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Analysis of a Fuzzy Logic Controller-Based Power Electronics for Electric Vehicle-Based Ac/Dc/Ac Power Conversion System

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Abstract:- Electric motors are replacing the Internal Combustion Engine (ICE) because they are more environmentally friendly and efficient. When it comes to the electric vehicle, battery and ultra-capacitor technology play crucial roles. The battery or ultra-capacitor of a plug-in EV is charged by an external AC supply connected to the grid line, while the battery or ultra-capacitor of a hybrid EV is charged by the internal combustion engine. Regenerative braking makes use of the traction motor to replenish the battery. Energy is transferred backwards from the AC grid line into the battery or ultra-capacitor, thereby powering the vehicle in reverse. Power electronic converters provide for the safe and efficient transfer of energy between the grid and the traction motor. Power electronics converters in an EV are the subject of extensive analysis. In this article, we investigate the power factor adjustment strategies utilised by single-phase AC/DC-DC power electronic converters installed in electric vehicles. Power factor correction (PFC) efficiency can be improved by employing a variety of solid-state DC-DC converters to keep up with the growing power demand. In order to evaluate the converters, the simulated data, such as power loss estimates and a harmonic analysis, are analysed and compared with fuzzy logic controller.

Keywords: *electric vehicle; fast charging; two/three level inverter; PMSM, Fuzzy logic controller.*

1. Introduction

Energy consumption rises alongside the human population, leading to the depletion of limited resources like oil and gas. For this reason, EVs powered by electricity rather than fossil fuels are being carefully examined [1], [2]. The Fuel Cell (FC) stack, the battery bank, and the Supercapacitor (SCs) bank are only a few examples of renewable energy sources used in EVs. Compared to a conventional Modular Boost Converter (MD-IBC), the ripple, current harmonics, reliability, efficiency, power, and voltage of the resulting Four-Phase Interleaved Boost Converter (FP-IBC) are all significantly lower. Energy storage technologies, such as fuel cells (FCs), solid-state capacitors (SCs), and batteries, can have their lifespans shortened by ripple and current harmonics [8]. However, a DC/AC converter is necessary to change the DC power source into the AC supply used by the electronics. Most DC/AC converters found in industries are two-level converters [9]. The significant harmonic contents of the output voltage introduced by this converter contribute to increased machine losses and reduced lifetime reliability. In high-power and medium-voltage settings, the multilayer converter has largely replaced the two-level converter. The AC electricity it supplies has minimal harmonic content [10]. Multilevel converters have more switching elements and a more complicated power circuit. As a result of this issue, scientists have been working to design more efficient multilevel converter circuits that use fewer switches. The purpose of this research was to create a high-voltage PCS for use in electric vehicle (EV) applications with the goals of improving system performance on the grid and machine sides and reducing the system's overall impact on the system On the machine side of a converter, two- or three-level hybrid inverters may be used. When compared to conventional two-level converters, this design, which uses 10 active switches to generate three separate output voltage levels, is a substantial improvement. The PMSM is powered by a 10-switch inverter, and the batteries would be charged using a Vienna rectifier, a three-level, dual-output AC/DC converter.

1.1 Extension with Fuzzy logic controller

The field of fuzzy logic control (FLC) is where fuzzy set theory, fuzzy reasoning, and fuzzy logic are being studied at the highest levels. FLC has several uses, including but not limited to industrial process control, biological instrumentation, and security. When a human operator can effectively control a complicated system without understanding its underlying dynamics, FLC has proven to be superior to more traditional methods of control.

A control system is a mechanical or electronic arrangement whose primary function is to modify another physical system to meet the designer's specifications. It is possible to classify control systems as open-loop or closed-loop. No information from the physical system is used by open-loop control systems to determine what to do next. In contrast, in a closed-loop control system, the input control action is decided by the physical system's output. Systems with only one open path of control are known as closed-loop control systems. If you want to get a handle on a particular physical factor, you need to start by measuring it. When the regulated signal is detected by a sensor, A plant is an example of a managed physical system. System reactions at the output end of a closed-loop control system are what ultimately determine the forcing signals at the system's inputs.

