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# DESIGN AND IMPLEMENTATION OF A MULTIPORT DC-DC CONVERTER FOR SMART GRID APPLICATIONS

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## ABSTRACT:

The increasing demand for renewable energy integration into smart grids has necessitated the development of advanced power converters capable of managing multiple energy sources and storage systems simultaneously. This paper presents the design and implementation of a multiport DC-DC converter for smart grid applications. The proposed converter is designed to integrate various renewable energy sources, such as photovoltaic (PV) and wind power, along with energy storage systems like batteries and supercapacitors. The multiport converter efficiently handles power distribution, provides voltage regulation, and supports bidirectional power flow, enabling seamless integration with the grid. The converter utilizes a modular topology with a hybrid control strategy, combining peak current mode control (PCMC) and average current mode control (ACMC) to optimize power transfer, minimize losses, and reduce harmonic distortion. The system is also equipped with maximum power point tracking (MPPT) for optimal energy extraction from renewable sources. Simulation and experimental results demonstrate the effectiveness of the proposed converter in improving the efficiency, flexibility, and scalability of smart grid systems. The proposed design offers a reliable and cost-effective solution for the integration of distributed renewable energy sources into modern grid infrastructures.

**KEYWORDS:** Multiport DC-DC converter, smart grid, renewable energy, power management, bidirectional power flow, hybrid control, MPPT.

## 1.INTRODUCTION:

NOWADAYS, the electrical power grids are going through a revolutionary phase where they are becoming more decarbonized, decentralized, and digitalized. DC microgrids (DCMG) have been gaining increasing interest over the past couple of years both in academia and industry. The advantages of DC distribution when compared to its AC counterpart are: higher reliability and efficiency, simpler interface control with renewable energy sources, electronic loads and energy storage systems.

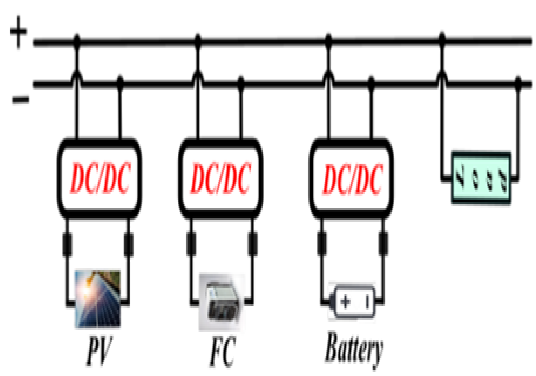


**Fig. 1: Typical DC MG Configuration**

In a typical DC microgrid configuration as shown in Fig.1, multipleDC sources such as, PV and Fuel Cell (FC) as well as battery storage system are interfaced to the DC point of common coupling (PCC) through individual converters. Dedicated converters in DC microgrids provide enhanced performance in terms of power management and control between different DC sources. However, this typical architecture leads to high system cost and large system footprint and weight. These issues have been addressed mainly by developing DC multiport topologies employing centralized control to manage power among sources.

