Abstract: Now a days, Solar Photovoltaic generation plays an important role to satisfy the energy demand and it provides numerous benefits such as it operates without pollution, no fuel is required and basically a clean energy source without polluting the environment. The main objective of this paper is to design and analyze a high gain converter namely Quadratic Boost Converter which acts as an interface with the solar Photovoltaic power generation. The performance parameters such as output voltage and output power are computed. A single PV cell produces a low output voltage and therefore a suitable interface circuit is required for DC applications. The Quadratic Boost Converter is best suited because of Less voltage spike, High output power, High efficiency, Less harmonics in output, Improved voltage regulation compared to the conventional boost converter. Also the limitation of switching frequency and voltage gain is overcome in this proposed topology. The design and testing of the Quadratic Boost Converter is done using MATLAB and SIMULINK.

IndexTerms--(PV) Photo voltaic panels, (QBC) Quadratic Boost Converter, (BESS) Battery energy storage system.

I. INTRODUCTION

Global warming and the depletion of fossil fuels are the major problems faced by every country in this world. These problems have threatening consequences. The world is on the verge of a larger calamity. These problems can be reduced by shifting the methods of generating power to a different method. The new growing field of generating energy is the renewable energy systems. There are numerous advantages associated with the renewable energy systems as they are environmental friendly. Few of the majorly used renewable energy systems are the Photovoltaic (PV) panels and the fuel cell stacks. These systems do not emit any greenhouse gases and so they are non-polluting and can produce clean electricity for decades. To store the energy, batteries can be used. But the power that we procure from these resources has a lower output voltage and so a bank of batteries might be required. This will lead to extra space and weight and higher cost leading to impracticality issues. So an interface is used to step-up the voltage obtained from these systems.

There are a lot of topologies that act as an interface. Such an interface is a Boost converter. Boost converter is a popular non-isolated power stage technology. Boost converters are used to step up an input voltage to some higher level required by the load. The boost converter has the advantage of storing energy in inductor and supplying it to the load at higher voltages. The input current for a boost converter is continuous or non-pulsating, because the input current is same as the inductor current. Small signal, transient performance, power dissipation and electromagnetic interference are some of the considerations taken while designing the converter circuit. But the conventional boost converter has certain drawbacks such as they are unable to switch faster; they are not suitable for high power conversion and also withstand high temperatures. Quadratic Boost Converter is a new topology which has certain advantages such as increasing the efficiency and voltage gain without increasing the number of switches used or the duty cycle. This converter injects less current ripple into the source and so the efficiency and the life span can be increased with that of the PV arrays.

The Quadratic Boost Converter has the following advantages compared to the conventional boost converter as:

1. Less voltage spike
2. High output power
3. High efficiency
4. Less harmonics in output
5. Improved voltage regulation

The scheme of the Quadratic Boost Converter in a simple two-bus system is illustrated in Fig.1.
II. BOOST CONVERTER

Boost converter is used to step up the given voltage to the desired voltage. The input to this converter may be from any DC source like rectifiers, solar panel, batteries etc.

There are two modes of operations to be presented.

**Mode 1:**
When the switch S is closed the inductor gets charged through the supply voltage and stores the energy. In this mode inductor current increases gradually, but we assume that the charging and the discharging of the inductor are linear. The diode blocks the current flowing and so load current remains constant which is being supplied due to the discharging of the capacitor.

**Mode 2:**
When the switch S is open, the diode becomes forward biased. The energy stored in the inductor changes it polarity to discharge through diode and charge the capacitor. Now, the capacitor supplies voltage to load. The load current remains constant throughout the operation.

A. Output Equation for Boost Converter
By neglecting the voltage drop across diode \( V_D \) and transistor \( V_{Tran} \),
\[ V_{out} = \frac{V_{in}}{1 - \delta} \tag{1} \]

Where, \( V_{out} = \) Output Voltage of the converter, \( V_{in} = \) Input Voltage to the converter, \( \delta = \) Duty cycle ratio

**B. Simulation results for boost converter**

The Boost converter based AC Micro grid system is simulated by using MATLAB 2012 and the circuit is shown in Fig.5. The input voltage given to the circuit is 48V and it works on 1 kHz switching frequency.

