

Fuzzy Logic based Switched Reluctance Motor for EV

Mohammed Mateen¹, S. Saravanan¹, D. Gireesh Kumar¹, K. Vijaya Bhaskar Reddy¹,
K. Mahesh¹, P. Chandrababu¹

¹Department of EEE, B V Raju Institute of Technology, Narsapur, Telangana, India
Email: mohammedmateen234@gmail.com

Abstract

Fuzzy logic control (FLC) can be used to mitigate the current ripple of electric vehicle (EV) switching reluctance motors. The main goal of this paper is to maintain a motor current value that fluctuates as little as possible while using SRM control with FLC. Depending on the speed of the motor, the PI controller is used to produce the reference current signals. For the controller's responsiveness in fault scenarios, the nonlinear model of the 10/8 SRM with symmetrical converter and C-code controller is applied during the simulation. FLC outperforms more traditional systems like hysteresis current control, according to studies of SRM current control under various fault scenarios.

Keywords. Fuzzy Logic Control, Electric Vehicle, Switched Reluctance motor

1. INTRODUCTION

A streamlined representation of the set of rules served as a model for the creation of computer systems based on fuzzy logic controllers. The most important components of a physical system may be observed through testing or modelling. A few of the technical fields where FLCs are used are dynamic modelling and signal processing [1,2]. Power electronics have employed FLC to control high-performance drives, manage power converters, and locate and identify electrical machine faults [3]. They are able to perform their duties despite the commotion. This technology has been used in hybrid electric cars, aviation starter/generators, washers and dryers, and vehicles over the past 20 years. The remarkable torque-to-weight ratio, straightforward structure, high reliability, and inexpensive price of SRMs are a few factors that contribute to this [1]. Only a few of the topologies supported by SRM are 6/4, 8/6, and 10/8. A nonlinear relationship between the magnetic characteristics of the SRM, phase current, and rotor position serves as the foundation for the controller model. Because the magnetic field is dynamic, it is challenging to develop a mathematical model of it [4]. In controller design and evaluation analysis, linear models have been used to streamline the procedure [5]. The present research focuses on the fuzzy controller of SRM. In order to determine

Proceedings of First International Conference on Smart Systems and Green Energy Technologies (ICSGET 2022)

how well the fuzzy controller (FLC) enforces an ideal current profile, controls speeds around a nominal operating point by mapping incremental changes to the reference current (output), and minimises speed errors, it must be compared to a conventional control system as a method of evaluation (and speed changes). The effectiveness of the suggested control method is shown using simulated data [6]–[7]. Unlike traditional AC and DC electric motors, SRMs offer the design with a machine that lacks a steady state, exhibits high localised saturation, and necessitates a novel power-electronic converter [8]. The SRM is the most cost-effective electrical machine to manufacture [9]. When designing an SRM, it is possible to minimize the thermal load by carefully selecting the various sources of loss [10]. Grid Interconnection of PV system Using Symmetric and Asymmetric MLI Topology and SHE Controlled CHB 7-Level Inverter with Unequal DC Sources using MPSO Algorithm [11]–[12].

2. FLC BASED SPEED CONTROLLER

This FLC relies heavily on the programming language's If-else statement and does not involve any kind of mathematical model. As a result, not only is it easier to execute a very complicated solution, but it is also simpler to analyze the offered solution. The diagram below demonstrates FLC's internal structure. It mainly contains 3 parts i.e., fuzzification, rule- based system and defuzzification.

2.1. Fuzzification

Simplistic definitions to an ever-expanding database: It is possible to map the membership intensity of a subcategory to a specific value, such as (x) (x). In order to flush a toilet, there are a number of steps. Experiments with the variables to see what happens. Computers change the range of each input variable and then transfer the new range into the matching discourse universe. Input data is transformed into language variables that may be used as fluorescence sets labels.

