



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 4, April 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

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A Novel Step-Up Multi Input DC-DC Converter For Hybrid Electric Vehicles

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ABSTRACT: A multi-input DC-DC converter is proposed and studied for hybrid electric vehicles (HEVs). Compared to conventional works, the output gain is enhanced. Fuel cell (FC), photovoltaic (PV) panel and energy storage system (ESS) are the input sources for proposed converter. The FC is considered as the main power supply and roof-top PV is employed to charge the battery, increase the efficiency and reduce fuel economy. The converter has the capability of providing the demanded power by load in absence of one or two resources. Moreover, power management strategy is described and applied in control method. A prototype of the converter is also implemented and tested to verify the analysis. The fuzzy control technique is used to control the motor of hybrid electric vehicle. The results of simulation are utilised to illustrate the suggested strategy, which is implemented for enhancing power quality using the MATLAB/Simulink.

KEYWORDS: Battery, Fuel cell, PV System, MPPT, Power Quality, Power management, Controlling, Hybrid electric vehicle.

I. INTRODUCTION

Hybrid electric vehicles are considered to be one of the most viable solutions to address environmental problems and reduce the world's dependency upon oil and other non-renewable energy sources in the field of sustainable transport. Due to its fuel efficiency mechanism employed by an internal combustion engine and an electric motor HEV produce less greenhouse gas emissions compared to conventional vehicles. However, there is a limited ability to manage and use two sources of energy and dissipate power among others, leading to an overall lower power electronics system performance. As a result DC-DC converters, which is a piece of equipment that allows for effective and efficient transfer of power from the battery towards the load, are critical in ensuring that HEV works as intended. Hybrid electric vehicles are an essential step in achieving sustainable transportation. To achieve a high efficiency of operation, the development of power electronics for energy conversion and management is required. A novel step-up multi-input DC-DC converter is proposed as a key element that allows for complex energy flow in an HEV system. The development is fundamentally new, as it is impossible to integrate energy from different sources using the voltage generated by one source or to realize with an acceptable level of energy loss. The receiver is designed to integrate energy from batteries, regenerative braking systems, and auxiliary power units. Due to the ability to raise the voltage with minimal energy loss, average performance and driving range improve. It also proposes the use of various sources, power electronics robustness, and control.

I.2 OBJECTIVES

- To enhance the energy conversion efficiency of the converter to maximize the utilization of power from multiple input sources.
- To minimize energy losses during power transfer and optimize overall system performance.
- To make the converter operation more reliable, easier to manufacture, and more economical for mass production in HEV applications.
- To enhance the converter's design and control strategies to ensure consistent operation and minimize the risk of system failures.

I.3 CONTRIBUTION

An appropriate control diagram based on pwm for a inverter three-phased with an fuzzy controller is created, which controls the motor of hybrid electric vechiles.

II. LITERATURE SURVEY

A. Ostadi, and M. Kazerani [1], Batteries are the most commonly used electrical energy storage devices. The cost and performance of an electric vehicle (EV) are strongly affected by the proper selection of technology, number, and arrangement of the battery cells used. The problem for this paper is the optimal sizing of the battery unit of the PEV, considering the PEV specifications, the battery cell data, and the drive cycle. To solve this problem, this paper attempts to find the optimal sizing of the BU using a metaheuristic optimization algorithm with the overall cost as objective.. Feasibility of the optimization results in terms of respecting the constraints is verified via simulation. The developed optimization platform is highly flexible and allows use of different vehicle designs, component data, and drive cycles.

P. Mulhall, S. M. Lukic, S. G. Wirashingha, Y.-J. Lee and A. Emadi In [2], "Auto rickshaws are three-wheeled vehicles that are extensively used in many Asian countries as taxis of people and goods. Although the vehicle design is probably well suited to the environment in which it operates, it is acruce and inefficient design.005%. However, due to poor vehicle maintenance and the use of inefficient two- or four-st Auto rickshaws are three-wheeled vehicles that are extensively used in many Asian countries as taxis of people and goods." The aforementioned facts show that people jeopardizing. This paper details the overall development of an advanced solar-assisted electric auto rickshaw. Research on the conventional auto rickshaw is presented, as well as future conceptual infrastructure designs for electric rickshaws and the recent design research, simulations, and experimental validation of the next auto rickshaw.roke engines with very little pollution control, auto rickshaws present a grave pollution problem in major Indian cities. This paper details the overall development of an advanced solar-assisted electric auto rickshaw. Research on the conventional auto rickshaw is presented, as well as future conceptual infrastructure designs for electric rickshaws and the recent design research, simulations, and experimental validation of the next auto rickshaw.

