RESEARCH PAPER

A FLEXIBLE MULTIPORT DC–DC CONVERTER FOR COORDINATED ENERGY MANAGEMENT IN HYBRID AC–DC MICROGRIDS

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ABSTRACT:

The increasing need for renewable energy integration into smart grids has prompted the development of advanced power converters capable of managing many energy sources and storage systems simultaneously. This paper details the design and execution of a multiport DC-DC converter that is specifically tailored for smart grid applications. The proposed converter is engineered to integrate various renewable wind and solar power, among others, photovoltaic (PV) power, with energy storage devices, such as batteries and supercapacitors. By efficiently controlling power distribution, regulating voltage, and enabling bidirectional power flow, the multiport converter enables smooth grid integration. The converter applies a hybrid control technique that combines peak current PCMC and ACMC are two controls that regulate the flow of current. in a modular topology to optimize power transmission, minimize losses, and reduce harmonic distortion. One such thing that helps get the most out using alternative power sources is optimal power point tracking (MPPT).

The proposed converter improves smart grid systems' efficiency, adaptability, and scalability, according to simulation and experimental results. A trustworthy and cost-effective method of integrating distributed renewable energy sources into modern grid infrastructures is offered by the proposed concept.

KEYWORDS: Many terms are used to describe power systems: MPPT, smart grid, renewable energy, power management, hybrid control, and multiport DC-DC converter.

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1. INTRODUCTION:

Electric power grids are currently undergoing a revolutionary period of digitization, decentralization, and decarbonization. Nowadays, DC micro grids (DCMG) have attracted more and more attention from both academics and businesses. Direct current distribution has many benefits over alternating current (AC) distribution, including improved efficiency and reliability as well as easier interface control with electronic loads, energy storage systems, and renewable energy sources.

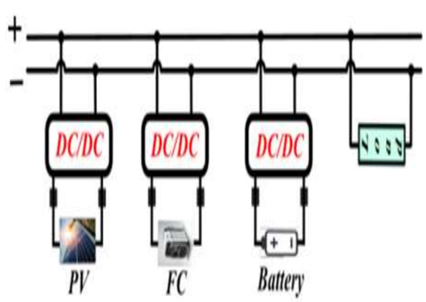


Figure 1: Common Setup for DC MG

Several DC sources, including photovoltaic At the DC point of common connection (PCC), systems for photovoltaic (PV), fuel cell (FC), and battery storage are linked. via separate converters in a conventional DC microgrid setup, as illustrated in Figure 1. When it comes to managing and controlling electricity across various DC sources, DC microgrids that utilize specialized converters offer better performance. Nevertheless, the usual design results in hefty system costs, footprints, and weights. Designing centralized DC multiport topologies for source-management has been the main approach to addressing these issues.

TABLE I: Evaluate the Suggested Topology in Light of Existing Four-and Five-Port Topologies

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	$S_1 : \frac{(1-d_3)V_2)}{(1-d_3)V_2+(1-d_1)V_1}$, $S_2 : \frac{(1-d_1)V_1)}{3(1-d_3)V_2+3(1-d_1)V_1}$ $S_3 : \frac{(1-d_1)V_1}{(1-d_3)V_2+(1-d_1)V_1}$ $S_4 : \frac{(1-d_2)V_1)}{d_4 V_2+(1-d_2)V_1}$	$Vo1 = \frac{V_2}{1-d_2} + \frac{V_1}{d_4}$ $Vo2 = \frac{V_1}{d_4}$	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:

To lessen use of fossil fuels and lessen the environmental effects of traditional energy production, there has been a lot of talk about incorporating alternative power sources like wind and solar into current power networks. The DC microgrid is an exciting new approach to localized renewable energy harvesting. A DC microgrid prioritizes efficient power management, sustainable power sources, batteries, and other energy infrastructure over conventional alternating current (AC) grids.

Design and Topology of Multiport DC-DC Converters

Power management, voltage regulation, and efficiency are three among the top important considerations when designing a multiport DC-DC converter. How well these difficulties are addressed is highly dependent on the converter's topology. A number of different converter topologies have been suggested to meet the demands of DC microgrids, with each one providing advantages specific to the application at hand.

