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Original Article

Optimal Charging Time for a Fuzzy-Controlled Electric Two-Wheeler Movable Charging Unit

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Abstract - *Globally, Electric vehicles are gradually becoming dominant in the transportation sector, which necessitates the growth of charging points. Apart from home chargers, the high installation cost and lack of space for public charging stations hamper achieving this. Another vital setback is the long charging time of an Electric Vehicle. Quite a number of research studies are being done to reduce the charging time of Electric vehicles. The Fuzzy-controlled movable charging unit, with its lesser space requirement, lesser cost and reduced charge time for Electric Vehicle, has been proposed in this paper, which can charge an electric two-wheeler. The case study where the Fuzzy-controlled movable charging unit charges an electric vehicle along with multiple loads was simulated in MATLAB R2021a, and studied. The hardware implementation was done, where the Fuzzy-controlled mobile charging unit prototype was built and tested with a 3.7V,4000mAh Lithium-ion battery. The fuzzy logic controller with constant current charging circuit was utilized in the implementation. The fuzzy logic controller operates based on membership functions with a set of defined fuzzy rules. Thus, fuzzy logic was introduced as an optimization tool, reducing the charge time to 7 minutes against 33 minutes when implemented with a conventional controller. The project satisfies UN Sustainable Development Goals 7(clean Energy) and 13(climate action).*

Keywords - *Charging time, Electric vehicle, Fuzzy logic controller, Lithium-ion battery, Mobile charging station.*

1. Introduction

The non-renewable resources have directed us to shift towards renewable resources because of an increase in demand, thereby culminating in extensive research on Electric Vehicles (EVs) [1]. Enormous surveys among users have been conducted to determine the willingness to move toward EVs [2]. With the growing demand for Electric Vehicles (EVs), it is essential to develop charging stations that minimize charging time while also addressing range anxiety. The range anxiety can be reduced by building Fixed Charging Stations (FCSs) with shorter distance gaps [3]. However, the lack of installation space and higher investment costs are contributing factors to the lack of availability of widespread charging stations. The Mobile Charging Station (MCS) can be considered an appropriate solution that renders the service when it is requested [4]. The movement of the MCS from place to place and customer satisfaction are the main attributes of the selection of an MCS. The Fuzzy-Controlled Movable Charging Unit (FCMCU) with solar panels and a hand generator is the source proposed in this paper. Long charging time is another critical factor that seeks immediate attention. Fast charging stations for DC electric vehicles typically take around 20 minutes to charge an EV [5]. However, they constitute only a lesser percentage of public charging stations. The use of MCS can be a viable alternative to the charging of EVs. Key research gaps currently include high installation costs, large space requirements, and long charging times. To address these challenges, a Fuzzy-controlled Movable Charging Unit (FCMCU) has been developed. Fixed Charging Stations (FCS) typically demand significant space and incur higher installation expenses, highlighting the need for a more compact and cost-effective solution like the FCMCU. Furthermore, this paper aims to tackle the critical issue of prolonged EV charging times through the implementation of the proposed FCMCU. A charging time of 7 minutes for the Mobile Charging Unit (MCU) prototype is presented in this paper, with fuzzy logic as the implementation tool. The paper is structured as follows. Section 2 explains the literature review. The methods utilized in FCMCU are discussed in Section 3. Section 4 explains results and discussion, followed by a conclusion in Section 5.

2. Literature Review

As discussed in [6] by the authors, FCS do not readily satisfy the charging needs of EVs. Hence, MCS has been identified as an alternative. MCS has been proposed to help FCS, and two offline heuristic algorithms have been proposed to solve the problem, where MCS is mapped to different FCS based on demands. A traffic assignment model was deployed based on the dynamic planning of MCS in [7], where the proposed method was space-saving compared to the usual FCS and captured maximum EV flow. A linear algorithm was used to transform a nonlinear integer programming model into a linear integer programming model to obtain a global optimal solution. The Return on Investment (ROI) estimations of public fast charging stations were done in Germany [8]. The result implied that the market situation was too dynamic to arrive at a conclusion to invest more in fast charging infrastructure [9]. The utilization rate of FCS is low in the main cities, which slows down the rate of Return on Investment of FCS. Though MCS slows down the upcoming of FCS, it improves the utilization of FCS, which ultimately increases the ROI.

The reduction in charging time of EV battery was achieved in [10], where a tradeoff between charging time and charging loss was done by a dynamic programming method, which gave the results - charging time increasing 0.30% and charging loss increasing 0.79%. The fast charging of lithium-ion batteries has been done by a multistage constant heating rates optimization method that reduces charge time and temperature increase using a genetic algorithm [11]. The experimental results indicated that the charging time is reduced by 1.90%, 5.30%, 8.56%, and 9.54%, and the temperature rise is reduced by 48.6%, 28.30%, 67.30%, and 17.9% compared to the Constant Current Constant Voltage charging under temperature,10℃,25℃ and 40℃, respectively. The charge speed and efficiency increased to about 23% and 1.6% by proposing the Grey Predicted Lithium-ion battery charge system compared to conventional constant current and constant voltage methods in [12]. A Grey Predicted Algorithm was built in the Grey Predicted Lithium battery system to speed up the charge trajectories. In [13], the authors achieved reduced time by employing optimized fuzzy controller with a genetic Algorithm. The proposed fuzzy controller with a genetic Algorithm controlled the charging current as a function of temperature.

A multistage fast charging technique was introduced in [14] for a high-power Lithium-ion phosphate battery, where the charge time was reduced to 20 min for 0-100% SOC. A new charging strategy of lithium-phosphate batteries was proposed in [15] based on the integration of the Taguchi Method (TM) and SOC estimation, where the charge time was reduced and efficiency was increased. The charge time was reduced by 22.50% and temperature variation was almost half, compared with the constant current and voltage method. A destructive model-based fast charging algorithm involving two closed loops was proposed in [16]. The first loop consisted of an anode over-potential observer that continuously monitored the lithium deposition status in real time. In contrast, the second loop used a feedback mechanism to adjust the charging current based on the observed lithium deposition. Around 96.80% of the battery capacity was charged within 52 minutes. A Constant Temperature Constant Voltage (CT-CV) method has been proposed in [17] where the charging current is adjusted to respond to temperature, affecting the ageing. The proposed CT-CV charging scheme utilized a straightforward, easy-to-implement PID controller enhanced with a feed-forward component. This approach achieved a 20% reduction in charging time while maintaining the same temperature rise as the conventional Constant Current–Constant Voltage (CC-CV) method.

In [18], the authors present an improvement to the traditional CC-CV charging method by integrating an LCL filter with an AC-DC boost converter. The enhanced CC-CV algorithm effectively increases the duration of the Constant Current (CC) phase while reducing the Constant Voltage (CV) phase. This optimization results in a shorter overall charging time and enables accurate State Of Charge (SOC) estimation. In [19], the authors focus on fast charging of lithium-ion batteries, emphasizing the use of lithium plating-free technology. They demonstrate that a 9.5 Ah battery can achieve a reduced charging time of just 15 minutes, even under extreme low-temperature conditions of −50 °C. Many research has been conducted to achieve the SDG goals. A review was conducted by [20] to make smart city solutions progress towards SDG goals, in which SDG7 was mainly addressed, by mentioning actions like promoting renewable Energy. Another paper [21] mainly discussed SDG 13, where climate action can be met, and solutions were identified, like electrification, as an alternative to decarbonization.

