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Soft Switching based High Gain Re-boost Luo Converter for PV System Applications

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ABSTRACT

This study introduces a novel Soft Switching High Gain Reboost Luo Converter designed to enhance the efficiency and performance of Photovoltaic (PV) systems. The proposed converter employs soft switching techniques to reduce switching losses and improve the system's overall efficiency, particularly beneficial for PV applications requiring high voltage gain. Through the integration of the Reboost Luo Converter, the system achieves significant improvements in voltage conversion ratio, ensuring optimal power extraction from PV panels under various environmental conditions. The MATLAB/Simulink simulation environment is utilized to model and analyze the converter's performance, demonstrating its capability to provide high gain, efficient energy conversion with minimized electromagnetic interference (EMI) and reduced stress on switching devices. The results validate the converter's effectiveness in improving the power output and reliability of PV systems, offering a promising solution for advancing renewable energy technologies.

KEYWORDS: Soft Switching, High Gain Converter, Reboost Luo Converter, Photovoltaic System, MATLAB/Simulink, Switching Losses, Voltage Conversion Ratio

1. INTRODUCTION

The world is currently confronted with a significant challenge as a result of the strain caused by fast increasing energy demands and depleting fossil fuel resources. [1]. To solve this issue, the global energy system needs to make the switch to a source of energy that is both more effective and sustainable over the long term. [2] Renewable energy are alternate ideas and technologies that have a lot of promise for the generation of electricity. Solar power generating is not only better for the environment than more conventional forms of energy generation, but it also offers significant economic savings. Additionally, factors such as decreased panel prices, speedy efficiency increases, and the repercussions of growing power bills have all contributed to an increase in the demand for solar PV arrays for the purpose of generating one's own electricity [3-4]. As a consequence of this, the emphasis is being placed on the integration of renewable energy technologies into the existing electrical infrastructure. The most significant benefits of utilising this technology include offsetting some portions of the daily electricity use of the premise, as well as the opportunity to produce value by contributing surplus power to the grid [5].

However, one of the most significant drawbacks associated with the generation of solar power is that the output power from solar photovoltaic panels is erratic and stochastic, which leads to the operation being subject to intermittency and fluctuations. Because of this, a battery energy storage system, also known as a BES system, is included in the system that is designed to make the PV power less intermittent [6]. The extra cost is justifiable as long as the BES is operated in the islanding mode (IAM), which supplies uninterruptible power to important loads linked to the system in the event that power is lost. In addition, the BES is able to supply the additional facilities in the grid-tied system by smoothing out the electricity that is fed into the grid. A great number of studies have produced a variety of control strategies [7–10] to optimise the size of BES for high use. The predictive energy management control that Jafari and his colleagues [10] provided was aimed at providing the most effective administration of BES's available capacity. [11] is the number of the publication in which Tran et al. present a power management control for a PVBES linked grid interfaced system. BES is able to take advantage of time-of-use (ToU) electricity pricing by storing energy from the grid during off-peak demand periods and then using this stored energy to meet peak demand during the day. Beniwal and his fellow researchers.

Power electronics play a crucial part in micro distributed generation (DG) because solar energy sources supply low DC voltage that needs boosting, a high-quality tracking algorithm. High efficiency, power quality, and usable life are goals. If solar inverters could survive as long as the panels they're attached to, that would be great. Because the most expected applications are linked to AC distribution networks, where no energy storage technology is needed, these requirements may be economically essential to the utilisation of renewable energy such as solar and wind today and in the future.

This article will examine popular non-isolated single-phase topologies for PV grid-tie applications, along with MPPT, island protections, and electrical safeties. Also exhibited and explored are experimental results for a structure that improved algorithm performance for this application. This effective structure was addressed.

