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Energy-Efficient High-Voltage Boosting Techniques for Electric Vehicles Using Multiphase Interleaved Soft-Switching Converters

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Abstract: Because coal and petrol have stricter emission regulations, the automobile industry is seeing an increase in the use of fuel cell electric automobiles or FCEVs. In this architecture, a 1.26 kW artificial network-based predominant feature presenting tracking (MPPT) controllers is suggested as a means of improving these vehicles' performance. Using a DC-to-DC energy conversion unit, this controller is made to maximise the surface transmembrane of a proton exchange membranes fuel cell (PEMFC), supplying electricity for electric cars. The suggested MPPT guarantees effective energy conversion by utilising maximal power point tracker (MPP) and radial basis functions network (RBFN). High switching frequencies and effective DC conversion are necessary for FCEVs to continue operating. In order to accomplish this, the FCEV system integrates a three-phase alternative energy converter (IBC). Alternating voltage is used in semiconductor electrical circuits to provide voltage control. Using a MATLAB/Simulink platform, the end-to-end RBFN of the FCEV system is when juxtaposed with fuzzy logic controllers (FLCs) to assess its efficiency.
Keywords: Fuel cell electric vehicle, high voltage gain IBC, PEMFC, MPPT, RBFN etc.

I. INTRODUCTION

Concerns about the environment and the depletion of fossil fuels have caused the automotive industry to become increasingly interested in electric cars, namely Fuel Cell electric vehicle (FCEVs). Fuel cells and power electronics have quickly advanced, generating attention due to their many benefits, which include excellent performance, longevity, low noise levels, plus the production of new energy. The fuel cells powering this breakthrough were solid oxygen fuel cell (SOFC), molten carbonate fuel cell (MCFC), alkaline substance energy cell (AFC), phosphoric acid fuel cell (PAFC), the fuel cell with proton-exchange membrane (PEMFC). PEMFCs in particular have attracted a lot of interest from the automotive sector because to their quick starting times and effective operation in both cold and warm environments.

- *FUEL CELLS -*
- The automotive industry is becoming increasingly interested in electric vehicles when fossil fuels runs out to environmental concerns gain hold.
- The capacity to produce clean electricity, high dependability, great efficiency, and low sound levels are just a few benefits of fuel cells.
- PEMFCs are highly favoured by the vehicle industry because of their low operating temperatures and rapid startup times.

- *MPPT -*
- Making simple, popular, and user-friendly usage of MPPT P&O algorithms. P&O) and project management methods offer fluctuations in the steady state, that might be a factor in the limited efficacy of mobile systems.
- In order to address this issue, a model utilising logic controllers and neural network techniques is then presented for determining the correctness and efficiency of the MPPT.
- The non-isolated, high-voltage intermittent enhances converter (IBC) lets you select a lower switching magnitudeand increased voltage gain in electric and portable devices, is the foundation of PEMFC MPPT Tracking.

It is based on the radial basic function of the network (RBFN) MPPT control foundation. The goal of criminal activity is to boost the dependability of mobile devices, which is currently quite high.

The car's power inverter supplies the output voltage from the voltage converter for the motor. The engine of the FCEV carries out this duty. The engine states that the cost and dimensions of the cell are extraordinarily low.

II. FUEL CELL APPLICATIONS WITH ELECTRIC CAR CHARGING

Fuel-cell electric vehicles, or FCEVs for short, generate energy not just from a battery but also from a hydrogen-powered fuel cell. The power of the FCEV is determined throughout the car's design process by the size of its electric motor or motors, which take power from both sides if the fuel cell or battery. The bulk of FCEVs rely on batteries for regenerative braking, additional power during moments of low acceleration, and attaching or detaching the fuel cell as needed. However, some FCEVs may be able to charge their batteries via a plug. In contrast to all-electric vehicles, where battery capacity primarily determines power and range, the size of the hydrogen fuel tanks determines how much energy is stored inside the automobile.