H. J. Chiu, and L. W. Lin. [3], This paper presents a power converter for a fuel cell electric vehicle driving system. A new bidirectional, isolated topology is proposed in consideration of the differing fuel cell characteristics from traditional chemical-power battery and safety requirements. The studied converter has the advantages of high efficiency, simple circuit, and low cost. The detailed design and operating principles are analyzed and described. The simulation and experimental wave forms for the proposed converter are shown to verify its feasibility.

T. Markel, M. Zolot, K. B. Wipke, and A. A. Pesaran. [4], the Z-source inverter (ZSI) for automotive applications. The first application proposes the using of the bidirectional ZSI (BZSI) supplied by a battery to drive an induction motor (IM) for hybrid electric vehicle (HEV) applications, by replacing the two stages conversion. The second application proposes the using of the BZSI in plug-in hybrid electric vehicle (PHEV) applications for replacing the bidirectional battery charger, which composed of two stages conversion. By using the BSZI, the battery can be charged from the grid during night and can be discharged to the grid during peak power demand, which increase the grid stability..

In [5], Power electronics interfaces play an increasingly important role in the future clean vehicle technologies. This paper proposes a novel integrated power electronics interface (IPEI) for battery electric vehicles (BEVs) in order to optimize the performance of the powertrain. The proposed IPEI is responsible for the power-flow management for each operating mode. In this paper, an IPEI is proposed and designed to realize the integration of the dc/dc converter, on-board battery charger, and dc/ac inverter together in the BEV power train with high performance. The proposed concept can improve the system efficiency and reliability, can reduce the current and voltage ripples, and can reduce the size of the passive and active components in the BEV drive trains compared to other topologies.

In [6], brushless DC motor (BLDC), fed by a Hybrid Distributed Generation System (HDGS). The HDGS is accompanied with photovoltaic (PV) array, fuel cell stacks and a battery to supply a fixed power for driving a BLDC motor. The HDGS employs a novel multi-input DC boost converter for utilizing DG sources in a unified structure.

In [7], High-efficiency converter with two input power sources for a distributed power generation mechanism. The proposed converter can boost the varied voltages of different power sources in the sense of hybrid power supply to a stable output dc voltage for the load demand. An auxiliary circuit in the proposed converter is employed for achieving turn-ON zero-voltage switching (ZVS) of all switches.

R. B. Mohammad, H. Arid, R. Alizadeh, A. Farrakhan [8], A new multi-input non-isolated DC/DC converter with high-voltage transfer gain is proposed in this study. The presented converter consists of the conventional buck–boost and boost converters. All the stages except the last stage are buck–boost converters. The last stage is the conventional boost converter. The proposed multi-input high-voltage gain converter benefits from various advantages such as reduced semiconductor current stress, no limitation for switching duty cycle and wide control range of different input powers.

[9], a multiple-input high step-up boost converter is presented for grid-connected photovoltaic power generation system. Firstly, the derivation of the converter with dual input is presented and its operation principle and steady state performance are analyzed in detail. Secondly, the n-input high step-up boost converter made up of n boost cells is deduced. Its high step-up ratio and the relationship among the input currents are analyzed.

In [10], a novel high step-up dc/dc converter is presented for renewable energy applications. The suggested structure consists of a coupled inductor and two voltage multiplier cells, in order to obtain high step-up voltage gain. In addition, two capacitors are charged during the switch-off period, using the energy stored in the coupled inductor which increases the voltage transfer gain. The energy stored in the leakage inductance is recycled with the use of a passive clamp circuit. The voltage stress on the main power switch is also reduced in the proposed topology. Therefore, a main power switch with low resistance $R_{DS(ON)}$ can be used to reduce the conduction losses.