2. PROPOSED SYSTEM

Solar photovoltaic (PV) power is fed into the grid through a combination of a DC-DC REBOOST LUO converter and a VSI of one. In order for a photovoltaic array to function properly, the converter power must be synchronised with the grid at the point of maximum power output. Connected to the landsman converter so that it can be controlled is a fuzzy logic controller. This controller monitors the maximum power available from the PV array by analysing both the voltage and the current that is drawn from it. It is responsible for regulating the reference voltage as well as the duty cycle in order to match the power to the instantaneous power point. The MPPT controller makes use of a fuzzy logic controller; it is non-linear, and its parameters change as the passage of time progresses.

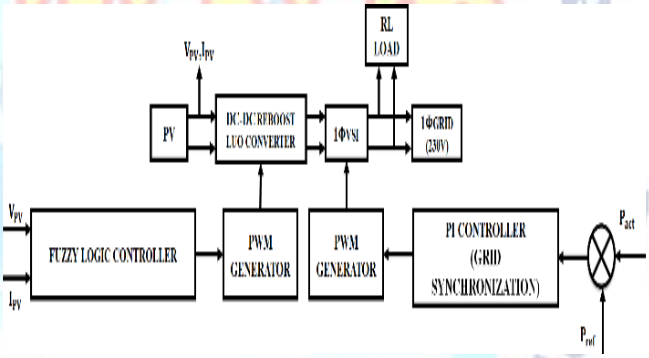

Figure1: Proposed System Block Diagram

A. PVSystem

The solar panel is the apparatus used to convert energy from sunlight into usable forms such as electricity or heat. A solar panel is a group of solar cells used to generate electricity via the photovoltaic (PV) effect. The system and solar cell type both affect the system's output of electricity (in volts or watts). The DC output power of each module varies from 100 to 365 watts under typical conditions. Most solar panels have solar cells arranged in a grid pattern on their surface. For this reason, it is sometimes described as a collection of modules attached to a larger framework. Assemblies of 6–10 PV cells are packaged and wired together to form a photovoltaic module. These panels have a good erosion resistance. In a year, solar panels lose only a small percentage of their efficiency. Crystalline silicon solar cells are the primary component of solar panels. Silicon, metal, and glass are the three basic materials used in manufacturing solar panels.

Each PV cell is part of a larger array that is housed in a metal frame within a solar panel or module. About 60, 72, or 96 photovoltaic cells make up a single solar panel. Numerous types of electronic devices, such as calculators, require solar panels to stay operational under bright light. Solar photovoltaics (PV) are among the most rapidly expanding, established, and competitively priced renewable energy technologies. There is little doubt that solar energy will remain a crucial renewable resource in the decades to come. Today, more and more people are opting to use renewable energy sources. Home solar panel installations mitigate the effects of global warming by cutting down on the release of dangerous greenhouse gases. Solar panels are the conventional power sources because they are clean and good for the environment.

B. DC-DC REBOOST LUO CONVERTER

The proposed converter is an evolution of the simple Super lift Luo converter and the more complex Fly back converter. The circuit uses one step-up isolation transformer, four capacitors, and four diodes. The transformer's coil is repurposed as an inductor. Figure 2 depicts the Re BoostLuo converter. The primary winding of the transformer is responsible for the continuous operation that is the main benefit of the proposed converter. Both modes of operation are broken down here, along with an examination of their respective on and off times. The diodes D1 through D4 are in their off states, and capacitors C1, C2, and C3 are in their discharging states, during the switch on period, when the magnetising inductance of the isolation transformer is being charged. Figures 3 and 4 show the polarity of the current flowing through the proposed converter when it is on and off, respectively.