The fuzzy logic was implemented along with temperature feedback in [22] to reduce the charge time of the EV. The temperature control was done in order to combat the effects of fast charging on the ageing mechanism. The method took 9.76% less time than the conventional method. In [23], the battery charger was designed with a Fuzzy Logic Controller, which accelerated the charging time up to 37.8% at the rate of 2C with an efficiency increase of 82%. The Fuzzy-Controlled Movable Charging Unit (FCMCU) with fuzzy logic has been introduced with a solar panel and a hand generator as sources. The charge time is reduced prominently by implementing an MCU prototype with fuzzy logic, which reduced the charge time to 7 minutes, as against 33 minutes with a conventional controller.

The fuzzy logic was implemented with an ATMEGA328P microcontroller for charge time optimization. Since FCMCU is a movable charging unit and utilizes low-cost sources of generation (solar panels and hand generator), it also serves as an economic tool when compared to a Fixed Charging station, which needs high installation costs and more space. In developed countries, MCS has been designed for vehicles that are provided with costly and huge batteries. However, this is not feasible in developing and underdeveloped countries, where the mentioned MCS is not cost-effective. A Fuzzy-Controlled Movable Charging Unit (FCMCU) has been proposed in this paper, which serves as an economic tool, especially for roadside vendors, to charge an

Electric vehicle (2-wheeler only). FCMCU aims to increase electric vehicle customer satisfaction and also provide extra income for roadside vendors. It was implemented with fuzzy logic that significantly reduced the charging time for the MCU prototype to 7 minutes. The FCMCU, due to its prominent charge time reduction, appears to be a viable and feasible option.

3. Materials and Methods

In this section, the process followed in FCMCU is presented, along with the description of the Constant current charging circuit and the Fuzzy logic circuit. It should be noted that a constant current is maintained with the help of a Constant current charging circuit, and the charge time of the EV battery is reduced by the Fuzzy Logic Circuit, where a Fuzzy Logic Controller (FLC) is utilized.

3.1. Process Flow in FCMCU

The comparison of FCMCU with a conventional controller and with fuzzy logic is carried out to emphasize the optimized time due to the fuzzy logic circuit, as in Figure 1. A voltage input of 12V has been used, with the sources being a hand generator and a solar panel. It has been observed that the FCMCU with a constant current charging circuit only took more time to charge the EV battery than the circuit with the fuzzy logic circuit. The FLC is employed in a Fuzzy logic circuit, where it uses the Fuzzy rules to optimize the charge time.

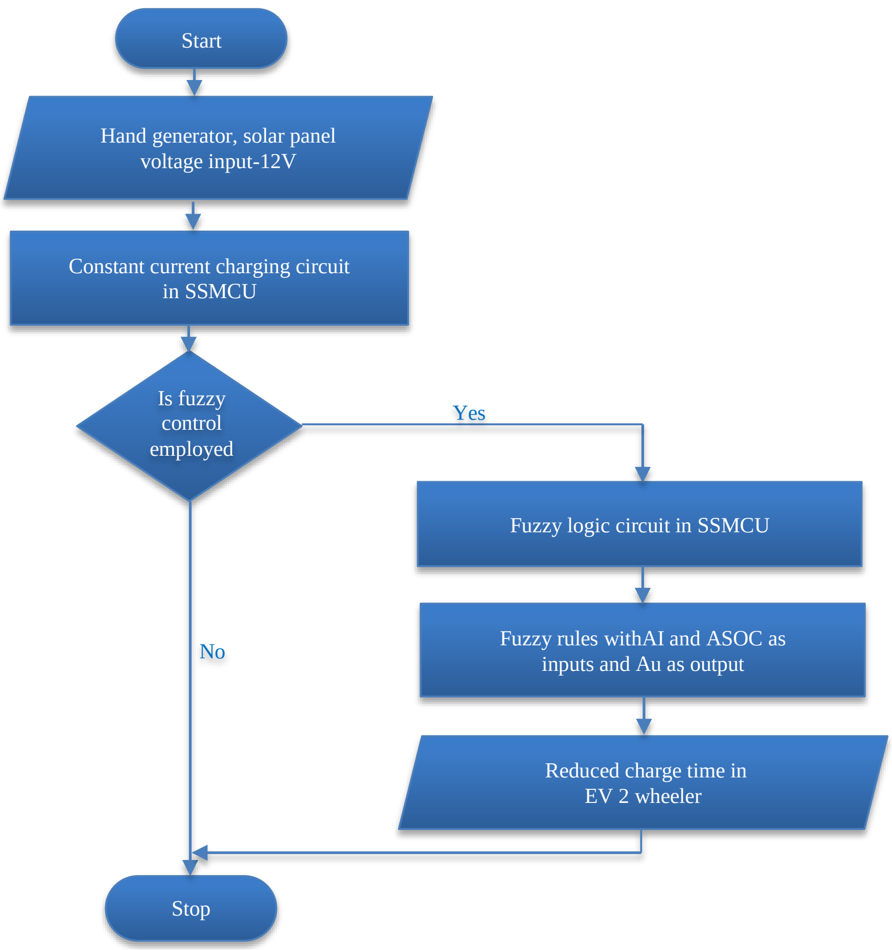


Fig. 1 Process flow of FCMCU

3.2. Constant Current Charging Circuit

The Constant current charging, as in Figure 2, continuously charges a battery at a constant current to prevent overcurrent charging. This method is widely used for NiCd, NiMH or Lithium-ion batteries. The charging current rate is the most important factor that influences the behavior of the battery. The main task is identifying the appropriate charging current rate that satisfies the charging time and utilization capacity. A high current affects the battery ageing cycle. A low charging current takes a long time to charge, affecting the application process. The advantage of the constant current charging method is that the charging current value can be found according to the capacity of the battery, and the charging amount can be calculated. At the same time, the charging time can also be found. It is also easy to implement, and the major disadvantage is low capacity utilisation.

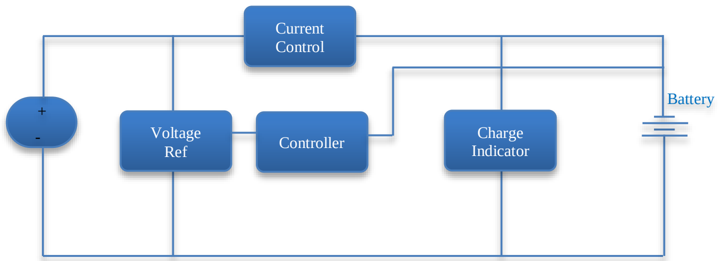


Fig. 2 Constant current charging circuit

3.3. Fuzzy Logic Circuit

The fuzzy logic circuit quickens the battery charging process by means of a Fuzzy Logic Controller which works on fuzzy rules as in Figure 3 and 4. Fuzzy logic is a mathematical approach that deals with reasoning based on degrees of truth, allowing values between 0 and 1 instead of relying solely on absolute true or false values. The Fuzzy Logic Controller operates using membership functions and predefined fuzzy rules applied to input and output variables.

