# Certain investigations on performance analysis of different converter designs for smart micro-grid systems

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ABSTRACT

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ABC-PI controller DC-DC Grid MPPT SEPIC-Luo converter This paper proposes a grid-connected hybrid renewable power system. A LUO converter driven by ABC-PI controller is used to produce stable DClink voltage. To enhance the voltage, a LUO converter is used, and the boosted voltage is regulated by an ABC-PI controller. Using the suggested optimization approach, the power fluctuation is kept at a low value. The execution of the proposed optimization is efficient, as it is simple and robust. It has a limited number of control parameters as compared to other approaches. The suggested method is described in complete detail, together with its converter and control mechanisms. The modeling and experimental results are validated to ensure that the system is feasible. The HRES is analyzed through simulation in MATLAB with converters like boost, SEPIC, and LUO. The results reveal that the LUO converter performs better with a minimum settling time of 0.175 seconds with a source current THD of 1.29%. From the modeling and the simulation results, it has been revealed that the proposed technology provides more reliable and steady power.

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# 1. INTRODUCTION

Energy is a basic need for all human activities like agriculture, transportation, manufacturing, and generating electricity. The accessibility of energy is directly related to the growth and development of the country; as there is a limited availability of fossil fuels, its usage leads to many environmental consequences. Also, developing nations and industries are in an urge to improve their living standards. Hence a non-polluting clean energy resource is needed, which satisfies the growing energy demand and also assists in achieving better living standards. Some of the available renewable energy sources (RES) are wind, solar, geothermal and hydropower. When analogized to other energy sources, the HES provides higher performance. Because of

climatic conditions, the output attained from these two energy sources is uncertain, i.e. one system provides more power, whereas the other system provides less power or no power. As a result, this system's output voltage needed to be stabilized. These two energy sources are linked in parallel, if one energy system is unavailable, then another energy system balances the control system. Therefore, these two energy sources operate individually and simultaneously. A LUO converter is proposed, which overcomes the drawbacks of SEPIC and boost converters, and also the THD has been further minimized.

# 2. PROPOSED METHODOLOGY

The renewable energy-based smart micro-grid is proposed. PV and wind turbines is integrated with the grid through three-phase inverters. The retrieved power from PV and wind turbines is to be regulated at a stable mode. To regulate a DC-link voltage, an LUO converter controlled by an optimized PI controller is used. LUO converter maximizes the voltage retrieved from renewable sources and to provide a steady state DC voltage to the grid, an optimized PI controller is used. To perform optimization, the Artificial Bee colony algorithm is used. It's a robust and facile algorithm and it requires few control parameters when analogized with other algorithms. To minimize the intermittent distribution of power from renewable resources, the battery is coupled with PCC to generate power at the time of lack of renewable sources [1]-[5]. The resulting voltage of DC-DC LUO converter is fed to the PI controller and analogized with the reference voltage which is fixed to 600 V. The fault that is observed is given to the comparator and it is utilized to produce manipulating pulses for LUO converter. The power from a wind turbine is obtained as AC electrical power. It is transformed to DC by making use of a PWM rectifier. The battery acts as a secondary storage device. When the voltage of the battery exaggerates above 560 V, the power from the battery will start released out to the inverter, and finally by using three-phase inverters, the DC voltage is transformed to AC and it is fed to the grid. The grid synchronization is carried out by using DQ theory [6]-[10]. The proposed system performs effectively in generating reliable and sufficient power to the grid displayed in Figure 1.



Figure 1. Control approach of HRES with LUO converter

## 3. MODELLING METHOD

LUO converter assists to lift the voltage retrieved from PV and wind turbine. The impact of circuit elements minimizes the resulting voltage and transfer efficiency of power. LUO converter acquires maximum output voltage with minimized ripples along with good efficiency. The positive LUO converter circuit diagram is represented in Figure 2. From source to capacitor, the inductor  $L_1$  transfer energy during turn off mode and after that, accumulated energy is fed to load when it is switched on. Therefore, if the voltage Vc is found to be higher than the resulting voltage Vo, the resulting voltage also gets maximized. When the switch S is turned to be in mode off position, the power starts flowing via diode D. If the power not reaches zero before turning on the switch again.

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This operating state is said to be in CC mode and if it becomes zero, then it is to be in discontinuous mode. The inductor and capacitor play a significant role and its computation is performed as follows: The inductor current IL2 is computed by using the (1).

$$IL_2 = \frac{(1-a)}{a}IL_1 \tag{1}$$

The resulting voltage equation as shown in (2).

$$V_o = \frac{a}{1-a} V_{in} \tag{2}$$

The average voltage across the capacitor is (3).

$$V_c = \frac{a}{1-a} V_{in} \tag{3}$$

The peak-to-peak inductor current is computed by (4).

$$\nabla IL_1 = \frac{aTV_{in}}{L_1} \tag{4}$$

From (4), inductor L1 value and L2 value are calculated as (5) and (6).

$$L_1 = \frac{aTV_{in}}{\nabla lL_2} \tag{5}$$

$$L_2 = \frac{aTV_{in}}{\nabla L_2} \tag{6}$$

The charge that is present in the capacitor exaggerates during off mode by IL2 and minimizes during on mode by IL1. The voltage across the capacitor is given by (7).

$$C = \frac{1-a}{\nabla V c_1} T_1 \tag{7}$$

The negative output LUO converter is shown in Figure 3. In the negative output LUO converter, the inductor L2 accumulates energy from PV and wind during switch-on mode and it carries out the accumulated energy to the condenser at the time of off mode.



