Artificial Optimal Fuzzy Control Strategy for Elevator Drive System by Using Permanent Magnet Synchronous Motor

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Abstract
There are many power electronic converters and motor drives connected together to form the electrical system of an elevator. In this paper, we have presented a modeling tool that has the advantages of utilizing capabilities of the PMSM software in detailed simulations of converters, motor drives, and electric machines. In addition, equivalent electrical models of Elevator drive system. This paper also gives a brief idea of PMSM validity as an elevator simulation tool. PMSM drive system is described and analyzed due to its importance in many applications especially in elevator applications. Applications are considered due to their high efficiency, low inertia and high torque to volume ratio. A closed loop control system with a PI control, Fuzzy, PSO in the speed loop with current controllers. The simulation circuits for PMSM, inverter, speed and current controllers include all realistic components of the drive system. Simulation results for SPWM control schemes associated with current controllers are given for two speeds, one below rated and another above rated speed. In this paper and it has been shown that the model is suitable for transient as well as steady state condition. These results also confirmed that the transient torque and current never exceed the maximum permissible value.

Keywords: elevator drive system, permanent magnet synchronous motors (PMSM), PI controller, fuzzy logic (FL), particle swarm optimization (PSO)

1. Introduction

The elevators are become more important with Increase the buildings and towering skyscrapers, it means of transport between less the upper floors and decks, the elevators for special the main means of transport, simplified control and elevators to deal efficiently demand for transport is complex [1]. The PMSM, it has significant advantages, attracting the interest of researchers and industry for use in many applications, that uses permanent magnets to produce the air gap magnetic field rather than using electromagnets [2]. The PMSM with high level energy permanent magnet materials particularly provide fast dynamics, efficient operation and good compatibility with the applications but only if they are controlled properly. The controller is using in order to overcome the non linearity problem of PMSM and also to achieve faster response [3]. Many industrial applications require new control techniques, the techniques used, applied in all regulation loops, Speed regulation of permanent magnet synchronous [4]. The development of power electronics and electricity Technology, PMSM for extensive applications in many control Systems. And PMSM, which are commonly used for Systems and control devices minute owns several Advantages over other machines Milan. Advantages PMSM include large torque coefficient, and high efficiency, high energy density, and a torque multiplier is small, Low-inertia, low noise, and high performance in a wide variety [5]. A way control (PI) in addition to the controller's integral relative formulated and implemented, using speed control magnet synchronous motor drive system and a permanent pilot phase. While the new strategy promotes traditional PI control performance to a large extent, and proves to be a model-free approach completely, it also keeps the structure and features of a simple PI control [6]. The using console mode instead of Fuzzy-PI control is to improve the performance of engines PMSM. To control the speed of PMSM motor using fuzzy logic (FL) approach leads to a speed control to improve the dynamic behavior of the motor drive system and immune disorders to download and parameter variations [7]. In the elevator drive systems, and gains from the

traditional can not usually be set in proportion-integral (PI) controller speed large enough because of mechanical resonance. As a result, Performance degradation and speed control. In our work described in this paper, has been adopted and fuzzy logic controller (FLC) for use in Elevator drive systems in order to improve the performance of the speed control. The proposed FLC has been compared with traditional PI control with respect to the speed of response and dynamic load Torque. Simulation and experimental results have proved that FLC was proposed is superior to the traditional PI. This FLC can be a good solution for the high-performance engine lifts Systems [8, 9]. A modern approach to control the speed of PMSM using particle swarm optimization (PSO) is to improve the algorithm parameters observer PI. Simulate the system under different operating year Conditions are prepared and the experimental setup. Use PSO algorithm and optimization makes a powerful engine, with faster response and higher resolution dynamic and sensitive to load variation [10, 11].

2. Model for a PMSM Drive

The complete nonlinear model of a PMSM without damper windings is as follows:

$$v_q = Ri_q + pL_q i_q + \omega_s(L_d i_d + \lambda_{af})$$ (1)

$$v_d = Ri_d + p\lambda_d - \omega_s L_q i_q$$ (2)

v_d and v_q are the d,q axis voltages, id and iq are the d,q axis stater currents, Ld and Lq are the d,q axis inductance, R and ω_s are the stater resistance and inverter frequency respectively. λ_{af} is the flux linkage due to the rotor magnets linking the stator.
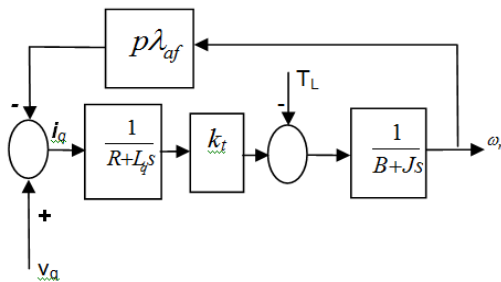

Figure 1. Block diagram of a PMSM   Figure 2. Block diagram of a PMSM Drive
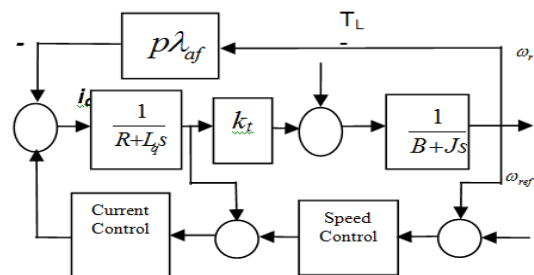
The electric torque:

$$T_e = 3P(\lambda_{af} i_q + (L_d - L_q)i_d i_q)/2$$ (3)