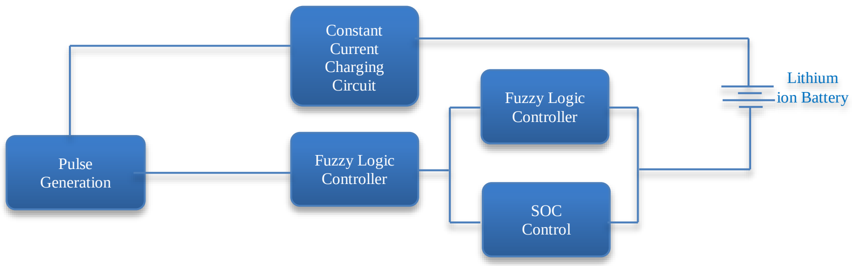


Fig. 3 Fuzzy logic circuit

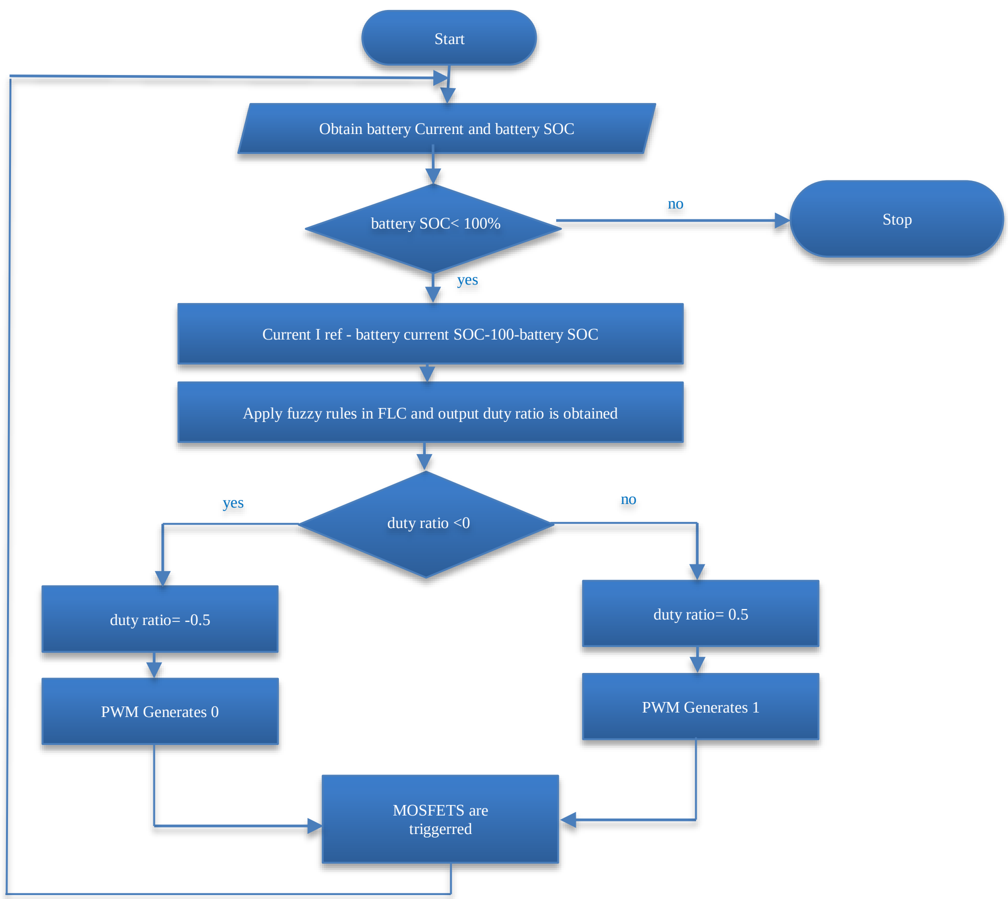


Fig. 4 Flow chart of fuzzy logic circuit

In this process, inputs are first fuzzified to generate fuzzy outputs, which are converted back into precise (crisp) values through defuzzification. The flow chart in Figure 4 explains the process followed with fuzzy rules applied to FLC.

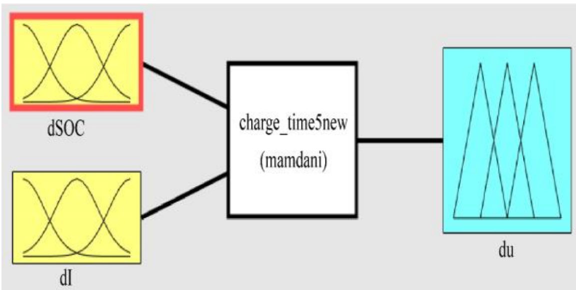


Fig. 5 Input and output membership functions

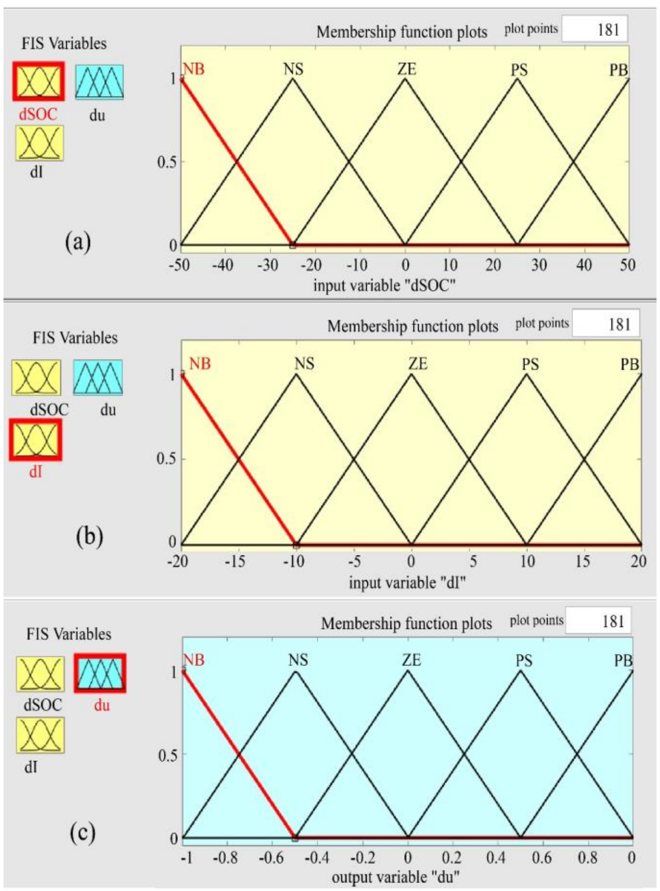


Fig. 6 Plots of membership functions, (a) SOC, (b) Current, and (c) Duty ratio.

Range:_ΔI(-20 20), ΔSOC(-50 50) and Δu (-1 1)

The above ranges are assigned to membership functions, i.e change in current Δi, change in State Of Charge ΔSOC and duty ratio Δu. The Δi and ΔSOC are the input membership functions, and Δu is the duty ratio, which is the output membership function. Figure 5 shows that the membership functions follow the Mamdani approach. Figure 6(a), 6(b), and 6(c) show the membership function plots for SOC, current, and duty ratio, respectively.