Basic Multiport Converter:

The most fundamental kind of multiport converter has several input and output ports that allow it to accept electricity from various sources and distribute it to various loads or storage units. To control the flow of current and voltage among the microgrid's components, these converters can be built using basic topologies like as buck, boost, or buck-boost. Simple as they are, basic multiport converters work well in small-scale microgrids when the voltages of the sources and loads are close to one another.

Bidirectional Multiport Converter:

These days, DC microgrids wouldn't be complete without bidirectional converters, which allow power to travel in both directions: from generators to consumers and vice versa. These converters enable the battery that has to be drained or charged according to the power needs of the system, making them a common component in systems that incorporate sustainable power sources that can be stored in batteries. When it comes to managing repeated cycles of charging and discharging efficiently, energy storage systems aren't complete without bidirectional converters.

Isolated Multiport Converter:

Particularly when working with varying voltages or combining specific energy sources with storage systems, electrical isolation between the converter's input and output stages may be required. The use of transformers, which create electrical isolation between the various stages, allows isolated multiport converters to accomplish this. For more complex systems with widely varying component voltages, these converters are an absolute must.

Hybrid Multiport Converter:

Multiple converter designs are integrated into a single system using hybrid topologies. For maximum efficiency and adaptability, a hybrid multiport converter may include elements of isolation, buck, and boost converters. These converters are perfect for complicated systems that need to manage various energy sources and storage options all at once because of their ability to adapt to microgrid conditions.

1.3PROJECT OBJECTIVE:

1. Basic Multiport converter:

A new energy management solution, DC microgrids, have emerged given that the widespread use of renewable energy sources (RES) in homes and businesses. When it comes to incorporating sources of renewable energy, such wind turbines and solar panels, which fundamentally use direct current (DC) electricity, DC microgrids have several benefits over conventional alternating current (AC) grids.

2. Bidirectional Power Flow and Voltage Regulation

The new multiport alternating current-direct current converter also aims to regulate the DC microgrid's voltage effectively and allow electricity to flow in both directions. Microgrids rely on energy storage devices like batteries, which necessitate bidirectional electricity flow during power loading and discharge. It is important for a multiport converter to effectively control dual-directional energy flow between the load, storage systems, and power sources.

3. Improvement of Efficiency in Power Conversion

One of the most important parts of contemporary power systems, especially DC microgrids that rely on renewable energy sources, is energy efficiency. High efficiency in converting and delivering electricity from renewable sources to storage units and loads is essential for multiport DC-DC converters. Energy losses caused by inefficient power conversion lower the microgrid system's overall performance and economic viability.

4. Fault Detection and System Protection

Reliability is crucial in any power system, especially in microgrids that run autonomously or in distant places. The multiport DC-DC converter must be designed with built-in fault detection and system protection capabilities to avoid 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

There has been a lot of focus on developing and deploying multiport DC-DC converters for smart grid applications due to the growing importance of efficient power management in modern energy systems. Power storage and renewable energy sources (solar, wind) working together devices (batteries, supercapacitors) into smart grids necessitates the use of complex power converters capable of controlling the flow of electricity between several ports. One of the biggest obstacles is ensuring steady power distribution while seamlessly integrating incorporating renewable power sources into the framework.

Several studies have looked into the possibility of using multiport Using DC-DC converters to these problems. By way of example, Liu et al. (2013) proposed a unique DC-DC converter with many ports for use in renewable energy applications; this converter would regulate the flow of power from many input sources (for example, solar panels and wind turbines) in order to multiple output ports (such as battery banks and DC loads). Their technique utilized an interleaved structure to decrease ripple current and increase efficiency. The converter's ability to make it easier for energy to be transferred from one various sources and storage components makes it ideal for use in smart grid applications.

In 2015, Zhang and Xu presented a multiport DC-DC converter that relies on a multi-phase buck-boost converter design. Their plan was to provide a versatile interface for renewable energy systems as a means to enable the bidirectional flow of electricity among energy sources, storage devices, and the grid. The study also highlighted the need of maintaining voltage levels and improving the overall power quality of the system. The converter's ability to operate efficiently under different input voltage and load conditions was due to the design's reliance on an average current-mode management method.

