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Original Article

High Gain Active Switched Network-Based Boost Converter for Dc Microgrids: Hardware Design and Setup

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Abstract: *In this project, we present a novel high-gain active switched network-based boost converter designed for DC microgrid applications. This converter addresses the limitations of traditional boost converters, which often struggle with achieving high voltage gains while maintaining efficiency and reliability. Our proposed converter integrates a switched network configuration, which enhances the voltage gain significantly without the need for extreme duty cycles or multiple cascaded stages. The active switched network configuration allows for the redistribution of voltage stresses across multiple components, thereby improving the overall efficiency and reducing the size and cost of passive components. Additionally, this design incorporates advanced control strategies to ensure stable operation under varying load and input conditions, which is crucial for the dynamic environment of DC microgrids.*

Keywords: *High-Gain Boost Converter , Active Switched Network, Dc Microgrids, Boost Converter Design, Power Electronics Hardware, Microgrid Optimization, Switching Network Converter, Hardware Setup For Boost Converters.*

INTRODUCTION

The electrical grid is going through a revolution since the years 2000s. Such revolution is composed first by economic aspects as the liberalization of power markets and the unbundling and privatization of previously state-owned power companies. Next, because of environmental and social concerns, there has been a choice for reducing the use of fossil-based sources, and to some extent even nuclear power. Such merge of traditional power grids with ICT is now known as Smart Grids. Smart Grids are composed of several elements, among them the concept of Micro Grids. Micro Grids are small portions of the electric grid that can to some extent balance itself with the production and consumption of electricity and can stabilize its fundamental states. In the case where the Micro Grid is always connected to the main grid, thus importing and exporting arbitrary amounts of power, the Micro Grid is said to be in grid-connected mode. But when larger shares of renewables are present in such grids, the problem may become very complex. Renewables have some characteristics that completely distinguish them from other power sources. The most important is the fact that renewables are not controlled. Wind, sun, tides, and other natural phenomena are uncorrelated with the needs of consumers.

Thus, renewables are mostly integrated into the low and medium voltage levels, which is in complete antagonism with the way power systems were designed. Another important aspect is the significant number of people in remote communities living without access to electricity. These villages may never have grid connection because of economic reasons and remoteness. On the other hand, many of isolated communities, such as African, Brazilian, or island communities, have great potential for solar radiation and wind, allowing for the use of renewables. Electricity supply can be seen as a contribution to social inclusion and improvement of the quality of life where electricity is mainly used for household purposes such as lighting, heating, and others to meet local energy demand. In addition, the transition for an electricity based energy usage avoids consuming local carbon-based resources like coal or wood. The result would be less expensive materials, and better efficiency (fewer losses). Also, direct current can be more efficient due to its simpler topology; the absence of reactive power and frequency to be controlled; the harmonic distortion is not a problem anymore; and there is no need of synchronization with the network. The consequence is a simpler control structure based on the interaction of currents between the converters, being the DC bus voltage the main control priority, that is, the voltage is a natural indicator of power balance conditions. At the same time, the DC Micro Grid is a challenge because the structure of the current power grid, power supplies, transformers, cables, and protection is designed in alternating current.

For this reason, hybrid AC/DC Micro Grid is seen as a compromise between AC and DC to allow for better integration of these new devices and the classical electric grid.

SYSTEM IMPLEMENTATION

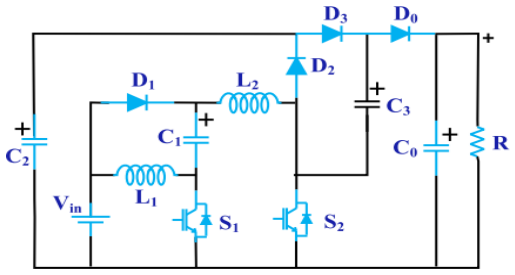
2.1 Existing System:

- The existing boost converters typically utilize traditional topologies like the basic non-isolated boost converter or the interleaved boost converter.
- The conventional Cascade boost, quadratic boost, traditional boost converter combined with switched- capacitor technique, voltage lift, and capacitor–diode voltage multiplier are a few most commonly usednon-isolated high gain converters.

