High-Performance DC-DC Power Converter with Fuzzy Logic Control for Microgrid Applications

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ABSTRACT: An innovative fuzzy logic controller (FLC)-operated high-gain DC-DC converter architecture based on non-coupled inductors is presented in this work. Integrating renewable energy sources as a microgrid is necessary to fulfil electricity demand. Typically, lower voltage levels are produced by distributed energy generation (DER) sources, such as solar panels and fuel cells. Connecting to the grid requires high gain DC-DC converters. How well these converters work determines how well the microgrid works as a whole. This study designed an FLC controller to improve the DC-DC converter network's operation, leading to higher voltage gains and power levels. The DC-DC converter is controlled by a single pulse width modulation (PWM) signal in the suggested method. Among the many benefits of the suggested converter topology is the fact that it allows for large voltage gains with a minimum amount of semiconductor components. In order to confirm that the approach is successful, a simulation study was run under two different dynamic operating conditions: one where the input voltage was altered while the load was kept constant, and the other where the load was varied while the input voltage remained stable. The suggested control method outperformed the alternatives in both cases, maintaining a stable state and devoid of ripple in the output voltage.

KEYWORDS: HIGH GAIN, DC-DC, FLC, DER, PWM.

I.INTRODUCTION: When working with low-voltage direct current (DC) inputs, high-gain DC-DC boost converter are crucial for increasing the DC voltage levels to much greater values [1]. The input current & step-up capability of these converters from DC to DC must be constant. Among the many uses for such converters are electric cars, robots, high-voltage DC systems, and solar photovoltaic, or PV, panels [2, 3]. Although fuel cells and solar photovoltaics provide very little energy, the output voltage needed for a wide range of residential and commercial uses is rather high. Because of these critical issues, scientists are able to devote more time and energy to creating high-step-up DC-DC converters. An assortment of diodes, capacitors, inductors, and switches make up a DC-DC converter. The interconnections between these parts allow the inductors and capacitors to exchange energy.

The first step is for the inductors to trade their stored energy for energy. Then, a greater voltage level is achieved by transferring this stored energy to the capacitors [4]. You may see a DC power system diagram in Figure 1. The DC voltage in a DC microgrid is controlled to a certain level via a high-gain DC-DC converter. A high-gain DC-DC converter and super capacitors are the tools of choice for modern DC microgrids. It is usual practice to provide alternating current (AC) loads in the islanded mode operating of a DC microgrid by pairing a transformer with a high-gain DC-DC converter. A growing number of applications have begun to choose high-gain DC-DC converters over more conventional boost converters and variations thereof [5]. The traditional DC-DC boost converter isn't without its flaws. For real-world uses where the ratio of duty goes above a certain point, it isn't a good choice because of issues including excessive voltage stress, surge EMI, unbearable current input ripples, and poor efficiency under light load situations.

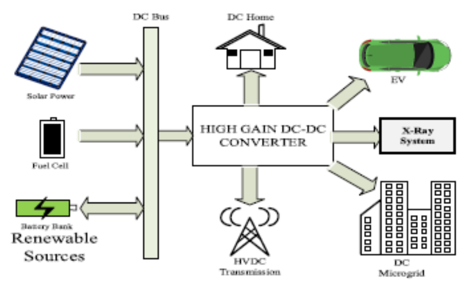


FIGURE 1. DC energy system.

Connecting the power supply to the load, DC-DC converters play a crucial role. There are two main kinds of these converters: isolated and non-isolated. When connected to microgrids, traditional boost converters, shown in Figure 2 (a), need to run at higher duty ratio levels. The converter is subjected to extreme voltage and current stress as a consequence of this. Increases in the duty ratio cause the inductor's and capacitor's parasitic resistance (ESR) to grow exponentially, cutting down the boost converter's voltage gain and efficiency. There are two further ways to categorise non-isolated converters: coupled inductor &

noncoupled inductor-based. Isolated converters separate the input power source from the load electrically. To stop electricity from flowing directly through the circuit, it uses a high-frequency transformer to split it in half. The downside is that it makes the converter bulkier and more expensive [6, 7, 8, 9]. When the source and load need to share a ground, such as in high-power applications, isolated arrangements are the way to go. At lower duty ratios, linked inductor designs may produce remarkably large voltage gains; but, at higher duty ratios, they pose problems such leaking inductance, poor efficiency, conduction loss, switch voltage stress, and other similar concerns [10]. In this study, non-isolated non-coupled circuit topologies are considered in detail. When there's no need to separate the input and output, non-isolated converters are the way to go.