2. Literature Review

One of the greatest climate change concerns that humanity has encountered in recent years is coping with carbon dioxide emissions caused by meeting rising energy demands to fuel expanding industrial activity across the globe [1].There is a growing international concern about the bad air quality in developing countries like China. Demand for autos and freight transportation is expected to rise along with developing countries' economy, compounding the difficulty of addressing these issues. Increased consumption of fossil fuels in diesel-powered vehicles is a major contributor to global warming and climate change [2,3]. One of the most pressing issues of the previous decade has been the automotive industry's soaring appetite for energy and growing reliance on carbon-based fuels. Numerous studies have found that the transportation sector alone is responsible for the emission of about 500 million metric tonnes of carbon-based components annually [4]. To combat this serious problem, electric vehicles (EVs) have emerged as a boon to help establish a world free from reliance on fossil fuels for energy [5]. In order to generate energy, fuel cell automobiles and trucks use hydrogen and oxygen instead of traditional fuels like gasoline or diesel. That's why their energy efficiency is great and their energy density is low. Electric vehicles (EVs) are quickly replacing traditional automobiles with internal combustion engines, which generally have hundreds of moving parts, with less than 20 moving parts. Energy storage (ES), traction motors, and power electronics are the new areas of concentration for EV innovation [6]. Innovations in these areas are spurred by the need for more efficient and environmentally friendly modes of transportation [7,8]. Power electronics are significantly responsible for processing and controlling the flow of electrical energy in EVs [9]. Moreover, they regulate the motor's top speed and torque. Vehicles use power electronics to convert and distribute electricity to other systems like climate control, electrical, and computer networks [10]. For instance, inverters, DC-DC converters, and chargers are all examples of power electronics components [11,12]. Song et al. [13] employed a unidirectional DC-DC converter to integrate a hybrid energy storage system based on a semi-active battery and ultracapacitors into an electric vehicle. This topology can simultaneously reduce the battery drain and the overall cost of the system. The expense and limited lifespan of the LiFePO4 battery are problems, despite the fact that this method can be used in a wide range of temperatures. As a means of managing battery energy and powering motors, Zheng et al. [14] implemented a cascaded multilayer converter. This converter can effectively make use of the energy stored in batteries, has reduced harmonics and DV-DT, and prevents SOC and voltage from becoming unbalanced. Non-isolated multi-input multi-output DC-DC boost converter designed by Nahavandi et al. [15] to make it easier to employ hybridised alternative energy sources in EV applications. The electric motor in EVs experiences less torque ripple thanks to this converter's lower voltage harmonics.

El Fadil et al. [16] used a hybrid energy storage system consisting of fuel cells, supercapacitors, a boost converter, and a boost-buck converter. To keep the supercapacitor's current under check and the voltage stable, a nonlinear control system has been designed.

3. Methodology

3.1 Proposed system

3.1.1 Power Conversion System

The 800 V electric vehicle's power conversion is shown in Fig. 1. Figures 2 and 3 show the components of this PCS, which include a PMSM, a 10-switch inverter, 800 V battery packages, and a Vienna rectifier functioning as a three-phase onboard charger.

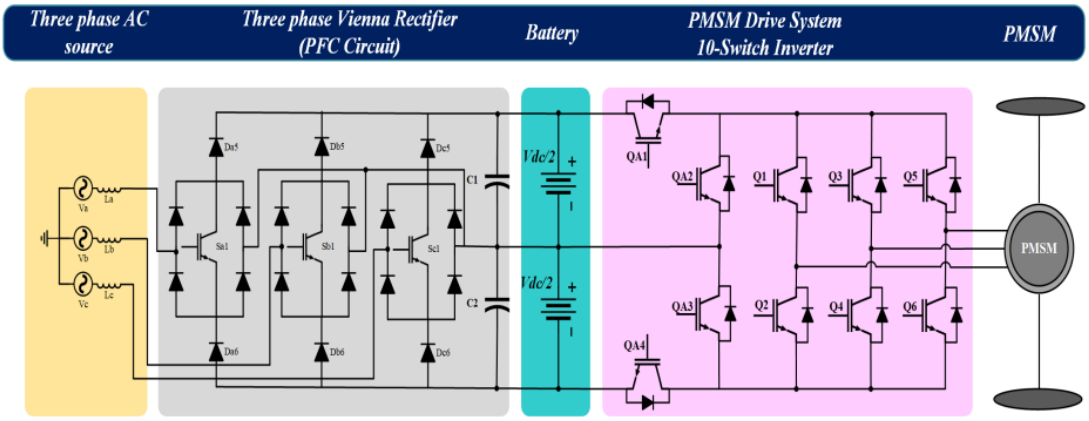


Figure 1. Using a 10-switch inverter, this diagram depicts the planned power converter's system structure for an 800 V EV system[3].

