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Multi-Port DC-DC Power Converter for Renewable Energy Application

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Abstract: As traditional energy sources diminish, renewable energy sources such as wind and solar power are crucial for sustainable power generation. The intermittent nature of these sources means that their output must be conditioned to meet grid requirements, typically through power converters. Current systems use separate converters for wind and solar, leading to high component counts and inefficiencies. The suggested system integrates various energy sources using a four-port converter: two input ports of wind and solar power, a bidirectional storage port, one an isolated load port. By adopting zero voltage switching, the system reduces costs, improves power flow management, and ensures seamless integration of renewable sources with the grid. This setup allows for more intelligent power flow between household users, the grid, and distributed generation units. The resulting DC voltage from the converter can be used directly for DC loads or converted to AC for household use, optimizing efficiency and resource use.

Keywords: Renewable Energy Integration, Four-Port Converter, Zero Voltage Switching, Flexible Output etc.

I. INTRODUCTION

As traditional fossil fuel reserves decline, the world's reliance on renewable energy resources becomes increasingly important. Natural gas, coal, and oil are examples of finite fossil fuels, because their ongoing use degrades the environment and depletes resources. Renewable energy sources, including solar, wind, tidal, or geothermal, supply long-term power through the use of natural processes which replace themselves over time. These resources provide a feasible, eco-friendly alternative to fulfill the world's rising energy demands while lowering carbon emissions and tackling climate change.

Among the different renewable energy sources, wind and solar power stand out for their abundance & ease of harnessing. Solar energy, obtained from the sun, can be captured through photovoltaic (PV) technology, which has significantly improved in efficiency and cost-effectiveness in recent years. Thin-film PV cells, for example, are now more widely used and accessible, making solar energy a promising candidate for large-scale deployment. Wind energy, in the other hand, is harnessed via wind turbines, which transform the kinetic energy of airflows to electrical power. Wind energy is quickly developing, with a yearly increase of around 20%, so its global capacity currently in use has reached significant proportions.

However, both solar and wind energy share a common challenge: their intermittency. Solar energy production depends on sunlight availability, which varies depending on the time of day, weather, and geographical location. Similarly, wind energy is reliant on airflow, which fluctuates throughout the day and year. This variability means that neither source can guarantee a constant and reliable energy supply, presenting challenges for their integration into the energy grid.

Integrating wind and solar power systems is one of the main ways to address the intermittent nature of renewable energy. By combining these two sources, the unpredictability of each can be reduced, resulting in a more steady and dependable energy supply. For example, solar energy is generally more abundant during the daytime, while wind energy can be more readily available at night or during different seasonal patterns. By integrating these sources, the variability of one can compensate for the other, smoothing out the overall energy production.

Furthermore, the reliability of combined wind and solar power systems is further improved by the addition additional energy storage devices, such as batteries. Excess energy generated during times of high production (like sunny and windy days) is stored in batteries and released during times of low production (like gloomy or windless days). This ensures a continuous, stable energy supply, reducing the reliance on backup power from non-renewable sources.

By maximizing the use of renewable energy sources and guaranteeing that the energy supplied to the grid or particular loads is dependable and consistent, wind, solar, & energy storage technologies can successfully handle the problems of intermittency.

The growing use of wind and solar power is largely due to the quick development of advances in the sector of renewable energy. For instance, innovations in photovoltaic cells have significantly improved the efficiency of solar panels, allowing for greater power output even in less-than-ideal conditions. In addition, developments in wind turbine technology—such as larger turbine blades and more efficient gearboxes—have made wind energy more accessible and cost-effective for both large-scale and decentralized energy generation.

In the last five years, there has been a notable global trend towards the increased usage of solar and wind energy. These sources are gaining popularity not only due to their environmental benefits but also because they are becoming more cost-competitive compared to traditional fossil fuels. Investments in innovative technology that can effectively capture and manage these resources are increasing in tandem with the growing demand for renewable energy.

One of the key challenges in integrating renewable energy sources is the management of power flow between multiple sources and the grid. In this context, multiport DC-DC converters have emerged as a promising solution. These converters are designed to handle multiple input sources (such as solar and wind) and integrate them into a single output, either for grid supply or direct consumption.

The seamless integration of various renewable sources with storage systems is made possible by the installation in a multiport DC-DC converter, which facilitates more effective energy management. By controlling the flow of energy between the sources, the grid, and energy storage units (such as batteries), these converters optimize the overall energy flow, reducing wastage and improving system efficiency.

The integration of solar and wind energy systems, supported by technological advancements such as multiport DC-DC converters and energy storage solutions, offers a viable and sustainable alternative to conventional fossil fuels. These systems can offer a dependable and regular energy supply by resolving intermittency issues and streamlining energy flow, which will lessen their negative effects on the environment and assist fulfill the world's energy demands.

The ongoing advancement and application of renewable energy technology will be crucial as the globe transitions to a more environmentally friendly energy future. Wind and solar power hold immense potential for driving this transition, and the innovations in power conversion and energy management will play a critical role in ensuring their effective integration into the global energy system.