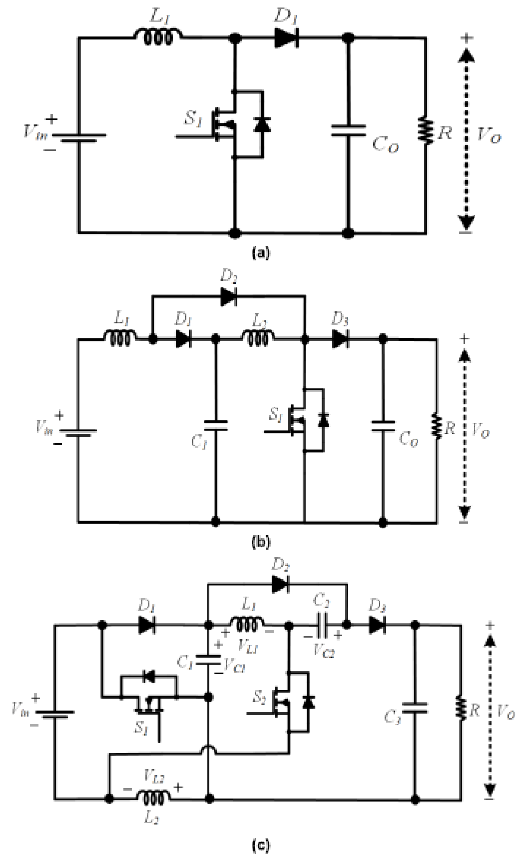


FIGURE 2. **(a) Conventional boost converter (b) Conventional quadratic boost converter (c) Proposed high gain boost converter.**

This article proposes a number of different DC-DC converter topologies to address these issues. A number of non-isolated high step-up DC-DC converters are compared in the proposed research. There have been several architectures of quadratic boost converters (QBCs) established. By reducing the load on the switching devices, these topologies are able to generate very high voltages at fewer duty cycles; but, the inductive core is more prone to saturation at higher duty ratios. Inductive current ripples & switch stress are minimised in this innovative quadratic boost converter. The suggested research reveals a quasi-z-source converter. Operating within a restricted duty cycle range, this converter substitutes an impedance network from the high-gain converter with boost design for the inductor. Presented here is an interleaved booster converter that improves efficiency and output voltage with a minimum of switches.

II.SYSTEM CONFIGARATIONS:

A high-gain DC-DC connection connected with an FLC is schematically shown in Fig. 3. Using active switches (S1 as well as S2) and passive parts to gate low voltage/high voltage, the converter combines buck and boost stages. In order to achieve the target output voltage (Vo), the FLC is crucial.

There are essentially two parts to the converter topology that has been proposed: The first switch, S1, controls the Buck Stage, which reduces the input voltage. o The boost stage raises the voltage that enters the buck stage to the level of the desired output; this stage is controlled by switch S2. By comparing the determined output voltage (Vo) with the original input voltage (Vref), the fuzzy controller gets feedback. The FLC's ability to operate the PWM generator is dependent on the error signal. In order to reduce ripple in the output voltage and load, this module converts the fuzzy controller's control signals into pulse width modulation (PWM) signals. These signals are then used to drive the two active switches (S1 and S2) in the electrical power stage, as well as a filter (C3).