2.2 Proposed System:

- This project proposes a novel converter topology with reduced current stress across active switches to provide a stable constant dc voltage. The proposed topology has the advantage of providing a high voltage gain, low current stress, and low conduction loss on the active switches, simplified control, andhigh efficiency.
- The current is equally shared by both the switches and thereby reducing the conduction loss. The proposed converter topology is a transformer-less design.
- Both the switches are connected in parallel and thereby reducing the switch current stress. Therefore, the power circuit of the proposed converter can be designed by using low current rating switches.

2.3 Proposed Converter:



2.4 Proposed Topology:

- It is consisting of two inductors L1 and L2 which have the same inductance value and switch S1 and switch S2 are both being turned ON and OFF at once.
- There are four diodes (D0 to D3) and four capacitors (C0 to C3) in the circuit. The working principlesand the steady-state analysis of the proposed converter in both CCM and DCM .
- First of all, considering all the circuit components to be ideal. Neglecting the ON-state resistance of the active switches, the forward voltages drop of the diodes and the effective series resistance (ESR) of theinductors and capacitors.
- However, it is assumed that both the inductors have equal inductance value and all the capacitors are large enough, and the capacitor voltages are considered to be constant.

2.5 Mode of Operation:

- The proposed converter consisting of two switches that are operating at the same time with the same duty pulse and duty ratio. Therefore, the proposed converter has two operating modes in CCM as

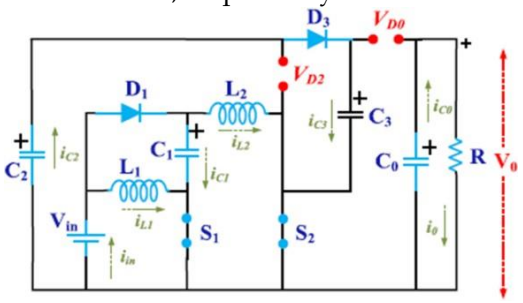
CCM 1
CCM 2

2.5.1 Ccm1:

- The switch S1 and switch S2 both are kept ON during mode I. The equivalent circuit of the proposedconverter for this mode is displayed in Fig.
- The input supply Vin charges inductor L1 via switch S1, the capacitor C1 via diode D1 and

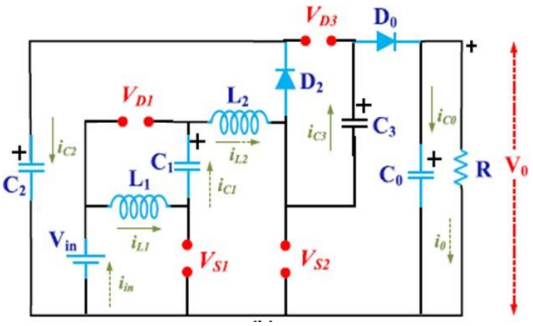
switch S1,and inductor L2 via diode D1 and switch S2, respectively.

- Simultaneously, capacitor C3 is charged by capacitor C2 via diode D3 and switch S2, and the energystored in capacitor C0 is transferred to the load R.
- Therefore, the voltages across the inductors L1 and L2, and capacitors C1and C3 can be expressed as, VL1 = VL2 = Vin , VC1 = Vin , VC3 = VC2 where, VL1 and VL2 are the voltages across inductors L1 and L2, respectively; the voltages across capacitors C1 and C3 are VC1 and VC3, respectively

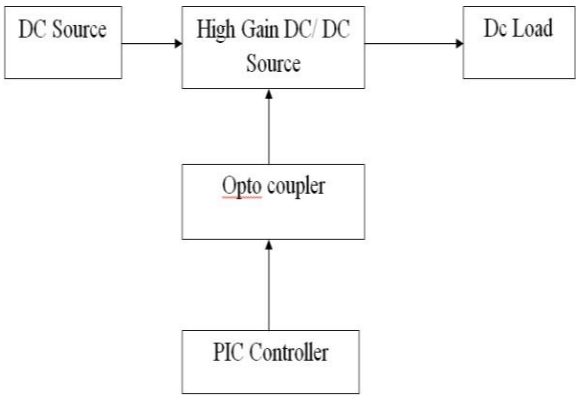


2.5.2 Ccm2:

- During mode 2, switch S1 and switch S2 are both being turned OFF simultaneously.
- Mode 2 equivalent circuit of the proposed converter is displayed in Fig.
- In mode 2, the input supply Vin charges the output capacitor C0, inductor L1, capacitor C1, inductorL2, and capacitor C3 via diode D0.
- At the same time, capacitor C2 is charged by the input supply voltage Vin, inductor L1, capacitor C1,and inductor L2 through diode D2