II. MULTI-PORT DC-DC POWER CONVERTER

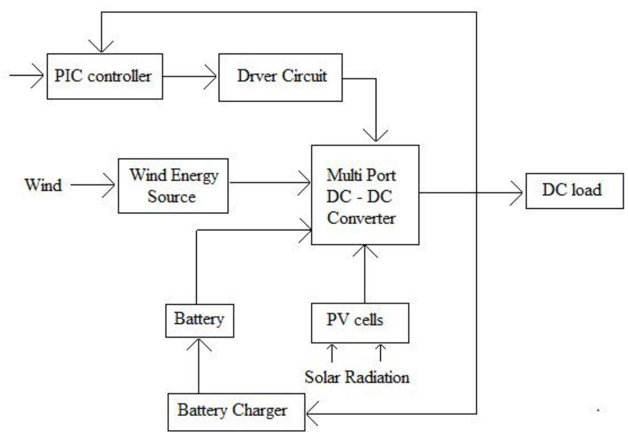

Fig.1.The proposed System

Because sources of clean energy like sun and wind are unpredictable, integrating them into a dependable power system poses a number of issues. Solar energy depends on sunlight, while wind energy is reliant on airflow, making their availability inconsistent. To address this, A multi-port DC to DC converter has been developed to combine a bidirectional battery pack with solar and wind energy. This setup ensures that energy from one source can compensate for the unavailability of the other, maintaining a stable energy supply. The system effectively manages the energy flow, storing excess power when both sources generate sufficient energy and discharging it when needed.

This design's suggested four-port DC-DC converter is a small, incredibly effective solution that combines solar, wind, and battery energy into a single platform. It employs zero-voltage switching (ZVS) technology to minimize energy losses and enhance efficiency, particularly during switching operations. To ensure that the converter runs smoothly and effectively, the system is controlled by a PIC microcontroller.

One of the key advantages of this system is its ability to handle the intermittency of renewable energy sources. By using intelligent power flow management, the converter ensures a consistent energy supply even during periods of low renewable generation. From bigger, grid-connected clean energy setups to domestic solar-wind hybrid systems, its small size and adaptability make it appropriate for a variety of uses. This strategy is an important advancement in contemporary energy management since it not only increases the dependability of energy from renewable sources but also fosters sustainability by permitting the effective use of natural resources.

III. SINGLE STAGE MULTIPORT DC-DC CONVERTER

Because renewable energy resources like photovoltaic, or PV, panels and wind turbines are unpredictable, hybrid energy production systems must contend with issues like stability, dependability, and power quality. These problems result from solar and wind energy's sporadic availability, which can interfere with reliable power delivery. Batteries and other energy storage components are incorporated into the system to overcome these difficulties. Batteries ensure a steady power supply by storing extra energy produced during periods of peak production and releasing it when energy from renewable sources is low.

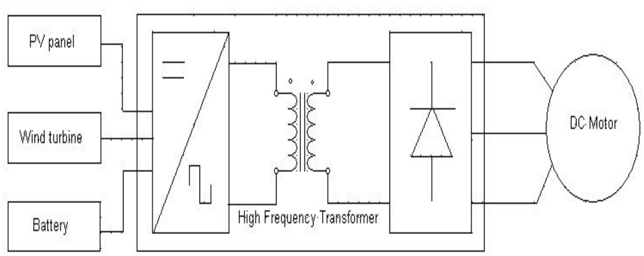

Fig.2. Configuration of single stage multiport dc-dc converter

To optimize energy management and handle multiple sources efficiently, multiport DC-DC converters are utilized. These converters allow seamless integration of different energy sources like PV panels, wind turbine generators (WTG), and batteries into a unified system. Electrical isolation among the input sources & the output load is provided by the separated DC-DC converter architecture, improving flexibility and safety. The system ensures efficient energy distribution while addressing the quality and reliability issues associated with hybrid energy systems, making it ideal for renewable energy applications in both residential and commercial settings.

An effective and affordable way to integrate energy from renewable sources such solar panels (PV) with wind turbines (WTG) is via a multiport DC to DC converter plus energy storage. Power management systems, fuel cell systems, hybrid automobiles, and energy-efficient applications all make extensive use of these converters. Power flow between various sources, such solar panels and turbines powered by wind, or a storage component, like a battery, can be controlled by the converters. This enables consistent and dependable energy delivery even in situations when wind and solar power availability is uncertain.

There are two types of isolated multiport converters: the common winding method and the separate winding method. By connecting several ports to a single wrapping on the transformer's primary side, the common winding technique employs fewer windings. As a result, the design becomes more affordable and compact, lowering the number of parts—especially bridge-type switches—and improving system reliability overall.

Fuzzy logic control is used to maximize power extraction while maximizing the utilization of solar and wind energy inputs. Each input source, like the PV and WTG, is connected to the converter via a single switch, while the secondary side uses a diode bridge rectifier without controlled switches, which simplifies the design and increases efficiency. The switching strategy minimizes energy losses by optimizing the switch ON/OFF intervals based on the current demand, further boosting the performance of the converter.

This multiport converter offers significant advantages, such as reduced component count, lower costs, and increased power transfer efficiency, making it an ideal solution for renewable energy systems, ensuring stable, high-level DC voltage output.

