# Power Optimization Scheme in Electric Vehicle Using Induction Motor Based FOPID Control Strategy

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## Abstract

The increased use of fossil fuel cars nowadays has increased the amount of $CO_2$ in the atmosphere. Electric vehicles (EVs) provide a way to lessen negative consequences. Despite the fact that induction engines are often used for exercising, synchronous engines are more frequently used in electric cars (EVs). Since electric vehicle (EV) battery storage capacity is limited, energy efficiency is critical. When employed in EV applications at less than full capacity, these vehicles face the risk of poor performance and more energy consumption than is really necessary to keep them operating. PID controllers, FUZZY Logic Controllers (FLC), and Fractional Order PID(FOPID). controllers are used in induction cars to overcome these issues. The feedback loops on the PID and FUZZY controllers are more varied, and thus need more time to relay error indicators back to the input so that errors may be fixed. Therefore, it was suggested in this project that FOPID techniques be employed to improve the induction motor's overall performance. To save more electricity, FOPID might change the initial modern amplitude. The suggested version's performance was evaluated using the MATLAB/SIMULINK tool.

**Keywords**. Electric Vehicle (EV), Induction Motor, PID, Fuzzy Logic Controller (FLC), Fractional Order PID(FOPID).

## 1. INTRODUCTION

As fossil fuel consumption has increased, $CO_2$ levels in the atmosphere have risen, particularly in the last few decades. Worldwide carbon dioxide emission reduction efforts are urgently needed to address climate change and increasing sea levels. Increasing the efficiency of automobiles is essential due to the fact that transportation accounts for over 20% of total carbon dioxide emissions [1]. The environmental benefits of electric cars (EVs) outweigh the drawbacks of gasoline-powered vehicles, as well as their quieter operation and reduced reliance on foreign oil. The efficiency and cost of a driving system are heavily influenced by the electrical equipment that power it. Even if a car is classified as an electric or a hybrid, it will not run without electric powertrain. There are two types of synchronous motors that can power electric vehicles: induction motors and synchronous motors (IMs). Propulsion for the EV-motor, according to [2], should include high torque density to deliver

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suitable driving force during start-up, ascending and accelerating; high efficiency to increase the driving distance; and flow regulation to widen the static power speed range. For electric vehicles (EVs), traction drives like the IM are becoming increasingly popular because of their great durability, low cost, and low maintenance needs. As a result of higher losses, EV applications have a poorer machine efficiency. Low energy density, increased weight, longer charging times, and longer battery life [5] are the major obstacles to the widespread use of these vehicles in transportation. Energy efficiency must be maximized in order for an EV to work correctly [6]. It is typical practice for industrial drives to use proportional integral derivative (PID) controls because of their efficacy and ease of implementation. The most frequent type of controller in current control loops is the PID controller, which is widely utilized in industrial settings. For example, a shift in working conditions might cause significant performance loss [7]. [8] For example, a fuzzy logic controller (FLC) is an intelligent control method that can improve performance because it is difficult to accurately express the precise analytical model of a managed system. Several strategy principles are simplified by the usage of language tags in the FLC framework. As a result, other examples have employed another technique to manage EV energy demand. FLC is a model-free approach, hence a mathematical model of the system under control is not required. Adaptive FLC system controllers are needed if we are to improve EV traction in areas where there are fixed defects. Other FLC trends to consider include low steady-state error, low overshoot, and a rapid rise time. As a result, the fundamental goal of contemporary design methods is to reduce steady-state losses. Typical induction machines designed for high stability efficiency may suffer from significant and excessive current peak losses during transit with variable flow linkages. In light of the EV's traction motor drive cycle's dynamic character, the focus of this research is on the losses of transient machines. In the literature, a variety of control schemes have been presented for electric vehicle applications. Among the most common linear control methods are sliding mode control [11] and field-oriented control [12]. A technique called the "golden section" is used to reduce secondary winding harmonic losses by employing a model reference adaptive system with an optimized base power scheme. Use speed error change as an input to build frequency by employing an adaptive quadratic interpolation and slip control (SC) based on fuzzy controllers with nine rules [14].

## 2. PROPOSED SYSTEM DESCRIPTION

The most prevalent kind of AC is a three-phase model. The gearbox and differential link the wheel hub to the gearbox and differential. Additionally, it has a DC/AC power converter and its own management system in addition to a chemical-based energy storage battery.

Figure 1 depicts the three major parts of a battery-powered vehicle's electric motor system, which is generally only one electrical unit. Finally, the electric automobile uses a three-phase frequency and voltage control system to power it. The accelerator and brake pedals are linked to this system. A phase-locked loop and the DQZ conversion formulas are used to achieve the goal of synchronizing the utility current regulator. The phase currents' coordinates are shifted to fit within a d–q frame in order to convert a–b–c coordinates to d–q coordinates.