Y. -K. Lo et.al [11], A new asymmetrical duty cycle control method for a three-port bidirectional DC-DC converter with two current-fed ports interfacing with low voltage battery and ultra capacitor in a fuel cell vehicle. Along with the phase shift control managing the power flow between the ports, asymmetric duty cycle is applied to each port to maintain a constant DC bus voltage at low voltage side, which as a result will achieve wide zero-voltage-switching (ZVS) range for each port under varied ultra capacitor and battery voltages. The ZVS range analysis of different duty cycle control methods as well as the circulation power loss between the ports have been analyzed.

In [12], A three-port dc-dc converter integrating photovoltaic (PV) and battery power for high step-up applications is proposed in this paper. The topology includes five power switches, two coupled inductors, and two active-clamp circuits. The coupled inductors are used to achieve high step-up voltage gain and to reduce the voltage stress of input side switches. Two sets of active-clamp circuits are used to recycle the energy stored in the leakage inductors and to improve the system efficiency. The operation mode does not need to be changed when a transition between charging and discharging occurs. Moreover, tracking maximum power point of the PV source and regulating the output voltage can be operated simultaneously during charging/discharging transitions.

This review of the literature reveals that the multi step up DC-DC converter are only considered from the perspective of power management for hybrid electric vehicle. The literature on power management in integrated hybrid energy systems is scarce. This work suggested to implement an FUZZY controller at motor side to control it.

III. PROPOSED STRUCTURE OF HYBRID ELECTRIC VEHICLE SYSTEM

Figure 1, shows the structure of hybrid electric vehicle . combination of PV panel, Fuel cell, Battery.

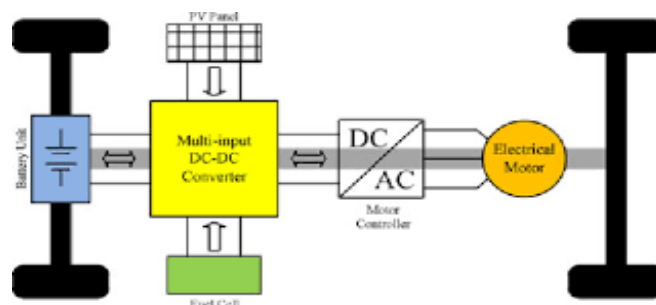


Figure 1: structure of hybrid electric vehicle
Source: Authors, (2023).

When it comes to PV and wind energy, this structure comprises of dc-dc converters to maintain consistent output from the systems [13]. A battery energy system was also installed in this construction to increase the consistency and dependability of supply to the load demand. a DC-bus is connected through PV, wind, and battery systems and

converting to AC using a PWN-based inverter. Main goal of this PWM controller is to maintain synchronization between the hybrid system and grid [13].

III.1 PHOTOVOLTAIC SYSTEM

The PV system's construction with the MPPT controller is depicted in figure 2. Photovoltaic system plays a major role in the present distributed energy source as it is freely available in nature and has better energy efficiency out of all energy sources. PV panel converts solar irradiance into electrical energy. The main components of PV system are

DC-DC boost converter, PV panel with MPPT controller [6]. Here, MPPT based boost converter is designed for extraction of maximum power from the PV panel.

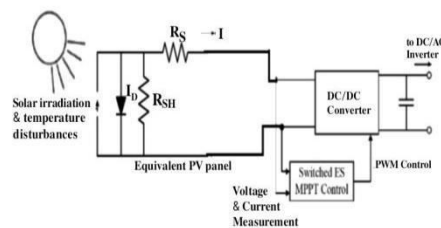


Fig :2 Line Diagram of PV System with Dc-Dc Converter Source: Authors, (2023).

$$I = I_{ph} - I_D - I_{sh}$$

$$I = I_{ph} - I_o \left[e^{\frac{qV_D}{nKT}} \right] - \left(\frac{V_D}{R_s} \right) \quad (1)$$

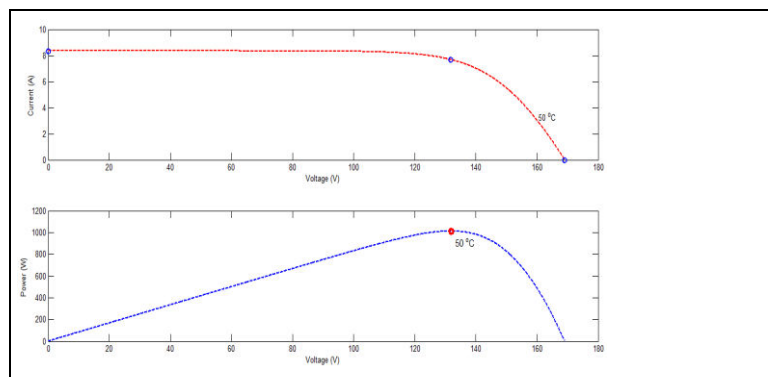


Figure 3: PV system characteristics in V-I Source: Authors, (2023).