IV. CONVERTER STRUCTURE AND OPERATION

Figure 3 illustrates the suggested multi-port dc-dc converter, which is composed of a high frequency transformer with a ferric core. Energy storage capacitor C & switches MOSFET1, MOSFET2, MOSFET3, and MOSFET4 are connected to the transformer's primary winding, correspondingly. The transformer's secondary winding is coupled to a full bridge diode rectifier. To lessen harmonics, an LC filter is positioned on the secondary side. The suggested converter's Fig. 3 circuit diagram is displayed below. Three parallel ports make up the primary side, and each port is connected to a PV panel, wind turbine, and battery. Capacitor C's primary side is linked between the transformer and ports. Each port has a programmable power switch, a power diode, and an inductor.

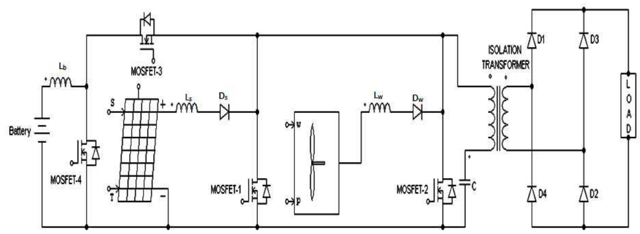

Fig.3.Circuit Diagram of MPC

With Np representing the number of turns on the primary winding and Ns representing the number for turns of the second winding, the transformer's total turns ratio(n) is n = Np /Ns. Power switches are in charge of controlling the converter. Capacitors are positioned between the ports in this suggested converter to reduce the ripples in the DC voltage. This converter is coupled with a motor load.

V. PHOTOVOLTAIC SYSTEM

Solar energy is directly transformed into electrical energy using a photovoltaic (PV) system. A photovoltaic system's basic component is the PV cell. Arrays can be created by grouping cells together. The current and voltage available at a photovoltaic device's terminals can specifically support small loads, such as DC motors and lighting systems, or link to a grid through the use of appropriate energy conversion equipment. The PV component, charger, battery packs, inverter, and loads are the main parts of this solar system. Semiconductor devices known as photovoltaic or photoelectric cells convert light into electrical energy through the photovoltaic effect. If the energy of the photon emitted by light is greater than the band gap, the electron escapes as the flow of electrons generates current. A photovoltaic cell and a photodiode are not the same thing, though. In contrast to a photodiode, which converts light into a current or voltage signal when it reaches a semiconductor junction's n channel, a solar energy device is always forward biased.

1) *PV Module:* Several PV modules are frequently arranged and parallelized to meet the vitality requirements. Commercial PV modules are available in a range of sizes, usually between 60W and 170W. For example, the average small-scale desalination equipment requires a few thousand volts of power.
2) *PV Modeling:* Numerous solar cells coupled in series and parallel make up a PV array. Series connections are responsible for increasing the module's voltage, whereas parallel connections are responsible for increasing the array's current. A solar cell can typically be simulated by placing an inverted diode in line with a current source. It has its own resistance in series and parallel. Leakage current causes parallel resistance, whereas blockages in the electron's flow path from the n through the p junction generate series resistance.

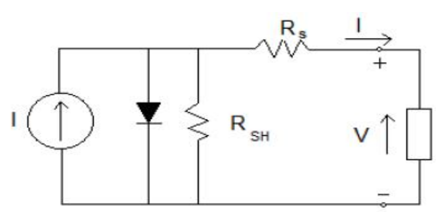

Fig.4: Single Diode Model of a PV Cell.

A current source (I), a diode, and the series resistance (Rs) are all taken into account in this model. In parallel, the resistance to shunting (RSH) is extremely high, insignificant, and easily disregarded.

VI. BOOST CONVERTER

As stated in the introduction, tracking the greatest power point is basically a load matching challenge. To match the input resistance of the panel to the resistance of the load (by changing the duty cycle), a DC to AC conversion is required. Research indicates that the most efficient DC to DC converter is a buck converter, which is followed by a boost converter and a buck-boost converter. However, we employ an increase converter because we intend to use our system as either grid connection or for a system of irrigation that requires 230 V at the power end.

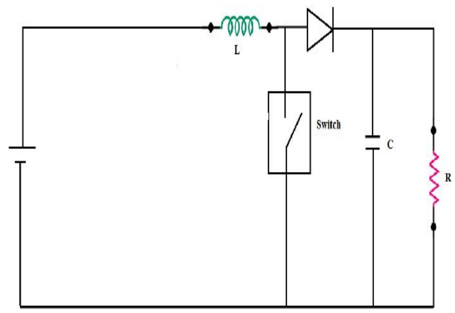

Fig. 5. Circuit Diagram of Boost Converter.

VII. MAXIMUM POWER POINT TRACKING

A solar panel converts sunlight into electrical energy. Using Maximum Power Point Tracking (MPPT), efficiency is optimized by matching the source and load impedance, as per the Maximum Power Transfer Theorem. A boost converter adjusts the duty cycle to match these impedances, enhancing output voltage for various applications, like engine stacks.

A. *Different MPPT Techniques*

The highest point of power can be tracked using a variety of methods. Among the most widely used methods are:

1) Perturb and Observe (hill climbing method)
2) Incremental Conductance method
3) Fractional short circuit current
4) Fractional open circuit voltage
5) Neural networks
6) Fuzzy logic.