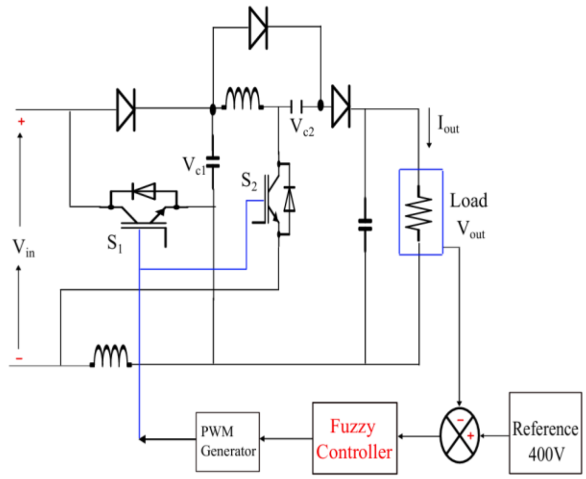


Fig.3 closed loop circuit diagram of fuzzy based DC-DC converter

High voltage increases are possible because to the buck and boost stages working together, making this an ideal DC microgrid component for a wide range of uses. Stable operation under changing load circumstances and input voltage variations is ensured by the robust and adaptive control provided by the fuzzy controller. The architecture and control technique of the converter are engineered to reduce power losses to an extreme degree, leading to an exceptionally efficient device. This system provides a potential answer for dependable and efficient power management in DC microgrid settings by combining the benefits of fuzzy logic control with a flexible power stage.

Proposed fuzzy controller:

Applications in control systems benefit greatly from fuzzy logic, a kind of if/else condition that enables approximate reasoning. Figure 4 shows the criteria that FLC utilises to find the right switching signals, which are based on mistakes and changes in errors. The DC-DC converter's input-output voltage profiles provide the basis for the organisation of these regulations. The DC-DC topology's performance may be optimised by using these principles to create a set of switch signals via the fuzzy controller.

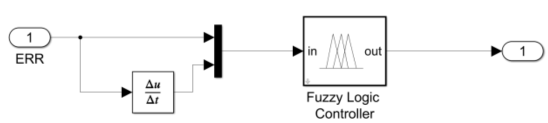
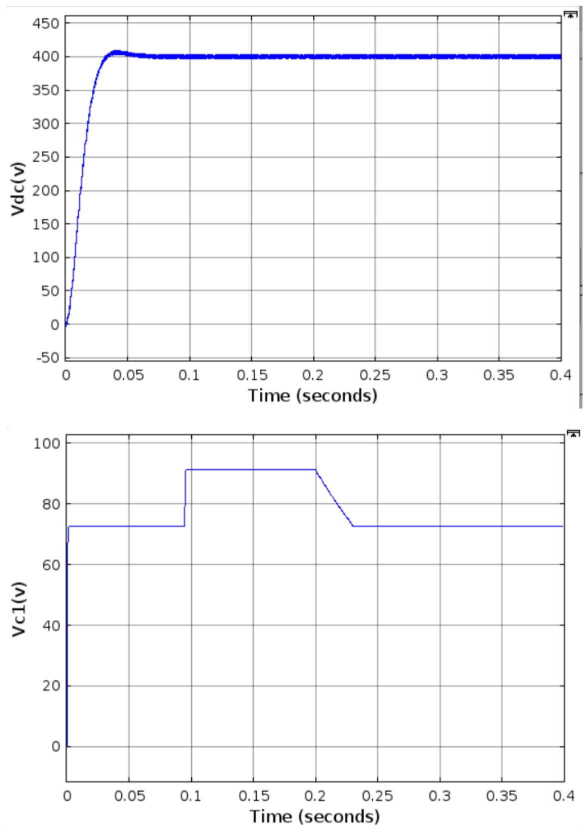
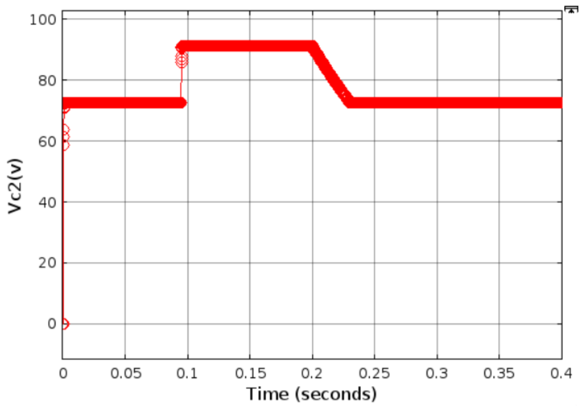