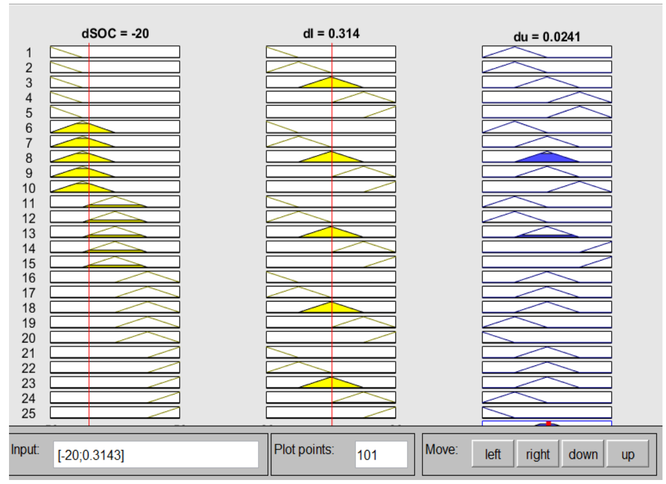


Fig. 7 Rule viewer representation

Table 1. Fuzzy rules in FCMCU

	ΔI					
	Δu	NB	NS	ZE	PS	PB
ΔSOC	NB	NS	ZE	ZE	PB	PB
	NS	NS	ZE	ZE	ZE	PS
	ZE	NS	NS	ZE	PB	PB
	PS	ZE	ZE	ZE	NS	NB
	PB	ZE	ZE	ZE	NS	NB

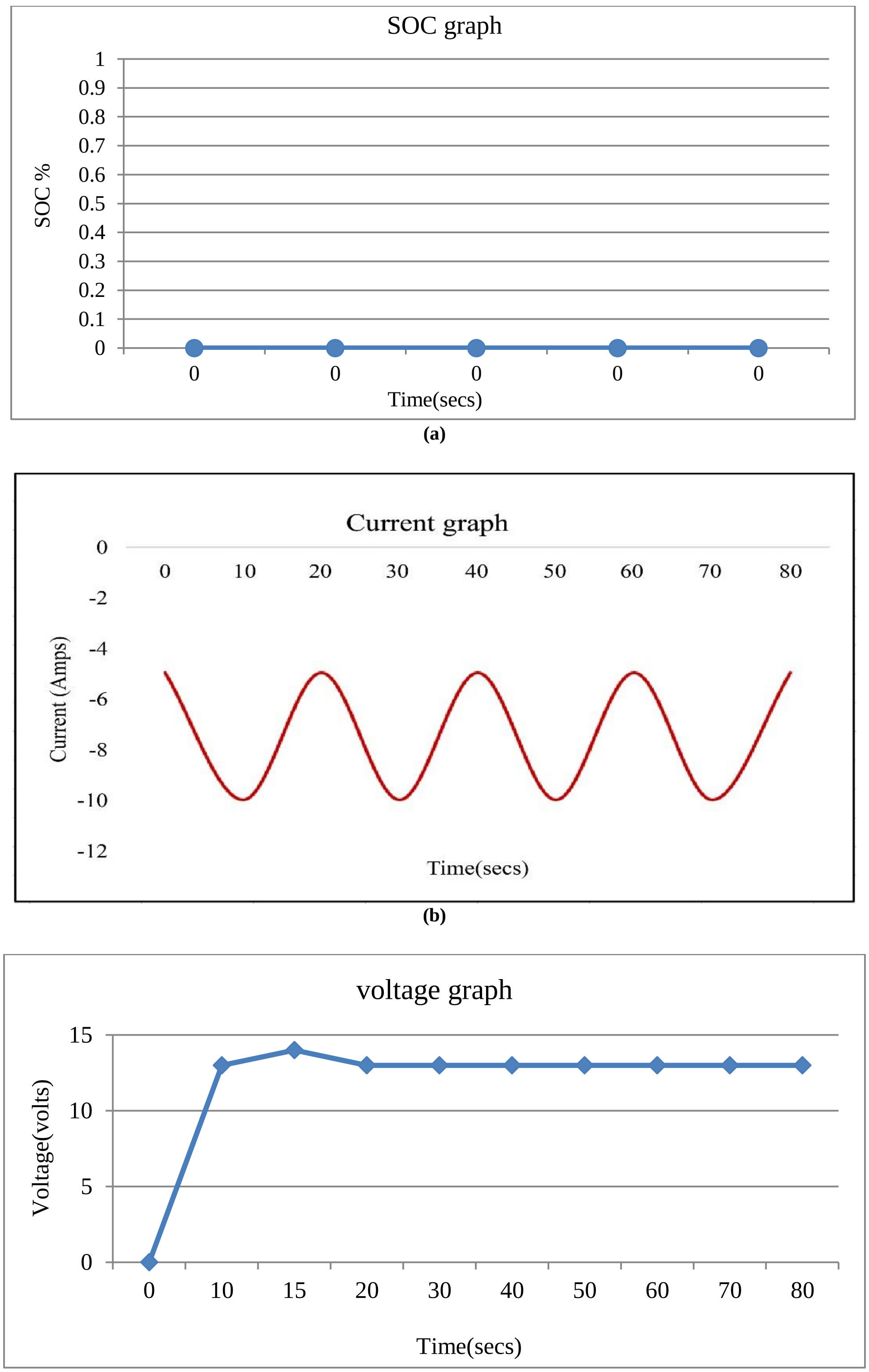
Table 1 outlines the fuzzy rules applied to the membership functions Δi, ΔSOC, and Δu. In these rules, the notations N, ZE, and P denote Negative, Zero, and Positive, respectively, while S and B stand for Small and Big. For example, NB indicates Negative Big. These fuzzy rules are implemented in the Fuzzy Logic Controller (FLC), which regulates the MOSFETs within the constant current charging circuit. The rule viewer representation for membership functions is as shown in Figure 7.

4. Results and Discussion

4.1. Case Study of FCMCU with EV and Multiple Loads

A case study was conducted where the FCMCU with FLC, as in Figure 9, was connected to multiple loads, namely a lamp, a fan, and an EV. The Li-ion battery 12V, 6 Ah, was simulated for test purposes in MATLAB R2021a. The lamp showed green when the voltage across it was less than 12V and turned blue when it had 12V across it. The fan load, namely a resistor, was also connected to the FCMCU.

The SOC, current and voltage graphs were monitored and plotted as in Figure 8(a), (b) and (c). The SOC increase is shown from 50% to 50.3% and the corresponding current (A) and voltage (V) are plotted. The observed increase in SOC from 50% to 50.3% reflects the initial segment of the full charging process, which spans from 50% to 100%. This initial increment, as shown in the graph, serves as a representative indication of the system's charging behavior and the responsiveness of the proposed FCMCU with fuzzy logic control. While the 0.3% increase may appear small, it validates the model's operation and efficiency during the early stage of charging, which is crucial for assessing fast-charging performance over the entire SOC range.



(a)

(b)

(c)

Fig. 8 Simulation results for the fuzzy logic circuit with EV and multiple loads

4.2. Hardware Implementation and Results

4.2.1. FCMCU with Conventional Controller

The solar panel 12V and the hand generator are connected as sources and connected to the boost converter circuit, which in turn is connected to the constant current charging circuit. The solar panel 12V and the hand generator are connected to the battery, giving a 12V output. The transistor BD139 is an NPN transistor that maintains the current preset in the current regulator. Besides, being a medium power NPN transistor with a collector current of 1.5A, it is used to control loads that take less than 1.5A. The readings are taken with current 190mA,250mA, 300mA and 250mA. Also, it has a lower saturation voltage, i., base emitter voltage of 5V..The transistor LM317 works as a variable positive voltage regulator. The ratings of LM317 are 1.35V to 37V and 0A to 1.5A. The linear voltage regulator LM317 regulates the voltage at 6.4V. The TIP 3055 is a silicon NPN transistor in a TO-247 package used as an amplifier. The two TIP 3055 get the trigger pulse from BD139. Three diodes, 1N5408, are connected so as to provide unidirectional current. 1N5408 is a power rectifier diode with a maximum forward current of 3A. Two wire-wound resistors, 1Ω, 5watts, are connected to dissipate the heat produced. A wire wound resistor is an electrical passive element that restricts the current.