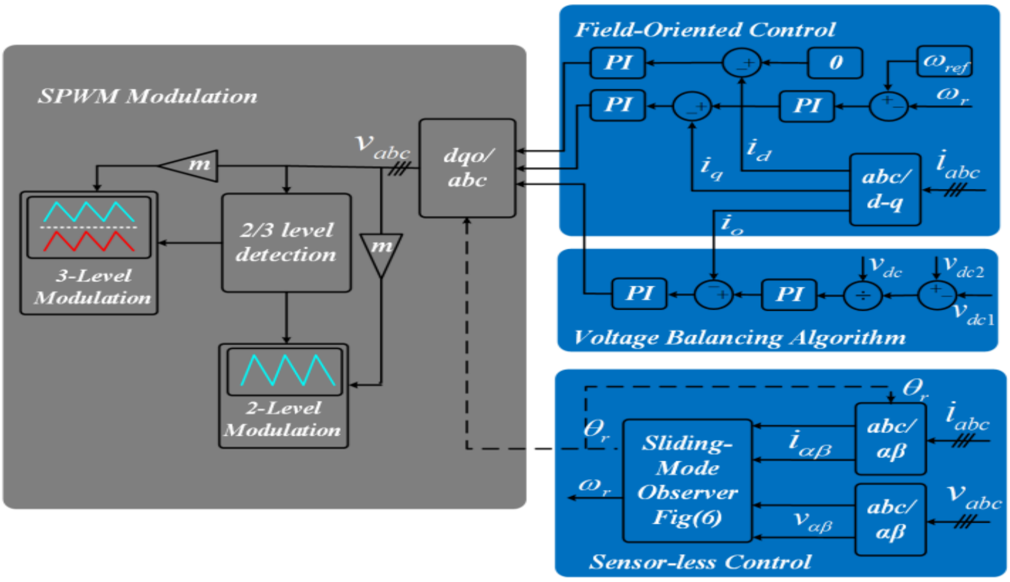


Figure 2. The attached block diagram shows the recommended control system for an 800 V EV system with a 10-switch inverter[4].

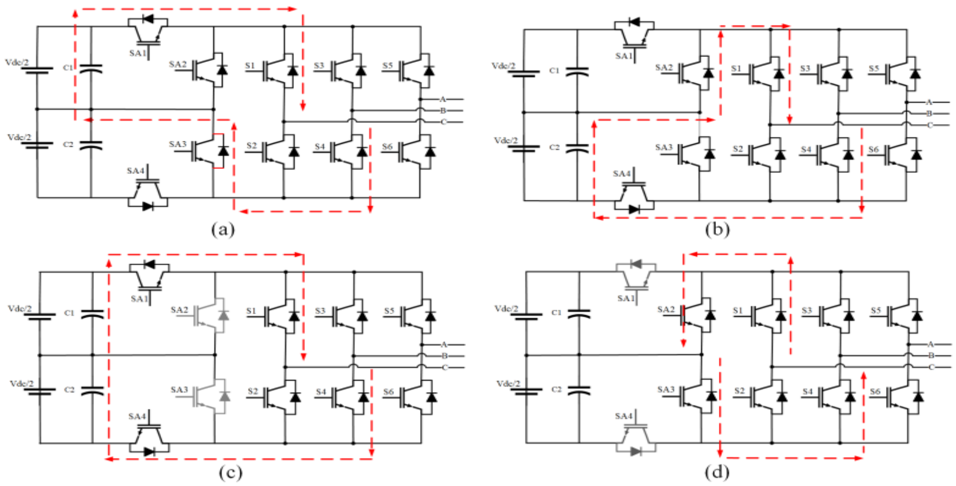


Figure 3. The inverter's 10 switches allow it to switch between two and three levels of operation, as shown below: (a) two-level operation (half DC-link voltage), (b) two-level operation (half DC-link voltage), (c) three-level operation (DC-link voltage), and (d) zero state operation[6].

3.2 Extension with fuzzy logic controller

Fuzzy logic theory is a branch of mathematics that attempts to mimic the human approach to problem solving by employing approximate reasoning to establish connections between sets of data and to reach a conclusion when necessary. This is achieved by the integration of AI, probability theory, and multi-valued logic. Fuzzy Logic Controllers have a long track record of success in the control theory community due to their ability to withstand fluctuations in the parameters of dynamic systems while still maintaining high levels of performance throughout transitions and steady states. Due to its simplicity of implementation and resistance to parameter changes in the operating system, the fuzzy logic controller is favoured over the more traditional PI and PID controllers. The suggested FLC scheme uses a controller and adaptation mechanism that are both based on Mamdani-type fuzzy systems, which take advantage of their inherent simplicity.