The motor dynamics:

$$T_e - T_L + B\omega_r + Jp\omega_r$$ (4)

P is the number of pole pairs, TL is the load torque, B is the damping coefficient, ω_r is the rotor speed and J the moment of inertia. The inverter frequency is related to the rotor speed as follows:

$$\omega_s = p\omega_r$$ (5)

The machine model is nonlinear as it contains product terms such as speed with id and iq. Note that ω_r, i_d and i_q are state variables. During vector control, i_d is normally forced to be zero.

$$T_e = 3P\lambda_{af}i_q\ /2 = K_t i_q \tag{6}$$

3. Speed Control of PMSM Motor

The PMSM is using control to suppress harmonic noise to a level. then, noise to a level below and vibration translates into a more comfortable ride for passengers. IGBT SPWM inverters make the ride smoother with precisely adjusting speed control with frequency and voltage regulation. It has the latest low-noise power units to make the ride even quieter.Elevator has directed high-speed used (1500 rpm) PMSM. Energy reform in the elevator geared for small rise because travel extremely small and fast.
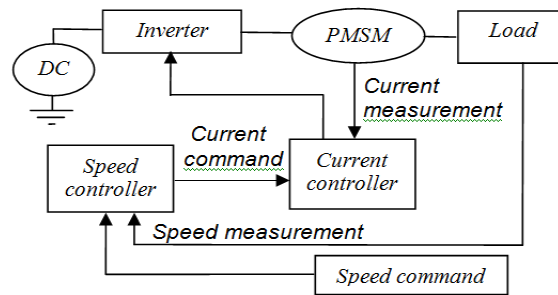

Figure 3. Block Diagram of Speed Control of PMSM

3.1. PI Controller Modeling

In the PI speed controller the motor speed is compared with the reference speed and the speed error is the nth sampling interval as:

$$\omega_e[n] = \omega_r*[n] - \omega_r[n] \tag{7}$$

The output of the speed controller gives the reference torque. Hence the output of the speed controller at the nth sampling interval is:

$$T[n] = T[n-1] + Kp(\omega_e[n] - \omega_e[n-1]) + Ki\,\omega_e[n] \tag{8}$$

For constant air gap flux operation reference quadrature axis current is given as:

$$i_q* = T[n]/Kt \tag{9}$$

The limiter is used to limit the maximum value of output of speed controller. The maximum motor rated current and device current of the converter dictate the limit.

Where,

$\omega e[n]$ is speed error at nth instant, $\omega r*[n]$ is the reference speed at nth instant;

$\omega r[n]$ is the actual motor speed at nth instant, $\omega e[n-1]$ is the speed error at (n-1)th instant;

T[n] is the reference torque at nth instant, T[n-1] is the reference torque at (n-1)th instant;

Kp is proportional gain of the speed controller;

Ki is integral gain of the speed controller is reference quadrature axis current;

Kt is torque constant

3.2. Fuzzy Logic Controller

The Basic configuration of a Fuzzy Logic Controller (FLC) consists of the following components:

1) Fuzzification Interface
2) Knowledge Base (KB)
3) Decision Making Logic
4) Defuzzification Interface

A fuzzy controller is a special fuzzy system that can be used as a controller component in a closed-loop system. The integration of a fuzzy system into a closed loop is shown. Special emphasis is put onto the transfer behaviour of fuzzy controllers, which is analyzed using different configurations of standard membership functions. An example for the design of a fuzzy controller for a loading crane is given. Finally, the module series is closed by a general discussion about the contribution of fuzzy control. For a PM motor drive system with a full speed range, the system will consist of a motor, an inverter, controller (constant torque and flux weakening operation, generation of reference currents and PI controller).

3.3. Particle Swarm Optimization

It is a technique used to explore the search space of a given problem to find the settings or parameters required to optimize a particular objective. PSO has two main concepts: the first is through the observation of human decision making, it was proposed that humans use both their own best experience and others' best experience to form a basis of making a decision, to develop the concepts of individual learning and cultural transmission. The second is to propose a simple theory to explain group behavior in nature, and to modularize the theory to create systems to simulate things. The biggest characteristic of PSO is in its simple structure, fast convergence, and its ability to prevent falling into a local optimum solution. At the same time, PSO is a random algorithm with a parallel structure. Firstly, a uniform distribution is used to randomly create a particle swarm.

Each particle represents a feasible solution to the problem, the particle swarm refers to the individual's best experience, and the group's best experience, and logically chooses the method it will move itself. After continuous iterations, the particle swarm will gravitate towards the optimum solution.