Two capacitors, 1000 μF, are used for storing the electrical Energy. Lithium-ion battery 3.7V,4000mA is charged from 3.01V to 3.6V by keeping different preset current values in the current regulator, as shown in Figure 10. The readings are taken for different current preset values, and a graph is plotted.

The constant current circuit maintains the current at one value, namely 190mA,250mA, 300mA, and 250mA, with the input voltage value being 6.4V. Li-ion battery 3.7V, 4000mAh is charged from 3.01V by keeping different preset current values in the current regulator as shown in the Figure 10. The readings are taken for different current preset values, and a graph is plotted. The graphs are plotted with constant current values in Figure 12. The battery voltage readings are taken for current being constant at 190mA, 250mA, 300mA and 350mA. The battery voltage graph, Figure 12, is plotted with voltage readings on the y-axis and time on the x-axis. The current graph, Figure 12, is plotted with current on the y-axis and time on the x-axis. It can be seen that the battery voltage increases with time and then reaches a saturation state. As the current increases, the time taken for the voltage to reach maximum battery voltage decreases. Table 2 shows the hardware circuit components for the FCMCU with a conventional controller.

Table 2. Hardware circuit components for FCMCU with conventional controller

Components	Specification	No. of Pieces
Battery	12V	1
A transistor that regulates voltage at 12V	LM7812	1
A transistor that regulates voltage at 5V	LM7805	1
A transistor that provides a trigger pulse to LM317 and TIP 2055, and is used as a current regulator	BD139	1
A transistor can be used as a voltage regulator	LM317	1
The transistor is used as an amplifier	TIP3055	2
Power rectifier Diode to provide unidirectional flow of current	1N5408	3
Wire-wound Resistor	1Ω, 5watts	2
capacitor	1000μF	1
EV (Lithium-ion) battery	3.7V,4000mA	1

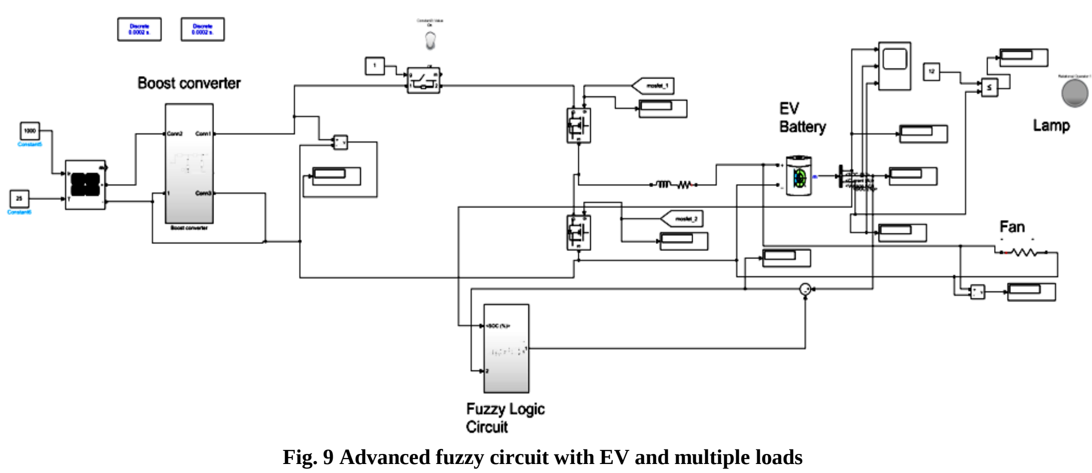


Fig. 9 Advanced fuzzy circuit with EV and multiple loads

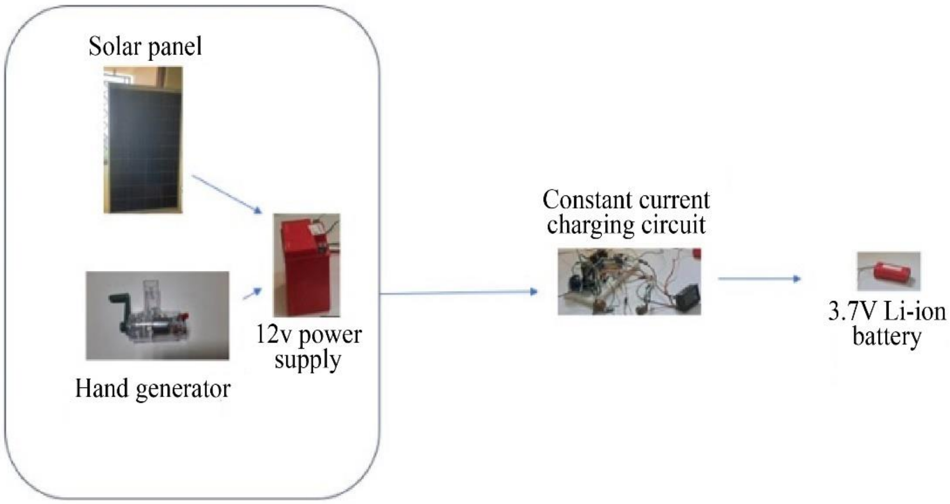


Fig. 10 FCMCU with conventional controller

When the current values are 190mA,250mA,300mA and 350mA, the time taken to reach maximum battery voltage is 1.05 hours, 59.5 min,43 min and 33.2 min, respectively. Figure 12 shows the current and voltage graphs with a conventional controller. Figure 12(a) represents the current constant at 350mA and the voltage graph, which raises the voltage from 3.1V to 3.6V in 33.2. Figure 12(b) represents the graph with a constant current of 300mA and the voltage graph, which rises from 3.1V to 3.6V in 43 mins. The Figure 12(c) represents the current constant at 250mA and the voltage graph, which shows the corresponding change of voltage from 3.1V to 3.6V in 59.5 mins. Figure 12(d) represents the current graph constant at 190mA and the voltage graph with a rise in voltage from 3.1V to 3.6V in 1.05 hours.

4.2.2. FCMCU with Fuzzy Logic

The solar panel and hand generator are sources that are connected to a boost converter, which, in turn, is connected to a constant current charging circuit. The constant current charging circuit serves as input to the fuzzy circuit. The microcontroller ATMEGA328P is programmed with Arduino software, which incorporates code to generate the PWM signal, which triggers the MOSFET1 and MOSFET2 as in Figure 11. The code incorporates the fuzzy rules and membership functions as shown in Table 1.

Table 1 explains the fuzzy rules with membership functions used in the Fuzzy logic controller. The ΔI (change in current) and ΔSOC (change in State of Charge) are the input membership functions, and Δu is the duty ratio, which is the output membership function, applied to the MOSFETs, which varies the battery voltage. This optimizes the charge time for different values of constant currents. Table 3 shows the hardware circuit components for FCMCU with Fuzzy logic. The IC LM7805 serves as input to the FCMCU with a fuzzy circuit. The 3-digit display initially displays 000. The battery 3.7V is connected for charging, and the switch 1 is pressed continuously for a few seconds, and then the second switch is pressed to fix a constant current. When switch 1 is pressed, the red LED glows. The microcontroller ATMEGA328P is programmed with Arduino software, which incorporates code to generate the PWM signal and to measure voltage. The reading of battery voltage in volts is noted along with the time taken, in minutes. The voltage and time are taken for different values of current -190mA,250mA,300mA and 350mA and the graphs are plotted in Figure 13.