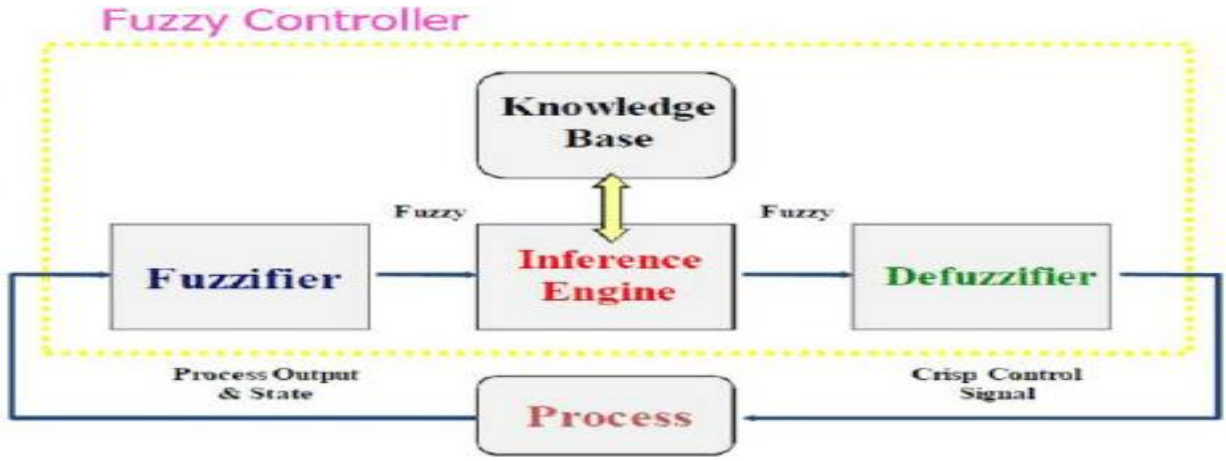


Figure 4: Block Diagram of Fuzzy Logic Controller[7].

Fuzzification

To "fuzzify" a number means to transform it into a format that may be used by a fuzzy set. Thus, the fuzzification block needs to compare the input data to the rule's condition to evaluate the degree to which they coincide. Values for membership functions are adjustable.

Control Rule Base

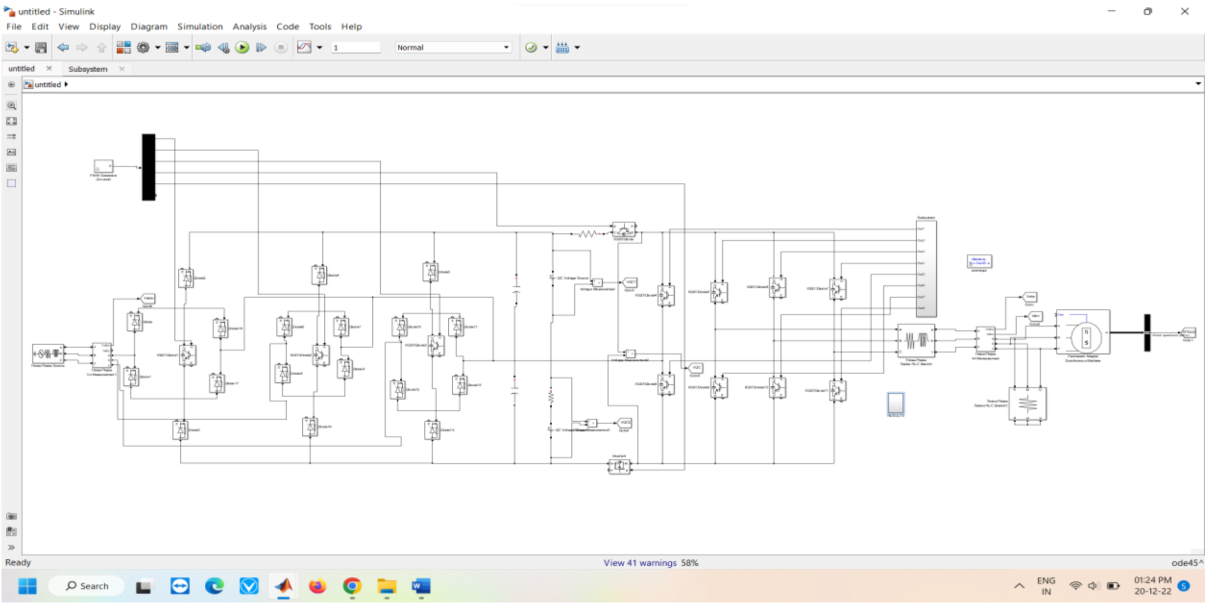
Working experience informs the control rule basis. Using that body of prior knowledge, a membership function is designed with a flexible authorising relationship that allows for input and output modifications dependent on membership status. The control rule base is organised using an IF-THEN structure, where NB = negative large, NM = negative medium, NS = negative small, ZE = zero, PS = positive small, PM = positive medium, and PB = positive big.