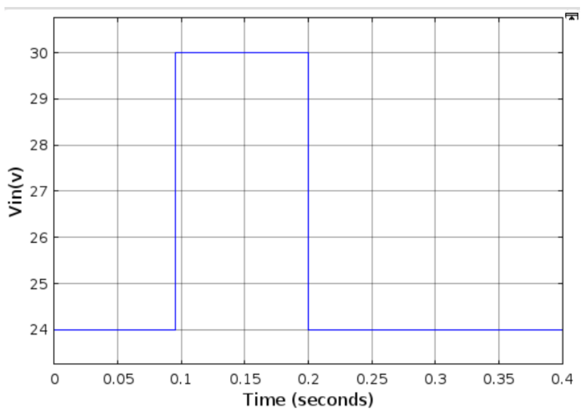
Fig.4 Schematic of FLC control

Several variables, including saturation, dead periods, and parasitic resistances, impact high-gain DC-DC converters, causing them to display nonlinearities. It greatly enhances the converter's stability and makes it capable of operating under dynamic load circumstances. The controller must function even in the presence of outside disturbances, such as changes in input voltage. These intricacies are often too much for traditional PID control approaches to manage. By simulating human-like thinking and decision-making, FLC provides a resilient and flexible solution.

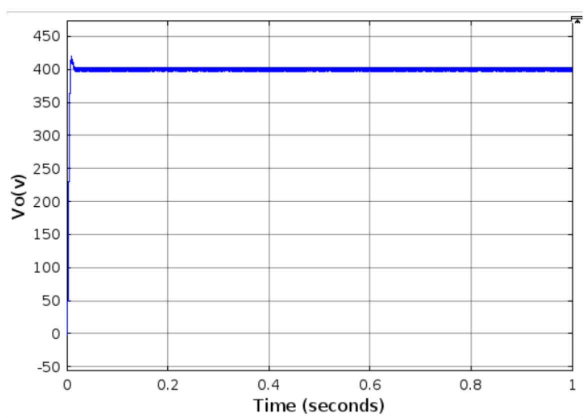
III.SIMULATION RESULTS

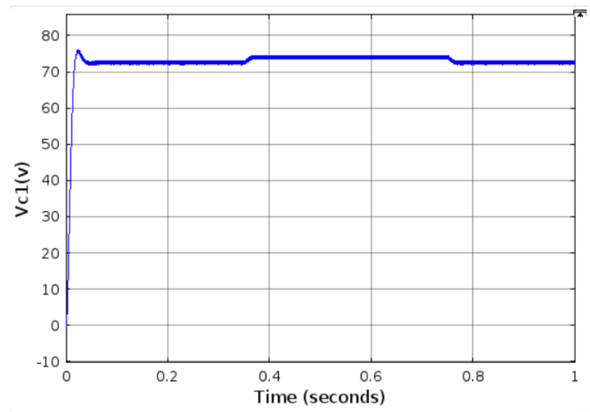


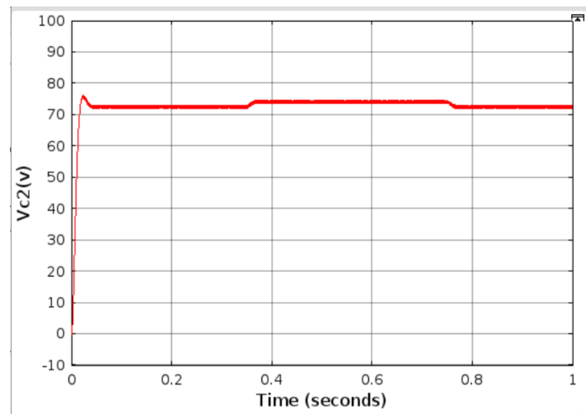


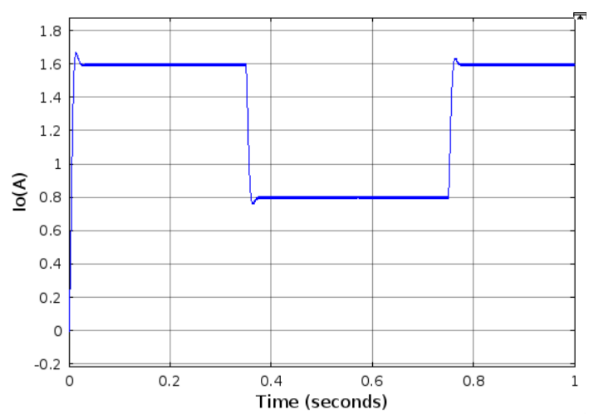


Case2



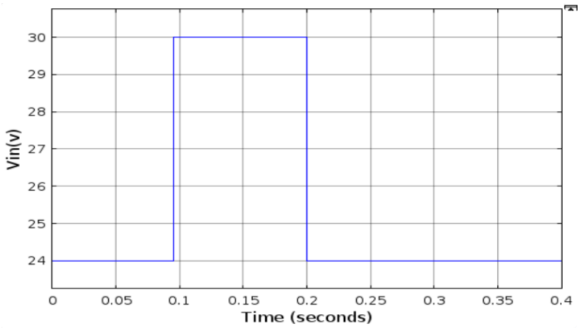


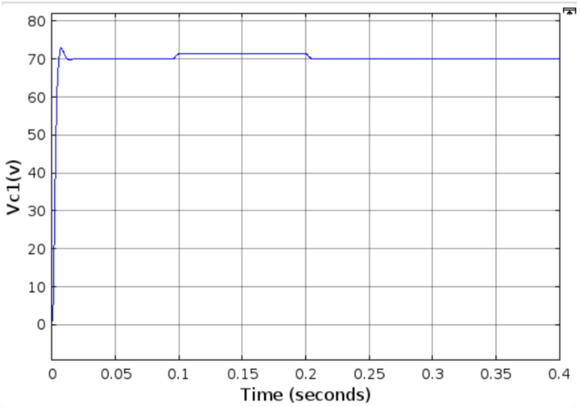


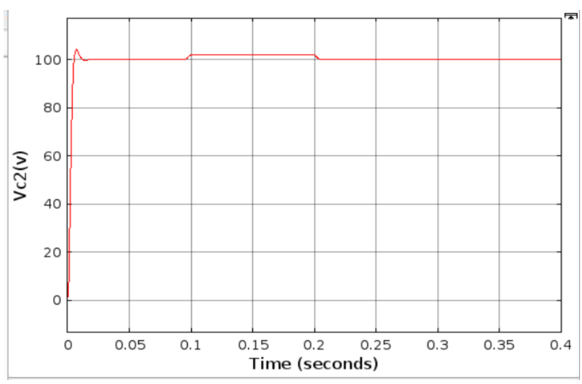


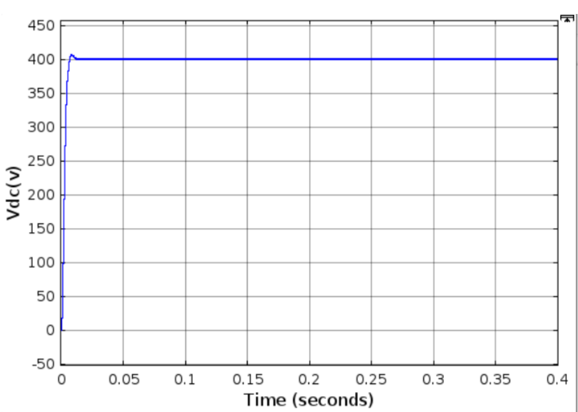
EXTENTION WITH FUZZY LOGIC CONTROLLER

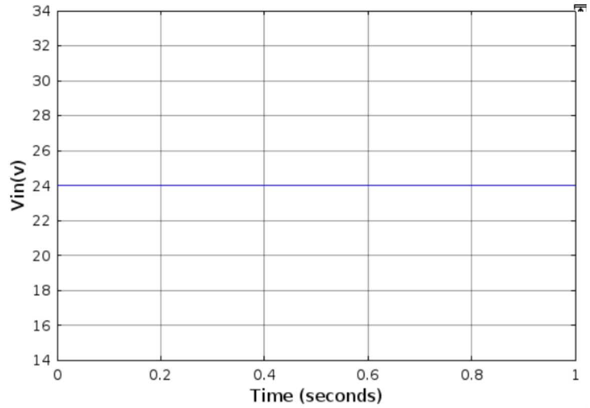
Case1

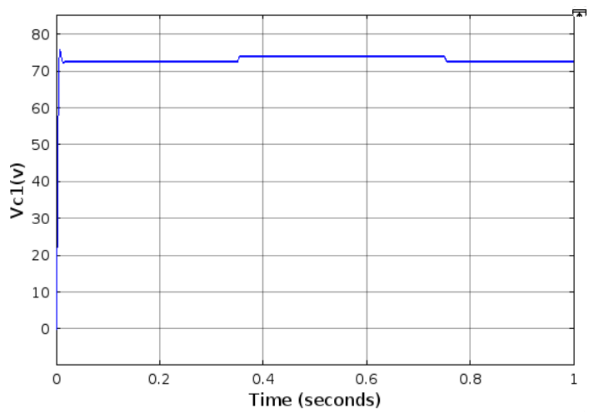

Vin(v)
30
29
28
27
26
25
24
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Time (seconds)