B. *Peturb & Observe*

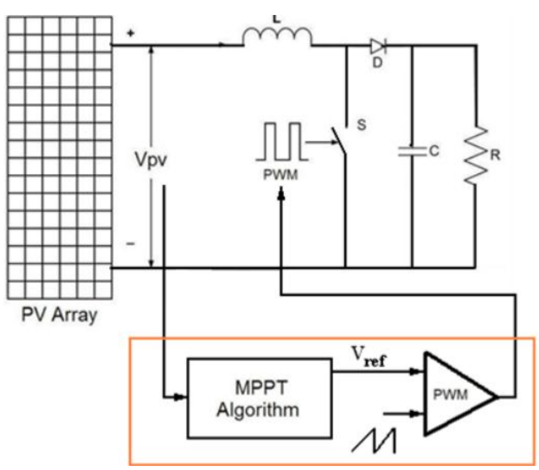

Fig. 6.Perturb & Observe (P&O)

The simplest approach is Perturb & Observe (P&O). This is simple to build and has a cheaper implementation cost because we only need single sensor—the voltage sensor—to detect the voltage of the solar array. Although this method has relatively low temporal complexity, it keeps on perturb in each direction as it approaches the MPP.

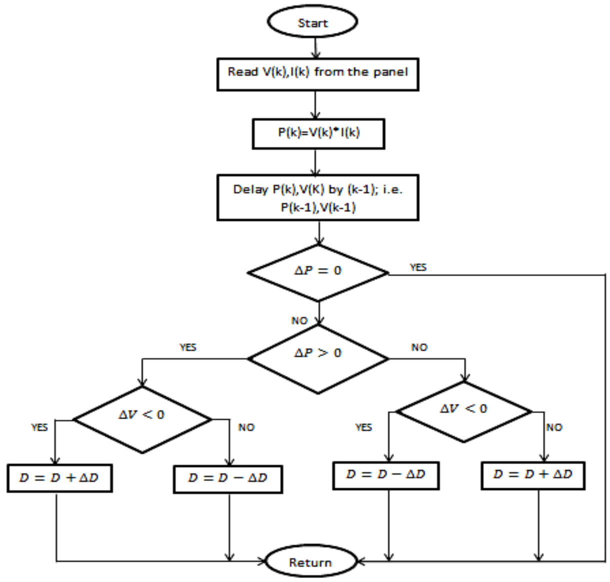

Fig. 7.Perturb & Observe algorithm

When the process nears the Maximum Power Point (MPP), setting an error limit or wait operation adds temporal complexity. However, rapid radiation changes can mislead algorithms like Perturb and Observe, resulting in incorrect MPP computation. The Incremental Conductance method effectively addresses this issue by adapting to dynamic conditions accurately.

VIII. MODES OF OPERATION

This converter component operates in three modes: 1) MOSFET switches 1 and 2 are on; 2) MOSFET switching 3 is on while MOSFET switches 1 and 2 are off; and 3) MOSFET switches 3 and 4 are on. The circuit operation occurs during the high phase of a high frequency square wave delivered to cause the MOSFET that turns on. The terminal's positive and negative power supplies are connected via inductor L. The current runs between positive and negative source terminals via the inductor L, which stores energy in the magnetic field it creates. The remaining circuit has no current flowing because the combination of D, C, and the load have a far higher resistance than the path directly via the heavily conducting MOSFET.

The current journey takes place during the transitional square cycle wave's low period. When a MOSFET was rapidly turned on, a sharp reduction in current creates a back emf of the opposite polarity too the voltage that runs across the inductive element for a short period of time, allowing current to flow.

Because of the electrical charge on the capacitor, the D of the MOSFET is more positive that its anode whenever it conducts. When the diode is turned off, the circuit's output is separated from the input, but the load is still supplied with VIN+VL from the charge on the capacitor. The following equations govern the charge and discharge processes of capacitors at initial conditions.

$$Ic = C\frac{dVc}{dt} \quad (1)$$

When switch is closed VC remains constant voltage, capacitor cannot change the voltage.

$$Vc(t = 0) = VcI \quad (2)$$

The current flow through the capacitor, it will energize to increase voltage.

$$Vc(t > 0) = VcI \quad (increasing) \quad (3)$$

When the capacitor voltage increases, capacitor current will decreases.

$$Ic(t) = \frac{Vs - Vc(t)}{dt} \quad (4)$$

1) Mode: I

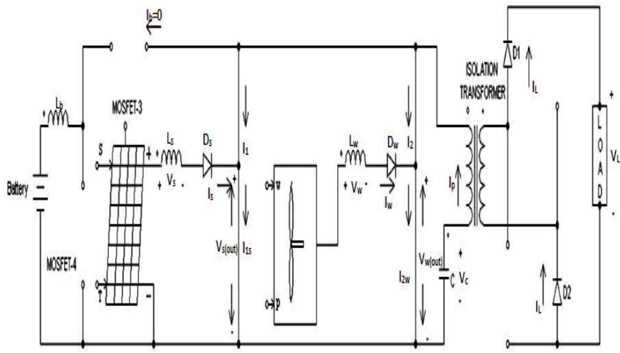

Fig.8. Circuit Diagram for Mode 1

When PV provides power for the load, the electrical current channel flows in a positive direction. The inductor Ls is utilized for boost operation, whereas the diode is employed to block voltage. When MOSFET switch 1 is turned on, the capacitor begins to charge. When MOSFET1 is turned on, the capacitor charges. When MOSFET1 is turned off, the capacitor discharges power to the load via the very high-frequency transformer, and D1 and D2 conduct. When MOSFET3 is turned on, an excess amount of electrical capacity is stored in the battery, and the battery current IB is zero.