2.6 Block Diagram Of Hardware:



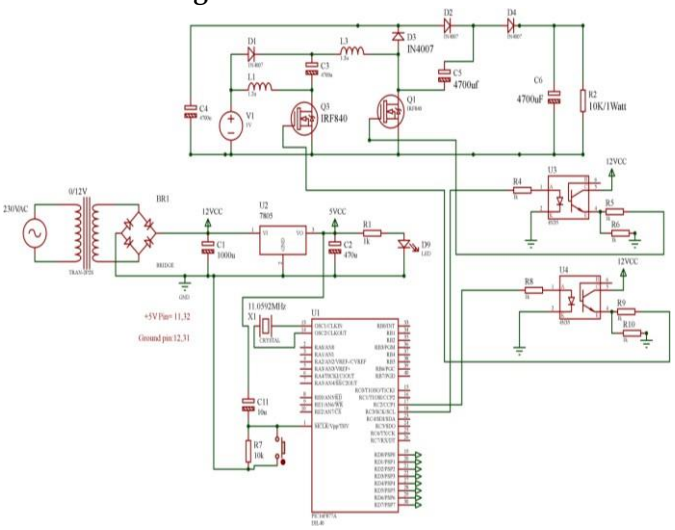
2.6.1 Block Diagram Description:

- DC Source: This is the primary power source for the microgrid, providing a DC voltage. It could be a solar panel, a battery bank, or any other DC power source.
- High Gain DC/DC Converter: This converter steps up or steps down the DC voltage to match the requirements of the load. High gain refers to its capability to handle significant voltage differences

between input and output.

- Load: This is the device or set of devices that consume power from the microgrid. It could be DC appliances, batteries, or other electronics requiring specific voltages.
- Optocoupler (Optoisolator): This component provides electrical isolation between different parts of the circuit. It transmits signals using light waves to prevent high voltages from affecting the control side of the circuit.
- PIC Controller: A microcontroller from the PIC (Peripheral Interface Controller) series, which manages the operation of the microgrid. It monitors the voltage levels, controls the DC/DC converter, and ensures efficient power distribution.

2.7 Circuit Diagram:



2.7.1 Circuit Diagram Description:

DC Source Connection The positive terminal of the DC source is connected to the input of the high gain DC/DC converter. The negative terminal of the DC source is connected to the ground (common reference point) of the circuit. DC/DC Converter The DC source's positive terminal connects to the input of the DC/DC converter. The output of the DC/DC converter is connected to the load, supplying it with the required voltage. The ground of the DC/DC converter is connected to the circuit ground. Load The load is connected across the output of the DC/DC converter. One terminal of the load is connected to the positive output of the converter, and the other terminal is connected to the ground. Opto coupler The opto coupler has an LED on the input side and a phototransistor on the output side. The input (LED side) of the opto coupler is connected to the output of the DC source or converter through a current-limiting resistor. PIC Controller The PIC controller is powered by a regulated low voltage supply (typically 5V or 3.3V). It receives signals from the opto coupler to monitor the voltage or current levels. The controller sends PWM (Pulse Width Modulation) signals to the DC/DC converter to adjust its operation based on the feedback from the opto coupler. It can also be programmed to perform other control tasks, such as load shedding, fault detection, and communication with other micro grid components.

HARDWARE DETAILS

3.1 DC To DC Boost Converter:

The low input DC voltage is converted into high output DC voltage using DC to DC boost converter. As the input voltage is stepped up compared to output voltage, hence, it is also called as a step up converter. Generally, DC to DC converters can be designed using power semiconductor switching devices and discrete electrical and electronics components.