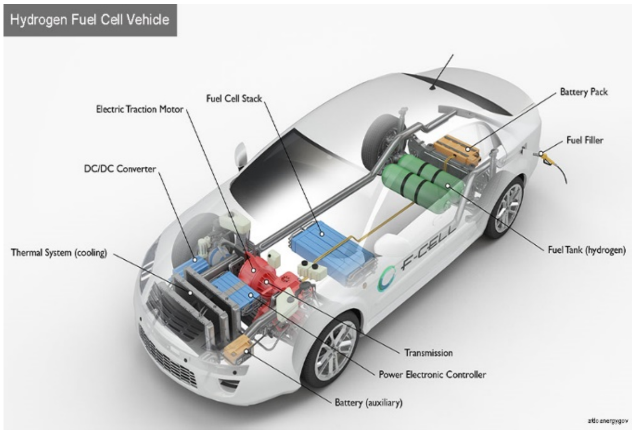


Fig1. Fuel Cell Vehicle

Fuel cell electric vehicles (FCEVs) function similarly to electric cars by using hydrogen stored in tanks to power fuel cells. The environment is protected by FCEVs as they produce no exhaust pollutants when compared to traditional internal combustion engine vehicles. Fueled by pure hydrogen stored in tanks, FCEVs have a range of over 300 miles, which is comparable to that found in traditional automobiles, and can be refuelled in a matter of minutes. They also employ state-of-the-art technologies such as regenerative braking buildings, which boost efficiency by recovering and storing energy consumed during braking. Leading automakers are introducing FCEVs to select regions in an attempt to boost uptake and construct infrastructure, which will enhance energy security and boost the economy.

III. EXISTING SYSTEM

An FCEV's wheelwork structure is shown in Figure 2. Low DC voltage produced by the PEMFC stack is uncontrollable. To control and boost the PEMFC output voltage, one needs a step-up or raise DC to DC converter.

One recommended method for achieving high voltage gain is to use the quadratic boosted converters, that are made up of two boost converters. However, using two boost converters could reduce the system's efficiency. Alternatively, a two-stage flexible conversion featuring DC-DC isolation is typically recommended. But this design is still less dependable and efficient.

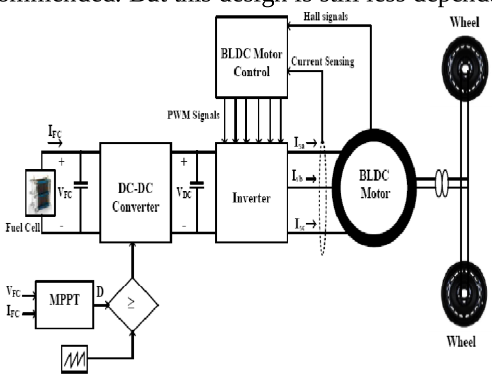


Fig 2. Traditional design of an electric car powered by a BLDC motor supplied by a cell

Disadvantages Of Existing Configuration :

- Unreliability
- Much lower level of output.
- Expensive
- Because of its limited contemporary management capabilities & thermal control difficulties, the upgraded converter is appropriate with greater power packages, while the obsolete boost converter is employed as a power digital link for small-scale use.
- To overcome the benefits of changing voltage that come with dc-dc facts.

IV. PROPOSED CONFIGURATION WORK

Three single-phase intermittent boost converters (IBC) will be used in this project in order to maximise voltage gains, lower switching losses, provide high voltage acquisition, and efficiently transfer power. By using this strategy, fuel cell dependability is increased and sufficient power is provided to operate the suggested FCEV system.

A BLDC motor, a voltage supply inverter (VSI), a three-phase electrical power supply (IBC), and a 1.26 kW PEMFC make up the FCEV system. To ensure effective power transfer, the VSI or PEMFC are connected in the third stage of the IBC.

Fuel cell power supply is optimised by the application of a radial basis function networking (RBFN) based methodology. Power transmission to a BLDC motor via the VSI is facilitated by the I-3-phase IBC, and the VSI conversion is managed by the circuitry of the BLDC motor. The vehicle is propelled by the motor, which is fixed on the wheels.

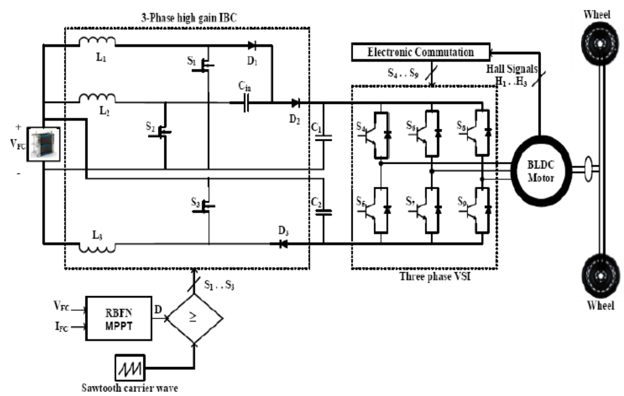


Fig.3. A BLDC motor powers the proposed three-phase, high-voltage increase IBC FCEV system.