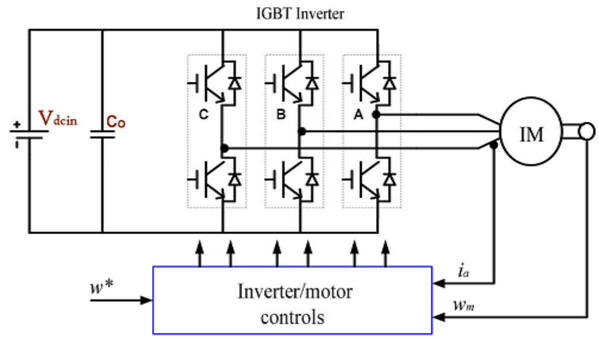

Figure. 1 Schematic representation of an induction motor-powered electric car drive system.

Conversions for the d–q components can be summarized as follows: A three-phase electric machine is shown in Figure 1 as a means of generating power. The differential gear ratios on the left and right wheels enable for high-speed electric motor shaft adjustment at low speeds. When a DC battery supply is converted into three-phase AC voltage, the inverter regulates it. Component losses must be taken into consideration when calculating the power consumption of an electric car not linked to the grid. Our ultimate goal is to develop electric vehicle (EV) controllers that are as efficient as feasible. To compensate for the controller's lack of adaptability, flexibility, and power, FLC techniques for EV applications can be used.

## 3. CONTROL STRATEGY

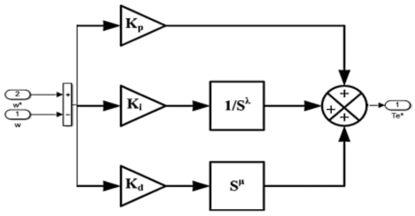

Figure. 2 A closed-loop process control system based on FOPID controllers.

As a general-purpose feedback control loop, PID controllers are commonly used in industrial control systems. When there is a disparity between a consistency process variable and the intended set point, the PID controller generates and executes corrective actions to correct it. PID controllers employ time constants that are both integral (Ki) and derivative (Kd) (Kd). These three variables make up the PID controller algorithm. The quantity of recent mistakes, the pace at which errors change, and the Integral all have an effect on error response. These three actions may be directed by the use of control devices such as a control valve or a heating element. Figure 2 depicts closed-loop control systems using a PID controller.

## 4. SIMULATION RESULTS

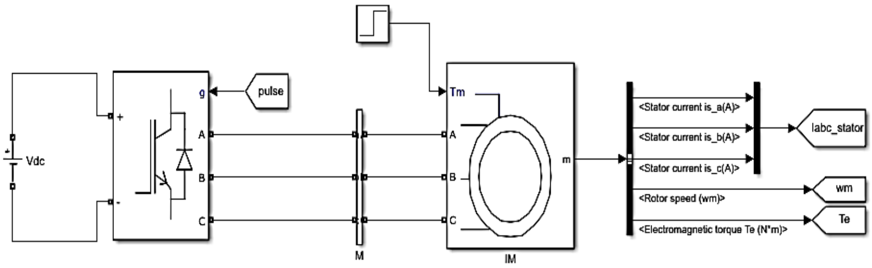

Figure.3 MATLAB/SIMULINK circuit diagram of the system

### A) EXISITNG RESULTS

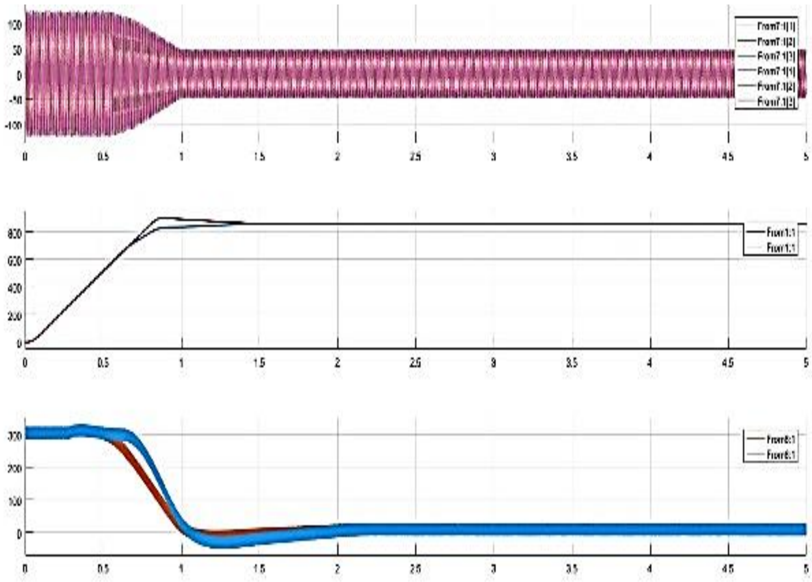

Figure.4 (a)3-phase stator currents of PID and FLC models (b) Rotor speed of PID (red) and FLC (blue) When $N_{ref}$ 859 rpm (c) Torque response of PID (red) and FLC (blue)