The P-V and I-V properties of a solar system are shown in Figure 3. This makes it possible to pinpoint the system's peak power point. Figure 5 [6] depicts the construction of the closed loop control diagram from the DC-DC converter. Here, the duty cycle for the dc-dc converter is produced by the PWM converter using the comparison between the PV system voltage and the reference signal from the MPPT.

III.2 BATTERY

A hybrid electric vehicle combines an internal combustion engine and one or more electric motors, which uses energy stored in batteries. A hybrid vehicle cannot be plugged in to charge the battery. Instead, the battery is charged through regenerative braking and by the internal combustion engine. The electric drive can be used to boost accelerating power, allowing for a smaller engine. The battery can power auxiliary loads to reduce engine idling when stopped. This features allows greater fuel efficiency with a performance level.

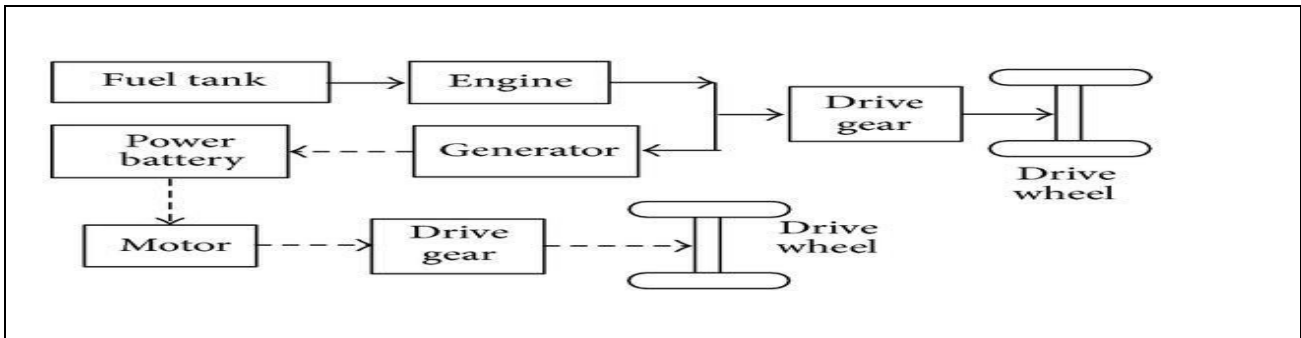


Figure 4: battery
Source: Authors, (2023).

III.3 FUEL CELL

An electric motor gets its power from electricity in a fuel cell electric vehicle. Unlike using a battery to get electricity for the electric motor like any other electric vehicle, the FCEV generates electricity through a fuel cell that is fueled by hydrogen. The vehicle manufacturer, when initiating design, defines what power takes on a vehicle is by the size of the electric motors used, each getting electric power from an appropriately sized fuel cell and another from a battery. An automaker can make FCEVs plug-in even the battery, but as of now, the battery recapture breaking energy could be used again providing extra power.