3.4. Elevator State Samples

In Figure 4 we find this states:

a) [1-2,2-3,3-2,2-1]; b) [1-2,2-3,3-1]; c) [1-3,3-1]; d) [1-3,3-2,2-1]

$1=1^{st}$ floor, $2=2^{nd}$ floor, $3=3^{rd}$ floor, $1-2=1^{st}$ floor to 2nd floor, $2-3=2^{nd}$ floor to 3rd floor, $2-1=2^{nd}$ floor to 1st floor, $3-2= 3^{rd}$ floor to 2nd floor, $1-3=1^{st}$ floor to 3rd floor, $3-1=3^{rd}$ floor to 1st floor ,We can write another sample $[1-2-1]$ that is mean: $1-2=1^{st}$ floor to 2nd floor and $2-1=2^{nd}$ floor to 1st floor
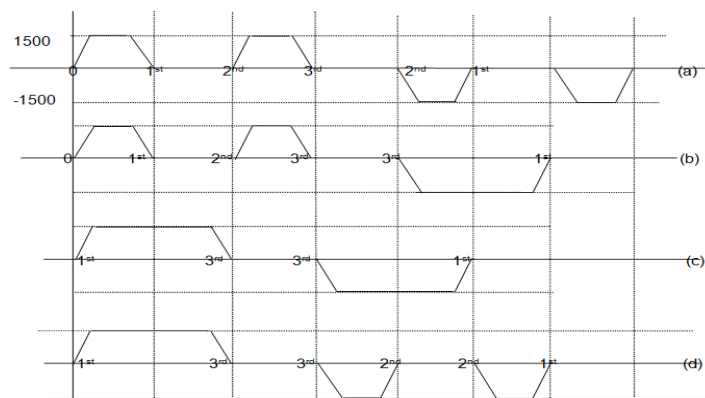

Figure 4. Elevator state samples a) [1-2,2-3,3-2,2-1], b) [1-2,2-3,3-1], c) [1-3,3-1], d) [1-3,3-2,2-1]

3.5. Elevator Control System Application Flow Chart
The Steps as follows (flow chart as Figure 5):

Step 1: Create the parameters of the elevator.

Step 2: According to the call signal and the current situation Elevator.

Step 3: by Reload squadron by using update value-weighted inertial, with the speed of convergence.

Step 4: use the acceptance criteria, to decide whether to accept these new particles or not, and to increase the diversity of the particles, with avoid trapping in local Optimization.

Step 5: The end of the iteration, then the global search the optimal solution. If not, step loop (3).

Step 6: by using Loop to step (2) until the end time simulation,then output the result.
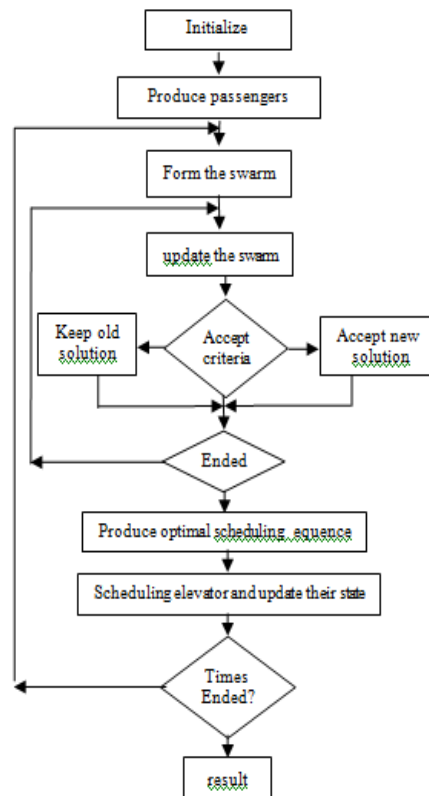
Figure 5. Elevator control system application flow chart

4. Simulation Results
By using Simulation model PMSM&Simulation of Elevator Drive system by using PMSM:

4.1. Simulation Model Permanent Magnet Synchronous Motor (PMSM)
Model of the system in Figure 6 is verified through the computer simulations using the software package MATLAB/Simulink. It summarizes the performance of the elevator's electric drive, both in computer simulation and experimental implementation. The analyzed elevator considers electrical drive (PMSM Drive System). Elevator motor is three-phase pmsm with. Drive converter is current regulated SPWM voltage source inverter (CRSPWM VSI) direct current power supply. The positioning system and position controller of Elevator are used for the task to provide position reference tracking and zero error in steady state. Constant load is usual for one elevator ride. Thus, a position controller with proportional and integral action (PI) is used, Block diagram of PI Controller is shown in Figure 7. Parameters of real elevator with pmsm drive were included in the model of elevator.

Simulation of the entire system with designed controller is made in the Matlab/Simulink and given results show that design controller meets the requirements completely smooth and precise position and speed.Input parameters for the dynamic of the elevator are:

a) Final position of car: 9 m,
b) Nominal speed of car: 1.5 m/s,
c) Elevator capacity: 1050 kg,
d) Weight of the car: 450 kg.

