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# **Efficient Energy Management in DC Nanogrids: A Dual-Buck-Boost Converter Approach using MATLAB Simulation**

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**ABSTRACT:** Because of the commonly used DC defined loads and growing localized power supply sources, and it's regarded as an alternate option for the AC power grid as DC nanogrid becoming very trendy. For safety reasons, the DC nanogrid must provide stable grounding that supports the consumption, which utilizes the lower voltage alternating current electrical system. Usual grounding topologies for a DC nanogrid are of three types: the unified grounding, the unilateral grounding, and a virtualized ground isolation. Individual grounding arrangement has distinct criteria to AC/DC converters. As part of this study, an AC/DC dual buck-boost converter to be utilized with a unified grounding system DC nanogrid comprising three terminal outputs has been suggested with the help of MATLAB software. The principle of operation of this converter has been explained thoroughly through studying the corresponding circuits. Studies were carried out to validate the theoretical evaluation in MATLAB simulation.

**KEYWORDS:** DC nanogrid, Grounding topologies, AC/DC converters, Dual buck-boost converter, MATLAB simulation.

## **I. INTRODUCTION**

The dispersed electricity production is growing more and preferable because of the long-term limited availability of electricity and the global difficulties created by the conventional energy. A significant amount of distributed generating infrastructure, like a solar power plant, are nowadays integrated with the AC power system, where they could generate challenges including power surge and complications associated with the safety [1]. Additionally, the increasingly loads show direct current attributes for instance, fluorescent lighting, machines supplies, and household utilizing variable frequency technology electric equipment. DC nanogrid can be a beneficial approach to deal with the power surge and safety complications of all traditional power distribution system and may eliminate the common AC/DC converters for DC specific loads, which can contribute with decreased power loss and resource reductions [2].

In recent years, studies on DC nanogrid establishes more and more significance, particularly for the controlling of AC/DC configurations, that are correlates with among DC nanogrid and its typical alternating current electrical scheme. It must be observed that while establishing the DC nanogrids AC/DC converters, and grounded structure needs to be considered [1], [2], as it affects the expenditures, the convenience of the assembly process and the effectiveness of the DC-based local power infrastructure. The DC nanogrid has the capacity to effortlessly introduced through the existing reduced voltage electrical grid to generate a composite electric system depending on the unified grounding. However, owing to the less withstanding capacity voltage over the switching elements; such arrangement needs sophisticated otherwise complex AC/DC converters to accommodate to the surge voltages. Due to the AC/DC converter, unidirectional grounding configuration could employ basic design converters. But the result from the step-down transformer employed in this development incapable of being linked to the additional low AC domestic loads straightaway. Constructing the DC nanogrid as required is highly adaptable in virtual isolation ground arrangement. But it dwells in the additional loss of power caused by the added isolation transformer in addition to the potential multiple converters. To assure the grid reliability, majority of home applications are necessary to relate to ground line. Therefore, in the DC nanogrid, similar to the AC grid with low voltage, it is very essential to have a ground line.

## II. LITERATURE REVIEW

The development and utilization of DC power sources from renewable energy is discussed in [3]. The demonstration of a novel buck-boost AC/DC converter designed for nanogrid with DC voltage and the increasing demand of two-terminal DC output over three-terminal output because of infrastructure considered. A comparison of various attributes of the suggested approach to current AC/DC buck-boost converters based on unified grounding configuration was additionally examined in this research. Researchers also conducted assessments with a 220-volt, 800 watt and 50 Hz prototype, generating AC grid voltage using an automated alternating current source (Chroma 6530) and evaluating the effectiveness of the converter with the help a digital energy meter. Experimental finding from the prototype verifies the efficient operation as well as performance of the proposed configuration of DC output in DC nanogrid applications. The constraint of the study is that it has lower performance in contrast to other converters because of the utilization certain laboratory resources, such as hardware. A dc/dc converter having three-port along with a system for control incorporating the use of solar panels and batteries for storage of energy in a DC nanogrid, providing efficiency and affordability, dependability, bidirectional flow of power, and versatility in supporting various applications is provided [4].