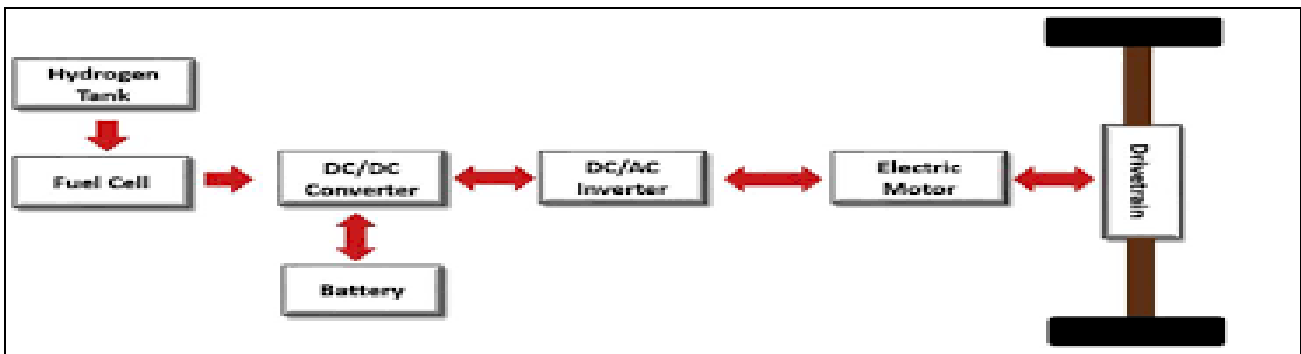


Figure 5: Fuel cell
Source: Authors, (2023).

III.4 DC-DC CONVERTER

In electromechanical terms, the DC-DC converter refers to any device or circuit that converts a DC voltage from one level to another depending on the demands of the circuit. This member of the electric power converter family can be employed for small voltage applications, such as batteries, or used for high voltage applications, such as HV power transmission.

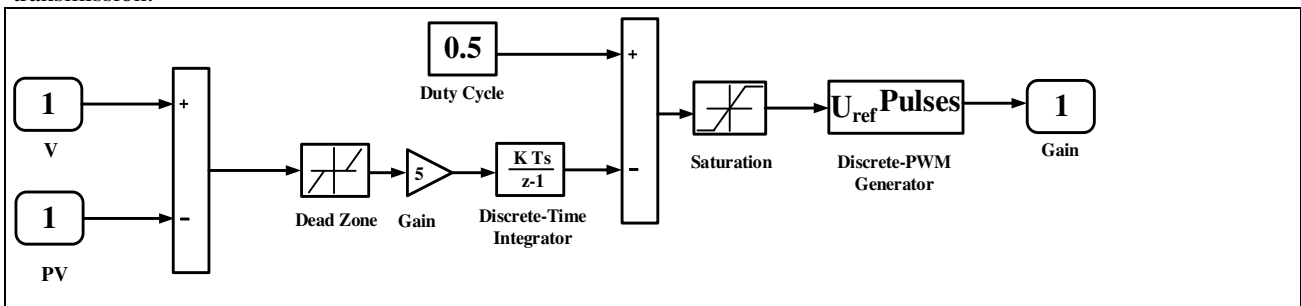


Figure 6: DC-DC converter
Source: Authors, (2023).

IV. A FUZZY LOGIC CONTROLLER

Fuzzy logic control (FLC) is the most active research area in the application of fuzzy set theory, fuzzy reasoning, and fuzzy logic. The application of FLC extends from industrial process control to biomedical instrumentation and securities. Compared to conventional control techniques, FLC has been best utilized in complex ill-defined problems, which can be controlled by an efficient human operator without knowledge of their underlying dynamics.

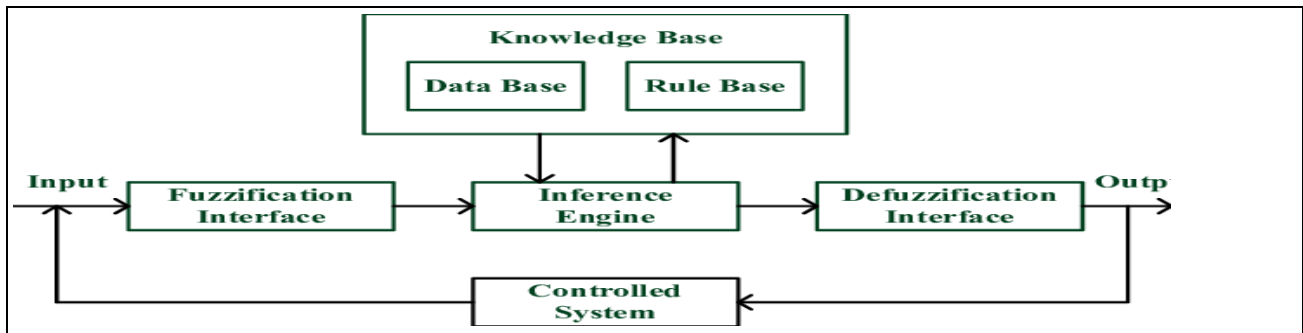


Figure 7: Architecture of Fuzzy logic control system
Source: Authors, (2023).

