A Novel Strategy to use Regenerative Power of Hybrid Electrical Vehicle with Regenerative Breaking System using Fuzzy Logic Controller

[1]Chandrakant Yadav, [2]Anurag Singh,

[1][2]Faculty of Engineering & Technology, Veer Bahadur Singh Purvanchal University Jaunpur, U.P. India

[1]yadavchandrakant78@gmail.com[2] anuragsinghucer123@gmail.com,

ORCID ID - https://orcid.org/0009-0001-6083-9794

Abstract— In light of global warming, automobile power systems are becoming more and more dependent on clean, renewable energy sources like battery and fuel cells. This paper looks into the viability of a hybrid electric vehicle, fuel cells, and batteries. both approaches are more significant to the proposed as discussed. A finished Hybrid Electric Vehicle system, which includes the electric. The vehicle's power-train system, control system, and power system are all modeled in a Matlab/Simulink environment. A fuzzy logic-based control system has designed. The development of an energy management strategy (EMS) with the goal of maximizing power of the battery, Regenerative Braking System is charging the battery when it applies. And various types of state-of-charge levels to provide the battery. According to the simulated results of the functional test, which involved idling, accelerating, and cruising at different fuel cell and battery states, the anticipated vehicular power system and the EMS perform rather well. By modelling a particular driving vehicle test in three common circumstances, the power system then demonstrates that it operates effectively and adaptably under the management of the EMS and exhibits superior fuel economy than utilizing a widely-adopted power-following control technique.

.

Index Terms— ***Hybrid Electric Vehicle, fuel cells, fuzzy logic-based Control System, energy management strategy (EMS), Matlab/Simulink environment.***

I. INTRODUCTION

One-quarter of total energy use in the world is accounted for by the transportation industry. the total global fuel consumption, which is anticipated to increase enormously, with an attendant negative environmental effect, such as climate change[1,5]. An investigation demonstrates that electric cars (EVs) would cut daily carbon emissions by 45% and are ecologically beneficial, as demonstrated. an increase in EV charging infrastructure has increased their dependability even further. Different type of motor used to drive the steady-state and dynamics application but induction motor has improved the efficiency, which are essential for modelling an electric vehicle (EV). For electric vehicles to function effectively, continuous study of various electrical and mechanical Induction motor parameters is required [7].

The IM better modelling is required for architecture and control techniques when the primary According to system demand, steady-state and dynamic response are considered[2]. For successful speed control in IM, many strategies have been tried in the past. Drives include closed-loop vector control strategies [6] When 3-∅ stator current's orthogonal components are mapped, this is pertinent to variable frequency drives. delivering an analysis vector This integrates all of the advantages of the IM and operates the device. Faster switching speeds and an acceptable degree of reference speed are features of vector control [4].

To fix problems that existed in earlier versions, namely torque fluctuations. The following are the study's objectives:

- Using fixed speed modes on an EV (40, 60, and 80 km/h)for a variety of loads and driving conditions without a load.
- To develop a powerful indirect vector-controlled IM-based Li-ion DC battery system. a Fuzzy logic-Proportional Integral controller working at specified constant speed settings in an EV model, with its operation being observed at certain speed modes, as was previously described.
- To store the data sets for the input voltage (Vab), stator winding phase current (I), winding torque (T), and results. examine the speed parameters using the many algorithm approach to get the specified speed setting.
- An EV's mileage usually increases while it is in fixed-speed mode. Performance of the FMPI controller has been studied. The existing model provides a dependable method for tackling a variety of driving circumstances.

II. PERMANENT MAGNET SYNCHRONOUS MACHINE

Both the generator and motor modes are supported by the block known as a permanent magnet synchronising device. The motor has moved in two direction positive mode and negative. Positive mode work as motor but negative mode work as generator. it is two (stator & rotor) independently installed as second-order state-space systems [8].

The sinusoidal model states that since the flux produced by the stator's permanent magnets is sinusoidal, the electromotive forces must also be sinusoidal. Three trapezoidal back EMF waves are produced by the permanent magnets' distribution of flux and windings, in accordance with the trapezoidal model [3].