**TABLE I: Comparison of Proposed Topology with Other Four and Five Port Topolog**

| Ref | No. of Switches | No. of Diodes | No. of L & C | Switches Max Voltage stress | Voltage Gain | No. of Ports | Availability and other limitations |
|---|---|---|---|---|---|---|---|
| [14] | 3 | 4 | 2 & 6 | $S_1 : V_{FC}$ , $S_4 : V_{C3}$, $S_2$ and $S_3 : V_{Bat}$ | $V_{out} = D_1 V_1 + (D_2 - D_1) V_2$ | 5 | Sources Availability (No restriction) but $V_1 > V_2 > V_3 > V_4$ |
| [15] | 2 | 3 | 1 & 3 | $S_1 V_{in}$ $S_2 : V_o$ | $V_1 = \frac{V_{in2} D_1 - V_T (1-D_2) + V_{in1}(1-D_1)}{D_2}$ | 4 | Sources Availability (No restriction) but $V_{pv} > V_o > V_{bat}$ and $R_2 > R_1$ |
| [16] | 3 | 4 | 3 & 5 | $S_1 : (V_0^+)/d_1$ $S_2 : V_{pv} - V_{bat}$ $S_3 : V_0^+$ | $V_{o1} = \frac{d_1 [V_{bat} d_2 + V_{pv}(1-d_2)]}{1-d_1}$ $V_{o2} = -\frac{d_1 [V_{bat} d_2 + V_{pv}(1-d_2)]}{1-d_1}$ | 4 | Sources Availability (No restriction) but $V_{bat} > V_{pv}$ |
| [17] | 4 | 2 | 2 & 3 | $S_1 : \frac{(1-d_3)V_2)}{(1-d_3)V_2 + (1-d_1)V_1}$, $S_2 : \frac{(1-d_1)V_1)}{3(1-d_3)V_2 + 3(1-d_1)V_1}$ $S_3 : \frac{(1-d_1)V_1}{(1-d_3)V_2 + (1-d_1)V_1}$ $S_4 : \frac{(1-d_2)V_1)}{d_4 V_2 + (1-d_2)V_1}$ | $V_o 1 = \frac{V_2}{1-d_2} + \frac{V_1}{d_4}$ $V_o 2 = \frac{V_1}{d_4}$ | 4 | Both sources should be available |
| [22] | 3 | 1 | 3 & 5 | $S_1$, $S_2$ and $S_4 : V_o$ | $V_o = V_{PV} + V_{bat}$ | 4 | Sources Availability (No restriction) but $V_o = V_{bat} + V_{pv}$ |
| Proposed | 4 | 0 | 2 & 5 | $S_1$ and $S_2$: $V_{pv} + V_{bat}$ $S_3$ and $S_4$: $V_o$ | $V_o = \frac{1}{1-D_4} V_{FC} + \frac{1-D_1-2D_4}{(1-D_4} (V_{PV} + V_{bat})$ | 5 | FC should be available no restriction for all sources voltages |

## 1.2PROJECT OVERVIEW:

The integration of renewable energy sources (RES) such as solar and wind power into existing power grids has gained substantial attention as a means to reduce dependency on fossil fuels and mitigate the environmental impacts of conventional energy generation. A particularly promising system for harnessing renewable energy at a local level is the DC microgrid. Unlike traditional alternating current (AC) grids, a DC microgrid operates with direct current (DC) and is primarily focused on renewable energy resources, energy storage systems

(ESS), and efficient power management technologies.

**Design and Topology of Multiport DC-DC Converters**

Designing a multiport DC-DC converter requires addressing several key challenges, including power management, voltage regulation, and efficiency. The topology of the converter plays a crucial role in determining how effectively these challenges are met. Various converter topologies have been proposed to address the needs of DC microgrids, each offering unique benefits based on the application's requirements.

**Basic Multiport Converter**: A basic multiport converter features multiple input and output ports to handle power from different sources and supply it to different loads or storage units. These converters can be based on simple topologies like buck, boost, or buck-boost converters, which are used for regulating the voltage and current between the various components in the microgrid. While basic multiport converters are relatively simple, they are suitable for small-scale microgrid applications where energy sources and loads operate at similar voltage levels.

**Bidirectional Multiport Converter**: Bidirectional converters are essential for modern DC microgrids, where energy can flow in both directions—either from the source to the load or from the energy storage back to the load. These converters are often used in systems with renewable energy sources and battery storage, allowing the battery to either charge or discharge based on the system's power requirements. Bidirectional converters are crucial for energy storage systems that need to manage both charging and discharging cycles efficiently.

**Isolated Multiport Converter**: In some cases, electrical isolation is necessary between the input and output stages of the converter, particularly when dealing with different voltage levels or when integrating certain energy sources with storage systems. Isolated multiport converters achieve this by using transformers, providing electrical separation between the different stages. These converters are highly beneficial in larger systems where voltage levels differ significantly between the components.

**Hybrid Multiport Converter**: Hybrid topologies combine different converter designs into one system. A hybrid multiport converter might integrate features of buck, boost, and isolated converters to provide greater flexibility and efficiency.