The suggested system for control effectively makes use of the duty cycle and frequency of switching to control power flow across the three ports. By combining theoretical research and practical findings, it verifies the practicality and better efficiency of the suggested converter. The recent resurgence of DC grids because of the research and implementation sustainable DC sources of energy, as well as the successful incorporation of AC electricity in various levels of voltage is explored in [5]. It also demonstrates the functionality of the hybrid grid in grid-tied mode, where the primary converter supplies steady DC bus voltage in addition to required reactive power. The process comprises theoretical reflection and simulation for validating the suggested method of control algorithms. The shortcoming of the research involves practical challenges with establishing the AC current dominated infrastructure for the hybrid grid and the fact that overall system performance relies on the elimination of losses during conversion and the increase for an additional DC link and it's challenging that businesses have to completely redesign their office and residential offerings without integrated AC/DC rectifiers. An in-depth study of enhanced quality of power converters (IPQCs) and their advanced level of advancement for AC/DC transformation, demonstrating high power factor, decreased harmonic currents, low interference from electromagnetic sources, and adequately regulated DC output for an extensive variety of applications is described in [6]. The shortcoming of the research involves the requirement for trade-offs among effectiveness and expense when determining an arrangement within the same class of IPQCs, the fact that there are additional possibilities for power quality enhancement in AC/DC conversion, and the opportunity for additional improvements in device technology, processors in the system magnetics, and algorithms for control that could improve IPQCs soon. The idea of microgrid and investigated difficulties associated with distributed energy systems and suggests active ways for reducing capacitance for single-phase inverters and rectifiers was implemented [7].

The approach comprises the development and manufacturing of a laboratory prototype, validation of the recommended power decoupling technique as well as control methods, and the presentation and evaluation of the results of the experiment. The key limitation of the study addresses the possibility that the lifespan of electrochemical capacitance's being lower than the lifespan of solar modules and semiconductors, establishing an obstacle to the entire long-term dependability of power sources. Also, the control strategy and monitoring is more sophisticated in three port converters and it is challenging than that of a two-port converter. An advanced AC/DC buck-boost converter having the ability of its voltage outputs self-sustaining by employing an integrated inductor developed [8]. The approach involved reviewing the corresponding components of the suggested converter, developing a small-signal analysis and control schematic, and evaluating its effectiveness through the construction of a prototype. They designed a 220-volt, 50 Hz and 1.5 Kw prototype, then implemented an algorithm for control utilizing a digital signal processor for taking measurements of input AC voltage, output direct current voltages, and inductors current. Reference [9] proposed a novel form of DC-DC boost converter for operations of DC microgrid. The primary outcome of the investigation is the performance assessment and contrast of the suggested converter design with current power converter architectures. The approach encompasses the incorporation of input sources, calculation of the steady-state output equation and a small-signal model. After that the simulation study was carried out and then production and testing of a laboratory prototype was completed with the execution of an algorithm for control using dSPACE 1104. The final performance evaluation compared with present configurations.

### III. METHODOLOGY

There are three main grounding setups: unified grounding, unidirectional grounding, and virtual isolation grounding. These will be explored in subsequent sub sections.

#### A. Configuration of Unified Grounding

In this approach a reduced power AC configuration and the direct current nanogrid utilize the common grounding connection. Fig. 1 illustrates a standard AC/DC converter schematic diagram [10]. Significance of unified grounding design is that the DC nanogrid may conveniently be introduced within the existing reduced voltage electric power grid to produce a hybrid electric system. The downside includes typically because of reduced voltage appliances, majority of the initial less voltage electric power grid systems are unable to utilize this design and shares the same grounding connection straight with the direct current nanogrid, if no particular or complex converters are chosen. Simultaneously, the direct current nanogrid must employ a bipolar voltage configuration with triple output terminals.

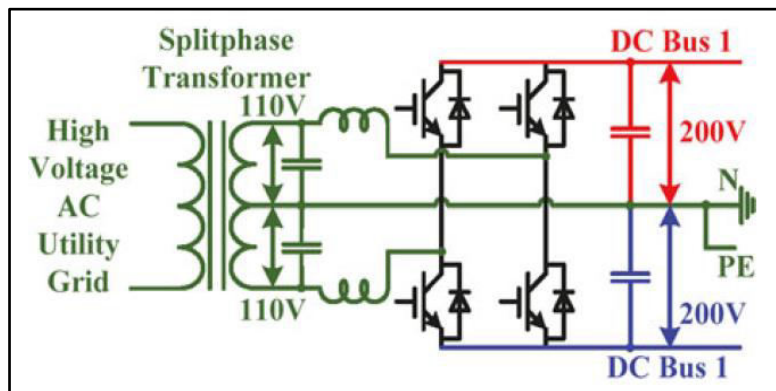


Fig. 1. Conventional AC/DC Power Converter for Integrated Ground DC Microgrid Setup.

