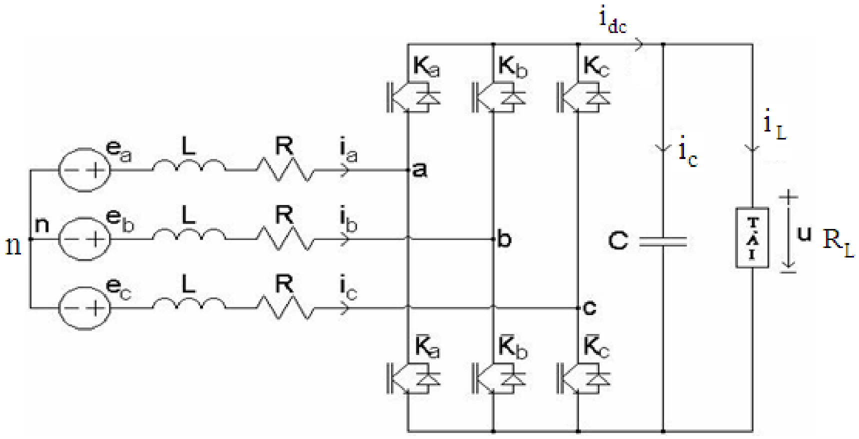

Fig 1: Three-phase rectifier circuit

2.2 Spatial vector pulse width modulation (SVPWM)

SVPWM is implemented by rotating a reference vector around the state diagram, which consists of six fundamental non-zero vectors forming a voltage-space vector diagram for the PWM rectifier as shown in Figure 2 [5], [6], [7].

The working principle of the pulse width modulation space vector circuit is: Control the switching of the keys K so that the output DC voltage reaches the desired set value. Control law: do not close two locks on the same phase to avoid output short circuit. IGBT trigger state according to the spatial vector according to Table 1 with the value 1 being locked, -1 is locking interrupt (State of locks $\overline{K_a}, \overline{K_b}, \overline{K_c}$ is not concurrent with state key K_a, K_b, K_c).

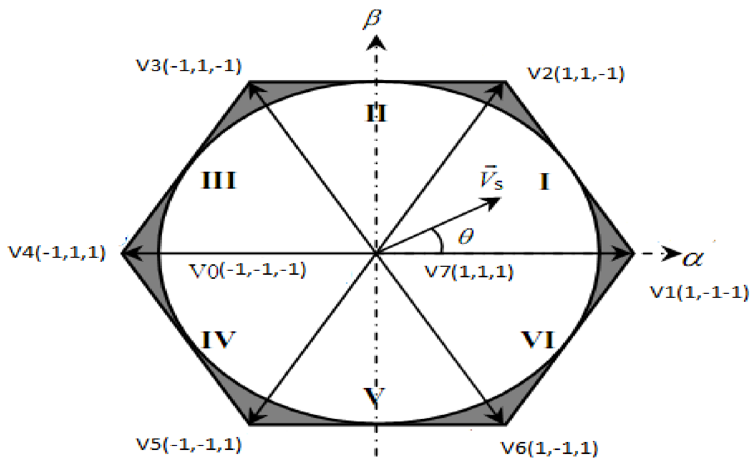

Fig 2: A voltage-space vector diagram for the PWM rectifier

Table 1: IGBT excited state table by space vector.

Status	V1	V2	V3	V4	V5	V6	V7	V0
Click angle position	V(1,-1,-1)	V(1,1,-1)	V(-1,1,-1)	V(-1,1,1)	V(-1,-1,1)	V(1,-1,1)	V(1,1,1)	V(-1,-1,-1)
K_a	1	1	-1	-1	-1	1	1	-1
K_b	-1	1	1	1	-1	-1	1	-1
K_c	-1	-1	-1	1	1	1	1	-1
$\overline{K_a}$	-1	-1	1	1	1	-1	-1	1
$\overline{K_b}$	1	-1	-1	-1	1	1	-1	1
$\overline{K_c}$	1	1	1	-1	-1	-1	-1	1

2.3 PSO Algorithm

The swarm optimization method is a form of population evolutionary algorithms known before such as genetic algorithm (GA), Ant colony algorithm. However, PSO differs from GA in that it favors using the interactions between individuals in a population to explore the search space. PSO is the result of modeling the flight of birds in search of food, so it is often classified as algorithms that use swarm intelligence [13], [14], [15], [16].

