2 Chapter 1: Introduction.

In this modern era, batteries are commonly employed as power sources for various devices including laptops, smartphones, lighting fixtures, and vehicles. These devices utilize rechargeable batteries, promoting cost-effectiveness and environmental friendliness. Our main objective is to design a battery charging system.

For the above mentioned purpose we are going to design a flyback converter using fuzzy control. The major components that are used in this study includes flyback converter, fuzzy logic controller, battery(64V, 8Ah).

3 Chapter 2: Modelling Of Charging System.

3.1 Objectives

- Design a flyback converter to charge a 64V, 8Ah battery using a 280V DC input.
- Simulate the flyback converter circuit and analyze the simulation results.
- Implement the fuzzy logic controller on a microcontroller in simulation.
- Test the flyback converter with the fuzzy logic controller.

3.2 Schematic block diagram

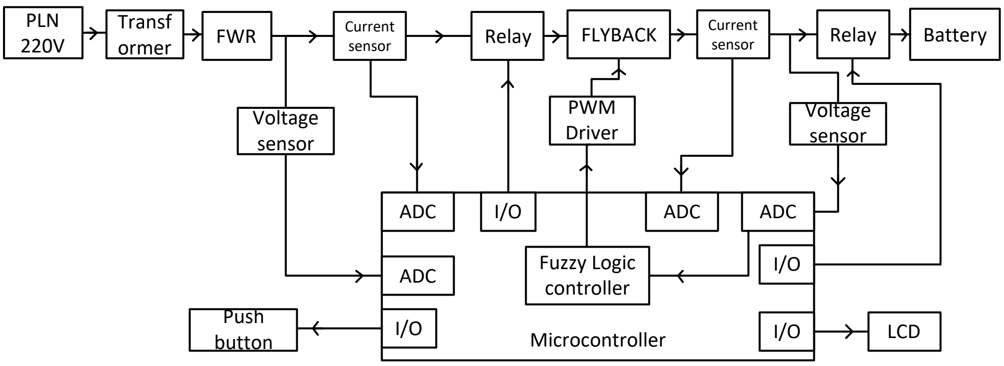

Figure 1: Block Diagram of charging system.

3.3 Theory.

3.3.1 Flyback Converter Theory:

- Operation:

  The flyback converter is a type of switching power supply that uses a transformer to transfer energy between the input and output circuits while providing isolation. During the on-time of the switching device (transistor), energy is stored in the transformer's magnetic field. When the switching device turns off, the stored energy is transferred to the output side through the diode, hereby charging the battery[1]. By varying the duty cycle of the switching device, the output voltage can be controlled.

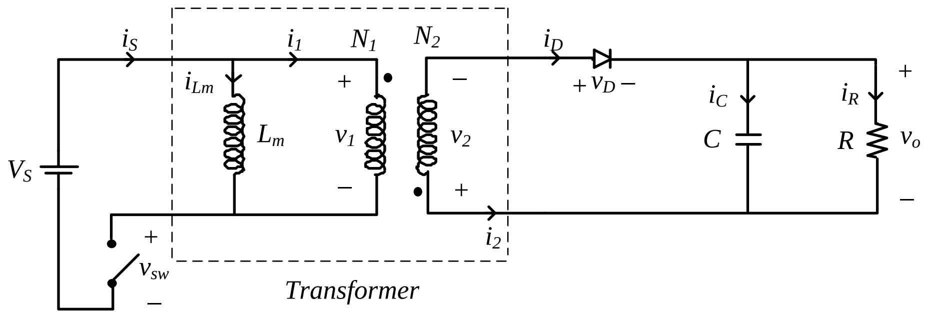

Figure 2: Equivalent circuit of the flyback converter.

- Buck Mode:

  For the desired application here, the converter is operating in buck mode, meaning the output voltage is lower than the input voltage. This can be achieved by adjusting the turns ratio of the transformer: the primary winding will have more turns than the secondary winding.

3.3.2 Fuzzy Logic Control :

- Concept:

  Fuzzy logic is a control method based on fuzzy sets and fuzzy rules rather than precise values. It can handle uncertainty and nonlinearity, making it suitable for systems with complex dynamics like battery charging.

- Benefits of Fuzzy Logic Control:

  The fuzzy logic controller can compensate for variations in the input voltage and battery characteristics to maintain a stable output voltage. It can achieve better performance compared to conventional linear control methods in this non-linear system[3].

