



COMPRATIVE ANALYSIS OF ZnO BASED ELECTRIC VEHICLE WITH FUZZY CONTROLLER

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1.ABSTRACT

This paper proposes a solution to find the best way to combine battery banks with Zinc Oxide (ZnO) capacitors so that electric vehicles can store more energy. The combination of ZnO capacitors, which have a high power density and can be charged and discharged quickly, with batteries allows for high energy density, long-term energy storage. To overcome the drawbacks of each technology when used separately, these two energy storage systems will be integrated.

In order to improve the system's performance, the converters have been regulated using both traditional controllers like PI and PID and intelligent controllers like fuzzy controller. A comparison of the results has been done. In order to assist the batteries, maintain their charge as efficiently as possible, an Arduino-based power circuit has been developed to interface the battery pack with ZnO capacitors, which are known for their high performance in high terrains and low charge batteries.

Keywords: Ttraditional controllers like PI and PID and intelligent controllers like fuzzy controller.

1.1 INTRODUCTION TO FUZZY SYSTEM

The idea of fuzzy logic was first proposed by L. A. Zadeh in 1965. According to him, classical theory is all about precision and not about efficient control. The classical theory could only take two values—one or zero—so it couldn't provide an efficient solution. This led to the development of fuzzy set theory, which allows for several analyses of the same solution instead of just two. The foundation of fuzzy logic is the rule-based system, in which a set of predefined rules is used to identify a solution for the system. The use of IF.THEN rules to generate member functions for the inputs is also an integral part of fuzzy solutions. In an IF-THEN rule, the IF statement serves as the antecedent and the THEN statement as the consequent.

1.2 SETS AND OPERATIONS

Sets are divided into two types namely: classical set and fuzzy set.

Classical Set: In this Set, it defines if a factor belongs to a particular set or does not belongs to which can be represented as

$$A = \{x \in U \mid x \text{ satisfies some conditions}\}$$

The above condition can also be represented as $\mu_A(x) = \begin{cases} 1 & \text{if } x \in A \\ 0 & \text{if } x \notin A \end{cases}$

Fuzzy set: In this set, it not only defines if a factor belongs to a particular set or not and also define how much the element belongs to that set can be represented as

$$A = \{(x, \mu_A(x)) \mid x \in U\}$$

Operations

There are some of the operations that can be obtained with the fuzzy sets which are described below:

Consider two fuzzy sets A and B, universe of discourse U and the operations union, intersection and complement.

- Union

It is the set of all the elements that contain in set A or set B that can be represented as $A \cup B$ whose expression can be given as

$$\mu_{A \cup B}(x) = \max \{\mu_A(x), \mu_B(x)\}$$

- Intersection

It is a set of all the elements that contain in set A or set B, can be represented as $A \cap B$ whose expression can be given as

$$\mu_{A \cap B}(x) = \min \{\mu_A(x), \mu_B(x)\}$$

1.3 ADVANTAGES OF FUZZY CONTROL

There are a number of benefits to using it instead of the more traditional controllers. Here they are:

- Easy to grasp as the controller's underlying principle is straightforward.
- It also includes seeing things through the eyes of a person who gains the strength to adapt to the challenges of controlling.
- It will also function better when inputs are interrupted. Also, according to rule theory, it can take in a lot of inputs and come out with a lot of outputs. Compared to providing operators for the proportional-integral-derivative controller, producing the rule-based system for the fuzzy controller is easy.
- To ensure the system continues to run safely, the sensor can be programmed to turn off when it ceases working.
- Rather of requiring complicated analytical analysis, it will be quickly applied.
- It leverages the accuracy of intuitive controllers while making efficient use of them, rather than relying on higher-accuracy sensors.
- This controller has an intuitive UI that even a non-technical person can pick up and use with ease.
- The simpler computations are incorporated into the controller.
- An often-used method of presenting unknown information is the fuzzy logic controller.

1.4 IMPLEMENTATION OF FUZZY LOGIC

It provides a highly ordered map of the effort to production, and the mapping is permissible even for those without extensive procedural expertise. The procedures that must be followed in Fuzzy control are as follows:

- It is essential to grasp the idea of applying the rule-based arrangement and the machinist to the controller.
- It is necessary to grasp the notion of linguistic variables and membership functions. It is necessary to do an analysis of the power system and its controls. The plant's status variables need to be determined.
- It is now necessary to construct the rule-based system for the input and output language variables.