Benefits Of The Suggested Configuration

- Production of clean energy,
- Excellent dependability, 3. Exceptional efficacy
- Quiet operation
- Elevated voltage gain.

Applications

- Uses for fuel cells
- Applications of solar electricity.

V. FUEL CELL MODELING

Hydrogen fuel is used in fuel cell engines, which are electrochemical devices that generate energy. The fuel the cell's input are fuel, air, & chemical reactions; its outputs are water and energy. Anode plus cathode, two electrodes, A single fuel cells consists of an electrolyte and a fuel source. Ions from the hydrogen-based fuel are separated by the electrolyte, independent of charge. An electrolyte that has hydrogen and oxygen added to it produces energy at the cell's output. The biological process's scattering fuel cells only produces heat and water.

TABLE 1.1.26kW PEMFC parameter specifications.

Parameter Description	Rating
Maximum power (P_{max})	1.26 kW
Maximum current (I_{max})	52 A
Maximum voltage (V_{max})	24.23 V
Temperature (T)	55°C
Number of cells	42
Nominal air flow rate	2400 lpm

- *Formulation*

An electrochemical apparatus that uses hydrogen fuel to create energy is called a fuel cell. Fuel and air are fed into the fuel cell, where they undergo chemical conversion to produce water and power. The PEMFC's cell voltage is provided as,

$$V_{FC} = E_{Nernst} - V_{act} - V_{ohm} - V_{con} \quad (1)$$

where ENernst, It is also known as the reversible thermodynamic voltage or open-circuit voltage,

$$E_{Nernst} = 1.229 - 8.5\times10^{-4}(T - 298.15) + 4.308\times10^{-5}\,T\left(ln(P_{H2}) + 0.5ln(P_{O2})\right)$$

Voltage of activation The term for Vact is as follows: T is the degree Celsius in the absolute sense (K), Vact is high voltage caused by the combined activation of the anode and cathode, and PO2 or PH2 are the partial pressures of oxygen and hydrogen in surroundings (atm), respectively,

$$V_{act} = -\left[\delta_1 + \delta_2 T + \delta_3 T ln(C_{O2}) + \delta_4 T ln(I_{FC})\right]$$

Where

The following equation is used to compute the dissolved oxygen content, or CO2, at the liquid/gas interface, where i (i = 1, 2, 3, 4) is an empirical factor for each cell,

$$C_{O2} = \frac{P_{O2}}{\left(5.08\times10^{6}\right)\times exp(-498/T)}$$

Ohmic overvoltage Vohm is expressed as

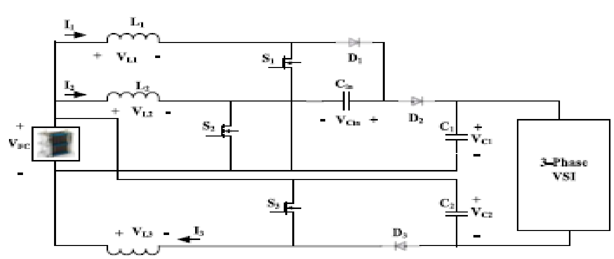
$$V_{ohm} = I_{FC}(R_C + R_M)$$

Using RC is a constant, where RC is the proton the resistance and RM is the electron flow that represents resistance.

VI. HIGH VOLTAGE GAIN, THREE-PHASE IBC

When assessing the IBC voltage evaluation, the following factors are taken into account: Three switches and a total of three (D1, D2, and D3) make up the suggested converter. (S1, S2, and S3). L1, L2, and L3 stand for phase 2, phase 3, and class 1 filters, respectively. The load connection is shown by R, the output power is shown by VO, and the input volume is indicated by VFC.