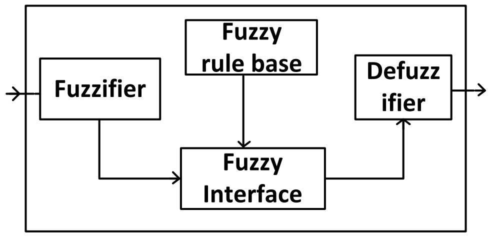

Figure 3: Block Diagram for Fuzzy Logic.

As shown in the above block diagram,there are steps to decide output fuzzy logic control.

- Fuzzification: Deciding fuzzy sets to decide the input variable and the output with changing crisp sets to fuzzy language.
- Rule Base: Selection of make decisions. Basic fuzzy rules using IF-THEN rule-based system. IF is the causes and THEN is the result. Fuzzy rules also have AND, OR connectors which will later be used for the decision process.
- Inference: Inference is decision maker from the rule base that has been compiled. This implementation process is the reason using the min-max method operation. At this stage, the decision is still in the language of fuzzy logic.
- Defuzzification : Defuzzification is the process of converting fuzzy output values from fuzzy sets to the firm or crisp values.The composition of the rules that will be used is the centroid method. This method will take the center point or midpoint as a crisp solution.

This fuzzy logic control is used to control the output voltage of the converter which becomes the charging voltage to the 12 V 80 Ah battery by the output voltage being made constant 76.8V.Fuzzy output regulates the work of duty cycle value set of the PWM driver.PWM will adjust the switching mosfet with the pulse width depending on the value from duty. In make the membership function there is a calculation for determining the membership function and its fuzzification[4].

3.4 Design of components

3.4.1 Design of Battery Capacity

we use the battery with battery capacity 64V 8Ah. Battery parameter used to calculate charging voltage and charging current.

- Parameter current charging: Using the capacity battery in this research is 64V 8Ah. The current charging can calculate as below.
  Icharging(Io) = 10percent of Ah rating = 0.1 x 8 = 0.8 A.

- Parameter voltage charging: In charging the battery, the charging voltage should be set at a value of 2.3 V-2.4 V per 2V cell ,battery 64 V consist of 32 cells of 2V.
  Vcharging(vo) = 32 x 2.4 = 76.8v(practical).

3.4.2 Design of Voltage Sensor and current sensor

The voltage sensor is used to sense the input voltage and output voltage in the converter, the input voltage and the output voltage used to monitor and control the input voltage for reprocessed into fuzzy control. Here we use two current sensors for the input current of converter and the output current used to monitor the current charging.

3.4.3 Design of Flyback Converter

$$V_o = (\frac{D}{1-D})\frac{N_2}{N_1}V_s \tag{1}$$

$$I_{Lm} = \frac{V_s D}{(1-D)^2 R}(\frac{N_2}{N_1})^2 \tag{2}$$

$$L_m(min) = \frac{Vs(1-D)^2 R}{2f}(\frac{N_2}{N_1})^2 \tag{3}$$

$$C = \frac{I_o D}{f \Delta V_o} \tag{4}$$

Here equation 1is to obtain the output voltage value, equation 2 is to obtain the induction current value, equation 3 is to obtain magnetizing inductance (Lm) minimum value, equation 4 is to obtain the capacitor value.

3.5 Theoritical calculations:

3.5.1 circuit parameters:

- Calculation of Transformation ratio:
  Input Voltage (Vs) = 280 V ; switching frequency (f) = 100 kHz; Output Current (Iout) = 0.8 A; Output Voltage (Vo) = 64 v; Max Duty ratio (Dmax) = 0.5 .

$$V_o = (\frac{D}{1-D})\frac{N_2}{N_1}V_s$$

$$64 = (\frac{0.5}{1-0.5}).\frac{N_2}{N_1}.280$$

$$\frac{N_2}{N_1} = (\frac{64}{280}) = 0.228$$

- Calculation of Magnetising inductance(Lm):
  R= Vo / Io = 64 / 0.8 = 80 ohms. value of R is 80 ohms.