These converters can adjust to varying conditions in a microgrid, making them ideal for complex systems where multiple energy sources and storage options must be handled simultaneously.

**1.3PROJECT OBJECTIVE:**

**1. Basic Multiport converter**:

The increasing deployment of renewable energy sources (RES) in both residential and commercial settings has led to the emergence of DC microgrids as a viable solution for energy management. DC microgrids offer several advantages over traditional alternating current (AC) grids, particularly when integrating renewable energy sources like solar panels and wind turbines, which naturally operate on DC power.

**2. Bidirectional Power Flow and Voltage Regulation**

Another critical objective of a new multiport DC-DC converter is to ensure bidirectional power flow and robust voltage regulation for the DC microgrid. Many energy storage devices used in microgrids, such as batteries, require bidirectional power flow to allow both charging and discharging processes. A multiport converter should efficiently manage the bidirectional energy exchange between the power sources, storage systems, and the load.

**3. Improvement of Efficiency in Power Conversion**

Energy efficiency is one of the most crucial aspects of modern power systems, particularly in renewable-based DC microgrids. Multiport DC-DC converters must ensure high efficiency in converting and distributing power from the renewable sources to storage units and loads. Inefficient power conversion leads to energy losses, which can reduce the overall performance and economic feasibility of the microgrid system.

**4.Fault Detection and System Protection**

Reliability is paramount in any power system, especially in microgrids that operate autonomously or in remote areas. The multiport DC-DC converter must be designed with built-in fault detection and system protection features to prevent damage from faults like overvoltage, overcurrent, or short circuits. These protections ensure the long-term reliability and safety of the converter and the entire microgrid system.

## 2.LITERATURE SURVEY

The design and implementation of multiport DC-DC converters for smart grid applications have received significant attention due to the growing demand for efficient power management in modern energy systems. Smart grids require the integration of various energy sources such as renewable energy systems (solar, wind) and energy storage systems (batteries, supercapacitors), which necessitate advanced power converters capable of managing power flow between multiple ports. One of the key challenges is the seamless integration of renewable energy sources with the grid while ensuring stable power distribution.

Several studies have explored the use of multiport DC-DC converters to address these challenges. For example, Liu et al. (2013) proposed a novel multiport DC-DC converter for renewable energy applications, where a single converter manages power distribution between multiple input sources (solar panels, wind turbines) and multiple output ports (battery banks, DC loads). Their system utilized an interleaved structure to minimize ripple current and improve efficiency. The converter was designed to allow for energy exchange between various sources and storage elements, making it highly efficient for smart grid applications.

In 2015, Zhang and Xu presented a multiport DC-DC converter that utilized a multi-phase buck-boost converter topology. Their approach aimed at providing a flexible interface for renewable energy systems, facilitating bi-directional power flow between the energy sources, storage devices, and the grid. The study also highlighted the importance of maintaining the voltage levels and improving the overall system’s power quality. The design was based on an average current-mode control method, which allowed the converter to operate efficiently across a wide range of input voltages and load conditions.

In 2017, Tang et al. introduced a multiport converter for smart grid applications that integrated multiple renewable energy sources, including photovoltaic and wind energy, with an energy storage system. Their proposed converter architecture was based on a modular multi-port structure, allowing the converter to simultaneously charge and discharge multiple storage devices while interfacing with the grid. The converter design used a novel control strategy to optimize the power flow and ensure efficient energy distribution across the system.

Another important contribution was made by Abdullah et al. (2018), who proposed a multiport DC-DC converter for electric vehicles (EVs) and smart grid integration. Their work demonstrated the application of a hybrid converter that supported bidirectional power flow, making it suitable for both charging and discharging EVs while also supporting energy transfer to and from the grid. This design showed that multiport converters could effectively manage the power flow between renewable energy sources, storage devices, and loads, enhancing the overall energy management system for smart grid applications.

The current research indicates that multiport DC-DC converters provide an effective solution for smart grid integration, offering efficient power management between various sources, energy storage systems, and loads. The integration of renewable energy sources with advanced converters allows for the efficient distribution of energy, improved voltage regulation, and optimized grid operations. However, challenges remain in terms of control strategies, protection, and system reliability, which are areas of ongoing research.