PSO is initialized by a random group of instances, then searches for the optimal solution by updating generations (iterations). In each generation, each instance is updated by two values: the first value PBest is the best solution obtained so far, the second value GBest is the best solution that the individual is neighboring to the individual. This has been achieved so far. In other words, each individual in the population updates the position according to the best position or other individuals in the population up to the present time. The process of updating instances is based on the following two formulas:

$$x_{i,m}^{(k+1)} = x_{i,m}^{(k)} + v_{i,m}^{(k+1)};\ i=1,2,\ldots,n \quad ;\ m=1,2,\ldots,d \qquad (1)$$

$$v_{i,m}^{(k+1)} = w.v_{i,m}^{k} + c_1 * rand * \left(Pbest_{i,m} - x_{i,m}^{k}\right) + c_2 * Rand * \left(Gbest_m - x_{i,m}^{k}\right) \ (2)$$

In there:

- n: number of elements in the group.
- d: population size (dimension).
- k: number of repetitions.
- $v_{i,m}^{(k)}$: velocity of the i-th individual in the k-th generation.
- w: weight coefficient of inertia.
- c_1,c_2: acceleration coefficient.
- $Rand$: is a random number in the range (0,1).
- $x_{i,m}^{(k)}$: position of i-th individual in k-th generation.
- P_{best_i} : the best position of the i-th individual.
- G_{best_i} : the best position of an individual in a population

2.4 Adjusting PID Controller using PSO algorithm

The PID controller uses the PSO algorithm to calibrate the parameters in the three-phase rectifier control Figure 3 as follows.

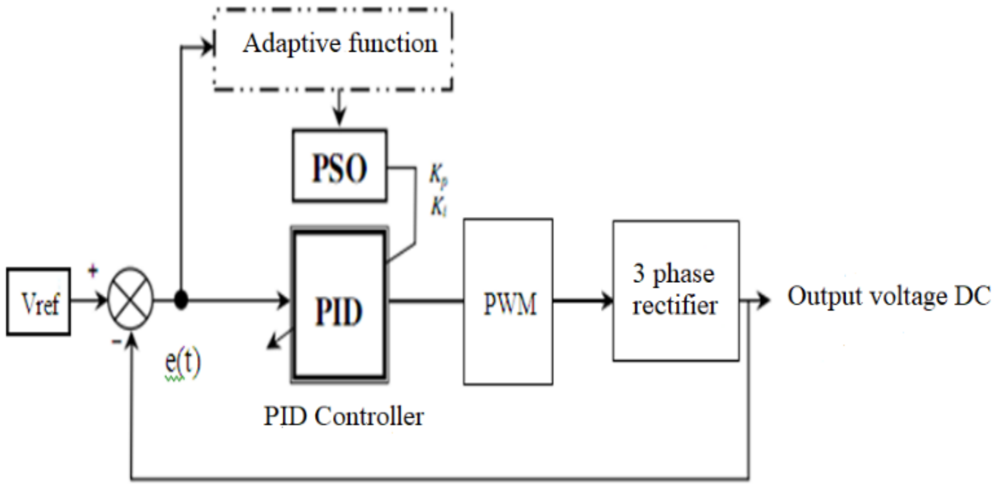

Fig 3: PID controller by swarm algorithm

The K_p, K_i detection block in the PSO algorithm: includes Vref, the PSO adaptive function finds the parameters K_p, K_i, and is placed in the PWM pulse generator block to control the power block for output voltage equal to the preset voltage. The objective of the PID correction method using the PSO algorithm is: to minimize the objective function; find the response step of the system and reduce the error e(t); Repeat the steps until the number of iterations is complete.