#### B. Configuration for Unidirectional Grounding

Considering step-down transformer provides an appropriate reduced voltage for direct current nanogrid, such alternating current voltage is often less compared to the typical AC voltage. For instance, step-down three-phase transformer might produce 200-volt phase-to-phase voltage, not meeting the 380-volt specification. Direct current power with the desired output DC voltage and energy rating is obtained using an AC/DC converter by changing the alternating current.

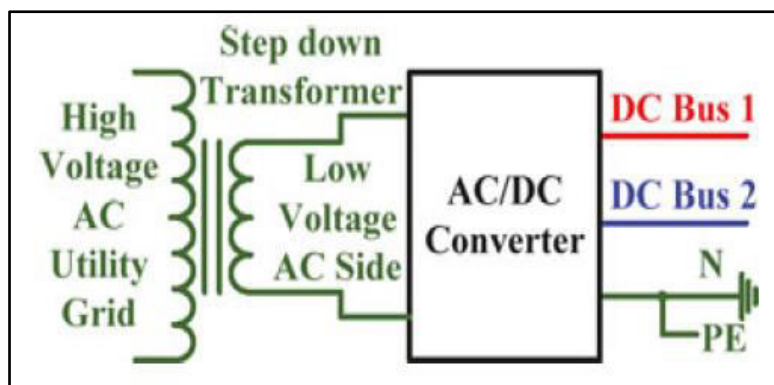


Fig. 2. Configuration for Unidirectional Grounding.

### C. Configuration for Virtual Isolation Grounding

As described in A and B sub-section above, it is not simple to comprehend that the hybrid alternating and direct current grid system with the common grounding connection because of the small voltage components. Therefore, the virtual isolation grounding arrangement was established [2], [13], [14], and it has two main approaches using distinct kinds of transformers as illustrated in figure 3. Figure 3 (a) illustrates the configuration of virtual isolation grounding employing a line transformer [2], [14]. This approach is identical to the unilateral grounding arrangement; however, the transformer typically links to the AC power network with low voltage. rather than with AC electrical high-voltage system. Figure 3 (b) demonstrates the ground isolation through high frequency linking transformer in a virtual configuration [13]. Distinct with this method indicated in Figure 3 (a), the linking transformer with high frequency is employed, and dual converters are employed to transmit the power. Because of the enhanced effectiveness of the converter, linking transformer technique with high frequency will be highly desirable than traditional transformer system with line frequency.