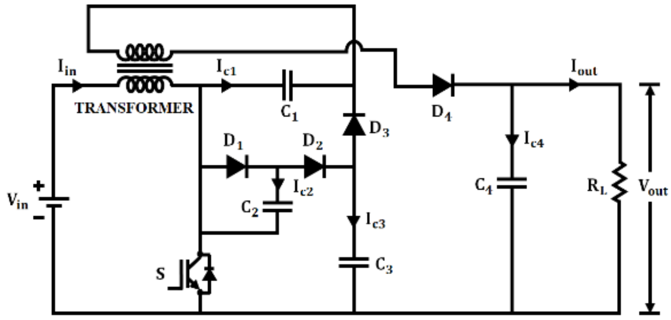

Figure 2:DC-DC Re-Boost Luo Converter

1.1. Mode 1 operation

As soon as Mode 1 is engaged, the Re-boost converter's On/Switch is activated. This charges the magnetising inductance of the isolation transformer's primary winding, while the secondary winding remains electrically isolated. Meanwhile, capacitor C1 is being charged by the charged capacitor Co. D3 has a tendency to lean towards the front side. When you turn off D2, the output capacitor Co is cut off from the rest of the circuit and discharges via the resistor RL.

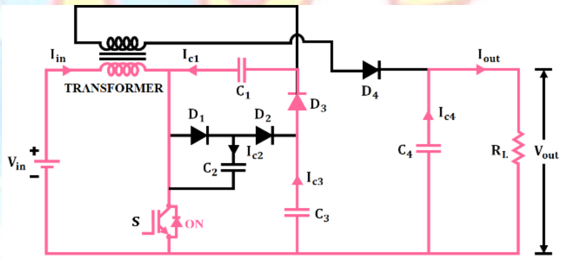

Figure 3:Switch On Mode Condition Flow Diagram

1.2. Mode 2 operation

In the second setting, S is turned off. Unlike other converters, the input current to a transformer is continuous because the direction of current flow across the transformer's primary does not change. With a forward bias, D1 turns on while D2 remains in its off state. The diodes D1 charge the second capacitor C2 while the charge from the first capacitor C1 is added to the charge in the main inductor and then travels to the output capacitor Co through the transformer's secondary winding, where it is amplified. Changing the duty cycle and the frequency may regulate this voltage..

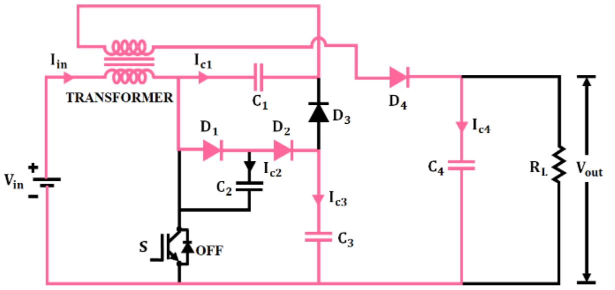

Figure 4: Switch Off Mode Condition Flow Diagram

1.3. Analysis of proposed Re Boost Luo converter

The output potential difference of the above elementary converter is,

$$V_0 = \left(\frac{2-\alpha}{1-\alpha}\right) V_{in} \qquad (1)$$

where a is the duty cycle. From the Eq. (1),

$$G = \frac{(V_0)}{V_{in}} = \left(\frac{2-\alpha}{1-\alpha}\right) \qquad (2)$$

When the main and secondary windings of the transformer are linked in a cascade, the device takes on the characteristics of an inductor. In order to do the necessary calculations, the proposed transformer is modelled as an inductor. The combined current from the inductor and capacitor is now the input current.

The electron flow rate at input, Iin, may be calculated as

$$I_{in} = I_{L1} + I_{C1} \qquad (3)$$

The ripple currents present in the inductor is given a

$$\Delta T_{L1} = \frac{V_{in}.\alpha.T}{L_1} \qquad (4)$$

in which T is the duration of the entire switching pulse The output voltage ripple is denoted by the expression,

$$\Delta V_0 = \frac{I_0(1-\alpha).T}{C_2} \qquad (5)$$

$$T = \frac{1}{f} \qquad (6)$$

$$I_0 = \frac{V_0}{R} \qquad (7)$$

Sub (6) & (7) in Eq. (5),

$$\Delta V_0 = \frac{V_0(1-\alpha)}{fC2R} \qquad (8)$$

From Eq. (1)

$$V_{in} = V_0\left(\frac{1-\alpha}{2-\alpha}\right) \qquad (9)$$

Input current,

$$I_{in} = \frac{V_{in}}{R} = \frac{V_0}{R}\left(\frac{1-\alpha}{2-\alpha}\right) \qquad (10)$$