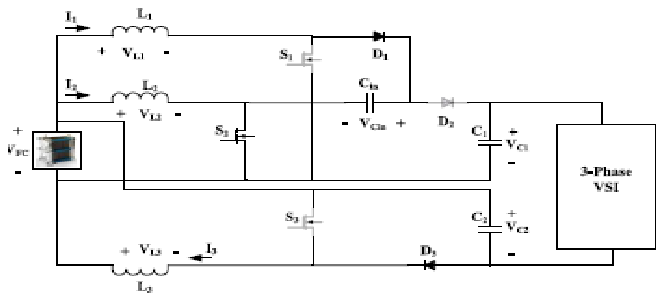
Mode-1 $(t_0 \leq t \leq t_1)$:



(a)

As seen in Fig. 4(a), all three evolves (S1, S2, before S3) are now operational, and all the three diode pairs (D1, D2, and D3) are reversed. The VFC supply to support input is made up of three inductive devices: L1, L2, and L3. As of right now, the three currents are rising in line with the (VFC / L) gradient. Neither the supply nor the load are connected to the input capacitor. There is a slope voltage drop across the load's resistor-powering capacitors that output C1 and C2(VC1 and VC2), (-VO/RC).

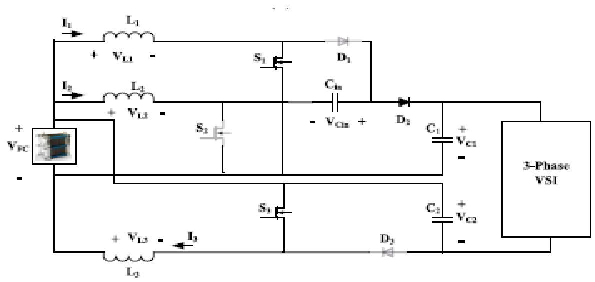
Mode-2 $(t_1 \leq t \leq t_2)$:



(b)

The S2 switch is turned on in this setup, and the S1 and S3 switches are off. As seen in Fig. 4(b), diode D2 has a reverse bias while diodes D1 and D 3 conduct forward current.The inductors L1 while L3 both experience current flow, with the former having a tendency to travel into (VFC-VCin) / L while the other in (VFC-VC2) / L.
On the other hand, inductor L2's current rises with an angle of (VFC / L). capacitors C2 & Cine load the VFC input current, whereas Capacitor C1 powers the loads.

Mode-3 ($t_3 \leq t \leq t_4$):



(c)

Mode-1 and this mode are comparable. S1, S2, and S3 are the three switches that are all ON, while D1, D2, and D3 are the three diodes that are all off.

VII. SIMULATION DESIGN AND ITS OUTPUT

With MATLAB/Simulink, the suggested BLDC motor-driven FCEV design's performance is assessed. The quick temperature variations of the fuel cell have been taken into account in the examination of the FCEV system's adaptability to change: T = 320^K = 0 to 0.3 seconds, T = 310^K = 0.3 seconds to 0.6 minutes, and T = 330^K = 0.6 seconds to 0.9 seconds are the timespans for which these values apply.