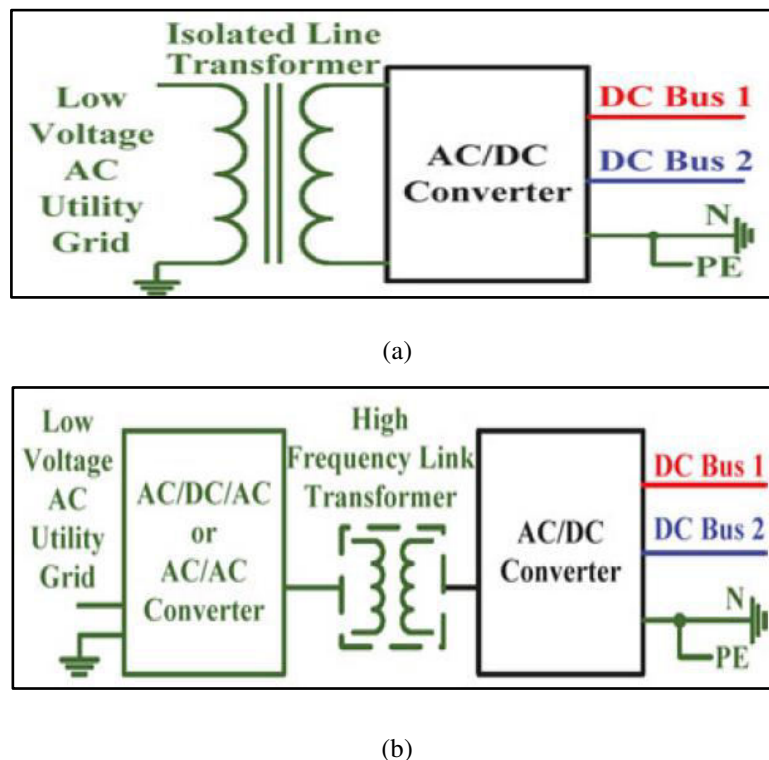


Fig. 3. Virtual Isolation Grounding Configuration (a) using Transformer with Line-Frequency [2], [14] and (b) using Linking Transformer with High-Frequency [13].

### IV. SIMULATION RESULTS

Typically, the direct current nanogrid is interconnected with the alternating current electrical system with AC/DC bidirectional converters, providing additional DC electric supply to be pumped again into the alternating current electrical system. In certain regions, because of the significant population density, the distributed power normally is unable to match the requirement of the regional loads, consequently the interface for power transfer between AC grid and DC nanogrid can be streamlined in the circuit for power factor regulation. In [15]–[18], AC/DC converters were studied and analysed. Nonetheless, for the unified grounding arrangement-based DC nanogrid, the suitable AC/DC converters implementation was unable to be established. The simulations of the AC/DC dual buck-boost converters with a DC nanogrid application are conducted by utilizing MATLAB software. The AC/DC converter is carried out in the AC grid environment with 110-volt and 50 Hz. Whatever Voltage that we obtain that corresponds to AC to DC, which is the conversion of electrical energy we'll be storing in the battery pack. Furthermore, in this phase, which is the

controlling phase that lies with respect with the PI controller that will determine the current state associated with the battery/electricity conversion. Therefore, based on that, we'll ultimately be obtaining the outcome that is our final result. For the purpose of this outcome, the top section of the model used for simulation is going to be engaged. The resulting situation will reflect the input you provided in that instance. The problem we have in this instance is that the highest possible value is repeated in nature. Based on the resultant waveform as shown in figure 4, we can determine that, we're obtaining a repeated saw tooth value frequently.