The subsequent equations are implemented by the block. Electrical System using a 3-Ø Sinusoidal Model

The reference frame for the rotor is used to write these equations. For all equation of motor are shown below as rotor reference frame, the stator stands as the reference point.

$$\frac{d}{dt}i_d = \frac{1}{L_d}V_d + \frac{R}{L_d}i_d + \frac{L_q}{L_d}p\omega_m i_q \quad (1)$$

$$\frac{d}{dt}i_q = \frac{1}{L_q}V_q + \frac{R}{L_q}i_q + \frac{L_d}{L_q}p\omega_m i_d - \frac{\lambda p\omega_m}{L_q} \quad (2)$$

$$T_e = 1.5p[\lambda i_q + (L_d - L_q)i_d i_q] \quad (3)$$

Where L_d, L_q are inductances axis.

R is stator winding resistance; i_q, i_d are current Direction; v_q, v_d are voltage Direction; ω_m is Angular velocity; λ is flux amplitude; p is No. of pole pairs; T_e is Electromagnetic torque.

Due to the saliency of the rotor, the L_q and L_d inductances describe the relationship between the phase inductance and the rotor position. Phase c is left open, therefore the inductance between phases a and b, for instance, may be calculated as follows:

$$L_{ab} = L_d+L_q+(L_q - L_d)\cos(2\theta_e+\pi/3) \quad (4)$$

θ_e represents electrical angle.

There is no fluctuation in the phase inductance for a round rotor.

$$L_d = L_q = L_{ab}/2 \quad (5)$$

The dq inductances for a prominent round rotor are provided by:

$$L_d = \max(L_{ab})/2 \quad (6)$$

and $$L_q = \max(L_{ab})/2 \quad (7)$$

III. Fuzzy Logic Controller

This is how fuzzy logic is utilised; we are suggesting it in the paper and providing more information about it below [10]. Fuzzy logic controller most utilize algorithm in various field i.e. optimize the system, it increase the efficiency overall the system.

- Input Scaling or Normalization: the input signal categories in several types i.e. input sets. Inputs set divide into error and change in error. it is classified into scaling factor.
- Fuzzification: Input sets are synthesizing based fuzzy logic rules. it align all the rules statement.
- The sets are specified using error and change in error using fuzzy logic rules and are converted and checked by an inference engine before being used to draw conclusions. The logic gated are satisfy its rules.
- Deffuzzication: input sets (Logic Gates) are combined into a fuzzy logic results during defuzzification, which comes after assessing the inference output. Logic is the cornerstone of inference.
- Denormalization: The fuzzy logic result has converted into the physical value by using scaling factor.

An artificial intelligence approach generally that leads to better performance without necessitating the solving of any mathematical equations is fuzzy logic control.

There is no fuzzyness in the input or output values. Basic Simulation Diagram of FLC is shown in Fig.1.

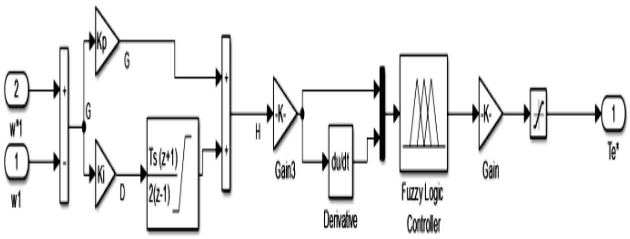

Fig. 1. Basic Simulation Diagram of FLC

Mamdani is being employed in this instance as a logic gates-based controller which received the two type signal error and change of error are sent to FLC. The error is measured by contrasting the inaccurate reference (REF) with the real reference error. The reference current (refi) of the FLC is treated as the controller's output, which is used as a reference current (refi).