Figure 7 shows the two inputs used to explain the fundamental design of a fuzzy logic controller.

V. RESULTS AND DISCUSSIONS

The suggested hybrid system is tested and validated in the Matlab/Simulink environment utilising the controller methods for inverter optimisation procedures. The design criteria for photovoltaic, battery and fuel cell

According to the modelling expressions shown in the preceding parts, the solar and fuel cell, battery in this are designed. The power management approach for various load conditions is displayed.

V.1 CASE-1: USING PI CONTROLLER TECHNIQUE

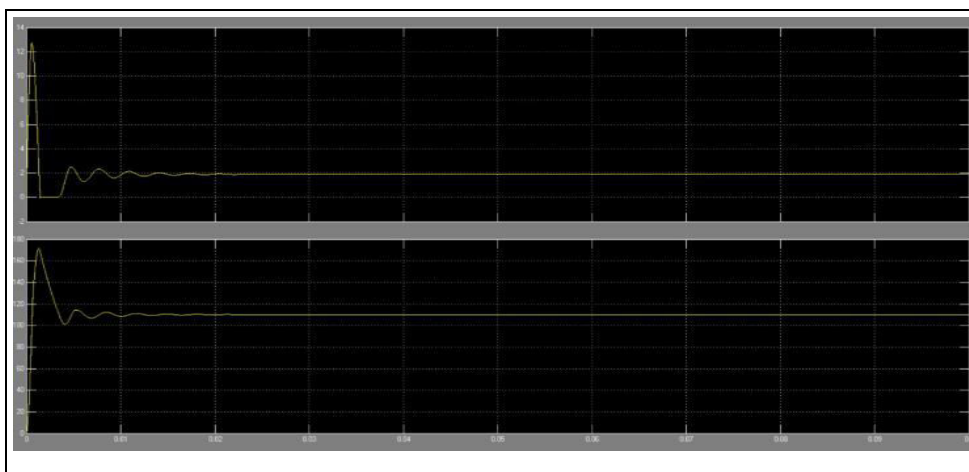


Figure 8: Simulation Results for output of existing system.
Source: Authors, (2023).

Based on the outcomes of the simulation, Figure 8 shows the power management techniques for the suggested system. Here, PV, Fuel cell and battery are chosen for power management. Figure 10 displays the power management strategies for the proposed system under fuzzy controller.

V.2 CASE-2: USING A PROPOSED SYSTEM AS INDUCTION MOTOR

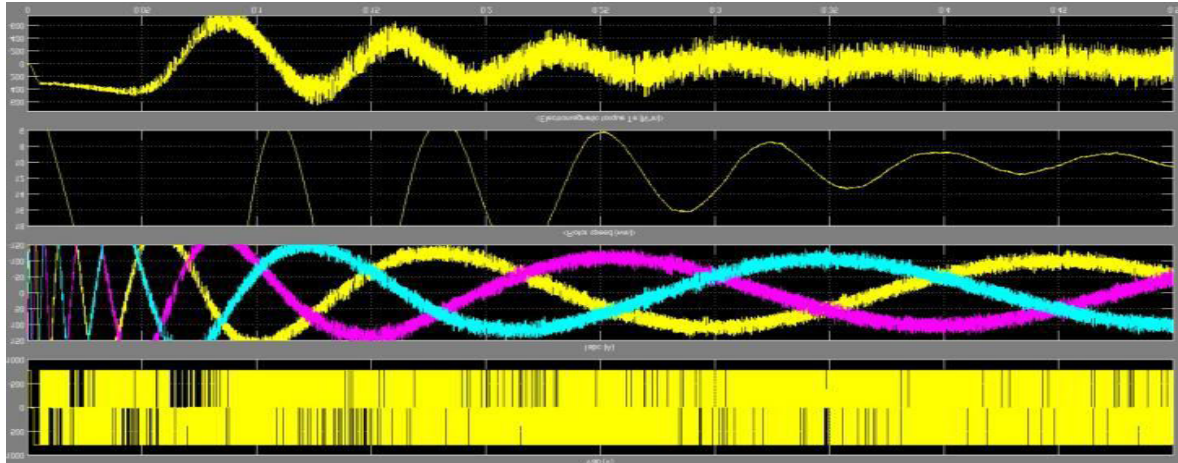


Figure 9. Inverter voltage,current ,torque and speed of induction motor simulation waveform
Source: Authors, (2023).