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The control objective is to control the output voltage of the 3-phase PWM rectifier to reach the set voltage without overshoot, fast response speed, and near zero setting error.

III. RESULTS AND DISCUSSION

3.1 Three-phase SVPWM rectifier with PID-PSO control

Figure 4 is a three-phase closed-loop rectifier with PID-PSO control simulated on Simulink on Matlab. With the 3-phase SVPWM rectifier closed-loop control block shown in Figure 5. And the 3-phase SVPWM rectifier PWM block with PID-PSO control as shown in Figure 6. With PSO running parameters: n=50; bird setp = 50; dim = 2; C2 = 1.2; C1 = 0.12; w = 0.9.

Simulink simulation results on Matlab will show that the control structure is capable of working well with a voltage of 400V; frequency 50 Hz as shown in Figure 7 and Figure 8. Loading time is about 0.1s as shown in Figure 9. We have a power factor Cosφ equal to 1. The grid current is sinusoidal, and the high-order harmonic wave is negligible. Stabilize voltage when carrying load and cutting load. The distortion of the THD waveform (%) is small as shown in Figure 10.

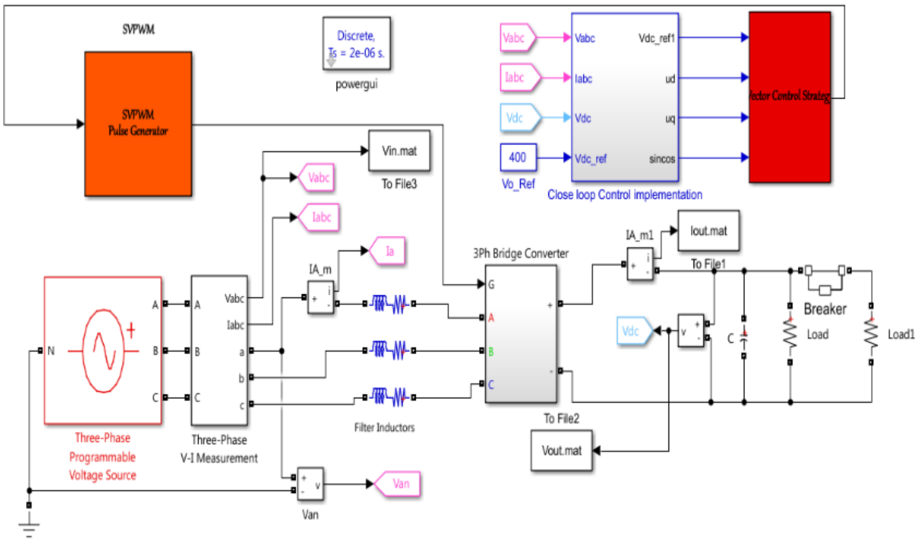

Fig 4: Simulink diagram of 3-phase SVPWM rectifier with PID-PSO control

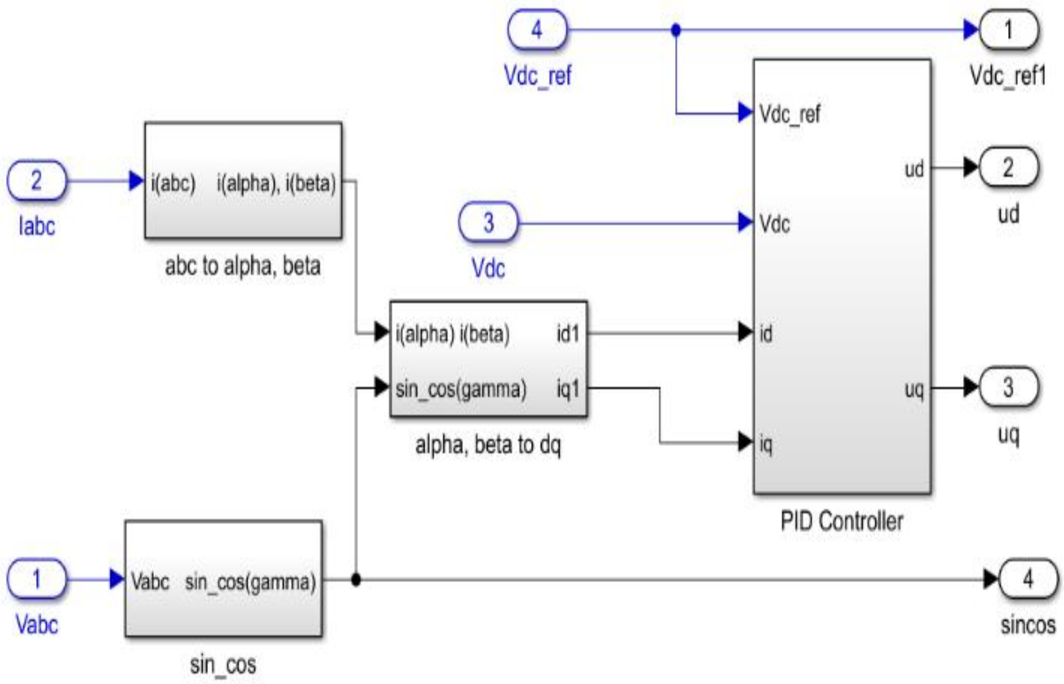

Fig 5: Three-phase rectifier closed-loop control block SVPWM

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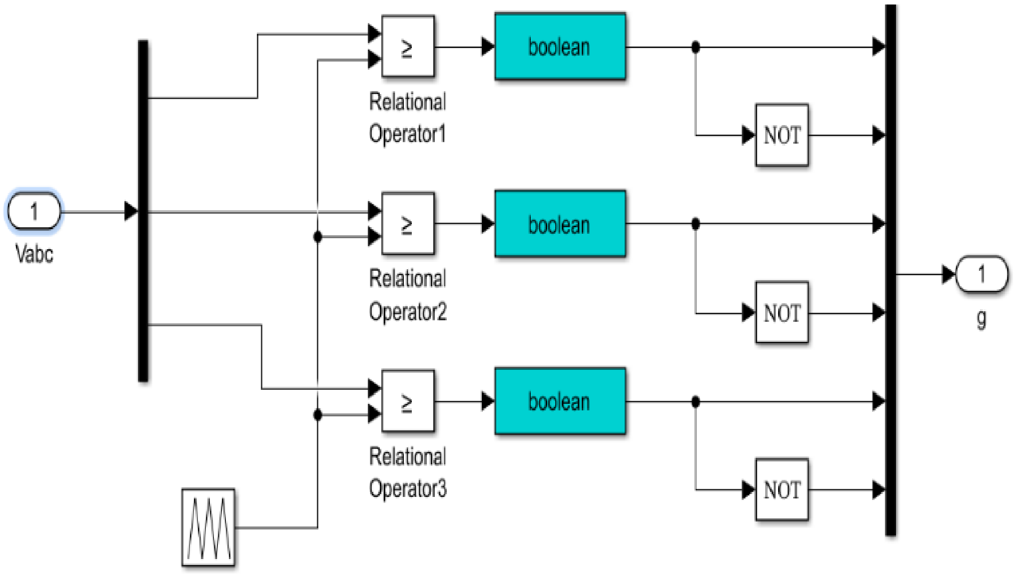