Therefore,

$$\frac{V_{in}}{I_{in}} = \left(\frac{1-\alpha}{2-\alpha}\right)^2 \cdot \frac{V_0}{V_0/R}$$

$$\frac{V_{in}}{I_{in}} = \left(\frac{1-\alpha}{2-\alpha}\right)^2 .R \qquad (11)$$

We can derive the Re Boost-Luo Converter model from the above equations. Re Boost-Luo Converter uses flyback converters and super life Luo Converter. Proposed converter has three diodes and three capacitors. Transformers are used as inductors to boost output gain. In proposed converter, input voltage changes C1. Primary winding ripple current is,

$$\Delta I_{L1} = \frac{V_{in}.\alpha.T}{L1_{(N1)}} \qquad (12)$$

L1 (N1) - Transformer primary winding inductance. C2 capacitor voltage is

$$V_{C2} = \left(\frac{2-\alpha}{1-\alpha}\right) V_{in} \qquad (13)$$

Luo's secondary winding ripples.,

$$\Delta I_{L2} = \frac{V_{C2}.\alpha.T}{L2_{(N2)}} \qquad (14)$$

Capacitor C3 voltage,

$$V_{C3} = \left(\frac{2-\alpha}{1-\alpha}\right) V_{in} \qquad (15)$$

C4 capacitor voltage is,

$$V_{C4} = V_0 \qquad (16)$$

The proposed Re-Boost Luo Converter's output difference is,

$$V_0 = \frac{N_2}{N_1}\left(\frac{2-\alpha}{1-\alpha}\right) V_{in} \qquad (17)$$

where

N2 - No of turns in the secondary winding.

N1 - No of turns in the primary winding.

Number of turns and converter duty cycle affect output voltage.

C. PWM GENERATOR

PWM control swiftly switches motor power ON and OFF. The DC voltage is transformed to a square wave signal, oscillating between full power (almost 12v) and zero, to "kick" the motor. PWM may improve a motor's starting performance by controlling its speed. PWM controls motor speed similarly. Instead of variable voltage, a set voltage (such as 12v) starts a motor instantaneously. The motor "coasts" without power. Continuing this voltage on/off cycle with a variable duty cycle controls motor speed. DC motor speed control uses PWM or duty-cycle variation. Duty cycle is the ratio of digital high to low plus high during a PWM period.

At 0% duty cycle, the average DC Voltage is zero; at 25%, it's 1.25V (25% of 5V). 50% duty cycle averages 2.5V, 75% 3.75V, etc. 100% duty cycle equals a DC waveform. By adjusting the pulse-width, we can change the DC motor's average voltage and speed..

D. PI CONTROLLER

The closed loop PI Controller measures the deviation between actual output and the target value to provide an error signal. By deducting the incoming process variable from the controller's chosen reference input, an error value is generated. By adjusting the inputs, the error may be decreased and the process variable can be brought closer to the set point. Apply this technique whenever the mathematical model of the process is time-consuming. Fig. depicts the PI controller's block diagram.

Because of the connection between the PI controller and the reboost luo converter, the steady-state error is minimised, and the system is stabilised, without experiencing any oscillations. Better transient response with increased gain margin and phase margin is what these controllers are good at..