2.2. Knowledge Base

Fuzzy MFs as input and output variables are based on definitions and control rules that govern when, how, and why to utilize them. A database and a set of language rules are part of the framework. The database serves as a resource for language control and pointless data processing. The basic rule structure uses a collection of language rules to establish control goals and controls for domain experts.

2.3. Defuzzification

Defuzzification is the preferred strategy for numerical values that are influenced by the language in which they are expressed. This inquiry used the centre method. Uses a mapping scale to convert input value ranges into sets of output variable names. A fluctuating control operation may be distinguished from one that is non-

fluffy using this method.

The error signal is computed as,

$$e(t) = x_i(t) - x_f(t) \quad (1)$$

Calculation of error change is as follows:

$$E(s) = X_i(s) - X_f(s) \quad (2)$$

The length of the service cycle might either shorten or lengthen as a dependent variable. Table-1 shows the controller's 49 rules. Figures 1 and 2 of the input and output demonstrate seven separate membership functions.

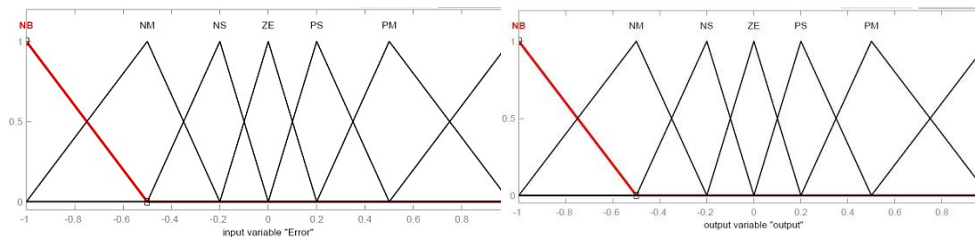


Fig. 1. Input error (Fuzzy set)

Fig. 2. Output delta PWM (Fuzzy set)

3. MODELLING OF ELECTRIC VEHICLE

Creating a new class of electric vehicles from the ground up. An electric vehicle's dynamics can be predicted using its total tractive force. The 'Tracy effort' refers to the total amount of work necessary to move a vehicle.

1. Rolling resistance force, $F_{rr} = \mu_{rr} \times m \times g$ (3)

Where, μ_{rr} is signifies the rolling resistance, m is the weight of vehicle & g is gravity.

2. Aerodynamic drag, $F_{ad} = \frac{1}{2} \times \rho \times A \times C_d \times V^2$ (4)

Where, ρ = air density, A = front area, V = velocity & C_d = drag coefficient

3. Hill climbing force, $F_{hc} = m \times g \times \sin(\psi)$ (5)

Where, ψ is slope inclination

4. Linear acceleration force, $F_{la} = m \times a$ (6)

5. Pointed acceleration power, $F_{\omega a} = I \times G_{ratio}^2 \times a / (\eta g \times r^2)$ (7)

Where r is radius of tire, I is motor inertia, G_{ratio} is transmission system gear ratio, and ηg is efficiency of gear. The switching reluctance motor specifications in Table 1 and their dynamics characteristics in Table 2 are provided to represent electric cars. The 48V/200Ah lithium-ion battery pack is available.

Proceedings of First International Conference on Smart Systems and Green Energy Technologies (ICSGET 2022)

Table-1 Motor Specifications

Sl. No	Vehicle model parameter	Values
1	Payload	830 kg
2	Gross wt-m	965 kg
3	Width(w) and Height mm	132.4 × 151cm
4	Frontal Area-A	1.53 m ²
5	Coefficient (μ_{rr})	0.005
6	drag coefficient (Cd)	0.6
7	Transmission coefficient (η_g)	0.95
8	Gear ratio	16
9	Gravity acceleration	9.81 m/s ²

Table-2 Dynamic Constraints of SRM

Sl. No	SRM parameter	Values
1	Model (generic)	10/8
2	Stator resistance	0.05 Ω
3	Stator inductance (L)	970 H
4	Friction (Nm-s)	0.005 Nm-s
5	Inertia (kg-m ²)	0.0082 kg-m ²
6	Unaligned (L)	0.00067 H
7	Aligned L	0.0235 H
8	Saturated L	0.00015 H
9	Maximum current	400 A
10	Max. flux linkage	0.486 Wb