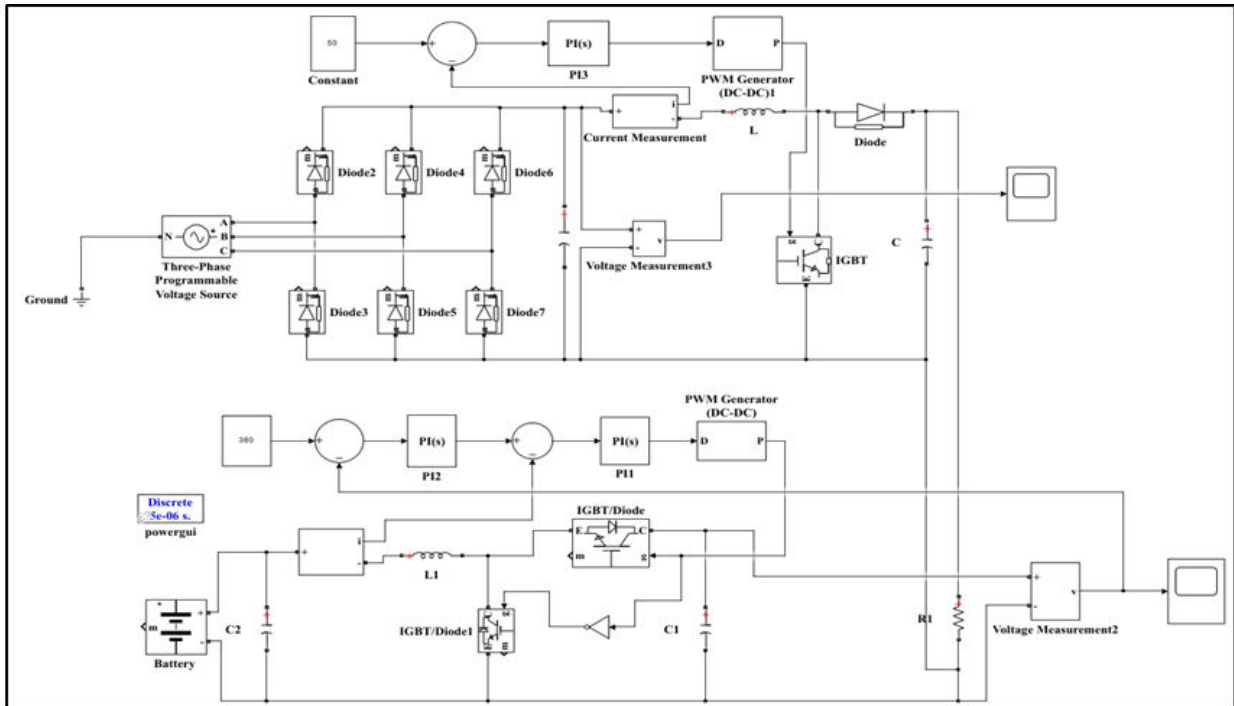


Fig. 4. Proposed Simulation Model of DC Nanogrid based AC/DC Converter for Unified Grounding Arrangement.

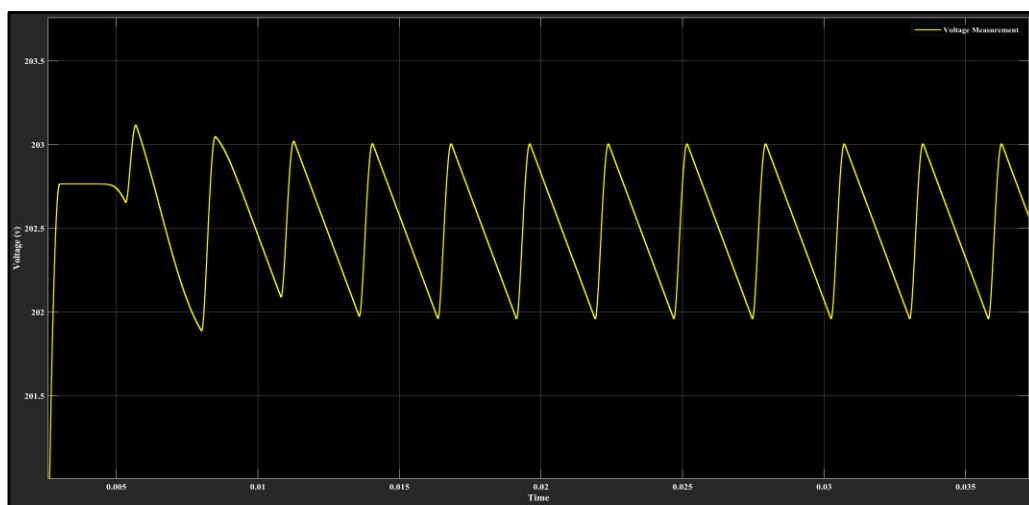


Fig. 5. Voltage with Saw Tooth Waveform.

Table. I. Design Parameters for the AC/DC Converter.

Parameter	Lg	C	Lp, Ln	Fs	E1, E2
Units	200uH	2uF	400uH	60kHz	90V

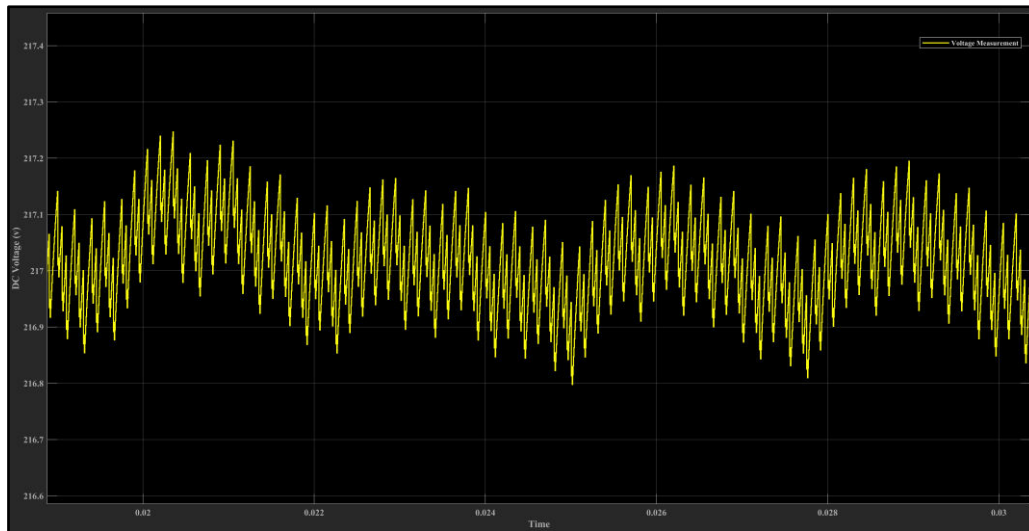


Fig. 6. Voltage with Discrete Variable Samples.