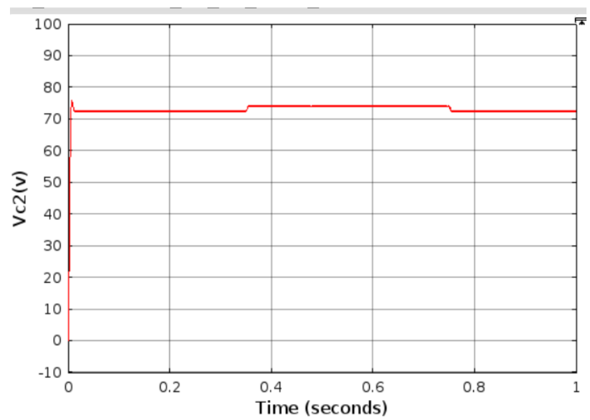

Vc1(v)
80
70
60
50
40
30
20
10
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Time (seconds)


Vc2(v)
100
80
60
40
20
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Time (seconds)

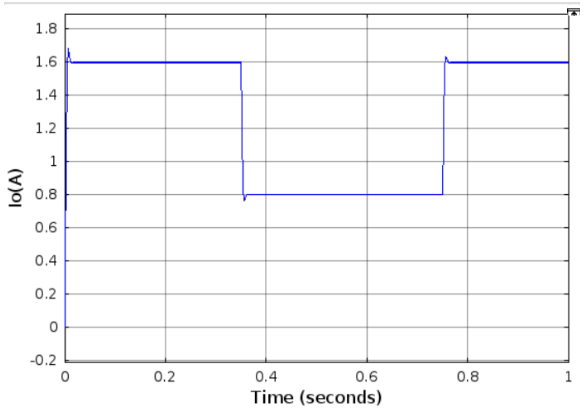

Vdc(v)
450
400
350
300
250
200
150
100
50
0
-50
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Time (seconds)

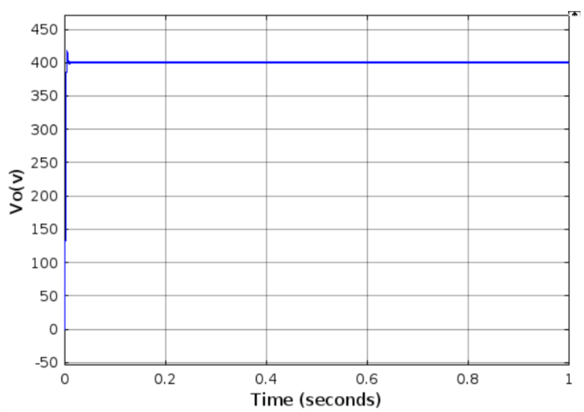

Vin(v)
34
32
30
28
26
24
22
20
18
16
14
0
0.2
0.4
0.6
0.8
1
Time (seconds)


Vc1(v)
80
70
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
Time (seconds)


Vc2(v)
100
90
80
70
60
50
40
30
20
10
0
-10
0
0.2
0.4
0.6
0.8
1
Time (seconds)

Case2





IV.CONCLUSION

This publication presents a new DC-DC converter that integrates renewable energy sources with microgrid applications. The converter is based on fuzzy controllers. Improving highly competent power converters is crucial for connecting solar and fuel cell sources to the microgrid because of the low voltage levels they often provide. With its straightforward design and potential for use in practical high-gain power applications, the suggested network architecture is an attractive option. The suggested converter outperforms the competition with a significant increase in voltage. Nevertheless, the suggested method does away with EMI interfering and its associated losses as it does not need connected inductors. The simulation results show that the suggested technique successfully maintains the target steady-state output voltage. Voltage gain is one measure of performance for the planned FLC-based DC-DC network.

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