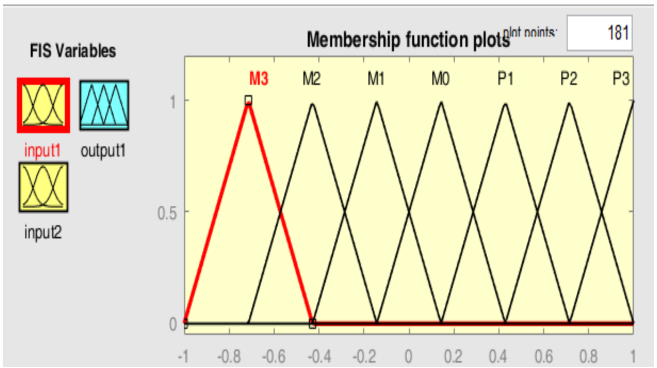

Fig. 2. Membership functions plots (Speed Error)

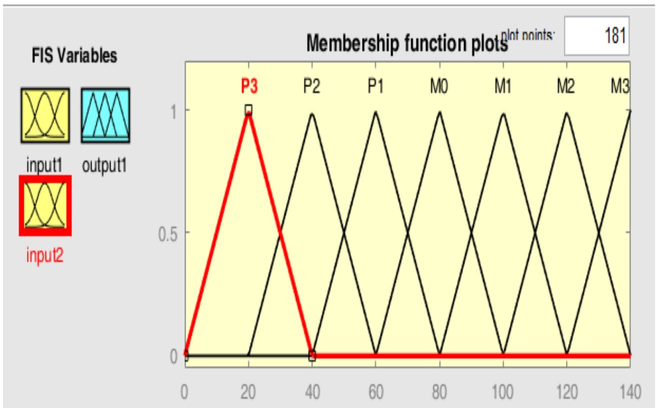

Fig. 3. Membership functions plots (Change in Speed Error)

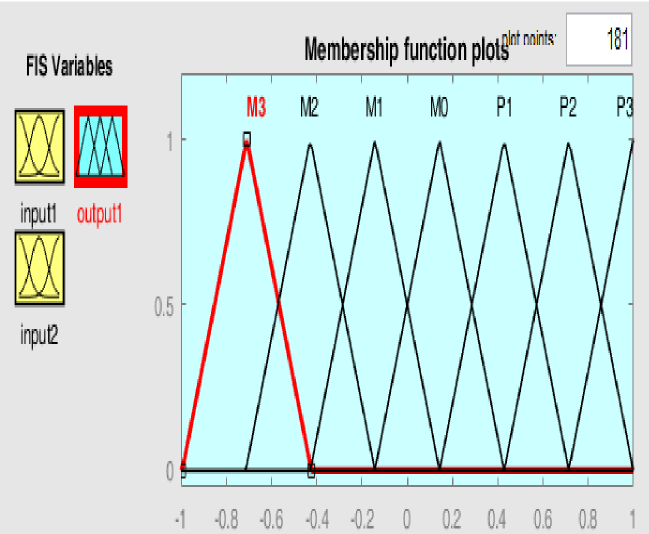

Fig. 4. Membership functions plots (output)

TABLE I. FUZZY LOGIC RULE BASE TABLE

ERROR/ CHANGE IN ERROR	M3	M2	M1	M0	P1	P2	P3
M3	M3	M3	M3	M3	M2	M1	M0
M2	M3	M3	M3	M2	M1	M0	P1
M1	M3	M3	M2	M1	M0	P1	P2
M0	M3	M2	M1	M0	P1	P2	P3
P1	M2	M1	M0	P1	P2	P3	P3
P2	M1	M0	P1	P2	P3	P3	P3

IV. SIMULATION MODEL

Prior to performing actual testing on automobiles, Simulation had been used to predesign the fuzzy RBS and analyse its performance and stability. It is also required to predesign the RBS in a variety of driving cycles in order to get information that would often take an excessive amount of time and effort. utilizing real-world tests. As a result, we created a vehicle model using specifications. using the simulation tool for electric vehicles, as shown in fig. This combined model is simulated using the battery and Motor. The findings of the simulation are contrasted with those of a traditional rule-based RBS that is integrated into electrical Vehicle in order to assess the effectiveness the fuzzy RBS. The shifting curve of battery SOC is depicted in Figure. The SOC curve when there is fuzziness in the RBS is represented by the red line. The prerequisites for the rule-based RBS are shown by the blue line.