1.5 BASIC COMPONENTS IN FUZZY CONTROL

Fuzzy logic controls (FLCs) are defined by a system that determines a set of language rules that describe the basic controls. Because the system defines the rules, mathematical modeling is not necessary. There are typically three main components that make up an FLC:

1. Fuzzification,
2. Interference engine, and
3. Defuzzification.

Further, the fuzzy controls are characterized by the following steps:

- For each input and output apply seven fuzzy sets
- For simplicity use triangular membership functions
- Implementation of using mamdani “s” min operator; and
- Finally defuzzification using “centroid” method

When faced with ambiguity or imprecision, FLCs are renowned for producing suitable outcomes. With its user-friendly interface and straightforward explanations, even a layperson can grasp the concept and create their own practical control algorithms. They provide comparable or even more accurate outcomes than conventional PID controllers and perform better overall.

• Fuzzification

Seven fuzzy subsets are used for fuzzification and for the linguistic variables, different membership values will be assigned.

1. Negative Big (NB)
2. Negative Medium (NM)
3. Negative Small (NS)
4. Zero (ZE)
5. Positive Small (PS)
6. Positive Medium (PM) and
7. Positive Big (PB)

The input scaling factor is taken into account in the system design to be with input values ranging from -1 to +1.

Furthermore, it is anticipated that the membership function will possess a triangle form, and for every given input, a singular type of domain fuzzy subset will be accessible.

- **Interference Method**

While other compositions like Max-Dot and Max-Min are available, the Min technique is used here. Currently, the minimum and maximum operators will determine the output membership function for every rule that is implemented.

- **Defuzzification**

Because non-fuzzy control values are required, defuzzification plays a crucial role. In order to determine the fuzzy logic output and subsequently alter the control output, the centroid approach is utilized.

You can control the inverter switches using the same FLC output. It is necessary to detect all of the control parameters and compare them to the reference values in order to carry out the necessary operations.

This thesis made use of a non-uniform fuzzifier for fuzzification. When the margins of error and the amount of change in error are negligible, they are divided up equally. But when they're really large, they're split open.

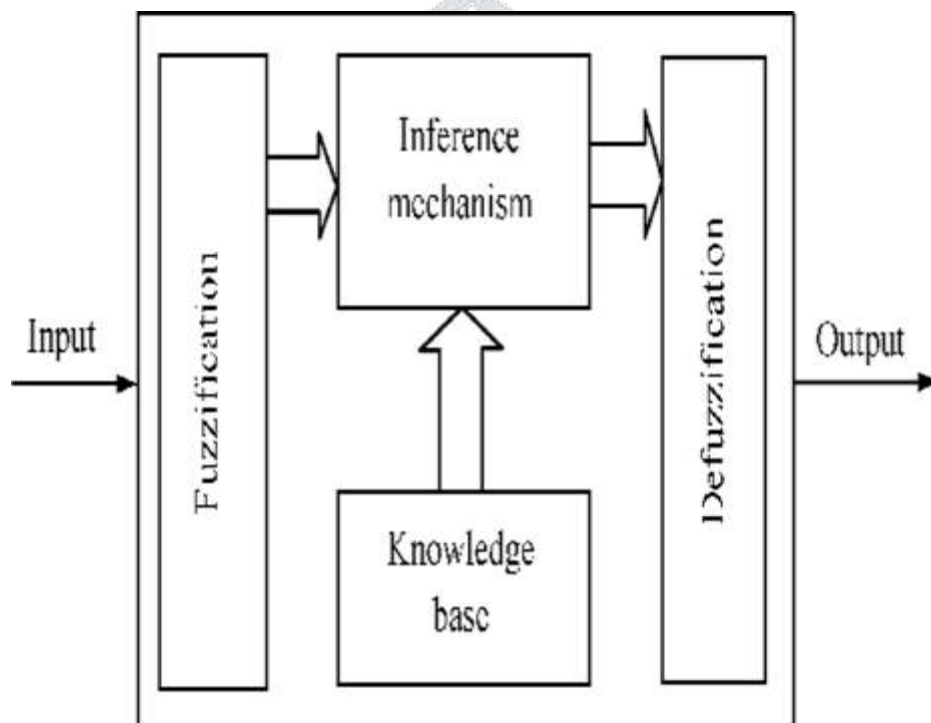


Figure 1. 1 Block diagram of fuzzy logic controller

General methods adopted for Defuzzification are:

1. Center of Gravity or Centroid Method: It finds the center point of the targeted fuzzy region by finding weighted mean of the fuzzy region.
2. Weighted averages Method: It assign weight to each membership function in the output by their respective maximum membership values.
3. Max membership principal Method: It chooses elements with max membership values.

A fuzzy logic controller takes as inputs, in accordance with the aforementioned principle, the difference between the reference and obtained voltages, and as inputs, in turn, the change in the differential. The fuzzifier takes these as input and uses them to transform crisp variables into fuzzy ones. Next, we look at the two transformed fuzzy membership functions using seven variables: PB, PM, PS, ZE, NS, NM, and NB. The output membership function is formed by applying 49 rules that are derived from the rule based system's IF-THEN rules. The centroid-type defuzzification method is then used to transform the fuzzy output membership function into a crisp value. The fuzzy logic table utilized by the DC link voltage controller is provided in the table below.