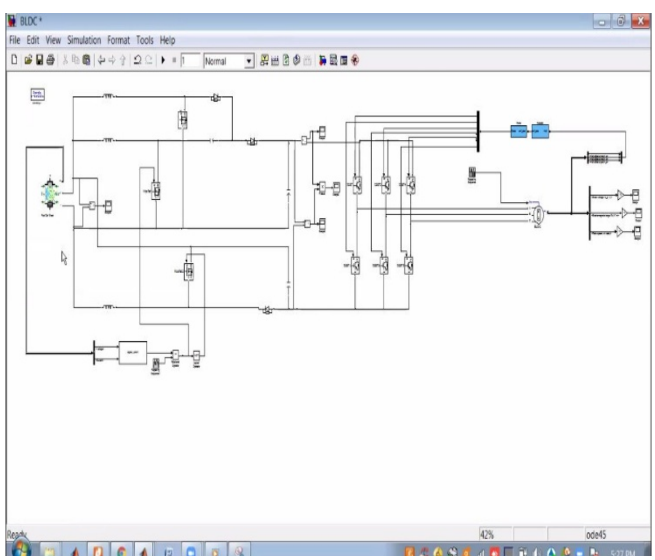


Fig5. Simulation Architecture of proposed system

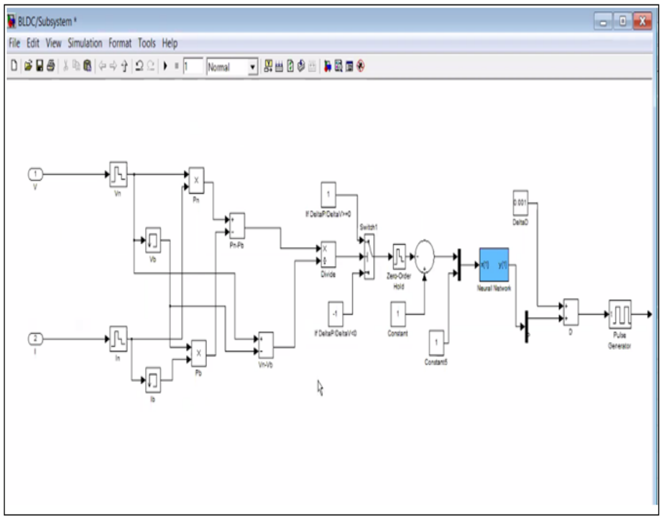


Fig6. Neural network based MPPT Algorithm

T = 302oK for 0–0.3 sec,
T = 310oK for 0.3–0.6 sec, and
T = 330oK for 0.6–0.9 sec are the times during which these temperatures occur.
The fuel cell generates 970W over 0.3Wec to 0.6W, 0.9Wec over 1220W for 0.6 seconds, and 1080W over 0 to 0.3 seconds.
The DC Link connects voltage, power, with current via F FLC based MPPT technology. It produces 1000W, 830W, or 1150W of power at 320oK, 310oK, or 330oK, respectively. Figure 8 uses the suggested RBFN-based MPPT controller to display the power, voltage, additionally power output of the DC connection. This suggested controller delivers 1200W at 330oK and 1050W at 900W.

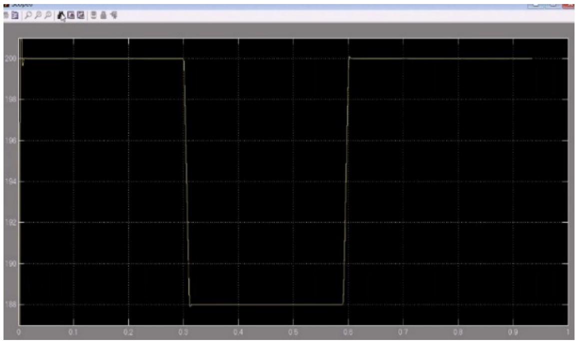
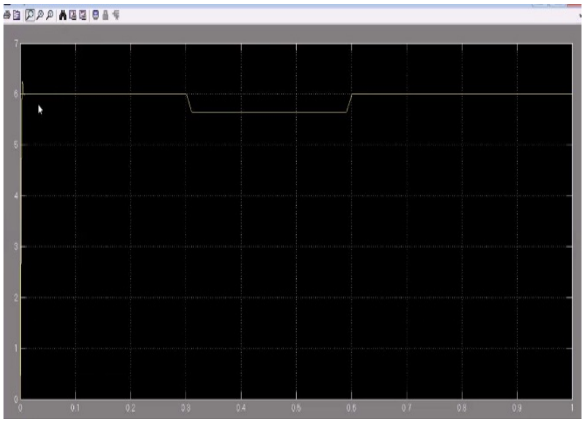


Fig7. Output voltage of Fuel Cell



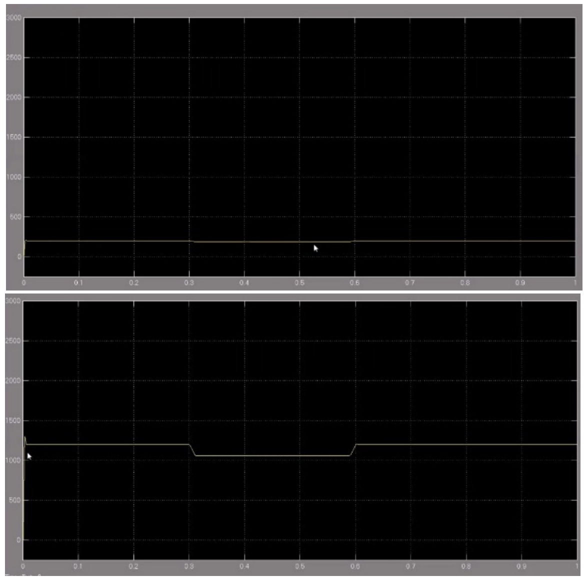


Figure 8. Using RBFN, DC link output power, current, and voltage at various temperatures