$$Ip = I1 + I2 \quad (5)$$

$$I1s = I1 + Is \quad (6)$$

$$I2w = I2 + Iw \quad (7)$$

Ip, Is, and Iw refer to the transformer's primary current, solar current, and wind current, respectively. Vs and Vw represent solar and wind voltage, respectively. Vs out as well as Vw out are zero.

$$Vs = ls\frac{dis}{dt} \quad (8)$$

$$Vw = lw\frac{diw}{dt} \quad (9)$$

$$Vc = \frac{1}{c}\int Ic(t)dt \ \ (Vc\ decreasing) \quad (10)$$

When wind generates power, the inductor is charged. When MOSFET 2 is turned on, the capacitor is charged, and the current flows in the positive direction. When MOSFET 2 is turned off, the capacitor discharges power to the load via a high-frequency transformer. If MOSFET 4 is turned off, an excess of producing power goes to the battery, while current flows in the opposite way.

2) Mode: II

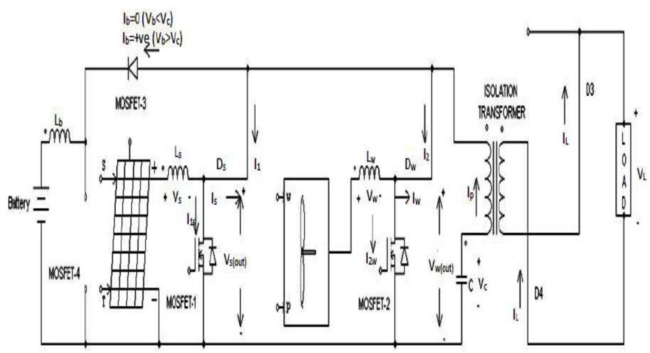

Fig.9.Circuit Diagram for mode 2

When both MOSFETs 1 and 2 are turned off, electricity passes through the diode. The current travels from the main winding inside the transformers to the second winding on the transformer to increase the voltage, and Diodes D1 and D2 conduct. When MOSFET switch 3 is turned on, electricity is supplied into the battery for charging, and the load voltage and current are VL and IL. Battery charging via bidirectional electrical power flowing exclusively to the battery.

$$Ip = I1 + I2 \quad (11)$$

I1 and *I2* both are having opposite polarity.

$$Vs\ out = Vs + Vls \quad (12)$$

$$Vw\ out = Vw + Vlw \quad (13)$$

$$Vc = \frac{1}{c}\int Ic(t)dt \ \ (Vc\ increasing) \quad (14)$$

When *Vc*<*Vb* the battery current Ib=0,battery current positive at *Vc*>*Vb*.

3) Mode: III

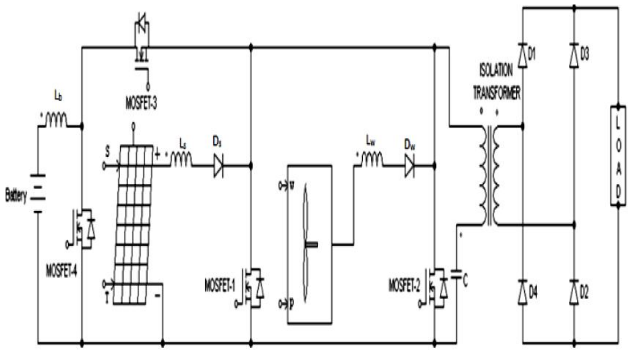

Fig. 10.Circuit Diagram for mode 3

When a MOSFET switch 4 is turned on, the capacitor is charged at the same time that the MOSFET switching 3 is turned on, and the battery is charged while the PV and wind generation voltages are turned off. MOSFET 4 is turned off, and the capacitor discharges voltage to the transformer's primary winding, while the secondary winding increases voltage to the load. A high frequency transformer delivers power to the load simultaneously. In battery discharge mode, the transformer's principal current is,

$$Ip = I1 + I2 + Ib \quad (15)$$

The wind and solar power voltages are similar to mode 2 operation, and the capacitor voltage rises to,

$$Vc = \frac{1}{c}\int Ic(t)dt \quad (16)$$

IX. DESIGN CONSIDERATIONS

The multiport dc-dc converters uses a single stage converting procedure for numerous ports. It is emerging to make the entire system smaller and straightforward. This multiport dc-dc converters not only connects all sources and loads, but it also modifies the electrical energy form and regulates the power flow between them. A high-frequency transformer has a ferric core that provides isolation or voltage matching between the source and loads. This formula is used to select the transformer's turn ratio,

$$\frac{Np}{V1} = \frac{Ns}{V2} = \cdots = \frac{Nn}{Vn} \quad (17)$$

where Np and Ns are the transformer's main and secondary winding turns, and V1 and V2 are the port voltages. The power through the converter should be maximized under all scenarios. When the frequency of the switch remains constant, the power supply is related with the leakage inductance,

$$P = \frac{NpVsVw}{2\pi NsFsLs} \quad (18)$$

where LS denotes the overall inductance to the transformer's primary and FS represents the switching frequency.