![Simulation Circuit for Boost Converter based AC Micro grid system](image)

The inductor values for the converter is designed by using the formula given below,
\[ L = \frac{(1-\delta)^2R}{2F_s} \tag{2} \]

Where, \( \delta = \) duty cycle, \( R = \) load, \( F_s = \) switching frequency

The capacitor values are designed from the formula given below,
\[ C = \frac{\delta V_o}{V_r RF_s} \tag{3} \]

Where, \( V_r = \) Ripple voltage, \( V_o = \) Output Voltage

Different characteristics of a Boost converter are observed in the following waveforms as:

![Fig.6 Voltage across PV](image)
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III. **QUADRATIC BOOST CONVERTER**

The quadratic boost converter with a single switch is shown in Fig.15 where E is the input voltage, \( V_{c2} \) the output voltage and S independent switch. This model usually requires active and passive switches to be appearing in pairs and to form a three-terminal network. However, this methodology can be extended for the analysis of the quadratic boost converter with a single switch, which contains an active switch and three passive switches. Thus, diode D2 and transistor switch S are replaced by the corresponding current source, and diodes D1 and D3 by voltage sources.
Mode 1:

The circuit operation is based on the assumption that the switch S is ideal in operation and capacitors C₁ and C₂ is taken as large value so that the voltage across the capacitors VC₁ and VC₂ are nearly constant over a switching period. When switch S is turned on D₂ is forward biased, whereas D₁ and D₃ reverse biased. Currents are supplied to L₁ and L₂ by Vin and C₁ respectively. The mode 1 circuit of quadratic boost converter is given below in Fig.16.

Mode 2:

In this condition D₁ and D₃ are forward biased, whereas D₂ reverse biased. L₁ and L₂ are charging with respect to C₁ and C₂ respectively. During this state, iL₁ and iL₂ is decreased. The mode 2 circuit of quadratic boost converter is given in Fig.17.

A. Equation for Quadratic Boost Converter

The capacitor (C₁) is selected as per the formula given below,

\[ C₁ = \frac{I₀δ}{(1 - δ)ΔVc₁Fₛ} \]  \hspace{1cm} (4)

\[ Vc₁ = \frac{Vₛ}{1 - δ} \]  \hspace{1cm} (5)

The capacitor (C₂) is selected as per the formula given below,

\[ C₂ = \frac{I₀δ}{ΔVc₂Fₛ} \]  \hspace{1cm} (6)
\[ V_{c2} = \frac{V_{c1}}{1 - \delta} \]  

(7)

**B. Simulation results for Quadratic Boost Converter**

The quadratic boost converter is simulated with the input voltage of 48V. The switching frequency used is 1 kHz. The simulation circuit diagram for the quadratic boost converter is given below in Fig.18.

![Simulation Circuit for Quadratic Boost Converter based AC Micro grid system](image)

Fig.18 Simulation Circuit for Quadratic Boost Converter based AC Micro grid system

Different characteristics for QBC are observed in the following waveforms as:

**Fig. 19 Voltage across PV**

![Fig. 19 Voltage across PV](image)

**Fig.20 Voltage across wind generator**

![Fig.20 Voltage across wind generator](image)

**Fig.21 Voltage across Rectifier**

![Fig.21 Voltage across Rectifier](image)
Fig. 22 Switching pulses for boost converter

Fig. 23 Voltage across quadratic boost converter

Fig. 24 Switching pulses for M1, M3, M5 of three phase inverter

Fig. 25 Voltage across RL load

Fig. 26 Output power
are presented in this paper. The performance parameters such as output voltage and output power are computed.

The proposed design and analysis of a high gain converter namely Quadratic Boost Converter which acts as an interface with the solar Photovoltaic power generation are presented in this paper. The performance parameters such as output voltage and output power are computed. The design and testing of the Quadratic Boost Converter is done using MATLAB and SIMULINK. The proposed scheme can be widely applied for the stand-alone power system in remote islands.

IV. COMPARISON RESULTS

The comparison of results of output voltage and output power with same input voltage using Boost converter and Quadratic Boost converter are tabulated below in Table 1.

| Converters             | Vin  | Vo   | Po   |
|------------------------|------|------|------|
| Boost converter        | 48V  | 340V | 486W |
| Quadrilateral Boost converter | 48V  | 415V | 750W |

V. CONCLUSIONS

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