As can be observed, the fuzzy RBS saves an additional 2% of the battery's capacity in a single charging cycle. This indicates that the motor produces and recycles more energy.

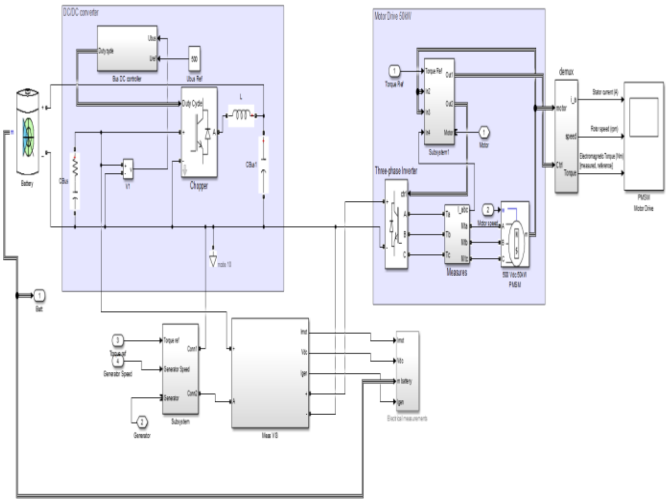

Fig. 5. Simulation model of proposed system

V. RESULT OF THE PROPOSED SYSTEM

The Simulink graph are contrasted using a traditional rule-based RBS assess the performance and efficacy of the fuzzy RBS. Fig.6. depicts the battery SOC's shifting curve. Under fuzzy RBS conditions, the SOC curve is represented by the red line. RBS conditions are represented by the blue line. In one UDDS cycle, it can be shown that the fuzzy RBS saves an additional 2% of the battery's energy.

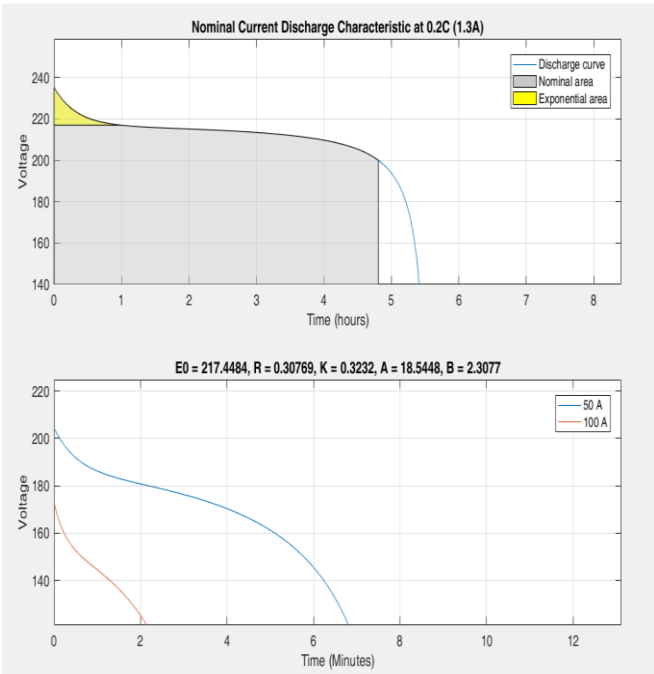

Fig. 6. Charging and Discharging of Battery

The motor produces and recycles more energy as shown in a result.