Figure 2. Positive output LUO converter



#### 4. RESULTS AND DISCUSSION

A simulation model for PV-wind battery based HRES with a LUO converter is instigated in MATLAB software to examine the system's effectiveness. This main goal of this approach is to provide the grid with stable power. Due to temperature changes, the power obtained is not retrieved in a balanced state. To overcome this, a LUO converter is utilized in this proposed control methodology, which provides a constant output and this converter is controlled with the aid of a PI controller. The specifications for LUO converter is represented in following Table 1. The DC-link voltage waveform with LUO converter using ABC is displayed in Figure 4. The DC-link voltage with LUO converter by utilizing PI, fuzzy and ABC are 600 *V*, but the settling time is different. By utilizing PI controller, the DC link is settled after the time of 0.29*s*, for Fuzzy controller, the DC link is settled

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after the time of 0.26 *s* and for ABC [11]-[15], the DC link is settled after the time of 0.175 *s*. The output voltage of PWM rectifier by utilizing LUO converter is displayed in Figure 5. The output attained from the WECS based DFIG is AC voltage, which is transformed in to DC voltage by utilizing a PWM rectifier [16]-[20].

The output voltage of PWM rectifier is noted as 600 V, which is highlighted in the above waveform and this output is similar to LUO converter's output. In the initial stage, the voltage shows fluctuations and after the time period of 0.11 s, it goes to steady state. The battery voltage and current waveforms by utilizing LUO converter are displayed in Figures 6 and 7. For the analysis of HRES, the battery plays an essential role in storing the excess energy, whereas the charging and discharging is carried out by utilizing a bidirectional buck-boost converter. The battery voltage of 183 V is attained after a time period of 0.132 s. The voltage fluctuations occurs in the initial stage and after  $0.132 \, s$ , it goes to steady state. In the current waveform, the current increases in the initial stage and then decreases to zero at a time period of 0.1s, which again slightly increases to 12.5 A as observed in the current waveform. The battery SOC waveform by utilizing LUO converter is displayed in Figure 8. From this waveform, it is noted that the battery's SOC is observed as 80%. The grid voltage and current waveforms by utilizing LUO converter are displayed in Figures 9 and 10. The HRES based PV-wind-battery system with a LUO converter is given to the grid through a  $3\phi$  VSI. The grid voltage is ranges from +370 V to - 370 V, whereas the grid current is ranges from +10 A to - 10 A are observed, which are highlighted in the above waveforms. The real and reactive power waveforms by utilizing LUO converter are displayed in Figures 11 and 12. The real power is noted as 5600 W with some distortions, whereas from the reactive power waveform, it is noted that the reactive power varies between -165 to -45 VAR. The power factor waveform by utilizing LUO converter is displayed in Figure 13. The unity power factor is observed in this waveform with the aid of a HRES based PV-wind-battery system along with a LUO converter. The grid current THD by utilizing HRES based PV-wind-battery system along with LUO converter power factor are displayed in Figure 14. The system's performance is assessed on the basis of THD observed [21]-[26]. If the THD is high, the system shows more harmonics; therefore, lower the THD, the performance becomes better. With the utilization of LUO converter, the THD attained is 1.29%.

Table 1. Specifications of LUO converter

Specifications	Values
Inductances $(L_1, L_2)$	4 mH, 6 mH
Capacitances $(C_1, C_2)$	220 μF, 100 μF
Switching Frequency $(f_s)$	25 KHz
Resistive Load $(R_L)$	15 Ω



Figure 4. DC-link voltage with LUO converter (ABC algorithm)



Figure 5. Output voltage of PWM rectifier by utilizing LUO converter



Figure 6. Battery voltage waveform by utilizing LUO converter



Figure 7. Battery current waveform by utilizing LUO converter



Figure 8. Battery SOC waveform by utilizing LUO converter

Figure 9. Grid voltage waveform by utilizing LUO converter



Figure 10. Grid current waveform by utilizing LUO converter





Figure 11. Real power waveform by utilizing LUO converter



Figure 12. Reactive power waveform by utilizing LUO converter



Figure 13. Power factor waveform by utilizing LUO converter



Figure 14. Grid current THD by utilizing LUO converter

# 5. CONCLUSION

A micro-grid-based HRES (PV-wind-battery) is presented in this research. The output power of solar panels and wind turbines is managed to obtain stable power. A LUO converter driven by ABC ABC-based PI controller is utilized to regulate the DC-link voltage. The power collected from renewable sources is increased by LUO converter and a steady-state DC voltage is supplied to the inverter by using the ABC-PI controller.

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When compared with several optimization algorithms, ABC is a reliable and simple approach with minimal control parameters. In order to tackle the intermittence in power obtained from renewable resources, a battery is incorporated to maintain the power availability when the RES are unavailable. Through a three-phase inverter, the renewable sources PV and wind turbines are connected to the grid. In WECS, the ac output from wind turbine is converted into DC with the assistance of the PWM rectifier and the battery serves as a backup storage device. The link voltage is fed to the grid via three-phase inverters, which assist in DC-AC conversion and finally, grid synchronization is achieved through DQ theory. A simulation model is created in MATLAB for the hybrid system to examine its effectiveness. SIM power system toolkit was used to implement the overall model. The goal of this technology is to provide the grid with stable power.

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