$$L_m(min) = \frac{Vs(1-D)^2R}{2f}(\frac{N_2}{N_1})^2$$

$$L_m(min) = \frac{280(1-0.5)^2 80}{2000000}(\frac{64}{280})^2 = 1.463mH$$

- Calculation of Output capacitance (C): Assume Ripple voltage to be 0.1 percent of Vo i.e 0.001 x 64 = 0.064 V

$$C = \frac{I_o D}{f \Delta V_o}$$

$$C = \frac{0.8}{0.064} * \frac{0.5}{100000} = 62.5\mu F$$

3.5.2 Fuzzy calculations:

a)Error (t) = reference - voltage
Error 1 = 64 - 57.38 = 6.62
Error 2 = 64 - 61.59 = 2.41
Error 3 = 64 - 63.7= 0.7
Error 4 = 64 -65.54 = -1.54
Error 5 = 64 -64.6 = -0.6
b) Delta error = error(t)- Error (t-1)
Delta error 1 = 6.62-0 = 6.62
Delta error 2 = 2.41-6.62= -4.21
Delta error 3 = -0.7-(-4.21)= 3.51
Delta error 4 = -1.54-3.51=- 5.05
Delta error 5 = -0.6-(-5.05)= 4.45
Membership function error
Error [6.62]

$$ePS = \frac{x-a}{b-a} = 0.324$$

$$ePM = \frac{c-x}{c-b} = 0.676$$

Error [2.41]

$$eZ = \frac{x-a}{b-a} = 0.482$$

$$ePS = \frac{c-x}{c-b} = 0.518$$

Error [0.7]

$$eNS = \frac{x-a}{b-a} = 0.14$$

$$eZ = \frac{c-x}{c-b} = 0.84$$

Error [-1.54]

$$eNS = \frac{x-a}{b-a} = 0.692$$

$$eZ = \frac{c-x}{c-b} = 0.308$$

Error [-0.6]

$$eNS = \frac{x-a}{b-a} = 0.88$$

$$eZ = \frac{c-x}{c-b} = 0.12$$

Membership function Delta error

Delta error [6.62]

$$dZ = \frac{x-a}{b-a} = 0.662$$

$$dPS = \frac{c-x}{c-b} = 0.338$$

Delta error [-4.21]

$$dNS = \frac{x-a}{b-a} = 0.579$$

$$dZ = \frac{c-x}{c-b} = 0.421$$

Delta error [3.51]

$$dZ = \frac{x-a}{b-a} = 0.351$$

$$dPS = \frac{c-x}{c-b} = 0.649$$

Delta error [-5.05]

$$dNS = \frac{x-a}{b-a} = 0.495$$

$$dZ = \frac{c-x}{c-b} = 0.505$$

Delta error [4.45]

$$dZ = \frac{x-a}{b-a} = 0.445$$

$$dPS = \frac{c-x}{c-b} = 0.555$$

$$Crisp\,output = \frac{(0.482X0.33) + (0.421X0.5) + (0.518X0.5) + (0.421X0.85)}{(0.482 + 0.421 + 0.518 + 0.421)} = 0.53$$

The output fuzzy determine duty cycle 0.53, that makes input voltage to load is 64V.

3.6 Simulation and Results:

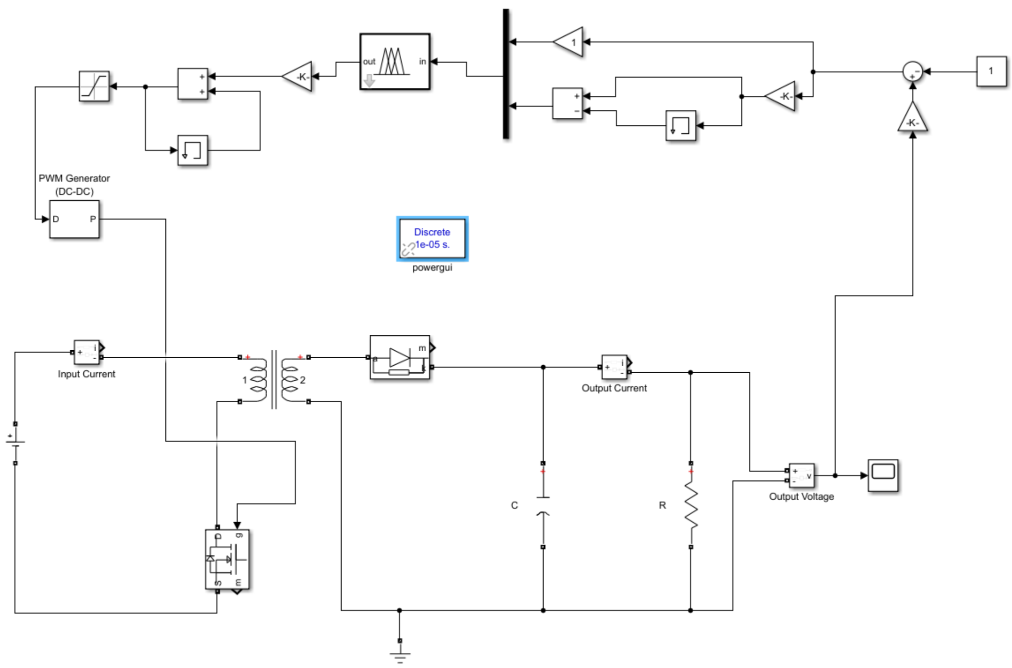

Figure 4: Simulation of Battery Charging System.