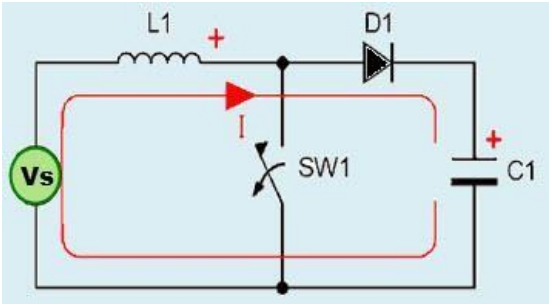


Figure. 3.1 DC to DC Boost Converter Continuous Conduction Mode Circuit

The continuous conduction mode circuit of the DC to DC boost converter is shown in the figure that consists of an inductor, capacitor, switching device, diode, and input voltage source. This boost converter circuit switch is controlled using a pulse width modulator (PWM). If this switch is in ON state, then energy willbe developed in the inductor and thus more energy will be delivered to the output.

3.2 Micro Controller Pic16f877a:

PIC 16F877 is one of the most advanced microcontroller from Microchip. This controller is widely used for experimental and modern applications because of its low price, wide range of applications, high quality, and ease of availability. It is ideal for applications such as machine control applications, measurement devices, study purpose, and so on.

3.2.1 PIC Controller Pin Diagram:

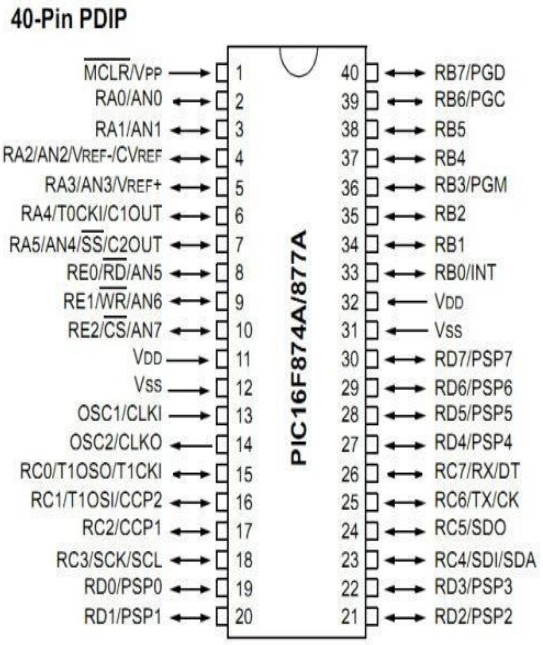


Figure. 3.2 PIC Controller Pin Diagram

3.3 Mct2e - Phototransistor Optocoupler :

MCT2E is a phototransistor Optocoupler, as the name "phototransistor" suggests it has a transistor which is controlled based on light (photon). When the IR led is powered the light from it falls on the transistor and it conducts. The arrangement and pin-outs of the IR LED and the photo-transistor is shown below.

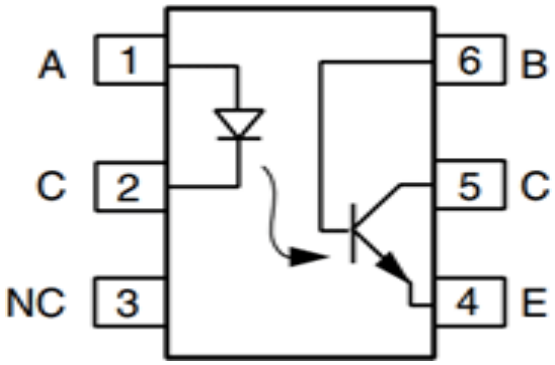


Figure. 3.3 Optocoupler

This IC is used to provide electrical isolation between two circuits, one part of the circuit is connected to the IR LED and the other to Photo-transistor. The digital signal given to the IR LED will be reflected on the transistor but there will be no hard electrical connection between the two. This comes in very handy when you are trying to isolate a noisy signal from your digital electronics, so if you are looking for an IC to provide optical isolation in your circuit design then this IC might be the right choice for you.

3.4 Single Power Supply:

Power supply gives supply to all components. It is used to convert AC voltage into DC voltage. Transformer used to convert 230V into 12V AC.12V AC is given to diode. Diode range is 1N4007, which is used to convert AC voltage into DC voltage. AC capacitor used to charge AC components and discharge on ground. LM 7805 regulator is used to maintain voltage as constant. Then signal will be given to next capacitor, which is used to filter unwanted AC component. Load will be LED and resister. LED voltage is 1.75V.if voltage is above level beyond the limit, and then it will be dropped on resister.