Accordingly, the shape of this waveform appears in terms of 0.2 to 0.3 which means a variation of 1 volt would be present and it could either be low or high in nature continuously. Fig. 6. Proposed simulation model of dc nanogrid based ac/dc converter for unified grounding arrangement. This variation in values we are observing is by implementing the filtering process. In the process of filtering, we have the total capacitance and because of that we are receiving the DC voltage. In this, the overall change that we are obtaining, it is going to be reduced and instead of a saw tooth shaped waveform, we are going to obtain the variable discrete samples which will provide us the average value. Thus, after receiving this average figure, we are going to sort out this information. In other words, this average value will be able to provide us overall stability. In the battery storage process, we have employed the PI controller and utilizing this PI controller, we can determine the overall stability of the voltage. In accordance with that stability, despite the voltage we've been determining, that will be the stored in the battery. In the final output that we get, we are able to observe that, in the input we provided 300 - 400 volts or approximately 360 Volts. Using the assumption of that voltage, we are going to calculate an output that is a DC voltage. Consequently, using the subsequent scope result, we are able to determine that the source of electrical output which we are obtaining is roughly 213 volts and relying on this, the battery storage/battery charging operation is being carried out.

### A. Operation Modes of Proposed System

1)  $|E1| \text{ or } |E2| \geq V_{gA}$ : Assuming the incoming DC voltage (E1 or E2) is greater than the magnitude of grid system voltage ( $V_{gA}$ ), the corresponding topologies are as indicated in figure 7. The inverter itself operates as a power factor correction circuit utilizing pure boost technology.

2)  $|E1| \text{ or } |E2| \leq V_{gA}$ : As the DC input voltages (E1 and E2) have less magnitude than grid voltage ( $V_{gA}$ ), the controlling gets a little bit more challenging. Figure 8 illustrates the ac/dc converter operating process of the presented model, when the magnitude of the DC voltage (incoming) is smaller than the grid power supply voltage, and that process can be divided in six intervals over a complete line cycle interval [10]

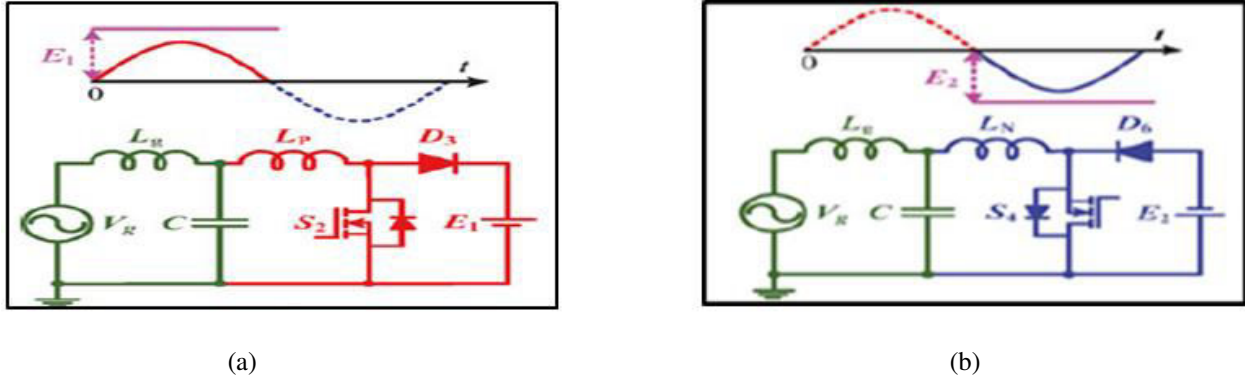


Fig. 7. Circuits Representing Cases where  $E_1$  and  $E_2$  Exceed the Magnitude of Grid Voltage, Working in Boost Mode: (a) Positive Cycle Operation (b) Negative Cycle Operation [10].