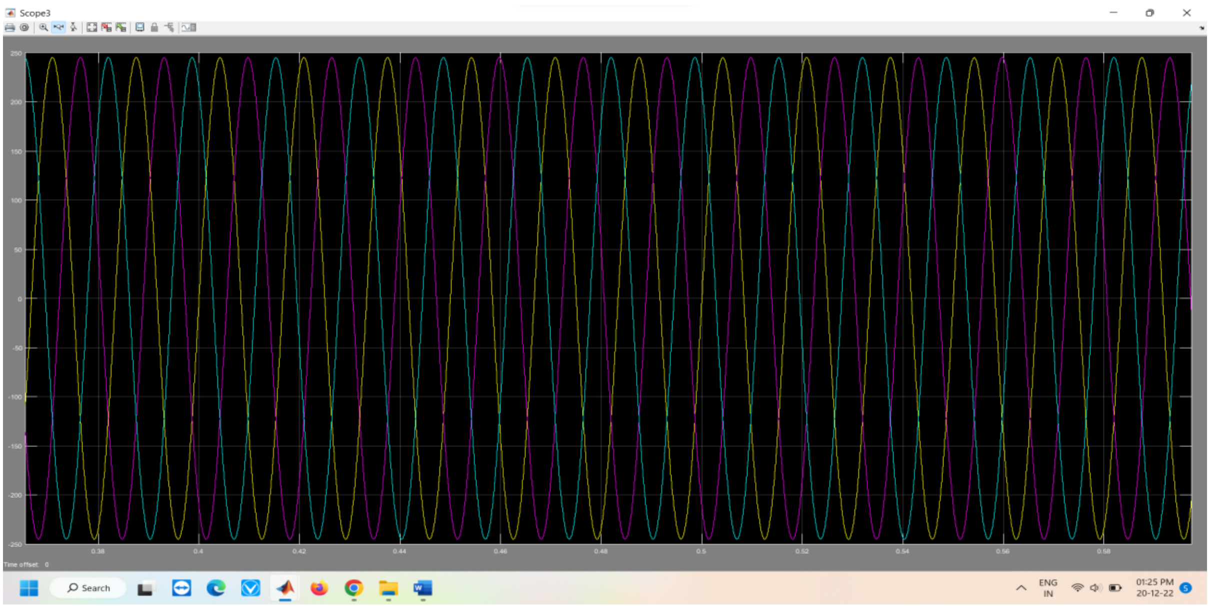
Defuzzification

Defuzzification is the process of restoring clarity after confusion. Defuzzification is the process of converting fuzzy output back to the usual crisp output.

4. Simulation Results

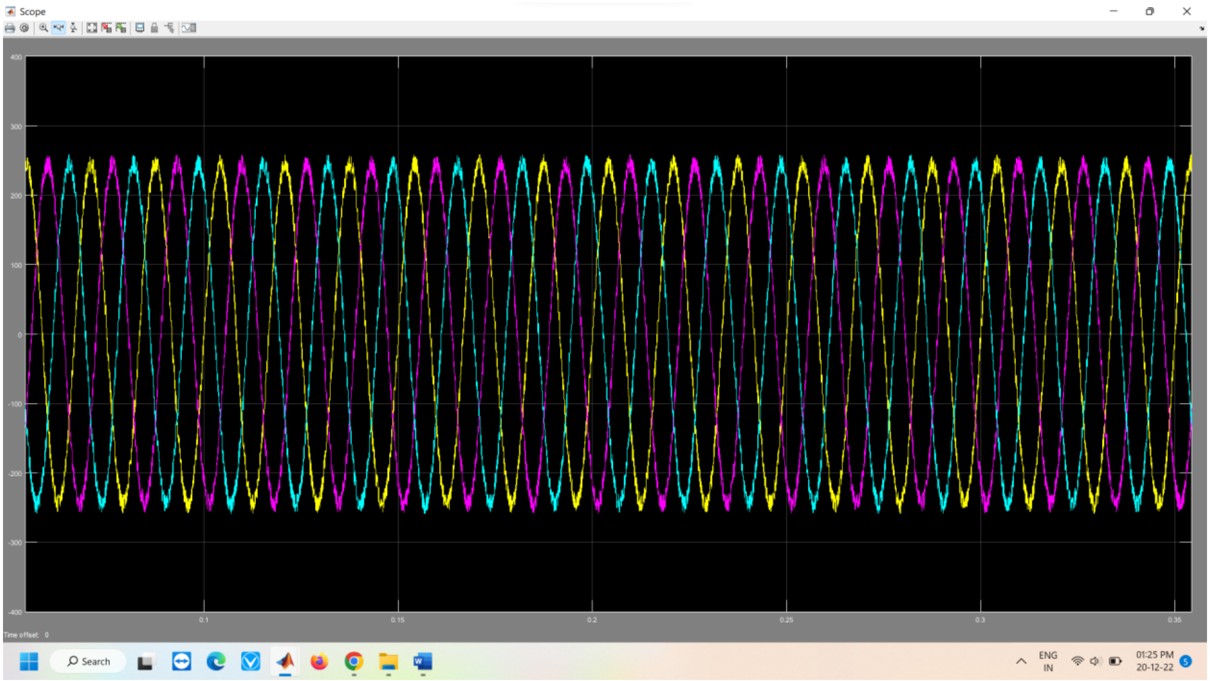
4.1 Proposed Pi Controller Simulation Results