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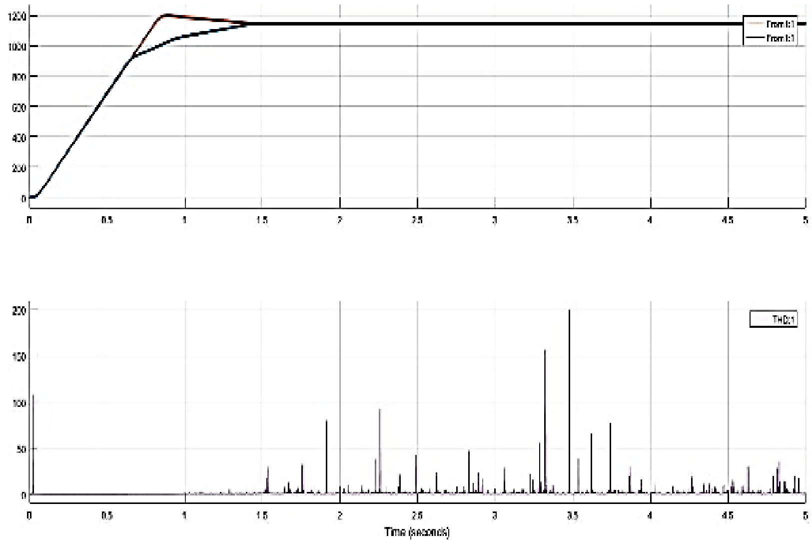

Figure.5 (a) Rotor speed comparison for PID (red) and FLC (blue) When $N_{ref}$ 1145rpm (b) Harmonic speed waveform

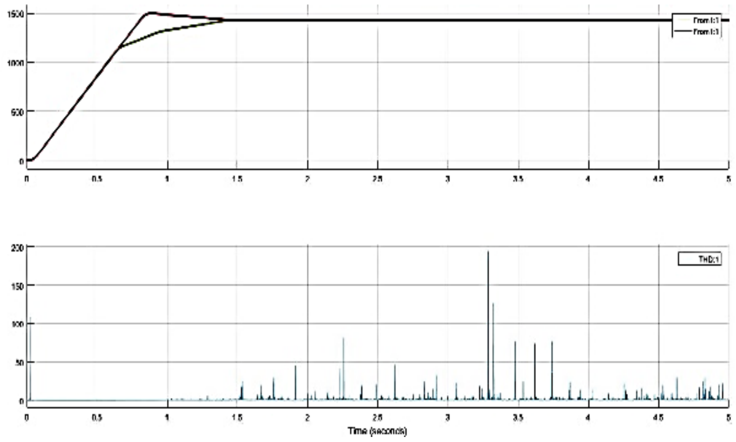

Figure.6 Rotor speed comparison for PID (red) and FLC (blue) When $N_{ref}$ 1432 rpm (b) Harmonic speed waveform

## B) EXTENSION RESULTS

Various PID, FLC, and FOPID simulations were done to control the IM speed. Figures 4, 5, and 6 show the results of testing the control unit using a constant load torque. For multistep speed input, FOPID provides faster rise and fall times than PID. FLC outperformed FOPID when compared to PID. Three-phase IM, on the other hand, benefited from FOPID's more precise and quick response, as well as the absence of overshoot or steady-state error. Simulated EV applications were utilized to test the effects of PID, FLC, and FOPID on the speed of the internal combustion engine (IM). The simulations took into account a variety of operational variables, such as the reference speed and the applied load. PID, FLC, and FOPID performance was compared.

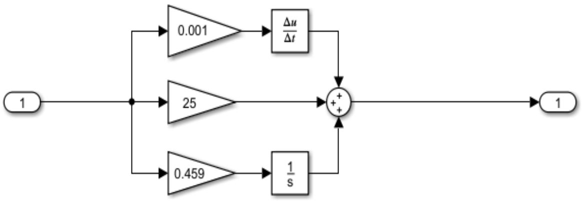

Figure.7 Subsystem of FOPID controller

Table 1. Comparison of the multistep speed response capabilities of FOPID, FLC and PID

| Reference speed, rpm | Rise time, s | | | Settling time, s | | |
|---|---|---|---|---|---|---|
| | FOPID | FLC | PI | FOPID | FLC | PI |
| 1432 | 0.821 | 0.731 | 0.681 | 1.890 | 1.982 | 2.584 |
| 1145 | 0.745 | 0.630 | 0.543 | 1.825 | 1.910 | 2.679 |
| 859 | 0.601 | 0.547 | 0.402 | 1.712 | 1.868 | 2.419 |