The waveforms of inverter voltage and current under fuzzy controller is shown in figure 10.

V.2 CASE-2: USING A PROPOSED SYSTEM AS INDUCTION MOTOR WITH FUZZY CONTROLLER

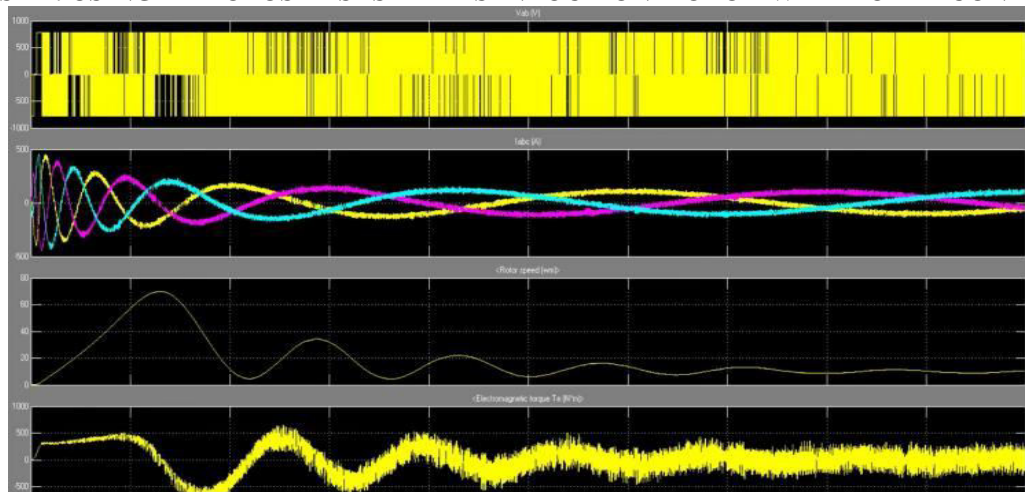


Figure 10: Results of the simulation utilising the FUZZY Controller for (a) load demand, (b) solar power, (c) battery power,(d) fuel cell
Source: Authors, (2023).

DISCUSSION ABOUT PROPOSED SYSTEM

In existing system there is a transient response up to 0.25 sec . After 0.25s there is a settling time .It has more losses. To overcome the losses we proposed a system with advanced controller i.e, Fuzzy logic controller in to the existing system . In this transient response is decreased to 0.2s.by this losses also decreased.

V.1 LIMITATIONS

In the existing system losses are more by the transient response is taking more time.

VI. CONCLUSIONS

A novel three-input DC/DC converter is proposed and analysed thoroughly. The converter has the capability of providing the demanded power by load in absence of one or two resources. The promising performance of the converter and employed control method offer a high reliability for utilizing the converter in industrial and domestic applications. The converter is modeled for three different operational states and utilized to design a proper controller. MPPT

algorithm is achieved and along power management is utilized to apply the commands of controller. Meanwhile, employing power management and MPPT procedure will enhance the efficiency of the converter. Finally, a laboratory prototype of the presented converted is implemented and results are taken and depicted. Results prove the analysis and performance of the converter.

VII. AUTHOR'S CONTRIBUTION

Conceptualization: S.Srinivasan, A.Srilekha , N. Sriyank, D. Chetan.
Methodology: N.Sriyank , A.Srilekha , D.chetan
Investigation: S . Srinivasan , N.Sriyank.
Discussion of results: S.Srinivasan, A.Srilekha , N. Sriyank, D.Chetan
Writing – Original Draft: A.Srilekha , N. Sriyank, D.Chetan
Writing – Review and Editing: S.Srinivasan, A.Srilekha , N. Sriyank, D.Chetan
Resources: S.Srinivasan..
Supervision: S.Srinivasan, A.Srilekha , N.Sriyank, D.chetan.

Approval of the final text: S.Srinivasan, A.Srilekha , N. Sriyank, D.Chetan.

VIII. ACKNOWLEDGMENTS

If necessary, quote entities that supported the development of the research.

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