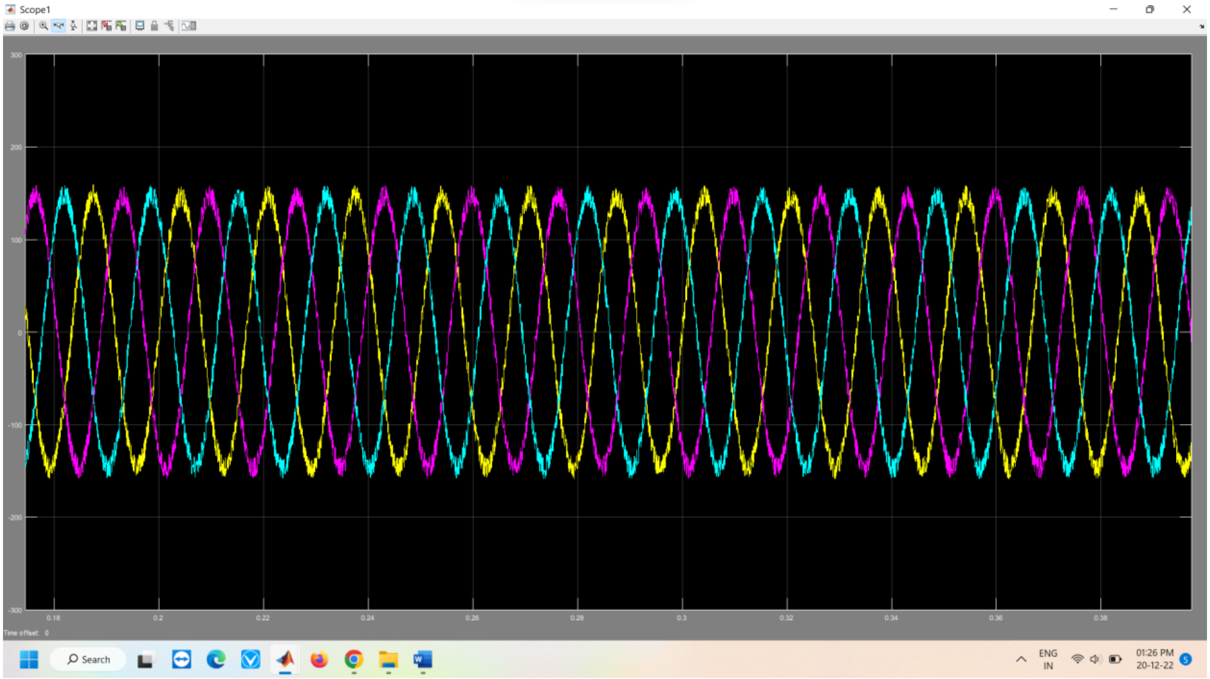


Vsabc

Vdc

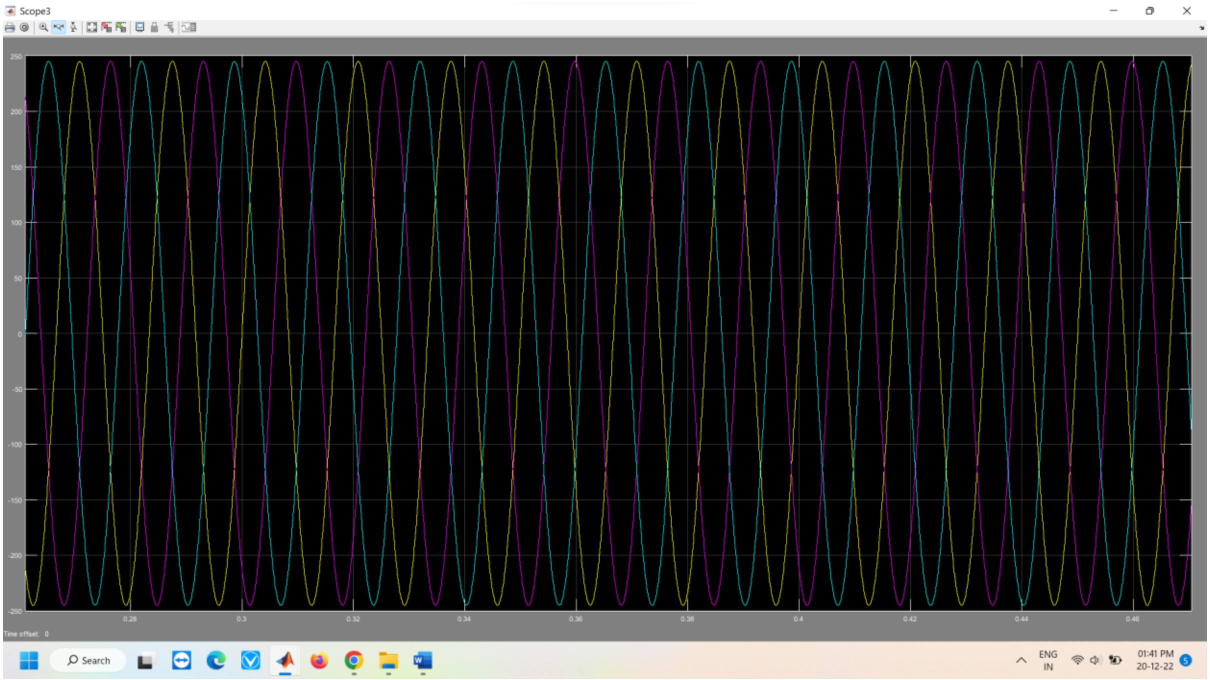


PMSM Voltage