To verify the feasibility of control, PMSM drive simulation model with control is created and studied using MATLAB. Simulation parameters: stator resistance Rs = 0.01Ω, inductance Ld = Lq = 0.01835H, flux Ψ = 0.4 V.s, pair of poles p = 3, inertia J = 0.029kg.m2. Simulation conditions: reference speed n = 1500 rad / s, start with TL = 5N.m. Simulation results are shown in Figure 8-10 speed is shown in Figure 8, Torque is shown in Figure 9, and current is shown in Figure 10. It is obvious that correct responses of speed, current, and torque in control system. Using PI control and Fuzzy control has a good application in PMSM drive. At the same time, with speed have faster response. Ripple of torque is obviously reduced. So the system performance is improved.
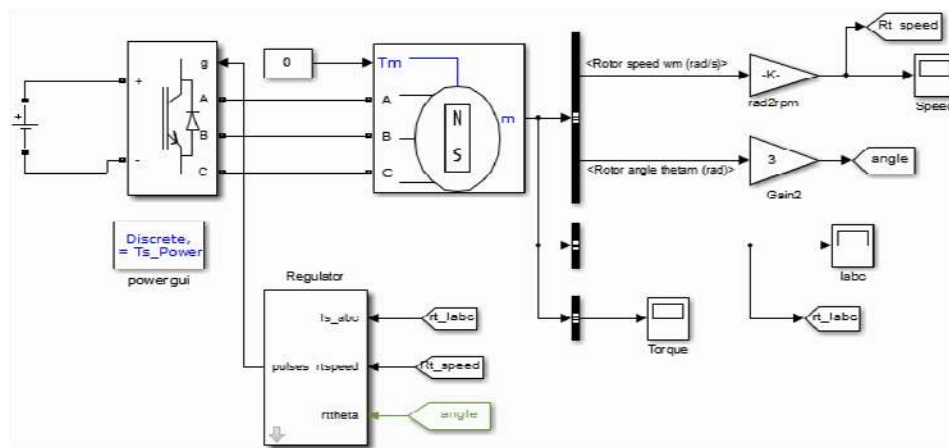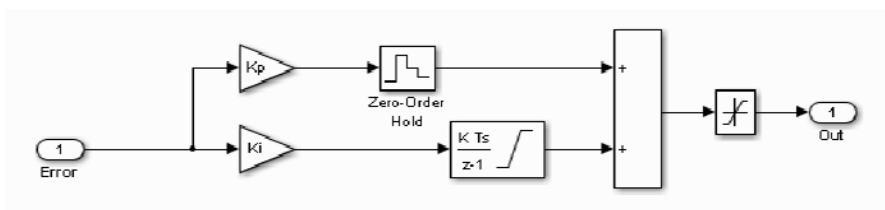

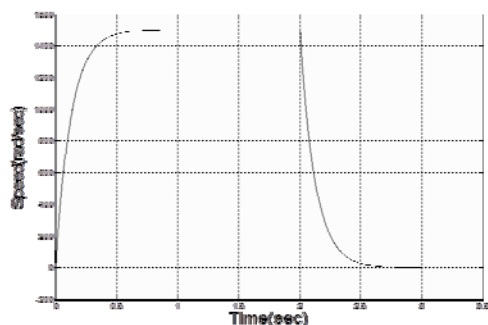Figure 6. Model of the system
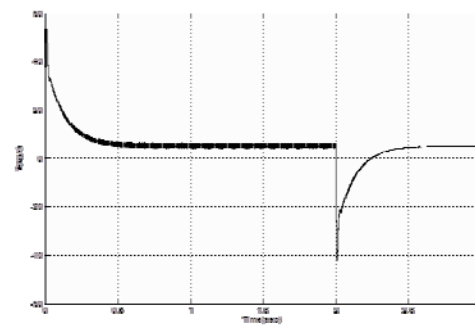

Figure 7. PI Controller

Figure 8. Speed Response, n=1500rad/sec   Figure 9. Torque Response, n=1500rad/sec
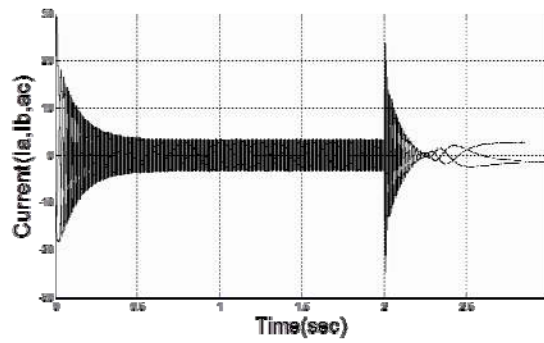
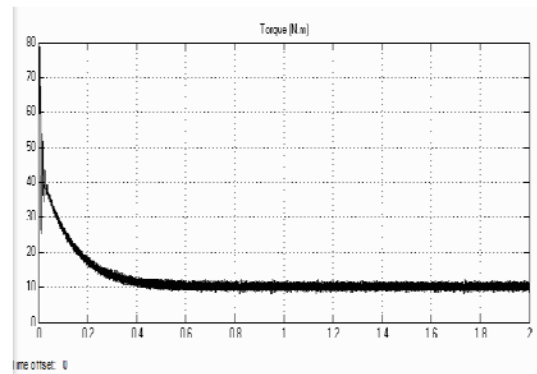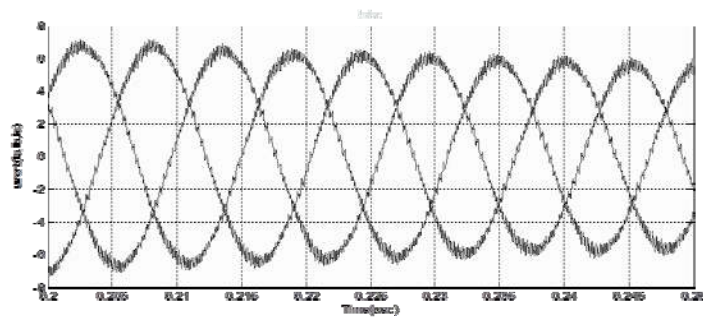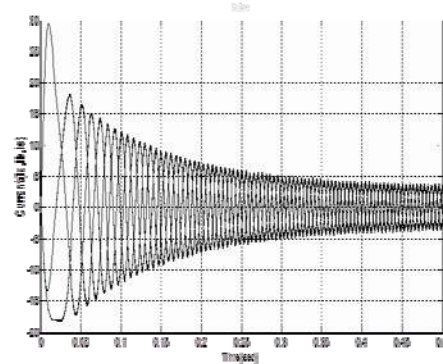Figure 10. Current Response, n=1500rad/sec&TL=5N