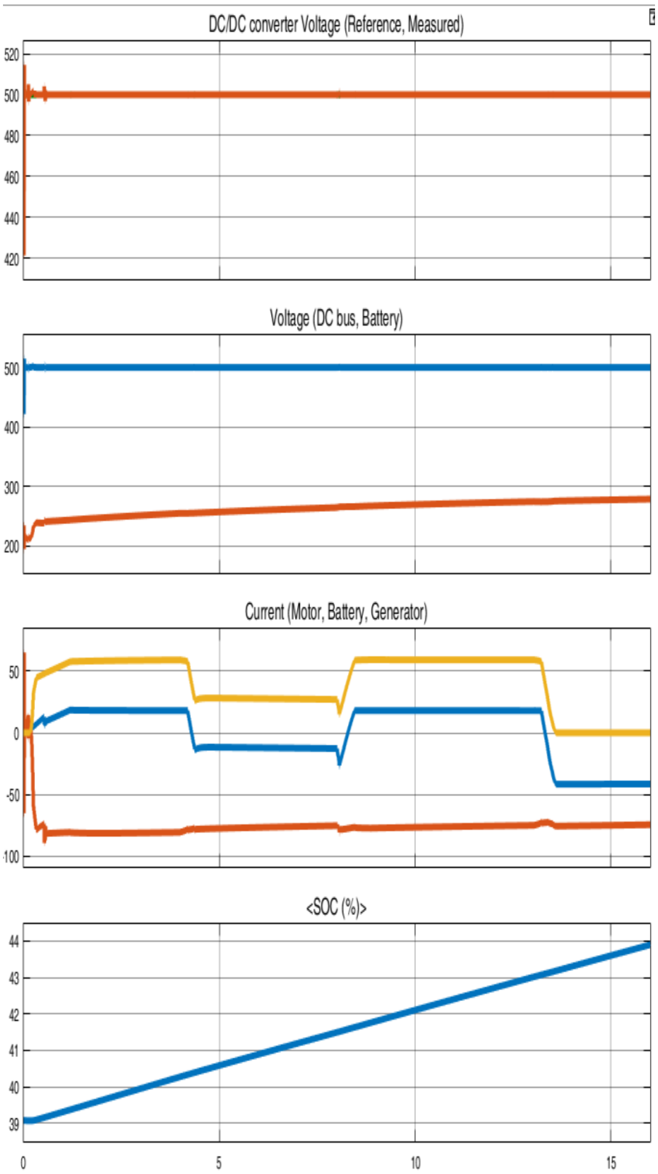

Fig. 7. Simulation Graph of the Result

In the simulation graph four result are showing first show dc-dc voltage second show voltage 3rd show current distribution in motor battery and generator and forth show soc of the battery. DC to DC converter high generate same amount of voltage as required it means reference value and measure value comparatively same. Second graph shows the DC bus has 500 volt and battery generated voltage nearly 250 volt. Third graph shows the total current has required or generated by motor battery and generator, in this graph motor and generator has generated or consume as respected requirement of the vehicle and battery provide the power supply of the motor. The SOC curve for foggy RBS settings is shown by the red line. The prerequisites for the rule-based RBS are shown by the blue line. It can be demonstrated that the fuzzy RBS saves an additional 2% of the battery's energy throughout one UDDS cycle.

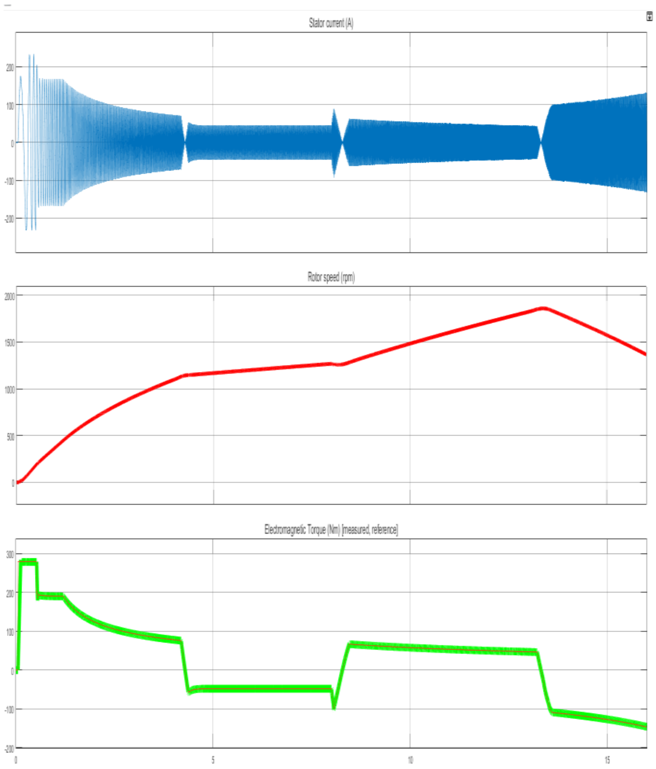

Fig. 8. PMSM Motor Drive Graph (current, speed, torque)