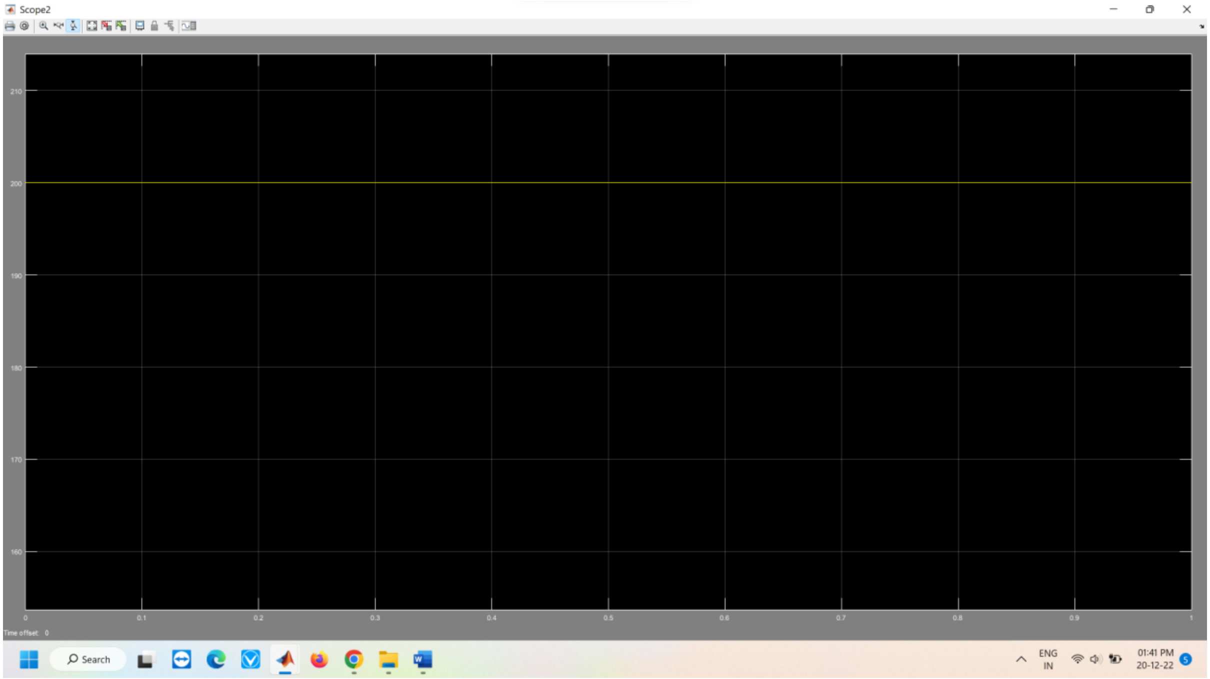


PMSM Current

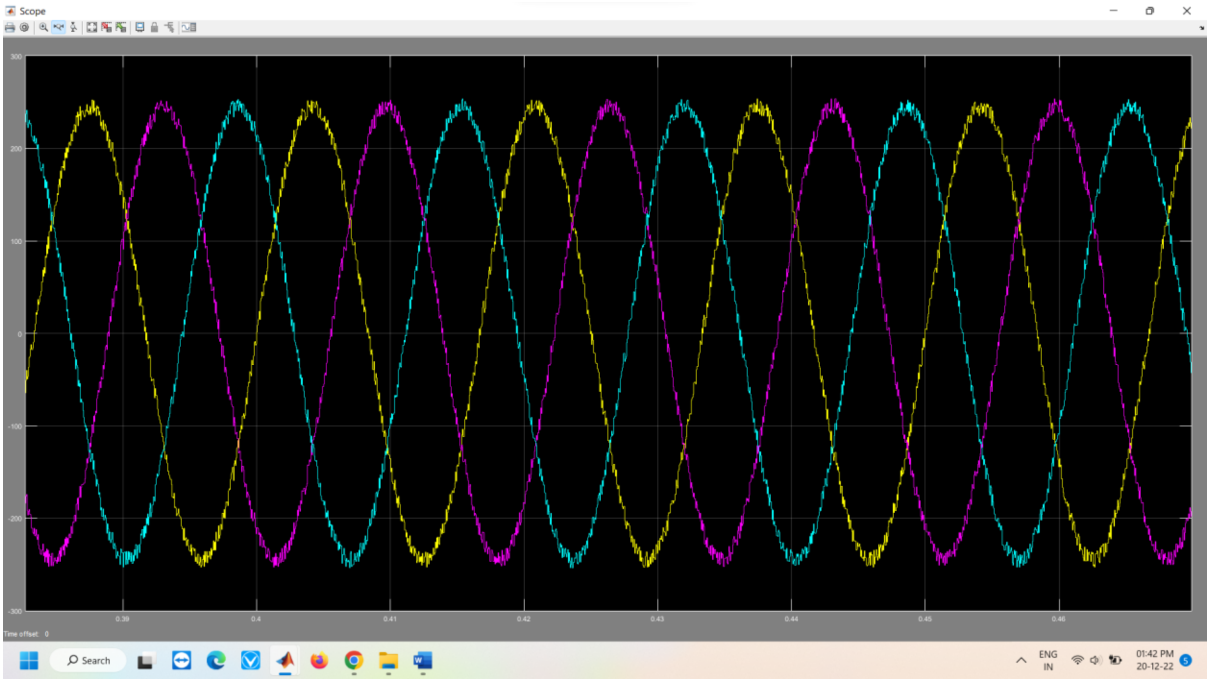
4.2 Extension Fuzzy Logic Controller Results