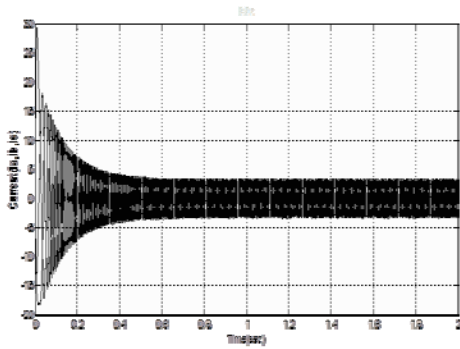## 4.2. Simulation of Elevator Drive System by using PMSM
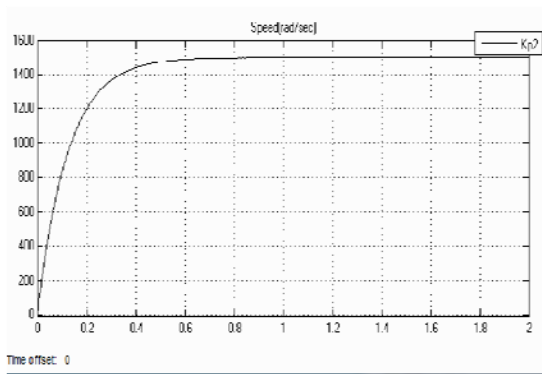
(a) Speed

(b) Torque

(c)

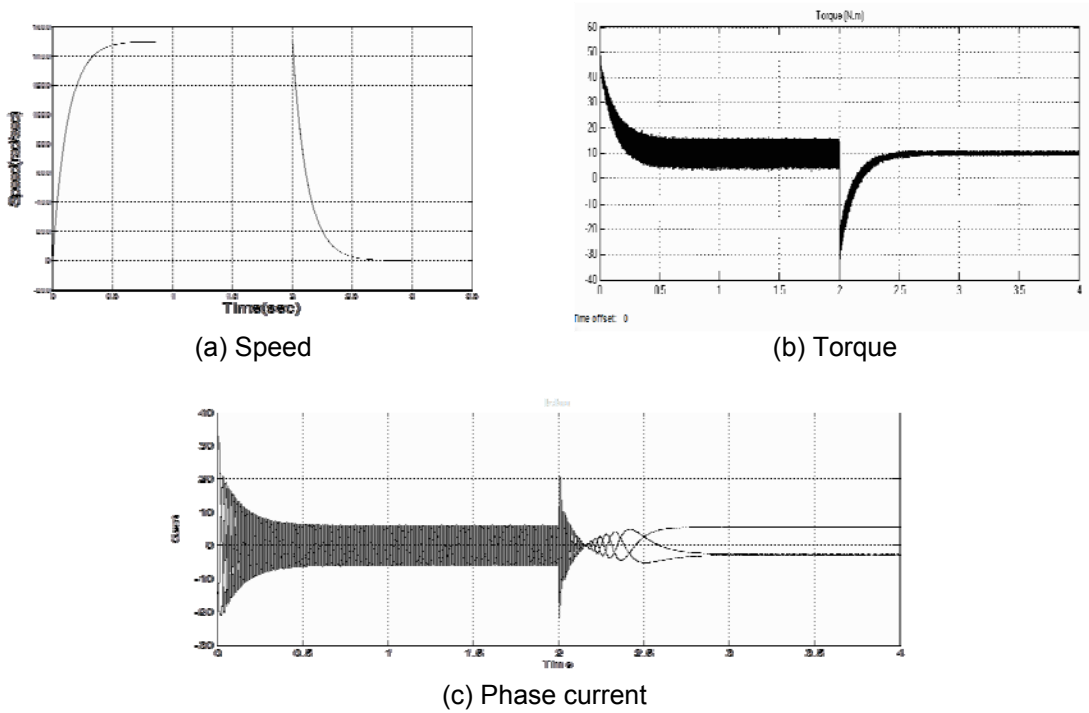Figure 11. Speed, Torque & Current Response, n = (0 ,1500)rad / s &TL = 10N.m