The region's operation requirements regarding the multiport dc-dc converters are as follows:

1) Supply load power independently from each source; 2) Share power between sources and loads.
2) The power generated by the regenerative load is used to electricity the battery.

When electricity flows from port 1 to the port 3, the voltage converter operates in boost mode to maintain the port 3 at its maximum desirable value. The other orientation of electrical flow, the converter. It operates in buck mode to generate electricity for the storage element battery.

Table .1 Multiport dc-dc converter parameter.

converter parameter	value
port 1 voltage	12V
port 2 voltage	12V
battery (lead acid) voltage	12V
resonant inductor	100mh
resonant capacitor	100µf
transformer turns ratio	1:2
capacitor	100µf
duty cycle	0.5

The following requirements should be met: To make several sources operate efficiently: The switch SK (K = 1, 2, 3, 4) ought to stay turned off until S1 is turned off; otherwise, LS would continue to store energy even when S1 and S2 are turned off, which is undesirable. To accomplish this condition, a multiport dc-dc converter must satisfy the following inequality, where VL represents the load's output voltage. The alternative source of power with the highest nominal voltage for its output will be linked to the converter port, which may result in one of the two additional scenarios.

a) *Scenario* 1: If no power can be obtained from Port 1, the condition is no longer relevant but ought to remain met. In this situation, the duty cycle of the first switch, S1, is configured to be a constant value, which is satisfied, and the switch S1's function is to alter the direction of the present IP address passing through the transformer. When S1 is turned off, current IP flows through other sources into the transformer, where it charges the capacitor Cs. When S1 is with, the capacitor Cs discharges, and the direction for the current IP reverses.
b) *Scenario* 2: The renewable source of energy that generates electricity at Port 1 is insufficient to meet the demand, but it should still be met. The fuzzy controller will increase the duty cycle for the switch S1 to a maximum value, ensuring that the purpose of the switch S1 is identical as in Scenario 1. The electricity produced by the source of clean energy linked to Port 1 may be less than its full capacity. In this scenario, on port 1 the variations in the electricity generated with the maximum amount of electricity is tiny since the highest level of power accessible at Port1 of a multiport dc-dc adapter is normally quite small.

X. SIMULATION AND RESULT

It contains three ports. There are three ports: main, battery, and load port. It functions in three modes. Under normal operation, one port is supplying, one is charging, and another is a load port. The simulation's parameters are as follows: the voltage input is 12V both PV and wind, and the battery charge voltage is 24V. The load power output is 90 watts.

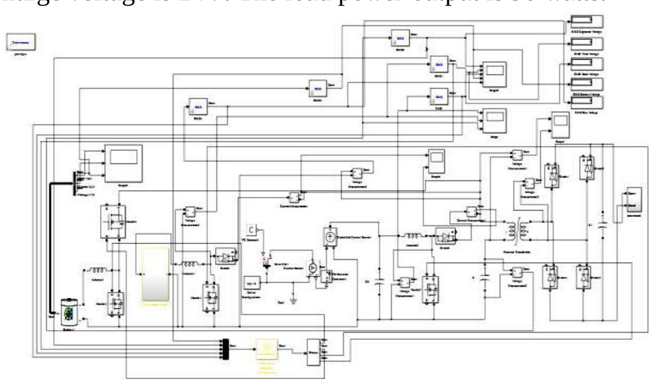

Fig.11. Converter Simulation

A. Simulated Input Voltage

Figure 12(a) shows the corresponding voltages of wind and solar. Wind strength is 12 volts with an amplitude of 0.5 volts. The firing pulse is produced using fuzzy control for MOSFETs. Voltage over a capacitor is 1.05 volts.

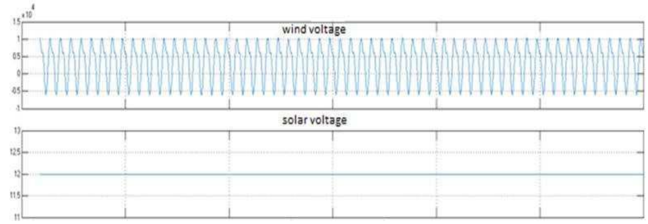

Fig.12.a.Input Voltage Waveform

B. Voltage Across the Capacitor

Figure 12(b) shows the observed voltage across the capacitor during charging and discharging conditions. Capacitor charges voltage until it equals the input voltage (12V) and then increases to 15V. The voltage of the capacitor will vary as a result of the switch on/off situation.

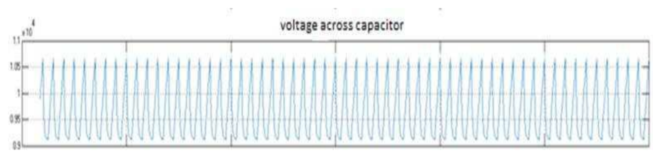

Fig.12.b Voltage across the Capacitor

C. Mosfet Firing Pulses

Figure 12(c) depicts the process of creating firing pulses for MOSFETs. Fuzzy control generates firing pulses through a rule-based mechanism. It is used to activate the MOSFET conductors. Fuzzy control pulse generator offers a large switching frequency, delay, width, and 50% duty cycle.