CONCLUSION

Using a model-based approach, this study examines the technical viability of hybrid electric vehicles and develops an energy management plan for them. A physics-based modelling approach is used to simulate a lightweight class system in the Matlab/Simulink environment, which includes the vehicle dynamics system, electrical system, and energy management system. The EMS is constructed based on the FLC strategy using the demand power, battery SOC, and reference power of FC as three input factors and as an output parameter.It has stochastic and intermittent properties, and rationally divide power flow among power sources.

The functional test and driving cycle test simulations are used to validate the model and the EMS. The following is a list of the main conclusions.

The planned electrical system demonstrates in the functional test that it performs effectively in terms of driving the vehicle and controlling power distribution under varied battery conditions. The outcomes support the viability. The modification of various degrees of battery SOC has improved charging efficiency. Additionally, compared to a power following control approach, it has greater fuel efficiency.

The experimental validation is a separate research thread that demands an equal or greater amount of work than the novel research thread that this study's modelling and simulations represent. Future work in this area might concentrate on developing and executing the experiments needed to validate. Fortunately, the incorporation of real physical component models in physical model in this work makes it easier to create experiment setups.

REFERENCES

[1] Angirekula, Bhanu Naga V., and Olorunfemi Ojo. 2014. "A Karnaugh Mapping Technique for the Modeling of Single Phase Multi String Multi Level Inverter." Conference Proceedings - IEEE Applied Power Electronics Conference and Exposition - APEC (1):239–46. doi: 10.1109/APEC.2014.6803316

[2] K, Deepa, Savitha P, and Vinodhini B. 2011. "Multilevel Inverter." 92–97.

[3] Kumar, Sanjiv, and Pramod Agarwal. 2015. "A Novel Eighteen-Level Inverter for an Open-End Winding Induction Motor." India International Conference on Power Electronics, IICPE 2015-May:2–7. doi: 10.1109/IICPE.2014.7145017.

[4] Kumar, Sanjiv, and Pramod Agarwal. 2016. "A Hybrid Nine-Level Inverter Topology for an Open-End Stator Winding Induction Motor." Electric Power Components and Systems 44(16):1801–14. doi: 10.1080/15325008.2016.1198844.

[5] Liao, Yi Hung, and Ching Ming Lai. 2011. "Newly-Constructed Simplified Single-Phase Multistring Multilevel Inverter Topology for Distributed Energy Resources." IEEE Transactions on Power Electronics 26(9):2386–92. doi: 10.1109/TPEL.2011.2157526.

[6] Peng, Fang Z., Wei Qian, and Dong Cao. 2010. "Recent Advances in Multilevel Converter/Inverter Topologies and Applications." 2010 International Power Electronics Conference - ECCE Asia -, IPEC 2010 492–501. doi: 10.1109/IPEC.2010.5544625.

[7] Rajeevan, P. P., K. Sivakumar, K. Gopakumar, Chintan Patel, and Haitham Abu-Rub. 2013. "A Nine-Level Inverter Topology for Medium-Voltage Induction Motor Drive with Open-End Stator Winding." IEEE Transactions on Industrial Electronics 60(9):3627–36. doi: 10.1109/TIE.2012.2207654.

[8] Rajeevan, P. P., K. Sivakumar, Chintan Patel, Rijil Ramchand, and K. Gopakumar. 2011. "A Seven-Level Inverter Topology for Induction Motor Drive Using Two-Level Inverters and Floating Capacitor Fed H-Bridges." IEEE Transactions on Power Electronics 26(6):1733–40. doi: 10.1109/TPEL.2010.2090541.

[9] B. K. Bose, "Scalar decoupled control of induction motor," IEEE Trans. Ind. Appl., Vol. IA-20, no. 1, pp. 216–25, Jan.1984.