In 2017, Tang et al. introduced a multiport converter for smart grid uses that integrated energy storage with various renewable power sources, including wind and solar. Their proposed converter design is based on a modular multi-port architecture, which allows it to charge and discharge multiple storage devices simultaneously and interface with the grid. A new control strategy was incorporated into the converter design to ensure efficient energy distribution and maximize power flow.

A multiport DC-DC converter for smart grid integration and electric vehicles (EVs) was proposed by Abdullah et al. (2018), who also made a significant contribution. They proved the feasibility of using a hybrid converter that could transfer power in both directions, which meant it could charge and discharge electric vehicles and connect to the grid. This design showcased the potential of multiport converters to enhance smart grid energy management systems by facilitating more precise regulation of power flows among loads, storage devices, and renewable energy sources.

Recent studies have shown that multiport DC-DC converters are an effective way to integrate smart grid technologies as they allow for efficient power management across various sources, energy storage systems, and loads. Modern converters, in conjunction with renewable energy sources, provide for better energy distribution, better voltage management, and more efficient grid operations. Nevertheless, there are still unanswered questions regarding the reliability of the system, security measures, and control mechanisms.

3. METHODOLOGY

Important aspects of designing and implementing a DC-DC converter with many ports for use in smart grid systems include system modeling, converter topology selection, control strategy construction, simulation, and hardware implementation. First, we need to figure out what the smart grid application requires. This includes things like hooking up to the grid, incorporating wind and solar power, and batteries, and supercapacitors are examples of energy storage devices.

The first stage of the methodology is system modeling. A system model is a representation of the interrelated components of a multiport converter, including resources, energy storage, and the burden. The purpose of the converter is to regulate the current and voltage between these components by controlling the flow of electricity between them. Among the many variables incorporated in the mathematical model the converter's performance its input and output voltages, current characteristics, and the dynamics of power flow. Using the model, we can optimise the converter's performance and study its behaviour under different operating conditions.

Next up is deciding on the best converter topology. The multiport DC-DC converter can be built on a number of different topologies, such as buck-boost, interleaved, or flyback. Topologies are chosen based on a variety of factors, including the quantity of input and output ports, the desired efficiency, and the voltage conversion ratios. Our goal in selecting this topology was to reduce ripple currents, power losses, and ensure reliable operation over a wide variety of input and output situations. Because it allows for the integration of several storage devices and renewable energy sources, a modular design is perfect for smart grid applications.

After deciding on the converter topology, the next step is to create an effective control strategy. The control strategy is crucial for ensuring the converter works well and meets the power flow requirements. Common control tactics for a multiport converter include regulating the output voltage and current, ensuring adequate voltage sharing among the ports, and maximizing power transfer. One common approach to achieving stable and efficient operation is to use a hybrid control system, such average current mode control (ACMC) or peak current mode control (PCMC). It is possible to employ fuzzy logic or a model predictive control method to handle unpredictable and ever-changing operational situations.

Following the development of the control plan, the system is simulated to ensure the converter is performing as expected. Using simulation tools such as MATLAB/Simulink, the system is modeled and its behavior is tested under various operating situations. The simulation findings inform the adjustments made to the design parameters, such as the switching frequency, filter components, and control gains. We measure efficiency, voltage control, and power quality as performance indicators.

Finally, the converter is built in hardware so that it may be tested practically. A variety of power electronic components, including diodes, MOSFETs, capacitors, and inductors, are selected based on the converter's design criteria. An FPGA or microcontroller is used as a digital controller to implement the control algorithm. The system is put through its paces in a controlled laboratory environment, where real-time data is collected to confirm the converter's functionality under different load conditions and disturbances. After the design is confirmed to be accurate and reliable, the results of the simulation and the hardware implementation are compared.

4. PROPOSED SYSTEM

Efficient management of power flow between the grid, energy storage systems, and renewable energy sources is the goal of the proposed system for the multiport DC-DC converter in smart grid applications. Solar panels, wind turbines, and batteries are just a few examples of the DC sources that can be integrated into this system's one converter. This paves the way for system-wide load sharing, effective power management, and voltage adjustment.