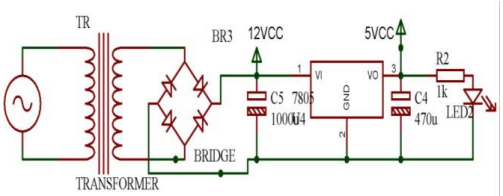


Figure. 3.4 Single Power Supply Circuit

3.5 Mosfet(Irf840):

Third generation Power MOSFETs from Vishay provide the designer with the best combination of fast switching, ruggedized device design, low on-resistance and cost-effectiveness. The TO-220AB package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50

W. The low thermal resistance and low package cost of the TO-220AB contribute to its wide acceptance throughout the industry.

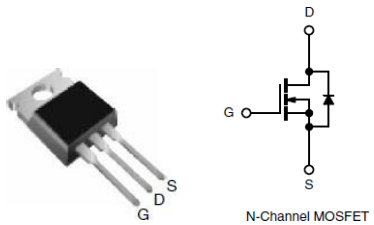


Figure. 3.5 Mosfet(Irf840)

RESULTS

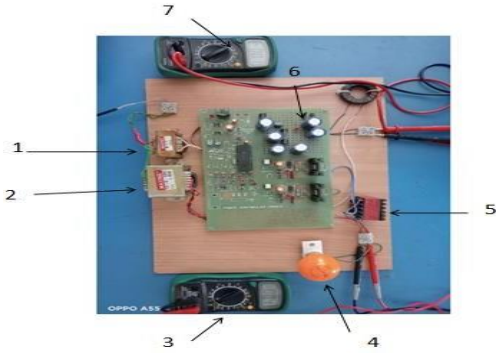


Figure 4.1: Hardware Prototype Model

The above figure 4.1 "A New High Gain Active Switched Network-Based Boost Converter for DC Micro grid" hardware model used components

1. **Power supply Transformer(0-9V) step down transformer**
2. **Converter Input Power transformer 12-0-12V 3Amps**
3. **Output Meter**
4. **Resistive Load**
5. **Inductor 18mH**
6. **Rectifier**

Figure 4.2: Input DC Voltage

The figure 4.2 is Input DC voltage (12V) for DC/DC converter for our prototype model.

Figure 4.3: Gate Pulse

The above figure 4.3 gate pulse for our hardware model MOSFET. The PWM pulse 10Khz infrequency and the amplitude 5V.

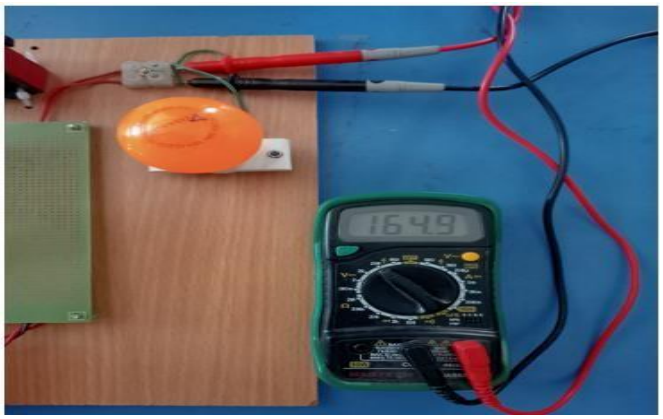


Figure 4.4: Output DC Voltage

The figure 4.4 is Output DC voltage (164V) for DC/DC converter for our prototype model. Our project High gain DC/DC converter is minimum 4 times increase of the output voltage. Our prototype model input 12V and output voltage 164V.

CONCLUSION

The DC-DC high gain boost converter with active switched inductor network and Model Predictive control for DC microgrid has been presented in the paper. The proposed converter has utilized two switches to reduce the current stress. The active switched inductor network and voltage multiplier structure have been effectively arranged to boost the output voltage and for the equal distribution of capacitor voltage stress. Furthermore, the presented topology drains a continuous current from the input supply. Hence, high-voltage boost ability and continuous input current make it suitable for DC source applications. A detailed CCM analysis of the proposed converter has been presented. The hardware prototype model has been made and tested successfully.

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