4. SIMULATION RESULTS

Figure 2 shows an SRM-powered electric vehicle with fuzzy controller modelled in Simulink Standard State. There is an SRM drive and a battery included in this schematic. The controller has two control loops: one for current and the other for speed. The controller uses the difference between the reference speed and the actual speed to create a reference current. Consistent current is maintained in the designated phase by the current controller.

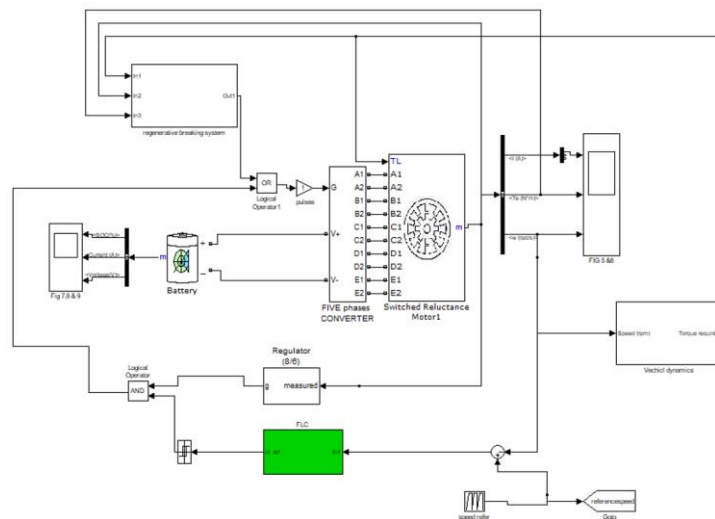


Fig. 2. Simulink model of SRM based electric vehicle with a fuzzy controller

5. FAULT INVESTIGATION

Electric drive systems must be reliable, and simulation, modelling, and fault analysis are essential tools in this process. It's because the SRM drive's components can fail in practice. Because of this, the electric car driven by SRM is examined in various fault scenarios in this research. Several elements are taken into consideration, such as:

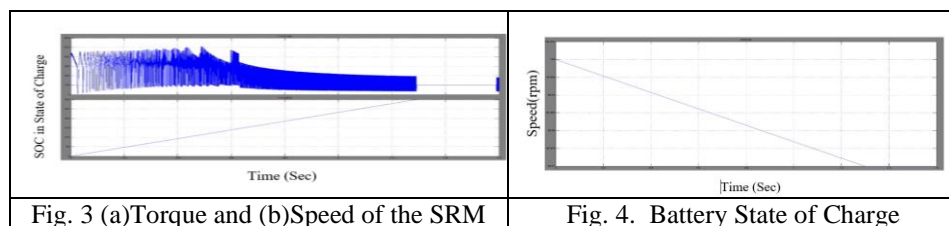
5.1. *Inaccessible stage circumstances*

In open circuit, the phase is separated, and the HRC fuse blows to isolate the faulty component, so that condition is taken into consideration.

The current situation may be summed up as follows:

- | | |
|---|-----------------------------|
| a) short circuit fault of converter switch, | b) Single Phase OC fault |
| c) Two phase Open circuit fault | d) Single phase SC fault |
| e) Two phase SC fault | e) Line to line short fault |

The figure 3 and 4 represents the torque, speed characteristics with respect to time under the consideration with Converter switch short circuit fault conditions.



5.2. *Impact of up and down climbing*

Regenerative braking effects may be seen during down-climbing experiments. An investigation of the methodology used to calculate torque ripple Subtract the greatest and lowest output torque numbers from each other to calculate torque ripple. [10]. To find the solution, formulas are used as,

$$\% T_{avg} = (T_{max} - T_{min}) / T_{max} \quad (8)$$

where, T_{max} = Maximum torque, T_{min} = Minimum torque, T_{avg} = Average torque.