## 3.METHODOLOGY

The design and implementation of a multiport DC-DC converter for smart grid applications involve several key stages, including system modeling, converter topology selection, control strategy development, and simulation and hardware implementation. The methodology begins with identifying the requirements of the smart grid application, which includes the integration of renewable energy sources (solar, wind), energy storage systems (batteries, supercapacitors), and connection to the grid.

The first step in the methodology is system modeling. The system is modeled to represent the interconnected components of the multiport converter, including the energy sources, storage devices, and load. The converter is designed to efficiently manage the power flow between these components, ensuring proper voltage regulation and current control. A mathematical model of the converter is developed, which includes the input and output voltages, current characteristics, and power flow dynamics. The model is used to analyze the behavior of the converter and to optimize its performance under different operating conditions.

The next step is to select the appropriate converter topology. The multiport DC-DC converter can be based on various topologies, such as buck-boost, flyback, or interleaved structures. The choice of topology depends on factors such as the number of input and output ports, the desired voltage conversion ratios, and the efficiency requirements. The topology is selected to minimize power losses, reduce ripple currents, and ensure reliable operation under varying input and output conditions. For smart grid applications, a modular design is preferred, as it allows for the integration of multiple renewable energy sources and storage devices.

Once the converter topology is selected, the next stage is to develop an effective control strategy. The control strategy plays a crucial role in ensuring that the converter operates efficiently and meets the power flow requirements. A typical control strategy for a multiport converter includes regulating the output voltage and current, ensuring proper voltage sharing between the ports, and optimizing the power transfer. A common approach is to use a hybrid control technique, such as peak current mode control (PCMC) or average current mode control (ACMC), which allows for stable and efficient operation. In some cases, a fuzzy logic or model predictive control strategy may be employed to handle dynamic and uncertain operating conditions.

After developing the control strategy, the system is simulated to validate the converter’s performance. Simulation tools such as MATLAB/Simulink are used to model the system and test its behavior under different operating conditions. The simulation results are used to fine-tune the design parameters, such as the switching frequency, filter components, and control gains. Performance metrics such as efficiency, voltage regulation, and power quality are evaluated.

Finally, the converter is implemented in hardware for practical verification. Power electronic components such as MOSFETs, diodes, inductors, and capacitors are selected based on the converter's design specifications. A digital controller, such as a microcontroller or FPGA, is used to implement the control algorithm. The system is tested in a laboratory setup, where real-time data is collected to validate the performance of the converter under different load conditions and disturbances. The results from the hardware implementation are compared with the simulation results to verify the accuracy and reliability of the design.

## 4.PROPOSED SYSTEM

The proposed system for the multiport DC-DC converter is designed to efficiently manage power flow between renewable energy sources, energy storage systems, and the grid for smart grid applications. The system integrates multiple DC sources, such as solar panels, wind turbines, and battery storage, into a single converter. This allows for efficient power management, voltage regulation, and load sharing across the system.

The system uses a modular multiport converter topology that supports multiple input and output ports. Each port is capable of handling power from a different energy source or providing power to different loads. The converter is designed to step up or step down the voltage levels, depending on the source and load requirements, while maintaining high efficiency and minimizing losses.

A key feature of the proposed system is its ability to support bi-directional power flow. This is important for applications such as grid integration and energy storage, where power may flow from the grid to the converter and from the converter to the grid or storage devices. The converter is also designed to operate under different modes, including charge, discharge, and grid-connected modes, ensuring flexibility and adaptability in smart grid applications.

The control strategy for the proposed system includes a hybrid approach that combines peak current mode control (PCMC) and average current mode control (ACMC). This ensures stable operation, improves efficiency, and reduces ripple currents. The system also employs maximum power point tracking (MPPT) algorithms to ensure optimal power extraction from renewable sources, such as solar panels. Furthermore, the converter's performance is optimized for low harmonic distortion and high power quality, ensuring compatibility with the grid and meeting regulatory standards.