(a) Speed   (b) Torque

(c) Phase current

Figure 12. Speed, Torque & Current Response, n=(0,1500 ,0)rad/s &TL = 10N.m

(a) Speed   (b) Torque

(c) Phase current
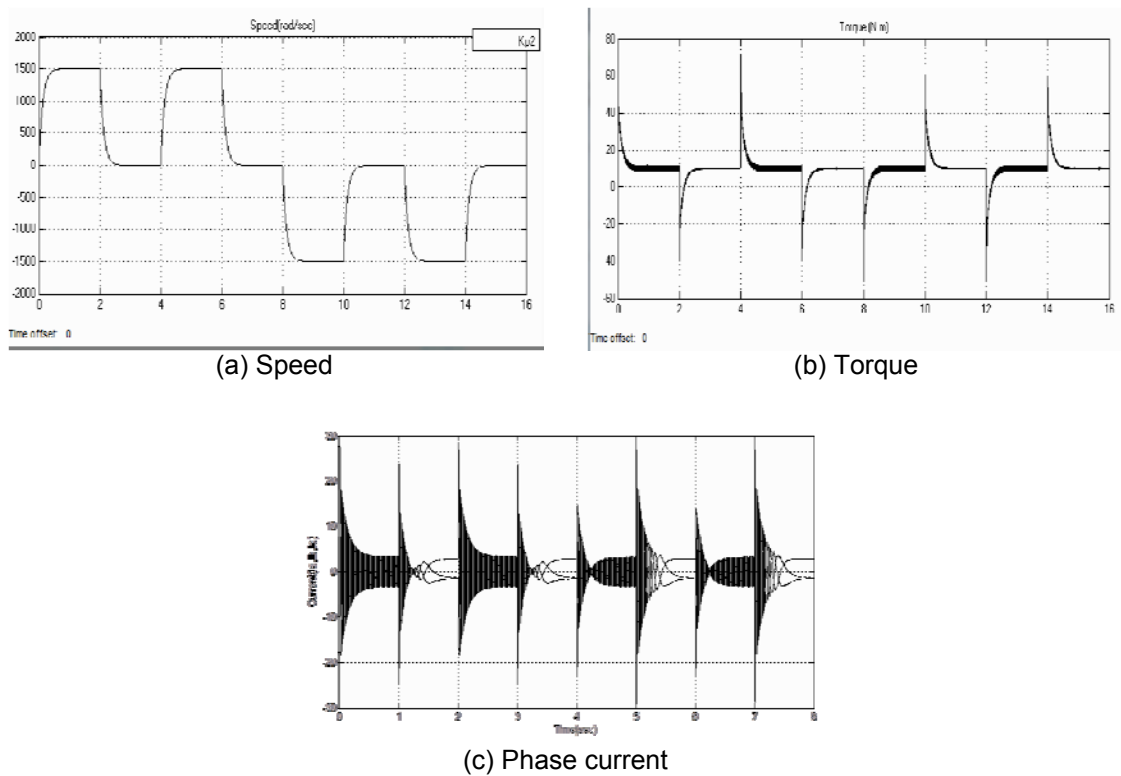
Figure 13. Speed, Torque& Current Response, n = (0,1500,0,1500,0,-1500,0,-1500,0)rad / s