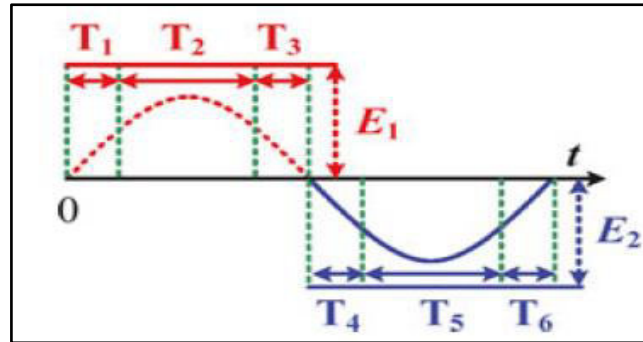


Fig. 8. Operation Sequence Under Conditions where  $E_1$  and  $E_2$  are less than Grid Voltage Magnitude [10].

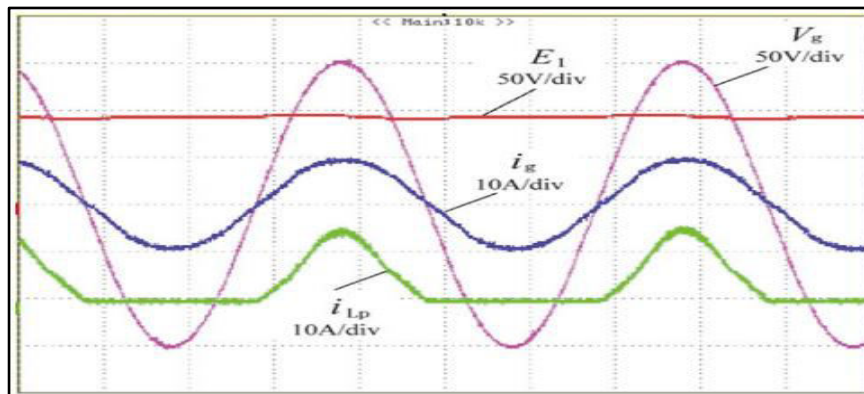


Fig. 9. Positive Measured DC Output Voltage  $E_1$ , Input Alternating Current Voltage  $V_g$ , Input Grid Current  $i_g$ , Inductor Current of  $L_p$  [10].

Figure 8 illustrates the input alternating current grid voltage  $V_g$ , positive measured DC output voltage  $E_1$ , the inductor current of  $L_N$ , and input grid current  $i_{Lg}$  [10]. A integrated ac/dc microgrid system is presented and thoroughly examined in this work. The modeling and coordination control strategies are presented for the all the converters to ensure steady operation of the system under diverse load and resource situations. The coordinated control techniques are verified by MATLAB/Simulink. Different control methods have been included to draw the optimum power from DC and AC resources and to supervise the power exchange between DC and AC grid. Different resource instances and load capabilities are executed to verify the control techniques.



## V. CONCLUSION

For domestic purposes, DC nanogrid can offer ground connection in order to provide protection. The grounded structure decides the diversified needs of the converters. During this study, for the DC nanogrid, three different kinds of the grounding arrangements are presented. The unified grounding design is the much attractive, considering the direct current nanogrid could be effortlessly linked to low power AC unit via the common ground line, that will firmly emphasize the good efficiency profile of the nanogrid. With this grounding methodology, it makes as simpler to establish a dc nanogrid depending on a primary level AC power grid with low voltage and assists in the dc nanogrid implementation. Nonetheless, compatible AC/DC power converters are presently unavailable for this arrangement of grounding. For the modern DC nanogrids, design of unidirectional grounding is commonly implemented. It is appropriate to develop a novel dc nanogrid independently. When comparing the arrangement of unified and unidirectional grounding, the virtual isolation grounding arrangements adaptability is advantageous, however it leads to a lower efficiency, additional resources, and consequently greater prices. Relying on the study of the grounding, an AC/DC dual buck–boost converter is presented for DC nanogrid dependent unified grounding arrangement. The concept of the suggested converter is demonstrated by making use of analogous topologies. Simulations are in accordance with the conceptual approach. The proposed AC/DC converter would enable to utilize the implementation of nanogrid with three output terminals for DC distribution.

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