Fig 6: Three-phase SVPWM rectifier PWM block with PID-PSO control

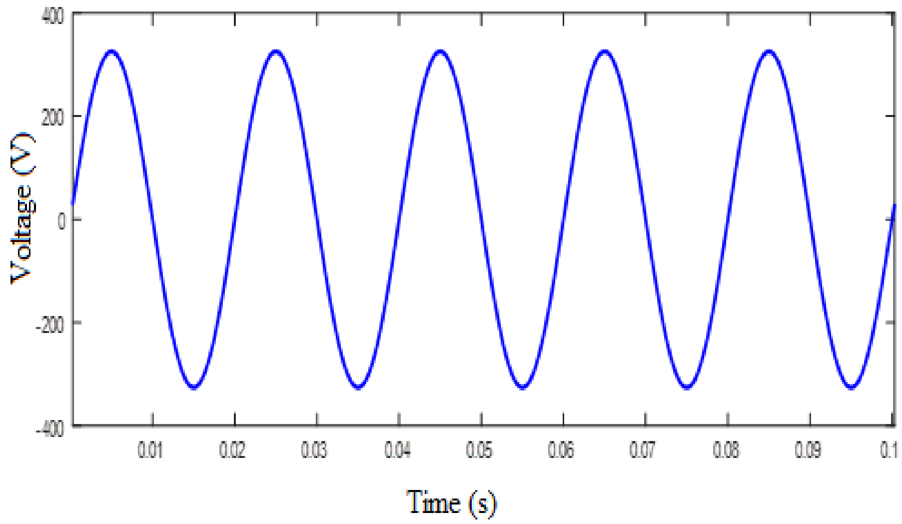

Fig 7: Three-phase rectifier A-phase voltage

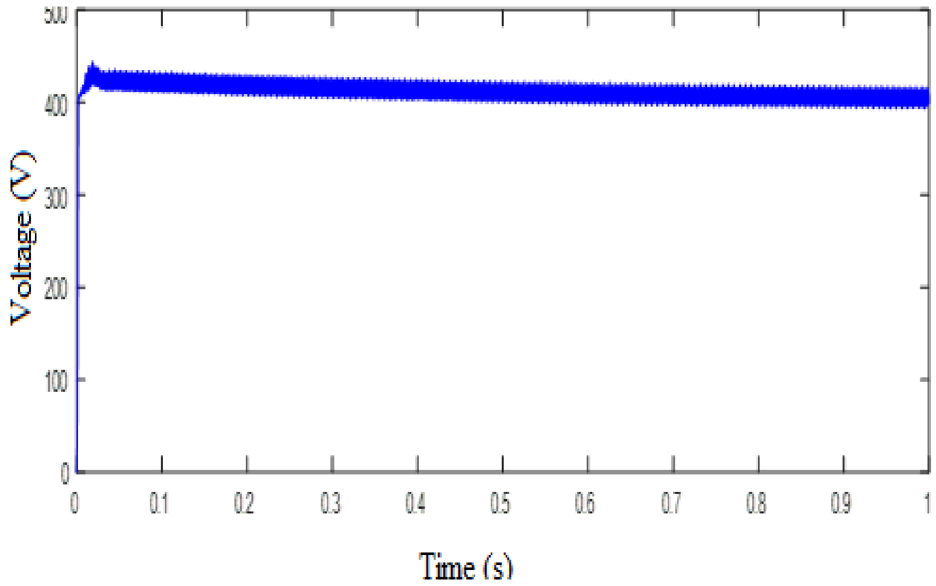

Fig 8: Three-phase rectifier voltage response

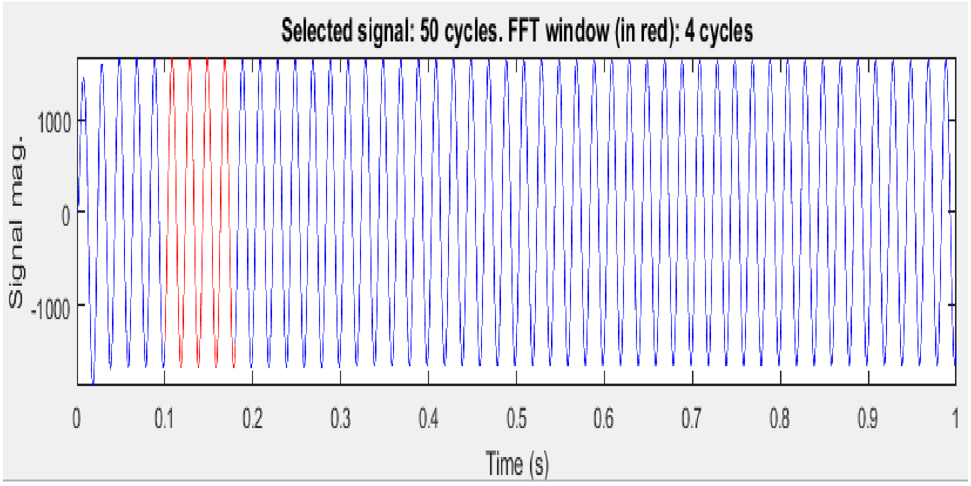

Fig 9: Three-phase rectifier phase current A when load changes

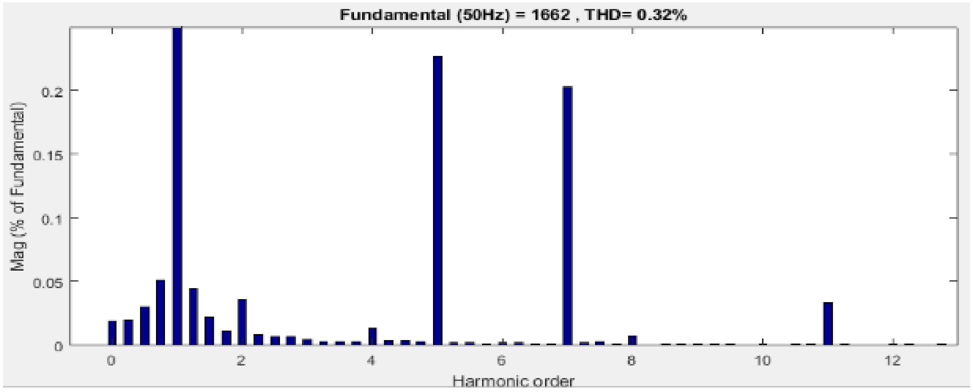

Fig 10: TDH index of phase A current under load change

3.2 SVPWM PSO 3-phase rectifier for DC motor control