The proposed system is designed to be scalable, allowing for easy expansion to accommodate additional renewable energy sources or storage devices. The modular design ensures that the converter can be adapted to different grid sizes and energy generation capacities. Additionally, the system is equipped with advanced protection mechanisms, such as overcurrent protection, overvoltage protection, and short-circuit protection, to ensure safe and reliable operation.

## 5.EXISTING SYSTEM

Existing systems for smart grid applications often use traditional DC-DC converters that are limited in their ability to handle multiple energy sources and storage systems simultaneously. These systems typically rely on individual converters for each source or storage device, which increases complexity and reduces overall system efficiency. In addition, the lack of integration between sources and storage devices can lead to poor power management, inefficient energy utilization, and increased system costs.

A common approach in existing systems is to use multi-stage converters, where a separate step-up converter and step-down converter are employed to handle different voltage levels. While these systems can provide the necessary voltage conversion, they suffer from increased losses and reduced efficiency due to the need for multiple stages of conversion. Furthermore, these systems often lack the flexibility to handle bi-directional power flow, making them less suitable for smart grid applications that require dynamic energy flow between sources, storage, and the grid.

Another limitation of existing systems is the lack of intelligent control strategies that can optimize power flow in real-time. Many existing converters use basic control techniques such as pulse-width modulation (PWM), which may not provide the level of dynamic control needed for smart grid integration. Advanced control techniques, such as model predictive control (MPC) or fuzzy logic control, are not commonly implemented in existing systems, limiting their ability to adapt to changing load conditions and renewable energy generation profiles.

Overall, existing systems are often less efficient and flexible compared to the proposed multiport DC-DC converter, which offers better power management, voltage regulation, and seamless integration with renewable energy sources and storage devices. The proposed system provides a more scalable, efficient, and adaptable solution for smart grid applications, addressing many of the limitations of existing technologies.

## 6.SIMULATION RESULTS AND DISCUSSIONS

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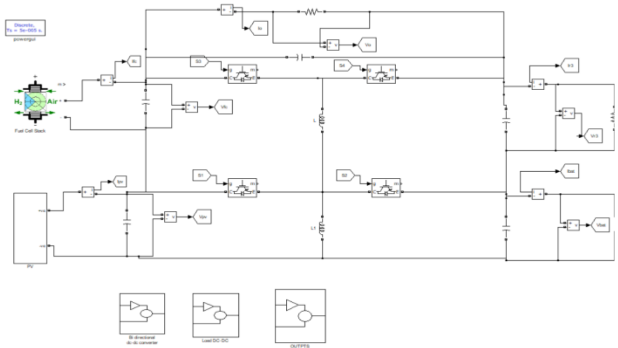
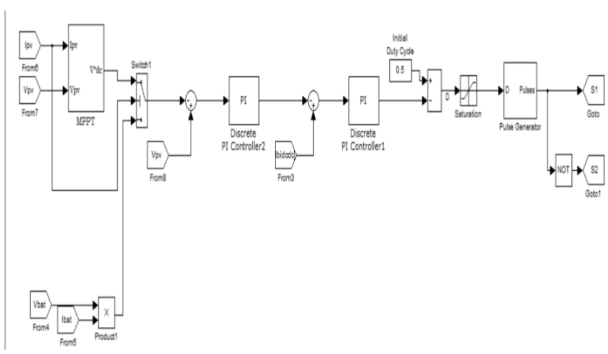
## 6.1 EXISTING SYSTEM:

### 6.1.1 CIRCUIT DIAGRAM:

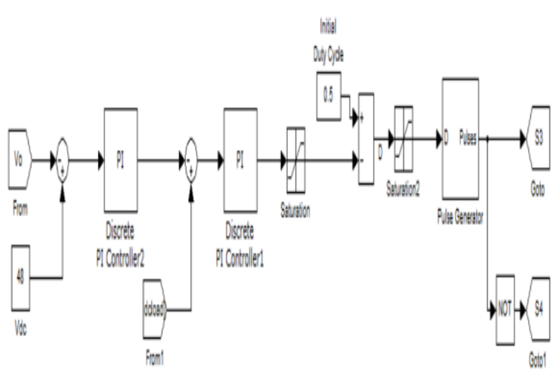


**6.1 Existing Multiport DC-DC Converter**

### 6.1.2 CONTROL LOOP:

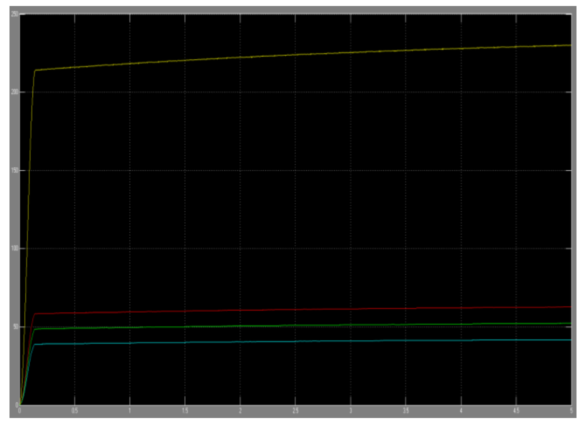



**6.1.2 Control structure of the existing topology.**

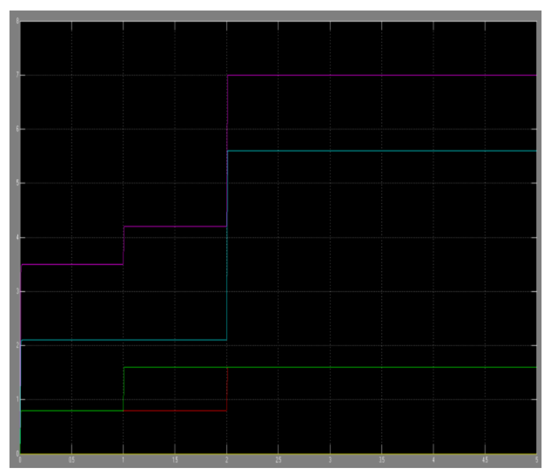



## 6.1.3 Control structure of the existing topology.

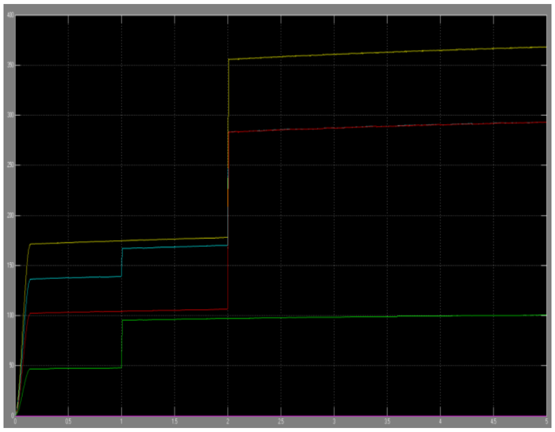
**OUTPUT VOLTAGE:**



**OUTPUT CURRENT:**

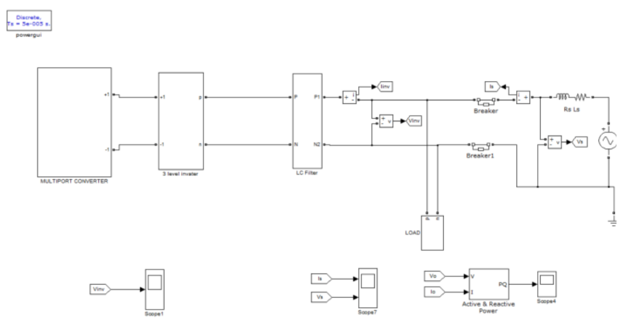


**OUTPUT POWER:**

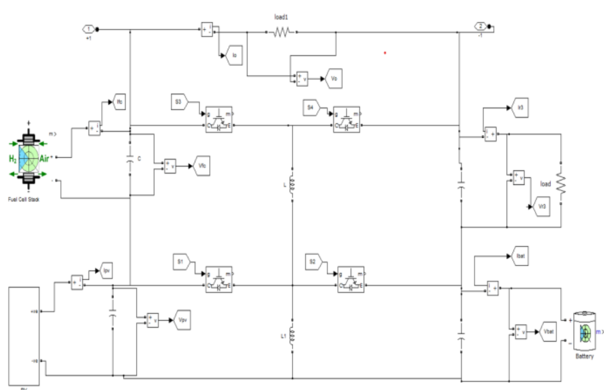


### 6.1.4 PROPOSED SYSTEM:

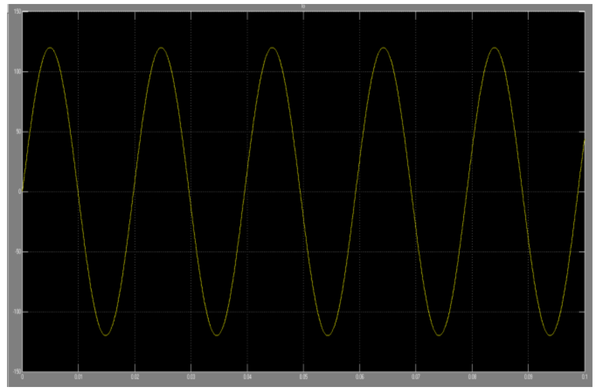
#### 6.1.4.1 CIRCUIT DIAGRAM:



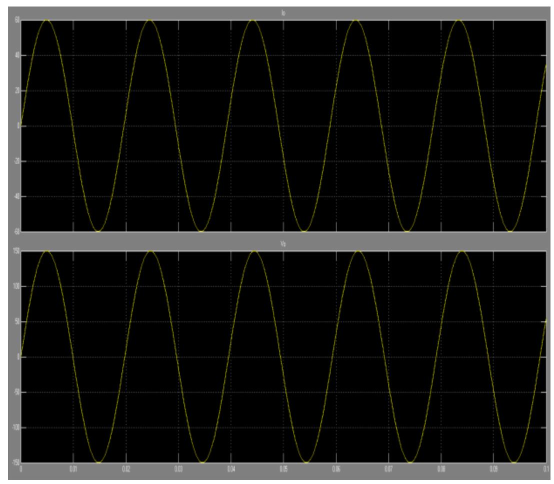

### OUTPUT:



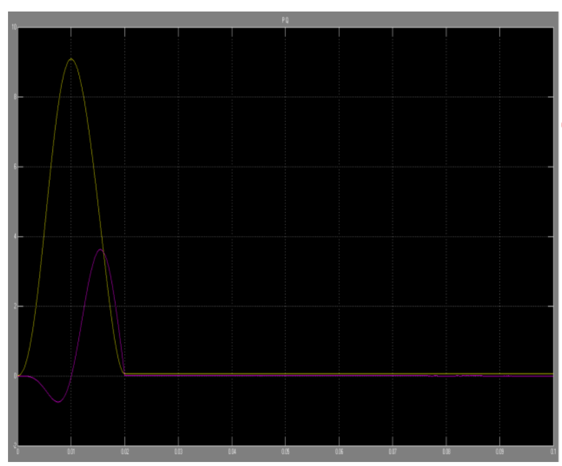

### VOLTAGE OUTPUT:



### CURRENT OUTPUT:



### POWER OUTPUT:



## 7. CONCLUSION

A new multiport DC-DC converter for DC microgrid applications had been presented. Three sources with two loads are interfaced to the proposed converter with minimum possible elements reducing power losses and system size. The bidirectional buck-boost structure of this new topology has shown a significant flexibility to connect sources and loads with different voltage and power levels. The control strategy is developed to achieve power control for renewable sources such as PV MPPT, in addition to a certain degree of resilience for DC sources availability maintaining boosted DC link voltage. The DC linkvoltage is strictly regulated in all operating modes proving that the proposed architecture has a substantial relevance among other configurations previously developed in the literature. The proposed converter's effectiveness and performance are evaluated and verified through both simulation and experimental results under different modes of operation.

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