Multiple input and output ports are supported by the system's modular multiport converter structure. Power can be supplied to various loads or received from various sources by means of each port. The converter's design prioritizes efficiency and loss minimization in order to step up or step down voltage levels in response to source and load requirements. Supporting bidirectional power flow is a crucial element of the proposed system. In grid integration and energy storage applications, this is crucial since power can travel in both directions: from the grid to the converter and back again. To further guarantee versatility and adaptability in smart grid applications, the converter is built to function under several modes, including as charge, discharge, and grid-connected modes.

An technique that combines peak current mode control (PCMC) and average current mode control (ACMC) is part of the control strategy for the proposed system. Stability, efficiency, and less ripple current are all guaranteed by this. In order to get the most out of renewable energy sources like solar panels, the system uses maximum power point tracking (MPPT) algorithms. In addition to being grid compatible and satisfying regulatory criteria, the converter's performance is tuned for minimal harmonic distortion and good power quality. Because of its scalable architecture, the suggested system may easily be expanded to incorporate more renewable energy sources or storage devices. The converter can be easily adjusted to accommodate various grid sizes and energy generation capacities thanks to its modular design. To further guarantee safe and dependable operation, the system is outfitted with modern protective systems including overcurrent, overvoltage, and short-circuit protection.

5. EXISTING SYSTEM

Current smart grid solutions frequently employ antiquated DC-DC converters, which are incapable of managing several energy sources and storage systems all at once. This kind of system is notoriously inefficient and complicated since it usually uses separate converters for each source and storage device. Additional issues including inefficient power usage, high system expenses, and poor power management might arise from sources and storage devices not being integrated.

The employment of multi-stage converters, which include a step-up converter and a step-down converter to deal with various voltage levels, is a typical strategy in current systems. The essential voltage conversion can be accomplished by these systems, but the necessity for several steps of conversion results in greater losses and decreased efficiency. In addition, smart grid applications need dynamic energy flow between sources, storage, and the grid, and these systems frequently can't manage bidirectional power flow.

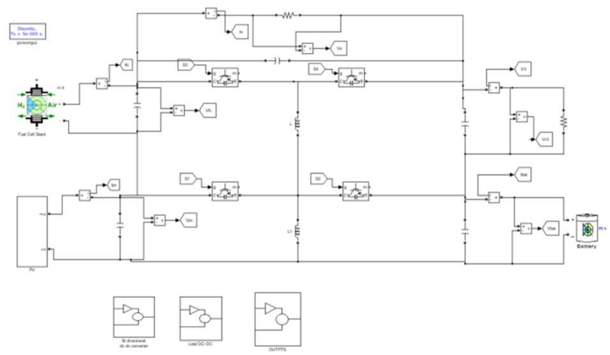
The absence of sophisticated control techniques capable of optimizing power flow in real-time is another drawback of current systems. It is possible that the current crop of converters, which rely on simple control methods like pulse-width modulation (PWM), lack the degree of dynamic control necessary to integrate with smart grids. Existing systems often do not use advanced control techniques like model predictive control (MPC) or fuzzy logic control, which limits their adaptability to changing load situations and profiles of renewable energy output.

The proposed multiport DC-DC converter provides improved power management, voltage regulation, and seamless integration with renewable energy sources and storage devices, outperforming existing systems in terms of efficiency and flexibility. By overcoming many of the shortcomings of current technologies, the suggested system offers a smart grid application solution that is more scalable, efficient, and flexible.

6.SIMULATION RESULTS AND DISCUSSIONS

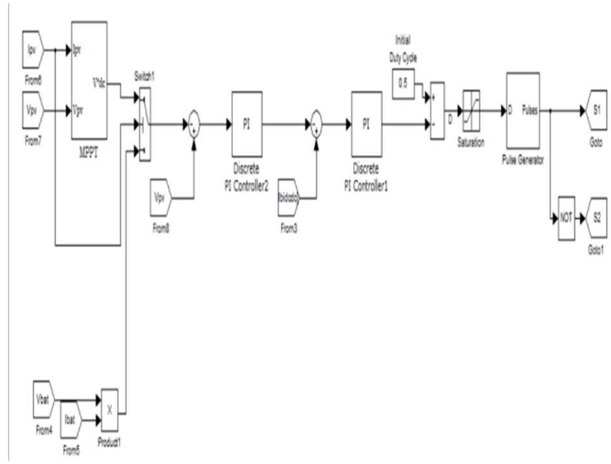
6.1 EXISTING SYSTEM:

6.1.1 CIRCUIT DIAGRAM:

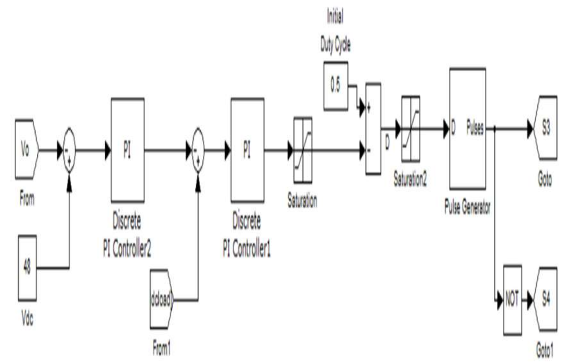


6.1 Existing Multiport DC-DC Converter

6.1.2 CONTROL LOOP:

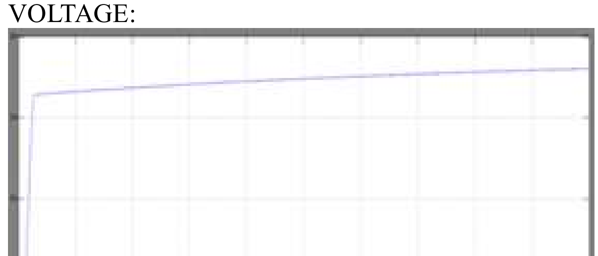


6.1.2 Control structure of the existing topology.

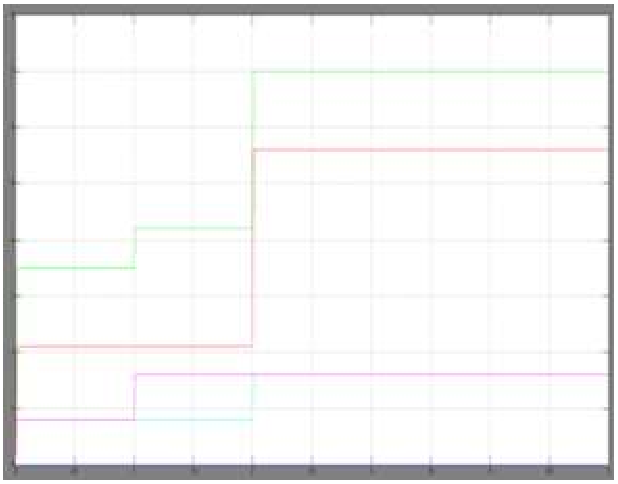


6.1.3 Control structure of the existing topology**.**

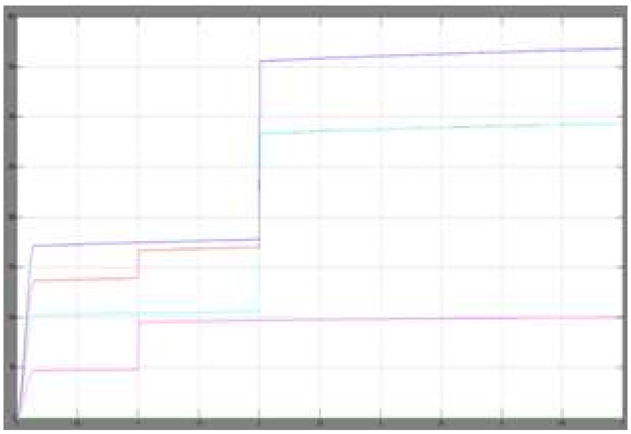
VOLTAGE:



CURRENT:

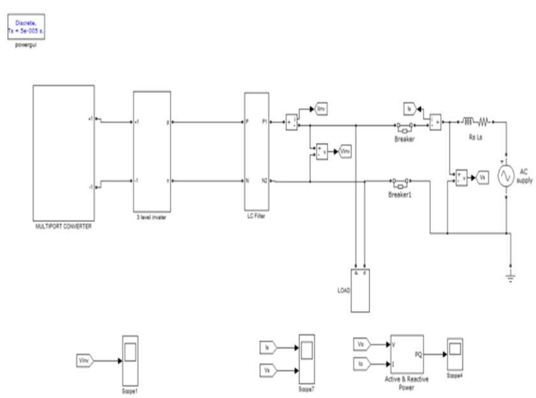


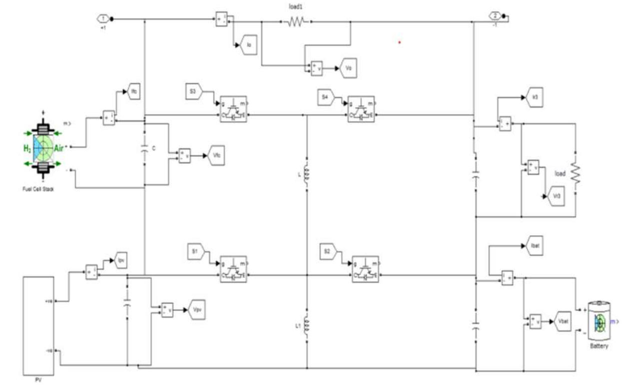
POWER:



6.1.4 PROPOSED SYSTEM:

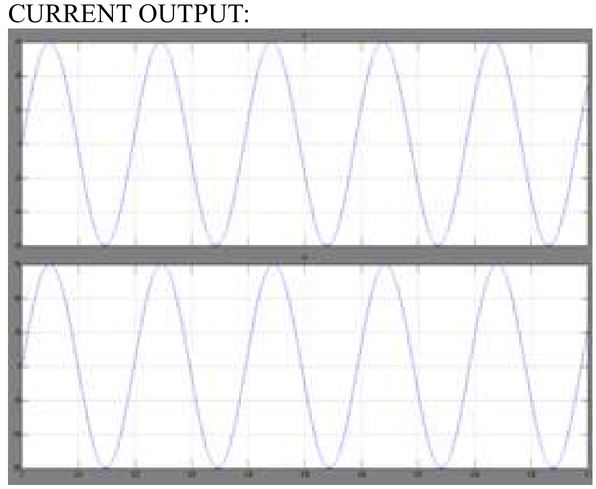
6.1.4.1 CIRCUIT DIAGRAM:



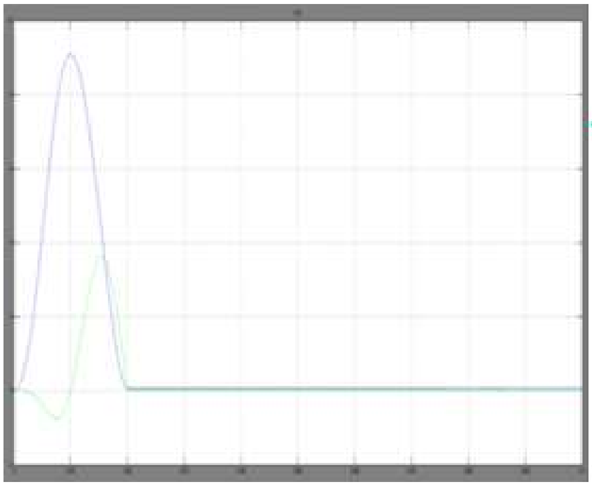


VOLTAGE OUTPUT:

CURRENT OUTPUT:



POWER OUTPUT:



7. CONCLUSION

For use in DC microgrids, a novel multiport DC-DC converter was introduced. The suggested converter interfaces three sources with two loads, using minimal components to reduce power losses and system footprint. This innovative topology's bidirectional buck-boost construction is very adaptable for connecting loads and power sources that vary in terms of both voltage and output. This method of control is specifically engineered to accomplish power control for renewable energy sources, such as PV MPPT. and to maintain boosted DC link voltage with DC sources must be resilient to a certain extent. By consistently controlling the DC link voltage throughout all modes of operation, the suggested design stands out from other setups seen in the literature. Results from both modeling and experiments, conducted under varying operating conditions, are used to assess and confirm the efficiency and performance of the suggested converter.

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