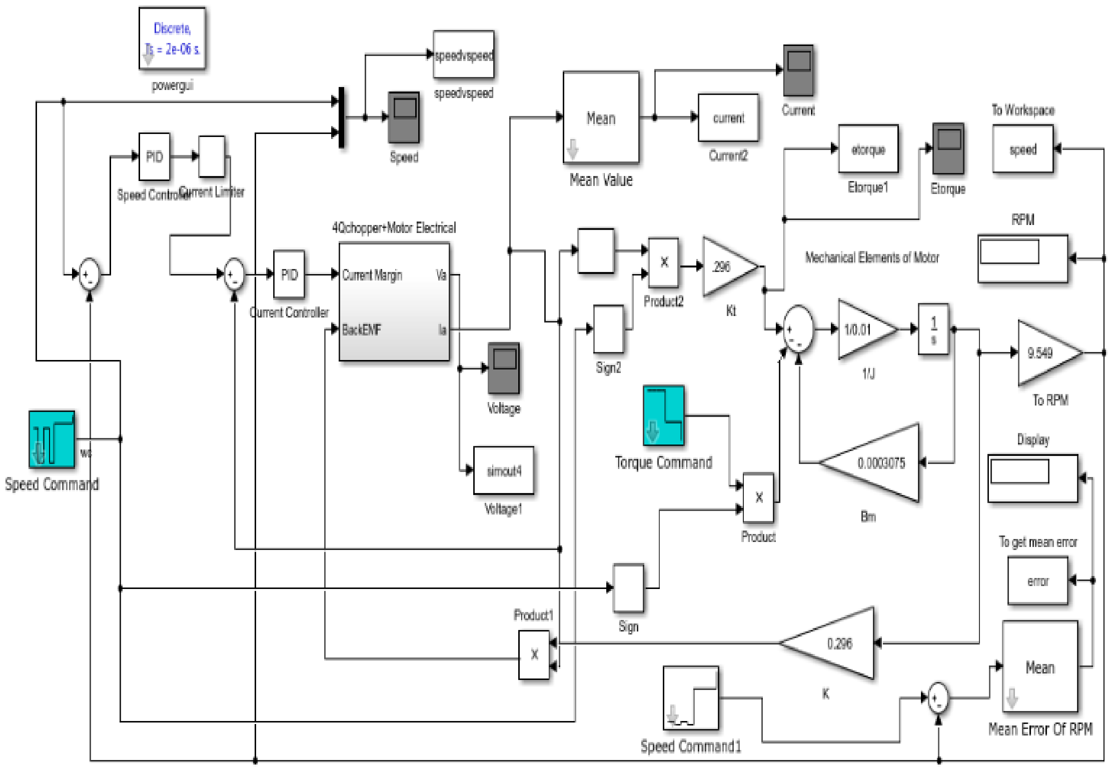

Fig 11: Simulink diagram of DC motor controller

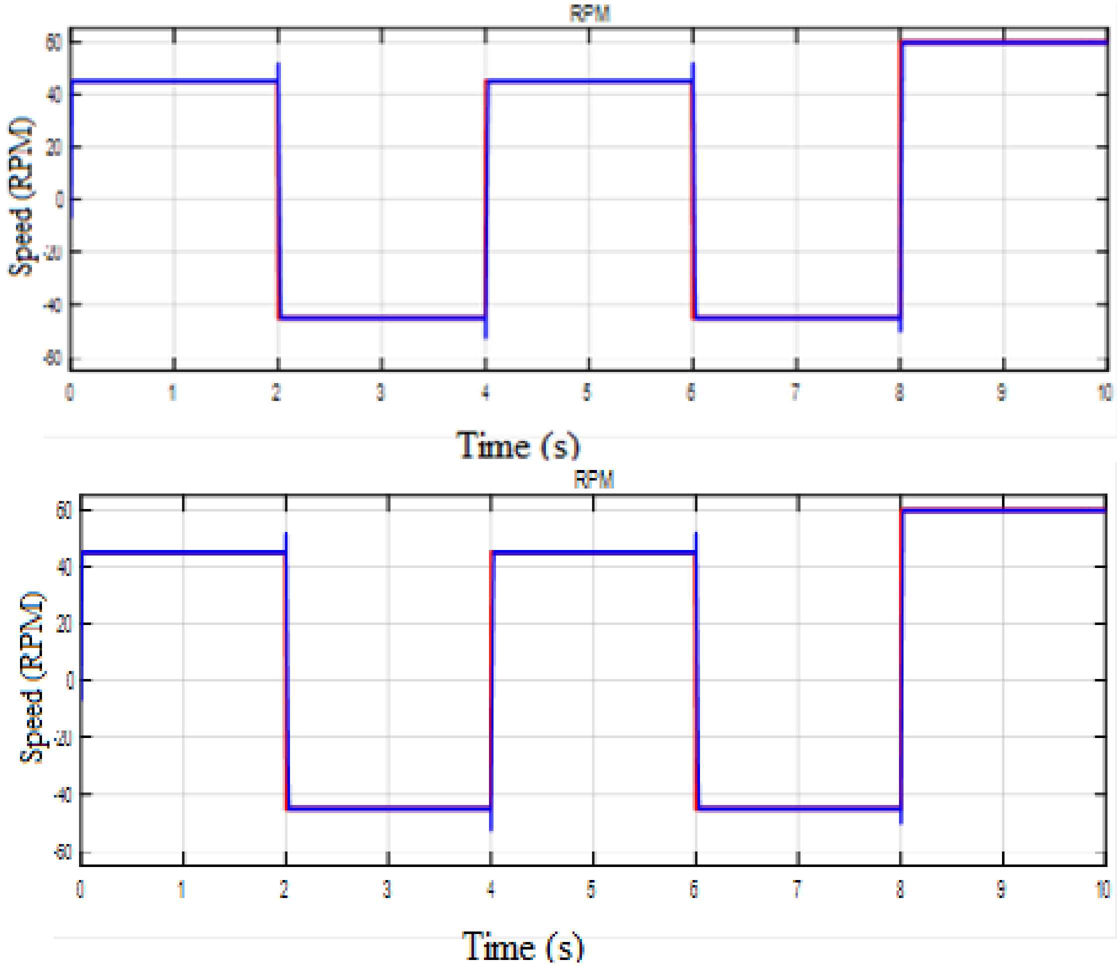

Fig 12: DC motor speed response

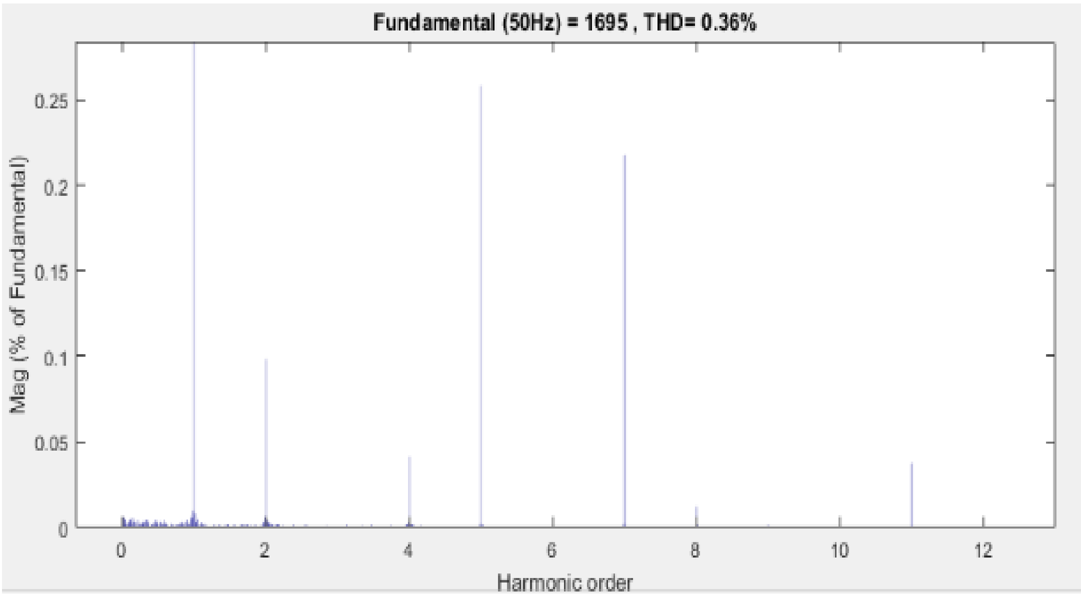

Fig 13: THD index of phase A current at variable speed

Figure 11 is a 3-phase SVPWM PSO rectifier applied to control a DC motor. The results shown in Figures 12, 13 show that the control structure is capable of working well with the following technical requirements: the set parameter is the time [0 2 4 6 8 15] corresponding to the speed [45 - 45 45 -45 60 80]. The speed response reaches the set speed with a small steady-state error of zero. Sinusoidal grid current, high-order harmonic wave is negligible. Stabilizes voltage when motor speed changes. The THD waveform's distortion (%) is small.

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IV. CONCLUSION

The simulation results on Matlab will show that the PSO controller with the parameters determined by the swarm algorithm achieves the following advantages: during the operation of the circuit, at times of load change, overshoot and stable output voltage without much change, output voltage control precisely according to parameter setting, good response time, fast setting time and small overshoot. The system adopts DC motor control which stabilizes the voltage well when the motor speed changes.

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