[10] B. Robyns, F. Berthereau, J. P. Hautier, and H. Buyse, "A fuzzy-logic-based multimodal field orientation in an indirect FOC of an induction motor," IEEE Trans. Ind. Electron., Vol. 47, no. 2, pp. 380–8, Apr. 2000.

[11] I. Takahashi and T. Noguchi, "A new quick-response and high efficiency control strategy of an induction motor," IEEE Trans. Ind. Applicat., Vol. IA-22, pp. 820–7, Sep./Oct. 1986.

[12] M. Depenbrok, "Direct self-control (DSC) of inverter fed induction machine," IEEE Trans. Power Electron., Vol. 3,pp. 420–9, Oct.1988.

[13] J. W. Finch and D. Giaouris, "Controlled AC electrical drives," IEEE Trans. Ind. Electron., Vol. 55, no. 2, pp. 481–91, 2008.

[14] J. Lettl, "Matrix converter induction motor drive," in IEEE 12th International Power Electronics and Motion Control Conference, Portoroz, Slovenia, 2006, pp. 787–92.

[15] M. Venturini. "A new sine wave in sine wave out, conversion technique which eliminates reactive elements," inProc. POWERCON 7, San Diego, CA, pp. E3_1-E3_15,1980.

[16] D. F. Chen, C. W. Liao, and K. C. Yao, "Direct torque control for a matrix converter based on induction motor drive systems," in 2nd IEEE Conference on Innovative Computing, Information and Control (ICICI), Kumamoto, Japan, Sept. 2007, pp. 101–4.

[17] D. Casadei, G. Serra, and A. Tani, "The use of matrix converters in direct torque control of induction machine,"IEEE Trans. Ind. Electron., Vol. 48, no. 6, pp. 1057–64, Dec.2001.

[18] R. B. Roy, J. Cros, E. Basher, and S. M. B. Taslim, "Fuzzy logic based matrix converter controlled induction motordrive," in IEEE Region 10 Humanitarian Technology Conference, Dhaka, Bangladesh, Dec. 2017, pp. 489–93.

[19] C. Venugopal, "Fuzzy logic based DTC for speed control of matrix converter fed induction motor," in IEEE International

[20] Conference of Power and Energy (PECCon2010), Kuala Lumpur, Malaysia, 2010, pp. 753–8

[21] Alishah, R. S., Hosseini, S. H., Babaei, E. and Sabahi, M. (2016), 'Optimal design of new cascaded switch-ladder multilevel inverter structure', IEEE Transactions on Industrial Electronics 64(3), 2072–2080.

[22] Kangarlu, M. F. and Babaei, E. (2012), 'A generalized cascaded multilevel inverter using series connection of submultilevel inverters', IEEE transactions on power electronics 28(2), 625–636.

[23] Kangarlu, M. F. and Babaei, E. (2013), 'Cross-switched multilevel inverter: an innovative topology', IET power electronics 6(4), 642–651.

[24] Kangarlu, M. F., Babaei, E. and Laali, S. (2012), 'Symmetric multilevel inverter with reduced components based on non-insulated dc voltage sources', IET Power Electronics 5(5), 571–581.

[25] Kangarlu, M. F., Babaei, E. and Sabahi, M. (2013), 'Cascaded cross-switched multilevel inverter in symmetric and asymmetric conditions', IET Power Electronics 6(6), 1041–1050.

[26] Karasani, R. R., Borghate, V. B., Meshram, P. M., Suryawanshi, H. M. and Sabyasachi, S. (2016), 'A three-phase hybrid cascaded modular multilevel inverter for renewable energy environment', IEEE Transactions on Power Electronics 32(2), 1070–1087.

[27] Karasani, R. R. and Suryawanshi, H. (2016), 'A modified switched-diode topology for cascaded multilevel inverters', Journal of Power Electronics 16(5), 1706–1715.

[28] Y. Shekhar and A. U. Ahmad, "A Performance Comparison Study of Hybrid Electric Vehicle Between Type-1 And Interval Type-2.0 FLC," 2023 International Conference on Power, Instrumentation, Energy and Control (PIECON), Aligarh, India, 2023, pp. 1-6, doi: 10.1109/PIECON56912.2023.10085834.