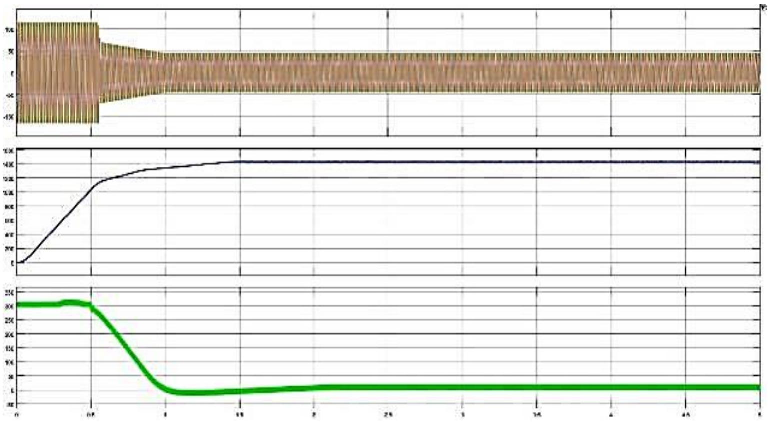

Figure.8 (a)3-phase stator currents of PID and FLC models (b) Rotor speed of PID (red) and FLC (blue) When $N_{ref}$ 1432 rpm (c) Torque response of PID (red) and FLC (blue)

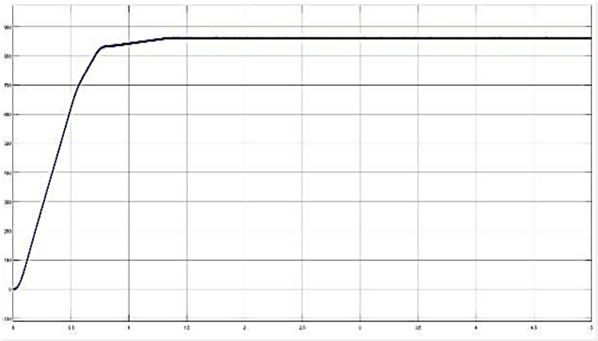

Figure.9 Rotor speed when $N_{ref}$ is 859 rpm by using FOPID controller

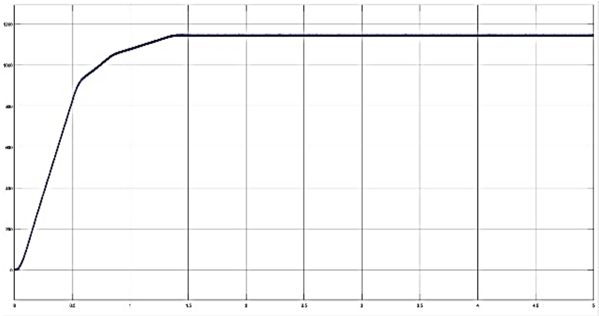

Figure.10 Rotor speed when $N_{ref}$ is 1145 rpm by using FOPID controller

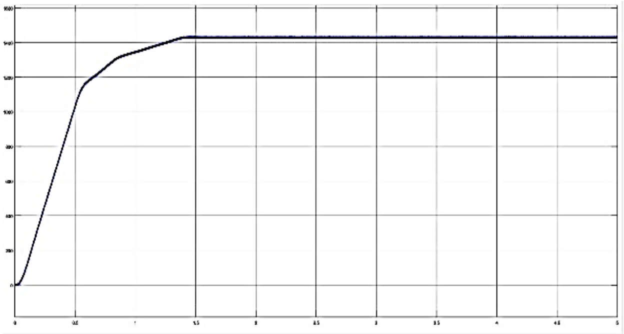

Figure.11 Rotor speed when $N_{ref}$ is 1432 rpm by using FOPID controller

## 5. CONCLUSION

By employing FOPID at the beginning of the charging process, more energy may be conserved. When an error is detected, the FOPID controller acts swiftly to construct an equal controller term for use outside of the FOPID controller loop. A 50-horsepower electric car was simulated in this experiment. It's being studied if peak overshoot and steady-state inaccuracy may be used as indications. Researchers' findings reveal that despite the decreased amplitude, the suggested system's phase current has more loss components (less overall amplitude). In the steady condition, the average loss amplitudes of real torque diminish. Maintaining a constant torque optimizes performance. The suggested FOPID controller system outperformed traditional PID controllers and even fuzzier ones in terms of stability and performance.

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