E. FUZZY LOGIC CONTROL

Certain numerical parameters, such as the thresholds for a significant error and a significant rate-of-change-of-error, are necessary for Fuzzy Logic to function; however, the precise values of these numbers are typically not critical unless very responsive performance is required, in which case they would be determined through empirical tuning. Error is calculated by subtracting the signal from the command signal in a basic temperature control system; the error slope or rate-of-change-of-error, henceforth dubbed "error-dot," is then calculated using time differentiation. An inaccuracy of 2 degrees Fahrenheit would be deemed minor, whereas an error of 5 degrees would be considered significant. In this case, the "error-dot" may be measured in degrees per minute, with a tiny error-dot equal to 5F/min and a big error-dot equal to 15F/min. No symmetry is required between these variables, and they can be "tweaked" once the system is live to get optimal performance. Since FL is so lenient, it's likely that the setup won't require much fine-tuning before it's ready for use.

3. RESULT AND DISCUSSION

The proposed work is implemented in MATLAB simulation and the following outputs are obtained. Figure 5 shows the solar panel voltage representation of input AC, the source of output voltage is 70(V) attained.Figure 6 shows the input current waveform of Luo converter .

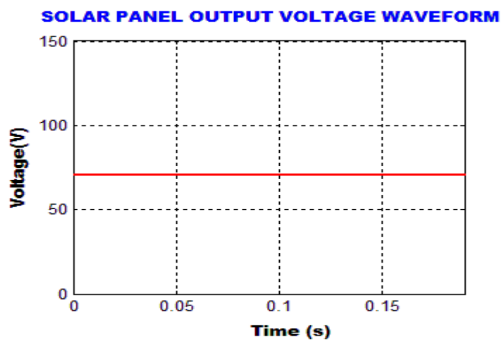

Figure5:Solar Panel Output Voltage Waveform

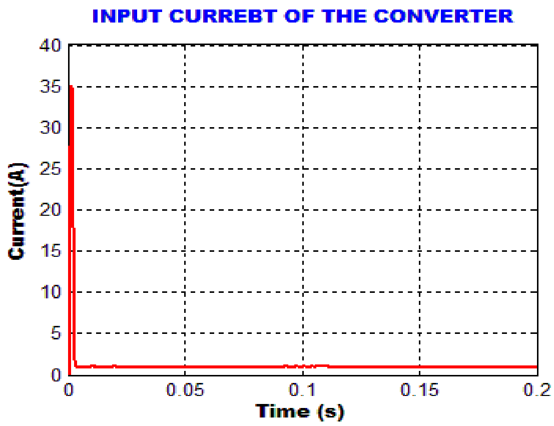

Figure 6: Input Current of the Converter

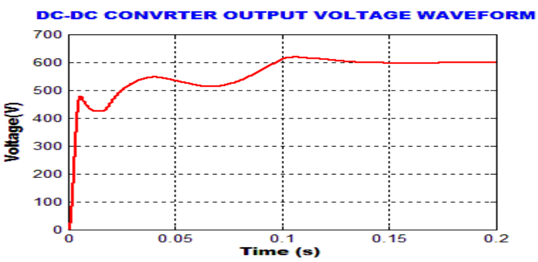

Figure 7:DC-DC Converter Output Voltage Waveform

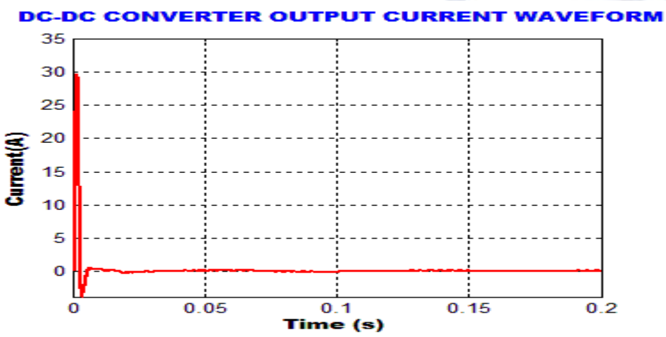

Figure 8: DC-DC Converter Output Current Waveform

The output of Luo converter voltage and current waveform are given in Figure 7 and 8 respectively.