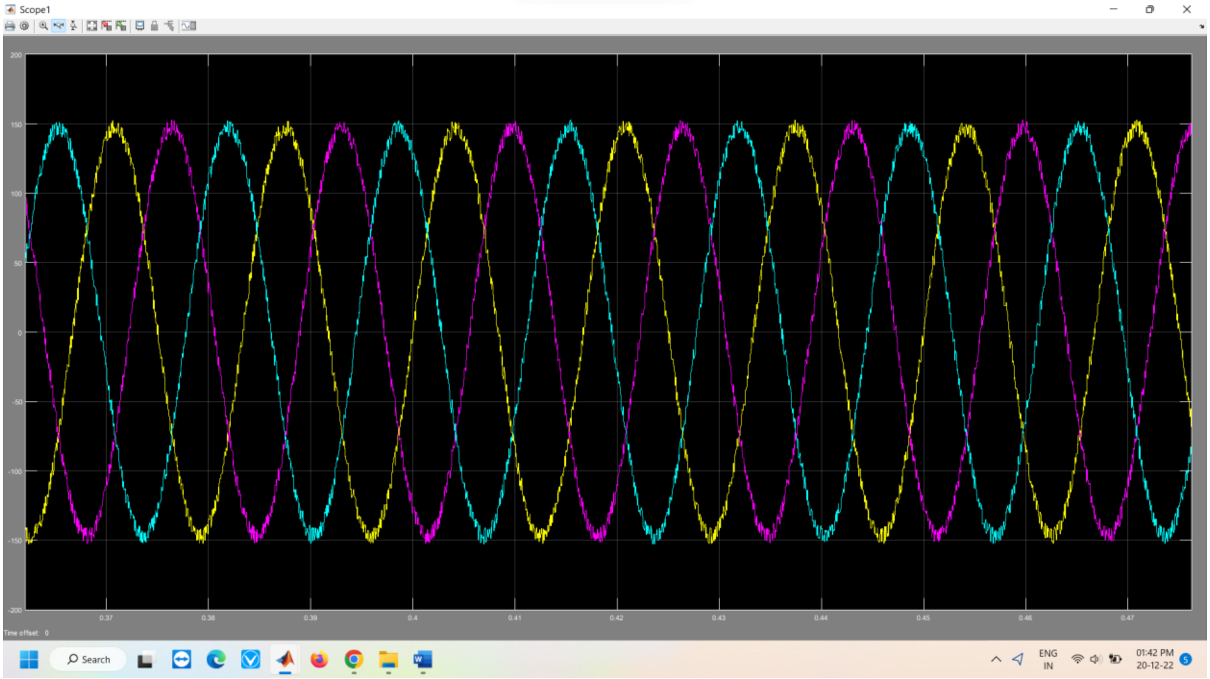
Source Voltage



Vdc



PMSM Voltage



PMSM Current

Table 1: THD Comparison for Proposed Method and Extension Method.

TYPE	THD FOR PROPOSED PI CONTROLLER	THD FOR EXTENSION FUZZY CONTROLLER
PMSM VOLTAGE	4.58%	2.95%
PMSM CURRENT	5.63%	3.27%

Conclusion

A fuzzy logic controller is used in this system to determine the most accurate conclusion. The auto-tuning feature of the Fuzzy logic control network simplifies the process of transferring power from the grid to the car or vice versa. The logic control may also generate PWM pulses, and the entire setup is very configurable. In this study, we use computer simulation to examine and understand the energy flow and waveforms involved in the ac/dc/ac power conversion system was proposed for use in electric vehicles.

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