&TL = 10N.m

(a) Speed

(b) Torque

(c) Phase current

Figure 14. Speed, Torque&Current Response, n = (0,1500,0,1500,0,-1500,0,-1500,0)rad /s & TL = (10,5,10,5)N.m, a Torque is variable
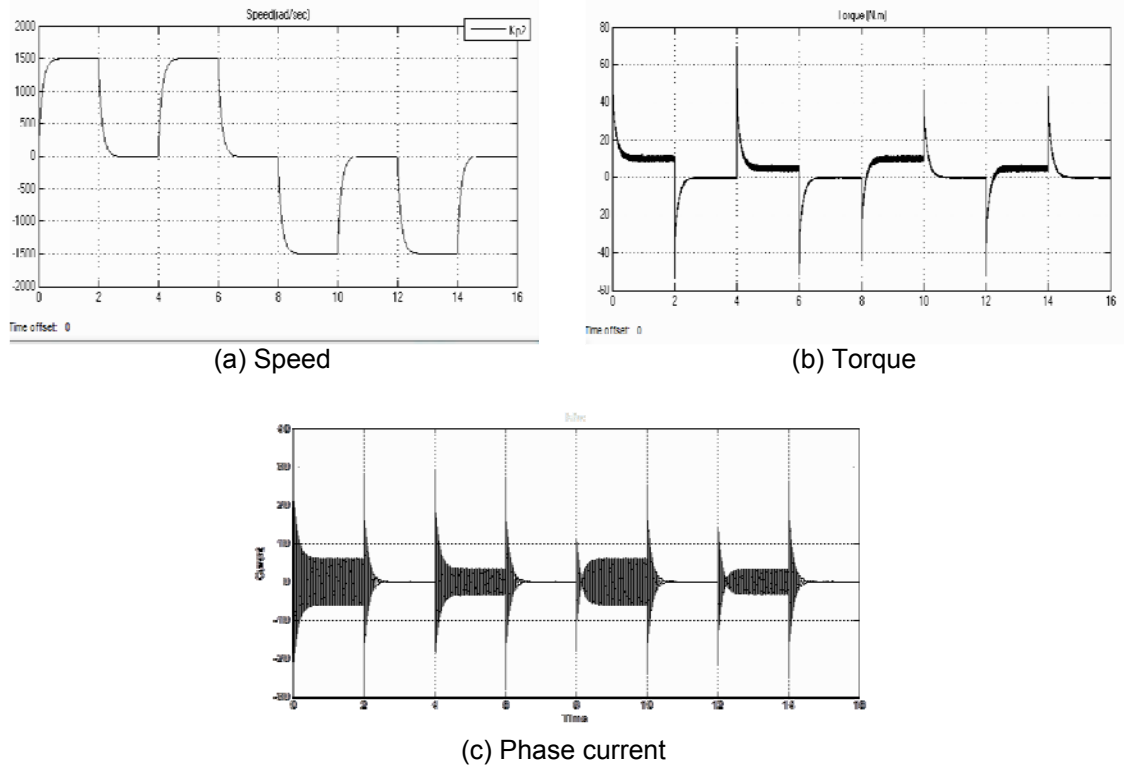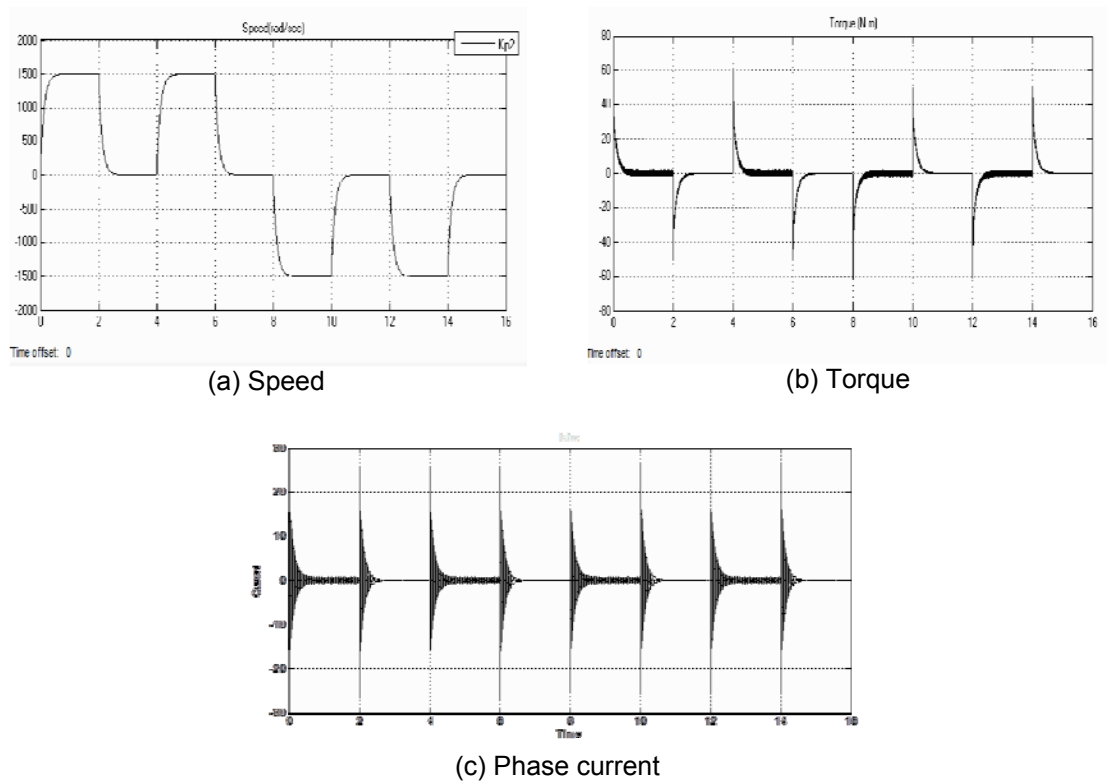