Table 3. Hardware circuit components for FCMCU with fuzzy logic

Components	Specification	No of pieces
Battery	12V	1
A transistor that regulates voltage at 5V	LM7805	1
EV (Lithium-ion) battery	3.7V,4000mA	1
Operation Amplifier	MCP602	1
Transistor	BC337	1
Blink LED	-	1
Switch	-	2
Micro controller	ATMEGA328P	1
Arduino board	-	1

The results are plotted with time in minutes along the x-axis and battery voltage along the y-axis for the battery voltage graph as in Figure 13. The current graph, as in Figure 13, is plotted with time in minutes along the x-axis and current along the y-axis. In the voltage graph, as in Figure 13, it can be seen that the battery voltage increases with time and then reaches a saturation state. As the current increases, the time taken for the voltage to reach maximum battery voltage decreases. The times noted were 15.2 min,12.02 min,10.1 min,7.19 min to reach maximum battery voltage for 190mA, 250mA, 300mA and 350mA current values, respectively. The current graph shows the constant current plotted along the y-axis.

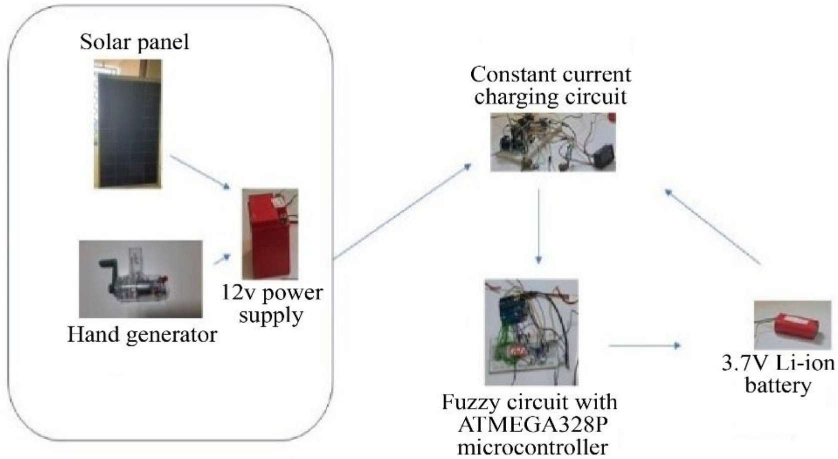
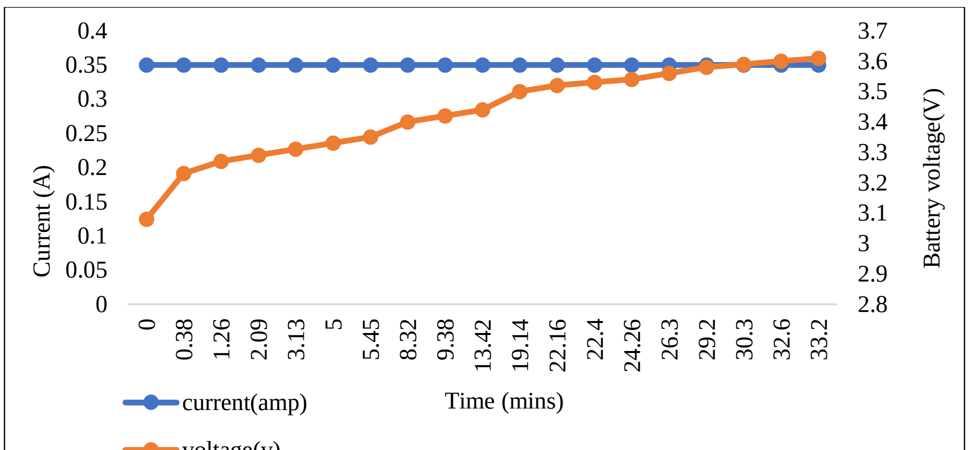
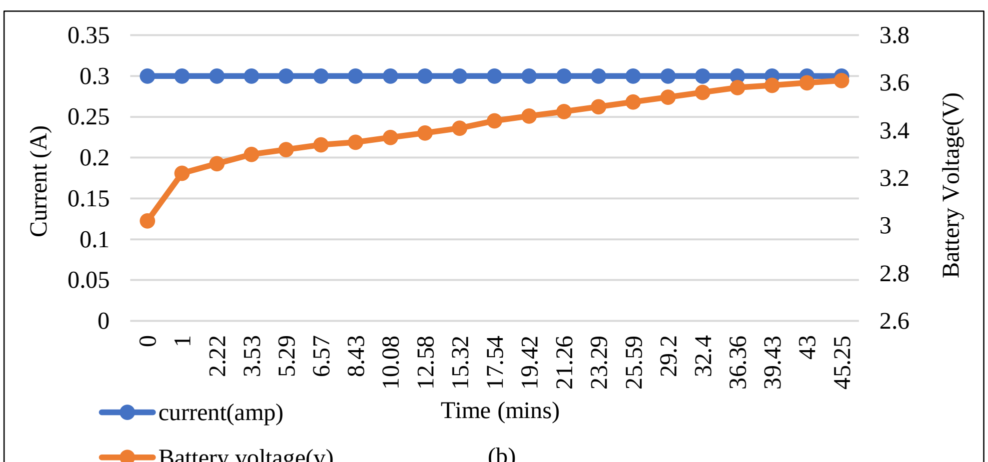


Fig. 11 FCMCU with fuzzy logic

Figure 13 shows the current and voltage graphs with fuzzy logic implemented. Figure 13(a) shows the current graph at 350mA and the voltage graph, with a raise in voltage from 3.1V to 3.6V in 7.19 min. Figure 10(b) shows the current graph at 300mA and the voltage rise from 3.1V to 3.6V in 10.1 mins. Figure 10(c) shows the current graph at 250mA and the voltage raise from 3.1V to 3.6V in 12.02 mins. Figure 10(d) shows the current graph at 190mA and the corresponding voltage rise from 3.1V to 3.6V in 15.2 minutes for a constant current of 350mA.