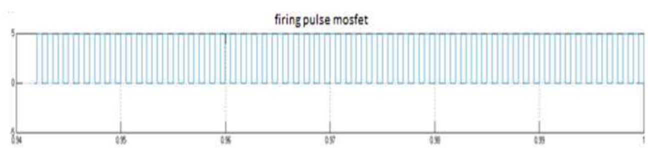

Fig.12.c firing pulses

D. Solar and Wind Current

A multi-port DC-DC converter supporting solar and wind current waveforms. The predicted output current can be measured at the point of failure for the motor load by connecting an electrical measuring scope.

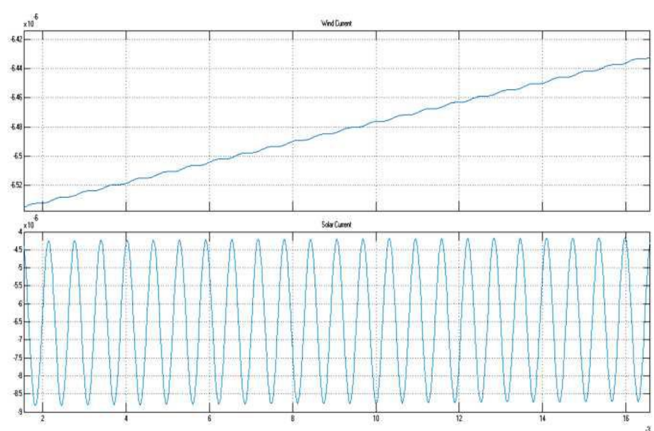

Fig.13. solar and wind current

E. Solar and Wind Diode Current

Simulation Diagram of a multi-port DC-DC converter with wind and solar diode current waveforms. The modeled output current can be determined across the output for motor load by connecting an electrical measurement with a scope.

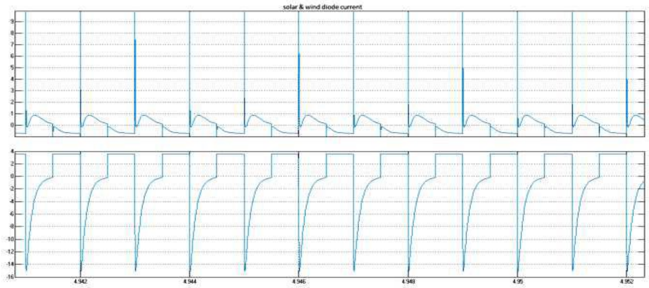

Fig.14. Diode Current

F. Battery Input and Output Waveform

The battery input as well as output waveforms for the converter are simulated. The simulated input as well as output voltage can be determined at the final product of motors loads through connecting a voltage meter with a scope.

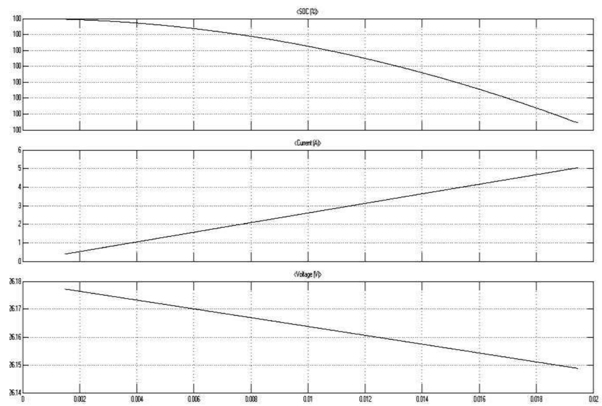

Fig.15. battery input and output

G. Wind Turbine Generator Model

This figure 13 depicts a wind turbine generator that operates at a low speed of 10W and then transforms to a high speed using a gearbox. To extract the greatest power from a wind turbine, adjust the pitch angle, while wind speed is determined by the pitch angle.

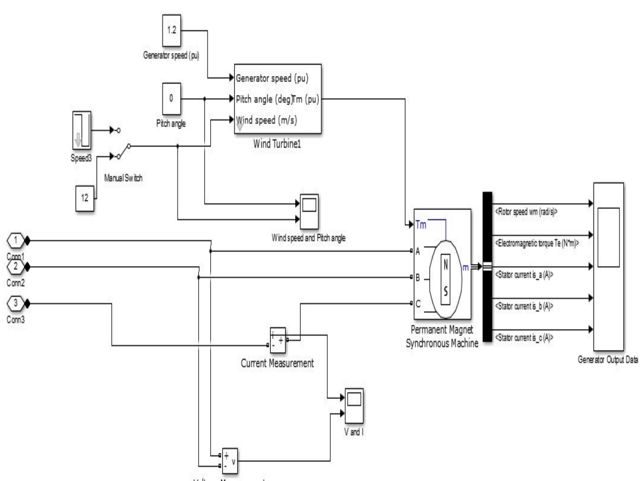

Fig.16.Simulation Diagram for Wind Turbine Generator

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H. Dc Motor Model

Simulation Diagram of a multiport DC to DC converter load. This direct current motor is used as a load. The performance is examined using the scope and the waveform. Load current and voltage are obtained using the DC motor load model.