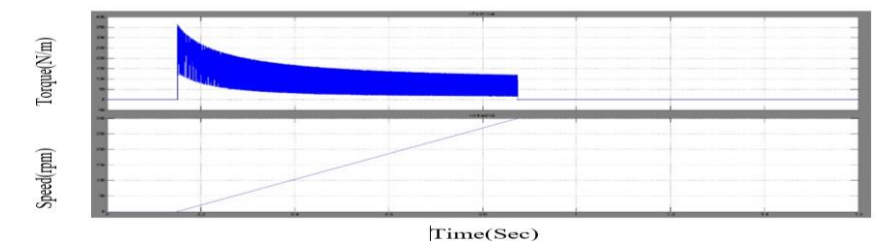


Fig. 5. (a) Current (b) Torque and (c) Speed of the SRM

The figure 5 shows that Current, Torque and Speed of the SRM with respect to time under the Up climbing at a slope of $\Theta = 20^\circ$

6. CONCLUSION

For use with the SRM drive, this research involves building a speed controller based on FLC. The FLC is suitable for a stable and simple-to-tune controller and controlling of SRM non-linear systems for EV applications in systems with a high degree of nonlinearity. Researchers are looking into FLC controller and have found it to be very helpful for a variety of problems. Both transient and steady-state control can be accomplished with the suggested fuzzy logic controller very well. This control strategy is the most suitable one for real-time use in EV applications because of its simplicity, robustness, and adaptability.

REFERENCES

- [1] K. S. Narendra, K. Parthasarathy, "Identification and control of dynamical system using neural networks", IEEE Trans on Neural Networks, vol.1 March 1990, pp.4-27.
- [2] F. Fillipetti, G. Franceschimin, L. Tassion, "Neural Network aided on line diagnostics of induction motor rotor faults", IEEE Trans on Industrial Application. Vol 3 June 1995, pp 852-889.
- [3] D. S. Reay. T.C Green and B.W. Williams, "Neural Network used for torque ripple minimization for SRM", EPE, Briton, Sep 1993, pp 1-5.
- [4] P. Vijayraghavan and R. Krishnan, "Front-End Buck Converter Topology for SRM drives-Design & Control", Proceedings of International IEEE Conference, 3 Feb 2003, pp. 3013-3018.
- [5] C. Muniraj and R. Jeyabharth, "High performance direct torque control for switched Reluctance Motor", Proceedings of International conference on ICSCI-2007, vol.2 Hyderabad, 13 Jan 2007, pp. 13-16.
- [6] C. Muniraj and S. Chandrasekar, "Fuzzy logic control and Faults Analysis of 6/4 Switched Reluctance Motor", Proceedings of international conference on modeling and simulation, CIT India, 27-29, Aug 2007, pp.909-915.

Proceedings of First International Conference on Smart Systems and
Green Energy Technologies (ICSGET 2022)

- [7] Krishnan, R., “Switched Reluctance Motor Drives: Modelling, Simulation, Analysis, Design, and Applications”, CRC Press, 2001.
- [8] Shyam S. Ramamurthy and Juan Carlos Balda “Sizing a Switched Reluctance Motor for Electric Vehicles” IEEE Transaction on industrial electronics, vol. 37.
- [9] V S Prasadarao K and V Joshi Manohar, "Grid Interconnection of PV system Using Symmetric and Asymmetric MLI Topology "International Journal of Power Electronics and Drive System (IJPEDS) Vol. 9, No. 4, December 2018, pp. 1616~1623.
- [10] Joshi Manohar, V Lakshmi Devi and Adinaryana "SHE Controlled CHB 7-Level Inverter with Unequal DC Sources using MPSO Algorithm" proceedings of IEEE International Conference on System, Computation, Automation and Networking (ICSCA), pp 1-6, 2018.