(a)



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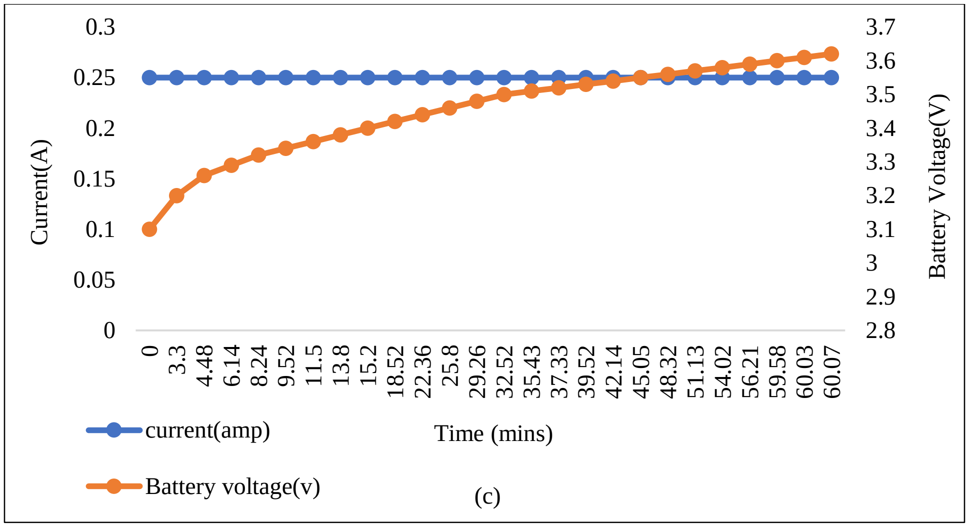


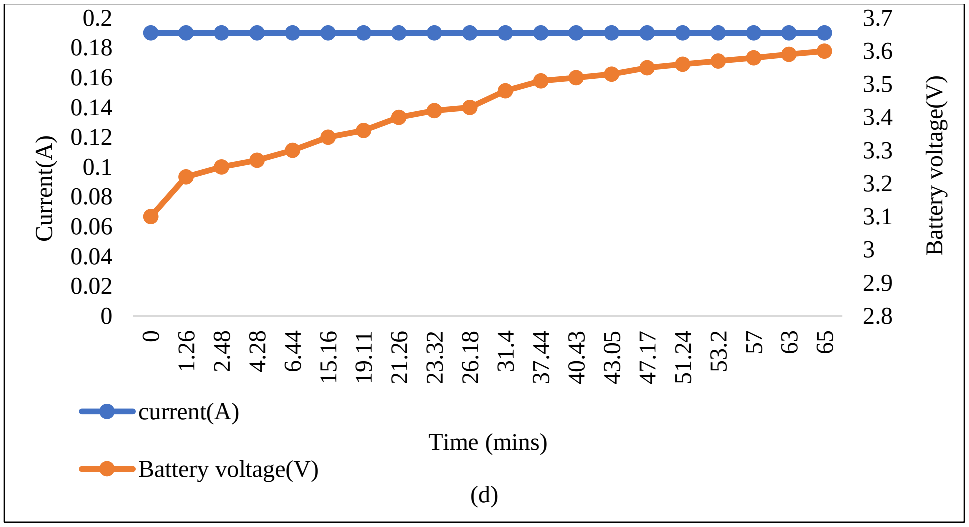
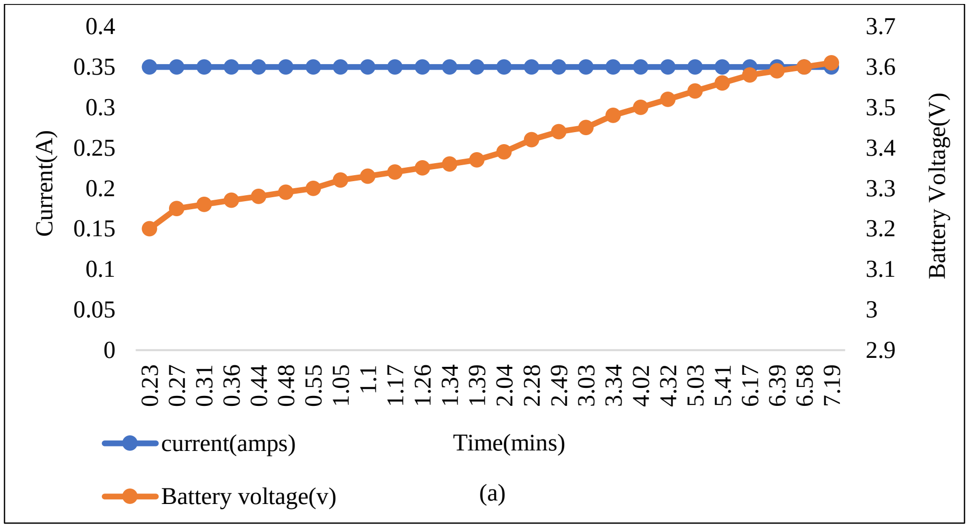


Fig. 12 FCMCU with conventional controller. The current graphs and voltage graphs: (a) For input source volt=6.4V and current=350mA, (b) For input source volt=6.3V and current=300mA, (c) For input source volt=6.4V and current=250mA, and (d) For input source volt=6.4V and current=190mA.