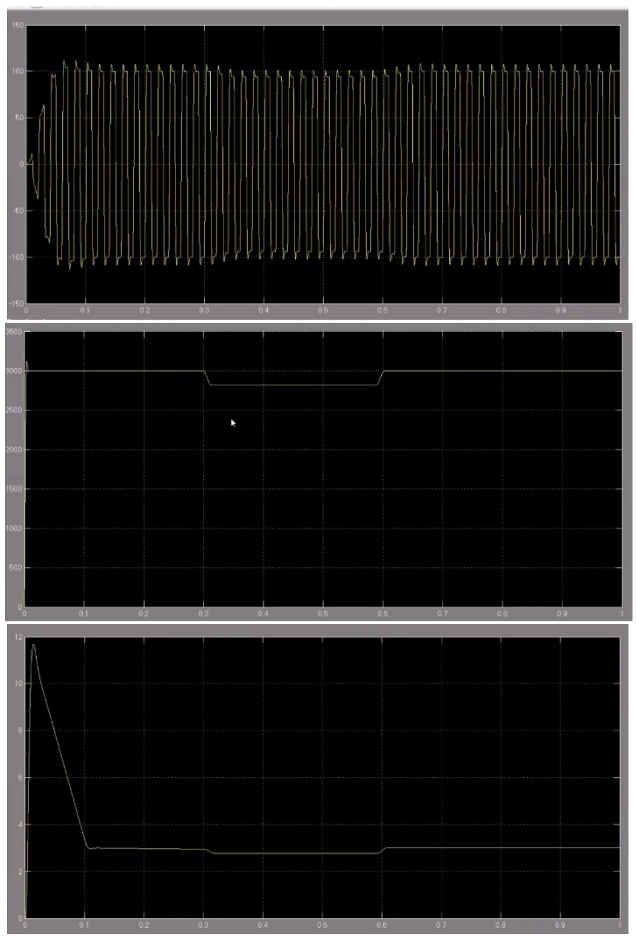


Figure 9: BLDC motor Power , Torque , Speed parameters

The fuel cell displays the BLDC motor's temperature-dependent starting and steady-state capabilities. Figure 8 shows that the suggested controller outperforms the FLC in terms of DC link power. Additionally, a comparison of RBFN and FLC controllers is shown in the table.

Parameter	1.26 kW PEMFC with fuzzy based MPPT			1.26 kW PEMFC with RBFN based MPPT		
Period (sec)	0 to 0.3	0.3 to 0.6	0.6 to 0.9	0 to 0.3	0.3 to 0.6	0.6 to 0.9
Fuel cell temperature (˚K)	320	310	330	320	310	330
DC link current (A)	4.71	4.3	5.1	4.8	4.4	5.21
DC link voltage (V)	212	193	225	220	205	230
DC link power (W)	1000	830	1150	1050	900	1200

Figure 9 shows motor parameters including stator power (ISA), back electrical magnetic field (E), electric torque (TE), or load force (TL) under fuel cell variable temperature settings. The BLDC motor runs in three different speeds: 0 to 0.3 seconds on 3300 rpm, 0.3 through 0.6 minutes at 2400 rpm, then 0.6 through 0.9 seconds on 3700 rpm. This variation in speed has no effect on the torque of the BLDC motor.

VIII. CONCLUSION

This study presents a high-gain DC for direct current (DC) with three phases of power that was specifically designed for fuel cell powered electric cars. (FCEV) software applications. Its main objectives are to reduce fuel cell current-injection implications and voltage stress for electricity semiconductor products switches. A membrane-based fuel-cell technology (PEMFC) system with a 1.26 kW proton transfer capacity is one of the configurations that is included. In particular, a Radial Basis pragmatic Network (RBFN)-based maximum power point the tracking system (MPPT) system has been created. This MPPT technique optimises fuel cell production of power at various operating temperatures.

We present an analysis and comparisons of the conventional Fuzzy Logic The control unit (FLC) the MPPT controller and the proposed RBFN-based MPPT controller. The simulation results demonstrate the RBFN-based MPPT device controller outperforms its FLC equivalent in terms of evaluation the maximum power limit more quickly and accurately.

Numerous performance parameters for a Brushless DC (BLDC) motor are also examined in the study, such as electromagnetic torque, speed, and the return electromotive force (EMF), across a range of operating settings that correlate to varied fuel cell system temperatures.

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