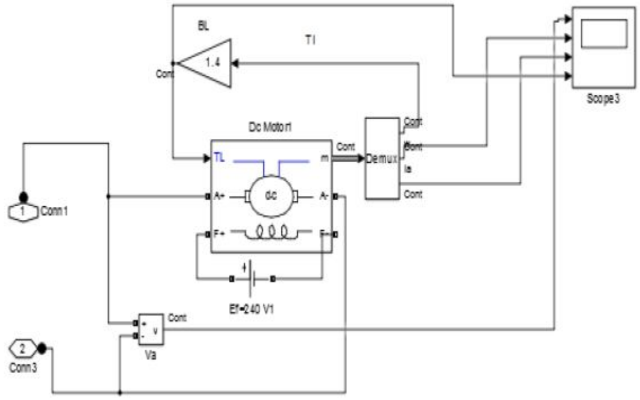

Fig.17. Simulation Diagram for DC motor

I. Output Waveform of Load

Multiport dc-dc conversion load model for solar and wind.

The three-phase waveform is depicted clearly.

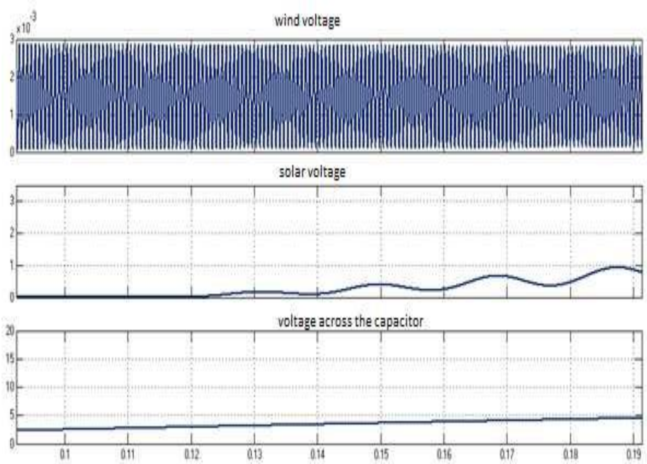

Fig.18. Load output

J. Efficiency

To determine the multiport converter's efficiency, three sources of voltage were attached to its three input ports. During the experiment, the currents of the three resources attached to the input terminals were set to 12V: solar and wind, and 24V for the battery.This fig.19(a) graph displays the input voltage & power-related curve.

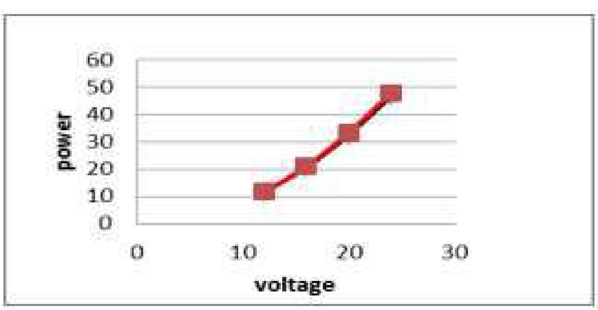

Fig.19.A.Input Voltage vs Power Curve

This graph, fig.19(b), depicts the measured efficiency in relation to the converter's output. Efficiency increases as output power increases. Once the output power hits 90W, the efficiency will be 91.8%.The efficiency gradually drops with increasing load but remains over 90%.

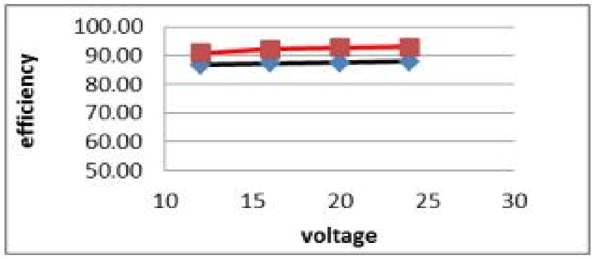

Fig.19.B Input Voltage vs Efficiency Curve

Table.2.Multiport dc-dc converter simulation parameters

Parameters	**Value**
Battery nominal voltage	24V
Fully charged voltage	26.1316V
MOSFET resistance	1ohm
Diode resistance	0.1ohm
Capacitor	100µf
Switching frequency	5KHZ
Carrier frequency	1080HZ
Motor current	1A
Inductor	.05H
Motor resistance	200ohm

XI. CONCLUSION

The proposed multiport DC-DC converter is designed to optimize power management for multiple renewable energy sources. By reducing the number of switches, the converter simplifies the topology while managing energy flow from hybrid generation systems and energy storage systems. It supports simultaneous power management and achieves soft switching through an isolated high-frequency transformer, ensuring efficient energy transfer. The converter operates in both buck and boost modes, controlled by the switching mechanism, and facilitates bidirectional power flow between two DC sources without altering voltage polarity.

This system remains stable and controlled under various load conditions, including normal, large, small, and even load scenarios, demonstrating robust performance. The closed-loop control enhances the converter's stability and adaptability, making it suitable for diverse energy systems.

Furthermore, advancements in multi-port DC-DC and DC-AC converters expand their application in renewable energy systems, such as solar and wind. By exploring modular configurations, advanced control techniques, and efficient topologies, the research improves the converters' ability to integrate multiple renewable sources seamlessly. These studies highlight the importance of efficiency and adaptability in managing renewable inputs, contributing to the reliable incorporation of clean energy into modern power grids. This progress is vital for advancing sustainable energy technologies and shaping the future of renewable energy integration.

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