(a) Speed

(b) Torque

(c) Phase current

Figure 15. Speed, Torque & Current Response, n = (0,1500,0,1500,0,-1500,0,-1500,0)rad / s &TL = 0N.m a Torque is equal Zero 0N.m (no load)

(a) Speed

(b) Torque

(c) Phase current
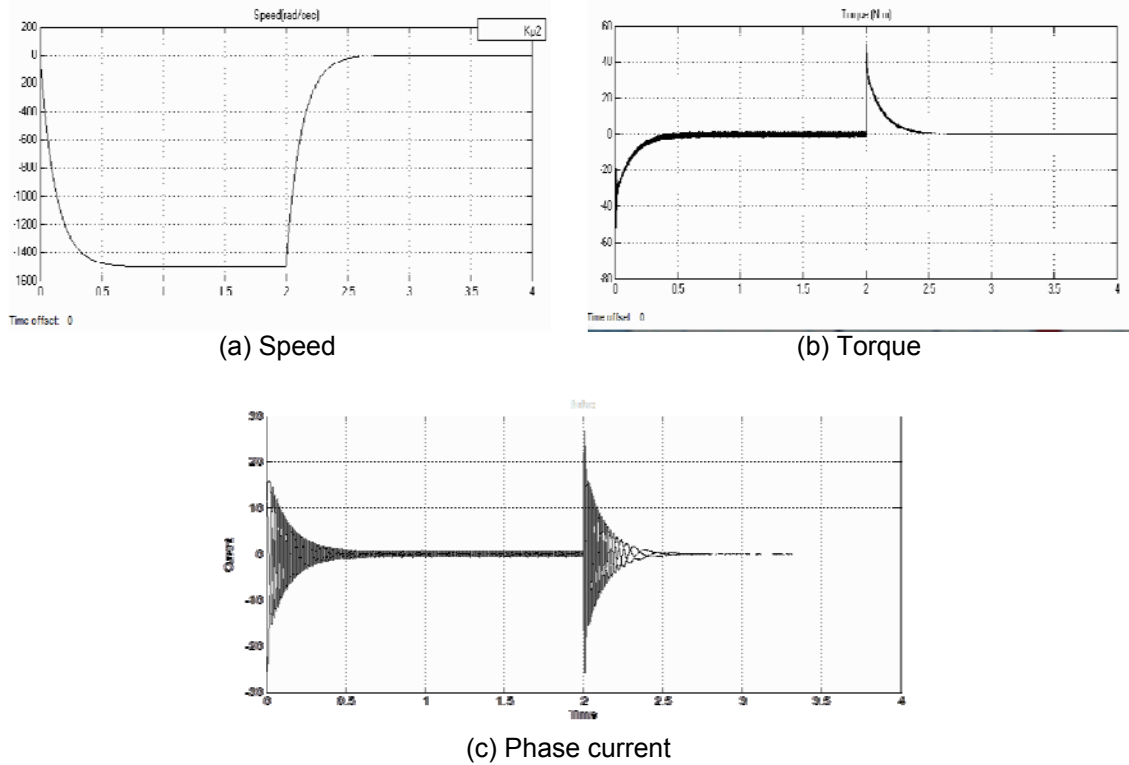
Figure 16. Speed, Torque & Current Response, n = (0,-1500,0)rad / s &TL = 0N.m a Torque is equal Zero 0N.m (no load)
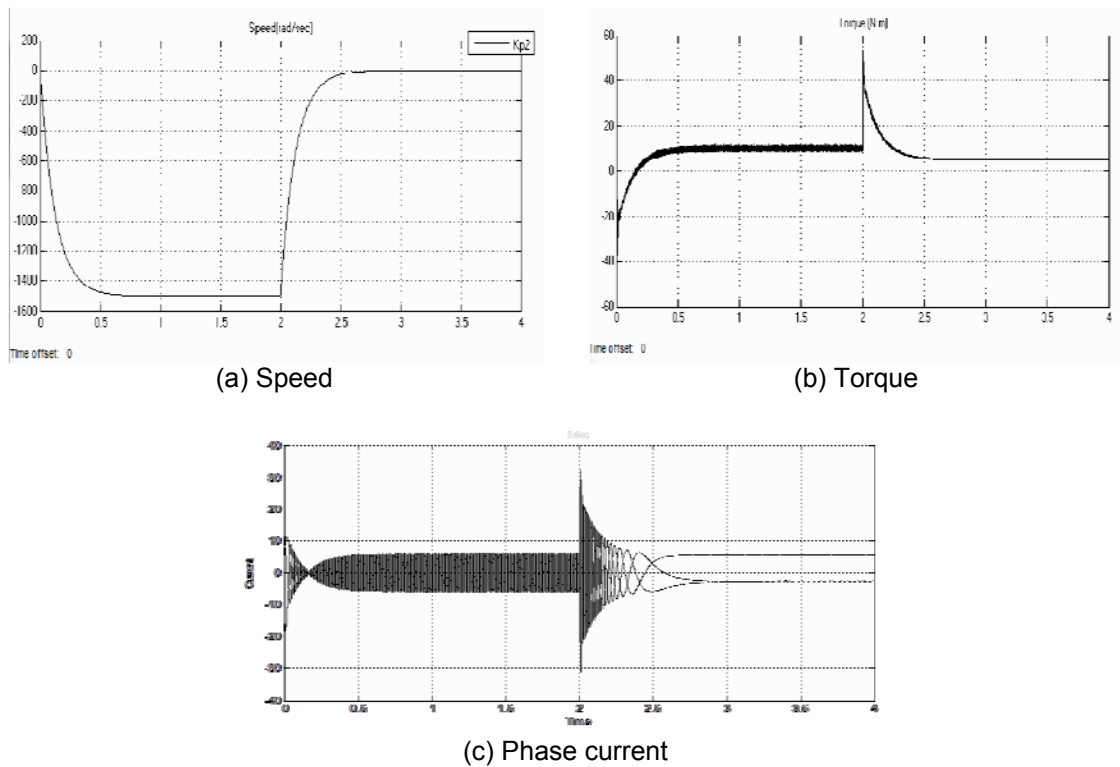

(a) Speed

(b) Torque

(c) Phase current

Figure 17. Speed, Torque & Current Response, n = (0,-1500 ,0)rad / s &TL = 10N.m

To Analysis simulation results, there are some cases to do it as a following analysis Elevator Drive System By Using PMSM (Speed, Torque, Current).

Firstly case: Elevator move with upside (0, 1500) in this case we can see the speed signal, it change with minimum value to maximum value (transient and steady), then we can look to the Torque and Current to see the change its.

Secondly case: Elevator move with upside (0, 1500, 0) it change thre states (Stop, Up and Stop).

Thirdly case: Elevator move with (up, down) side (0, 1500, 0, 1500, 0, -1500, 0, -1500, 0) in this case (Stop, Up, and down) it mean zero is Stop state, up state at (1500) and down state at (-1500), then we can look to the Torque and Current to see the change its. Finaly, there are two states it has different in Torque (constant and variable) with it a current is change.

1) Elevator move with upside (0 , 1500)
2) Elevator move with upside(0 , 1500 ,0)
3) Elevator move with (1st,2nd,3rd,2nd,1st) a Torque is Constant
4) Elevator move with upside (1st,2nd,3rd,2nd,1st) a Torque is variable
5) Elevator move with upside (1st,2nd,3rd,2nd,1st) a Torque is equal 0N.m (no load)
6) Elevator move with upside (0,-1500,0)a Torque is variable

5. Conclusion

This paper will cover the simulation, and implementation of a PMSM controlled by a control system to drive a electric elevator system. The implementation of an electric elevator drives by the electric drive through the addition of control systems and switching power supplies. Simulation of elevator drive system by a permanent-magnet synchronous motor (PMSM) is used for this paper. There are some tasks to achieve an electric elevator drive, determining the parameters of PMSM, designing a control system to direct the motor as desired, and verifying the performance of the system through use of computer simulations and experimental testing. The implementation of an elevator driven by a PMSM is successful and provides an illustrative example to those who wish to apply electric drives to various mechanical systems.

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