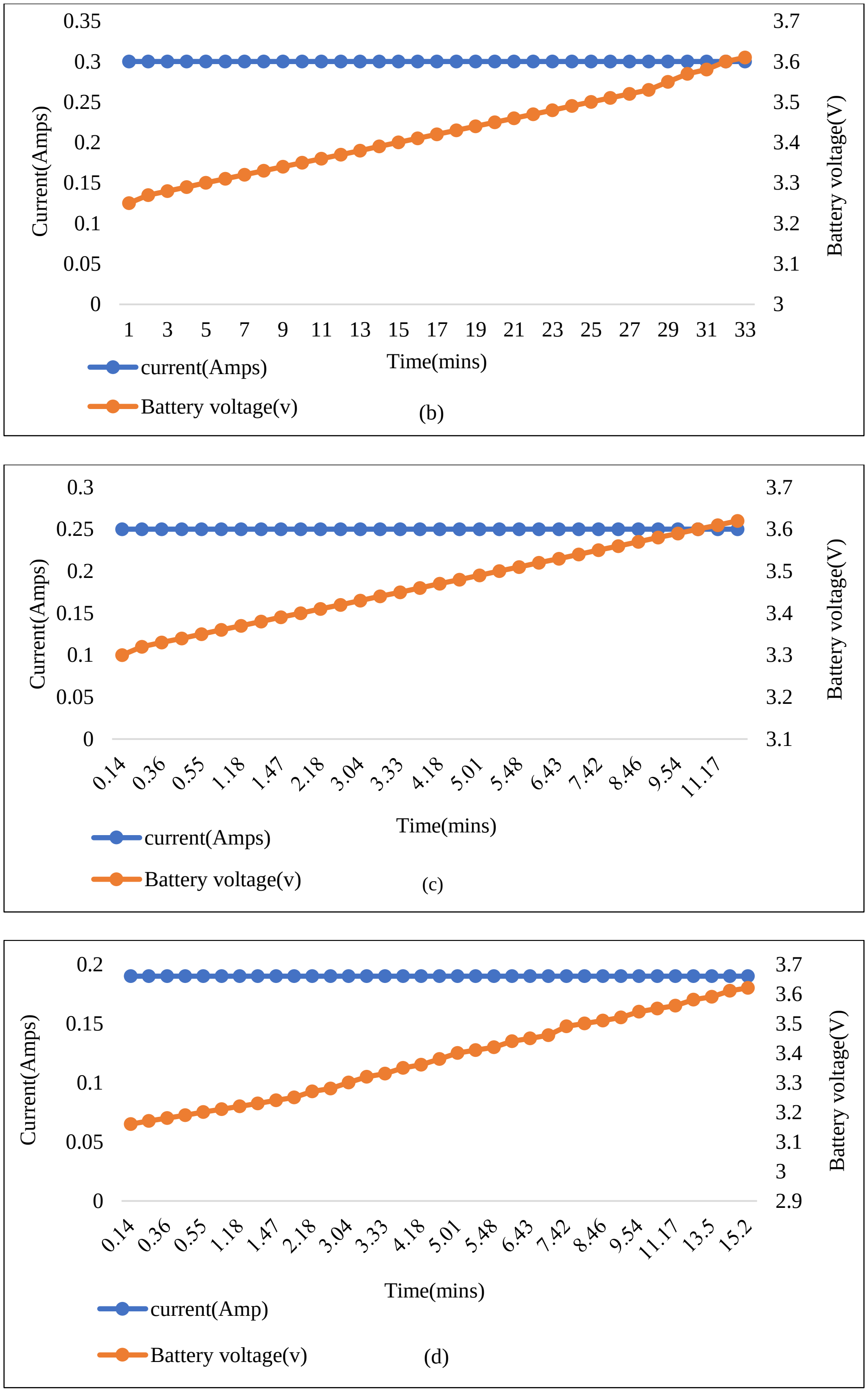


Fig. 13 FCMCU with fuzzy logic. The voltage and current graphs: (a) For input volt=5V and current=350 mA, (b) For input volt=5V, current =300mA, (c) For input source volts=5V and current=250mA, and (d) For input source volts=5V and current=190mA.

Figure 12 shows the current and voltage graphs for FCMCU with a conventional controller. Figure 12(a) shows that the voltage graph shows the curve from 3V to 3.6V in 33 minutes at a constant current of 350mA. Figure 13(a) represents the voltage curve from 3.1V to 3.6V in 7 mins for constant current 350 mA for FCMCU with Fuzzy logic. The experiment is done for a prototype model with a 3.7V 4000mAh battery. Unlike a standard electric two-wheeler battery that operates at 48V, the prototype utilizes a 3.7V battery to simplify testing and validation. The fuzzy logic control circuit is implemented using the ATMEGA328P microcontroller, programmed through Arduino software. In this setup, reaching 3.6V is treated as nearly a full charge for the prototype cell, effectively demonstrating the goal of optimizing charging time for electric two-wheeler applications.

The Proportional–Integral–Derivative PID), fuzzy and Reinforced Learning were compared in [24] for higher efficiency, reduced charging speed and longer life-span. The results proved that fuzzy provided balanced, robust handling, adaptive and linear control, with reasonable complexity in implementation and good charging performance.

The fuzzy with constant current charging method proved the best in [25] when compared to the CCCV method. The results revealed that CC-fuzzy charging is faster than the CCCV method by 25% and 12.5% in buck and boost modes, respectively. These improvements in control, adaptability, and charging speed directly contribute to the superior charge time reduction of 7 minutes, as achieved in the present study. The [26] presents an ultra-rapid charging charger that significantly reduces charging time. By applying a charge rate ranging from 2C to 3.6C, the time required to charge the battery from 5% to 80% State of Charge (SOC) is brought down to approximately 15 minutes.

In comparison, the proposed work utilizes a Fuzzy Logic Controller (FLC) in combination with a constant current charging circuit, integrated in a Fuzzy-Controlled Movable Charging Unit (FCMCU). This approach successfully reduces the charging time to just 7 minutes, demonstrating a substantial improvement over existing ultra-rapid chargers. The proposed method achieves faster charging with lower system complexity.

4.2.3. Comparison of FCMCU

The time taken by FCMCU with a conventional controller and with fuzzy logic is compared and plotted as in Figure 14. The results reveal that fuzzy logic is an efficient tool that optimizes the time when compared to the FCMCU with a conventional controller.

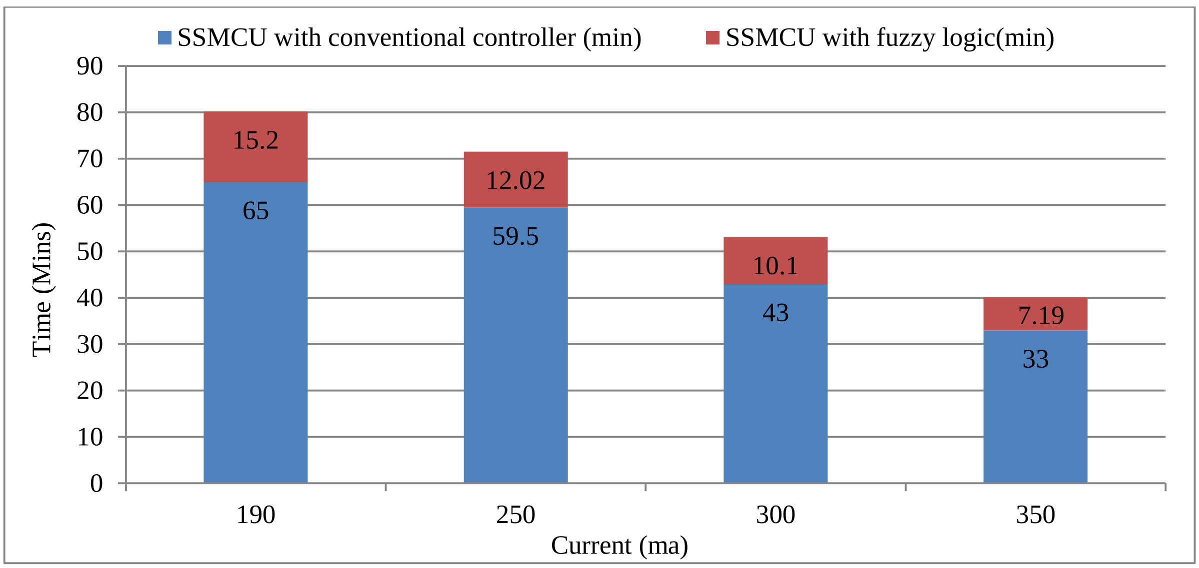


Fig. 14 Comparison of FCMCU

The essence of the paper is as follows, in a nutshell, below:

- The design strategy of the FCMCU is explained with the constant current charging circuit and the fuzzy logic circuit.
- The simulation study is performed in MATLAB R2021a and FCMCU, and EV, along with multiple loads, are discussed.
- The experimental setup of FCMCU with a conventional controller is explained, and the results are discussed.
- The experimental setup of FCMCU with fuzzy logic circuit is explained, and the results are discussed.
- The results of FCMCU with fuzzy logic and a conventional controller are compared.
- The project satisfies United Nations Sustainable Development Goals (UN SDG) 7 and 13 as it provides a clean and healthy environment.

5. Conclusion

The upcoming EV necessitates the growth of the MCU compared with FCS, due to factors like high installation cost and lack of space. Thus, an FCMCU is designed to charge an EV (2-wheeler only), which would serve as an extra income for roadside vendors, particularly in developing and underdeveloped countries. In this paper, the FCMCU prototype was set up experimentally, and the charge time of a 3.7V, 4000mAh battery was studied. The fuzzy logic was proven to be a good optimization tool, which reduced the time from 33 minutes to 7 minutes when employed in the FCMCU circuit. The simulation of FCMCU with EV and multiple loads is also studied. The project satisfies the UN SDG goals 7 and 13, which are a step towards a healthy environment. The current limitation of the mobile charging unit is that it is specifically designed for charging electric two-wheelers. Future development could focus on extending its functionality to support electric four-wheelers using the FCMCU. Additionally, integrating the FCMCU with the grid power supply is a promising direction for further enhancement. The system could also be upgraded to accommodate multiple charging points, allowing simultaneous charging of several electric vehicles.

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