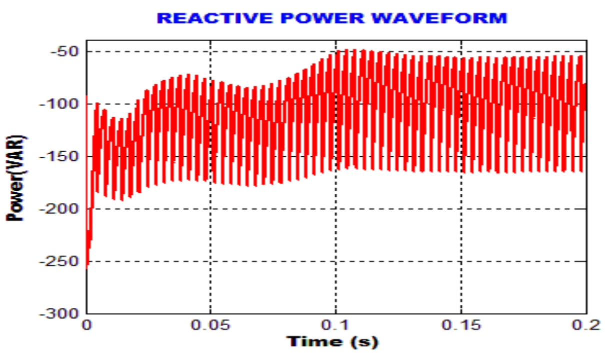

Figure 9:Reactive Power Waveform

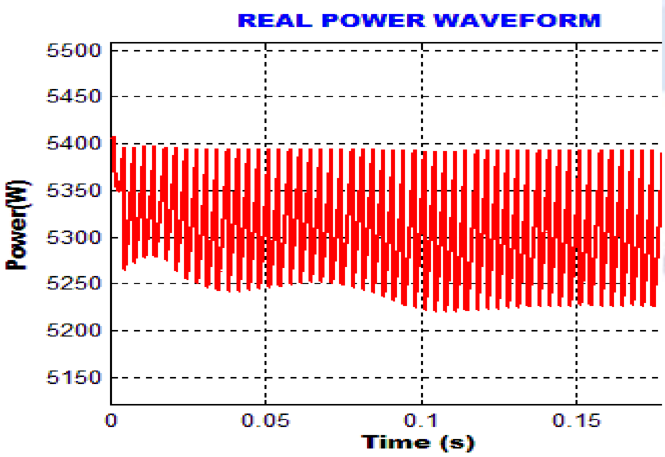

Figure 10: Real Power Waveform

The Figure 9 and 10 show the reactive power and real power waveforms of the proposed work.

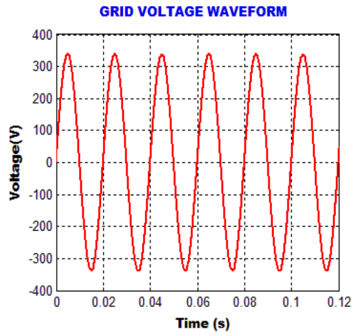

Figure 11:Grid Voltage Waveform

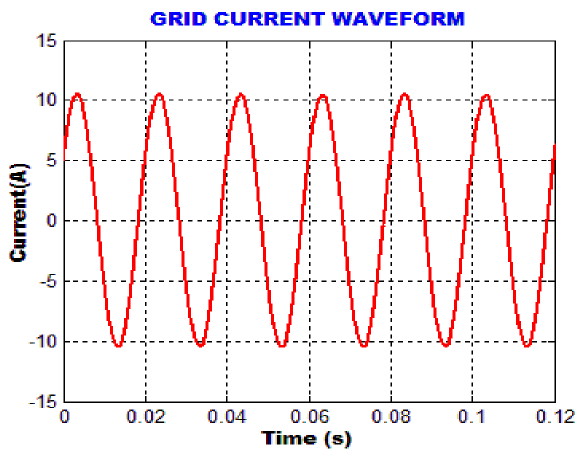

Figure 12: Grid Current Waveform

Figures 11 and 12 show grid voltage and current waveforms. PI-based grid synchronisation compensates reactive power..

4. CONCLUSION

This study predicts the performance of a REBOOST LUO CONVERTER equipped with FUZZY MPPT for a grid-connected photovoltaic system. Since the PV system's output voltage is inefficient, it is fed through a REBOOST LUO CONVERTER, which produces a higher voltage output with the same polarity as the input. This converter works regardless of changes in light intensity, and it provides higher voltage gain with lower switching losses. In order to convert DC voltage into AC voltage with varying frequencies, a 3 VSI is used. To dampen the switching frequency harmonics, an LC filter is used. As a result, the planned infrastructure reduces distortion and ensures better power quality through grid synchronisation.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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