Table 1. 1 Rule Based System of Fuzzy Controller

$\begin{matrix} e \\ \backslash \\ e \end{matrix}$	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZO
NM	NB	NB	NB	NM	NS	ZO	PS
NS	NB	NB	NM	NS	ZO	PS	PM
ZO	NB	NM	NS	ZO	PS	PM	PB
PS	NM	NS	ZO	PS	PM	PB	PB
PM	NS	ZO	PS	PM	PB	PB	PB
PB	ZO	PS	PM	PB	PB	PB	PB

1.6 SIMULATION OF INTELLIGENT CONTROLLER FOR PROPOSED ELECTRIC VEHICLE:

Using MATLAB Simulink, we created models with fuzzy controllers for buck boost converters; Figure 1.2 shows the suggested electric car model of the buck boost converter with fuzzy regulators. Figure 1.3 shows that the 48 volt output voltage of the converter settled at 0.025 seconds.

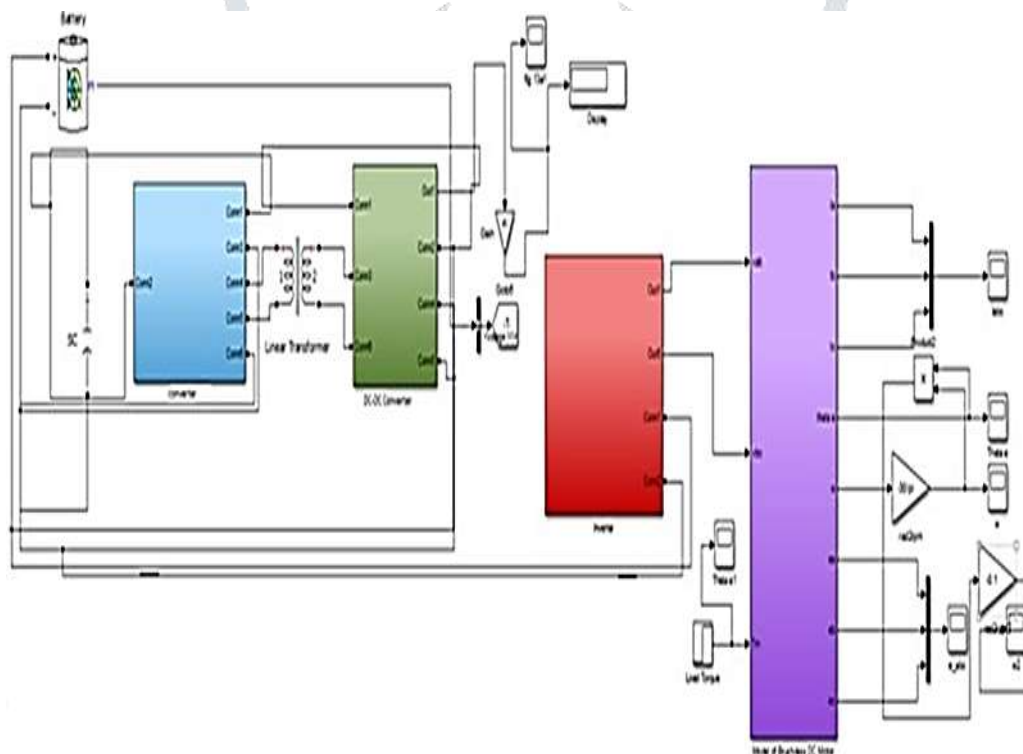


Figure 1. 2 Simulink diagram of Electric Vehicle with Fuzzy controller

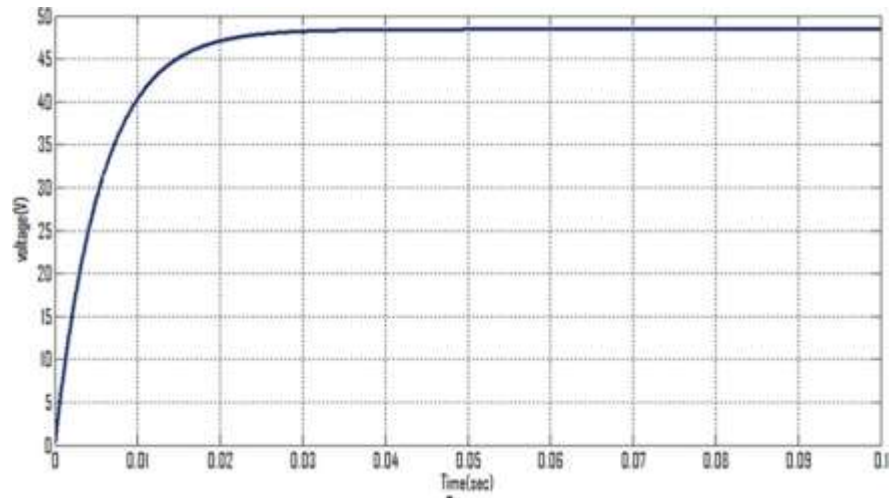


Figure 1.3 Output voltage of the Converter

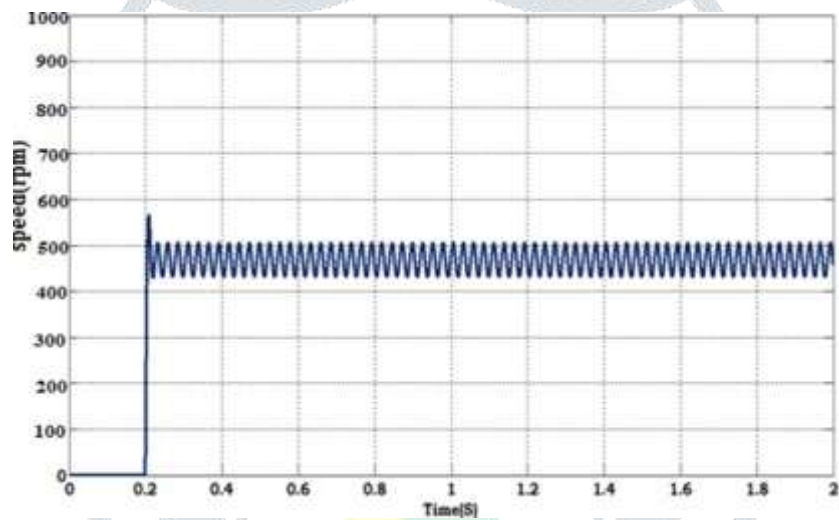


Figure 1.4 Speed of the motor

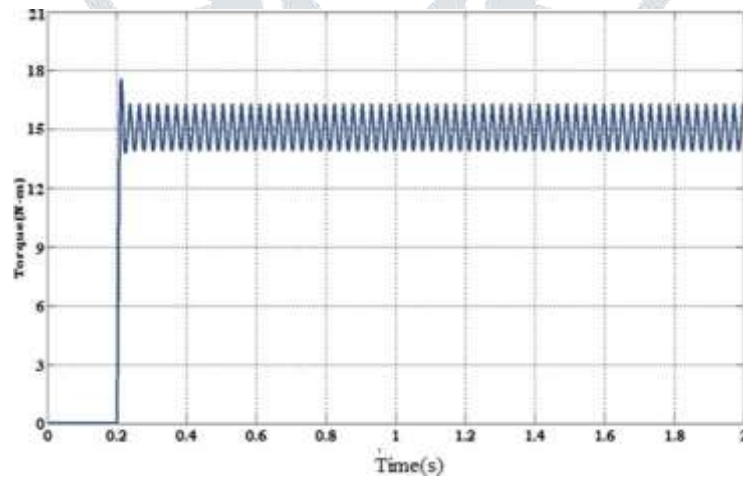


Figure 1.5 Torque of the Motor

Figure 1.4 indicates that the BLDC motor is operating at a speed of around 420 revolutions per minute. The BLDC motor's torque, as shown in figure 4.5, starts at approximately 13 N-m and drops to around 17 N-m after $t=0.2$ sec.

The comparison of the buck boost converter with various controllers is shown in table 4.2. Among these, the converter with the fuzzy controller outperforms the converter with the PI and PID controllers.

Table 1. 2 Comparison of Buck Boost Converter with controllers

Parameter	PI	PID	Fuzzy
Kp	53	52	-
Ki	25	17	-
Kd	-	7	-
rise time	0.01	0.02	0.012
Settling time	0.17	0.1	0.04
Peak time	0.03	0.03	0.04
Peak overshoot	10.4%	7%	0
Steady state error	0.7	0.6	0.01
Efficiency	90.1%	90.5%	91%

When compared to PID controllers, fuzzy controllers significantly improve the performance of buck boost converters, with 50% shorter settling periods, 100% less peak overshoot, 50% less stable state error, and 91% efficiency.

This section compares the efficiency of converters using PI, PID, and fuzzy controllers and details the design and construction of an electric vehicle using a fuzzy controller. Fuzzy controller achieves 50% better settling time, 100% better peak overshoot, 50% better steady state error, and 91% better efficiency than PI and PID controllers, which in turn increase the performance of EVs. With the fuzzy controller, the electric vehicle's speed and torque are increased by 10%.

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