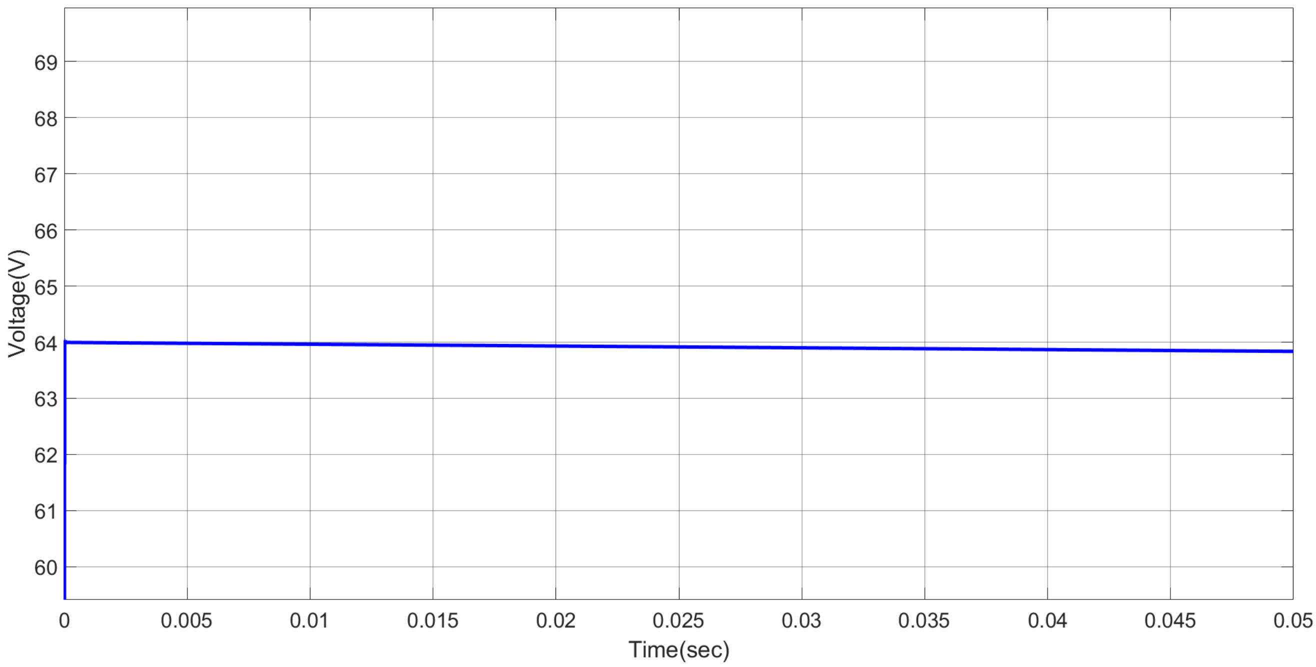

Figure 5: output voltage with out fuzzy logic controller.

3.7 Conclusion and future scope

- Implementation in different battery types and capacities: Investigating the applicability of the design to charge batteries with different sizes.
- Advanced features: Incorporating additional functionalities like battery health monitoring, temperature regulation, and charge scheduling.

3.8 References

[1]P. M. Barbosa and I. Barbi, "A single-switch flyback-current-fed DC-DC converter," in IEEE Transactions on Power Electronics, vol. 13, no. 3, pp. 466-475, May 1998, doi: 10.1109/63.668108.
[2] Hart, Daniel W. 2010. "Power Electronics",(America : The McGrow- Hill Companies,2011),216.
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[4] M. A. Goodrich, W. C. Stirling and R. L. Frost, "Model predictive satisficing fuzzy logic control," in IEEE Transactions on Fuzzy Systems, vol. 7, no. 3, pp. 319-332, June 1999, doi: 10.1109/91.771087.