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# Dual-Stage Grid Connected PV System with LUO Converter and Easy Power Regulation

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**Abstract**: *The increasing demand for renewable energy integration into modern power systems has driven significant advancements in photovoltaic (PV) technology. This project proposes a dual-stage grid-connected PV system incorporating a Luo converter and an efficient power regulation mechanism to enhance power conversion efficiency and ensure stable grid interaction.*
*In the first stage, the PV array output, characterized by low and variable DC voltage, is boosted using a Luo converter a high performance DC-DC converter known for its ability to provide high voltage gain, improved efficiency, and reduced output ripple compared to conventional boost converters. The Luo converter is operated with Maximum Power Point Tracking (MPPT) algorithms to extract maximum power under varying environmental conditions.*
*In the second stage, the regulated DC output is fed into a Voltage Source Inverter (VSI), converting DC to AC suitable for grid synchronization. An intelligent control strategy is implemented for easy power regulation, managing both active and reactive power flow to maintain grid stability and meet power quality standards.*
*The proposed control schemes were tested on a 250 Wp solar panel feeding power to a 230 V, 50 Hz single-phase grid through a two-stage converter. The entire scheme was modeled using the Matlab/Simulink platform, and the same was validated by hardware experimentation using Chroma Solar Simulator and NI myRIO controller under varied irradiation, temperature, and reserve fractions. The simulation and hardware results are compared and reported.*

**Keywords**: MPPT,SPV,PV PANEL, POWER REGULATION, LUO CONVERTER

## I. INTRODUCTION

The increasing global demand for clean and sustainable energy has accelerated the development of photovoltaic (PV) systems. Among various configurations, grid- connected PV systems have gained significant attention due to their ability to directly supply renewable energy to the utility grid, thereby reducing dependency on conventional fossil fuels. However, the intermittent nature of solar energy poses challenges in maintaining stable power output and efficient energy conversion. To address these challenges,

dual-stage conversion topologies have emerged as a reliable solution. In such systems, the PV array output is first processed by a DC-DC converter, followed by a DC-AC inverter stage that ensures synchronization with the utility grid. This separation of power conditioning and grid interfacing enhances system flexibility, control, and efficiency.

In this context, the Luo converter, a type of high-efficiency DC-DC converter, offers several advantages, including high voltage gain, continuous input current, and reduced ripple content, making it highly suitable for PV applications. When integrated into a dual-stage configuration, the Luo converter effectively steps up the low and variable DC voltage from the PV array to a stable DC level required by the inverter.

Additionally, the incorporation of easy power regulation techniques ensures that the system can quickly and accurately adjust its power output in response to variations in solar irradiance and load demands. This regulation not only optimizes the energy harvest from the PV source but also contributes to grid stability by maintaining consistent power quality and reducing fluctuations.

This paper (or report) presents the design and analysis of a dual-stage grid- connected PV system employing a Luo converter with easy power regulation. The proposed system demonstrates improved voltage boosting capability, efficient power regulation, and reliable grid interfacing, making it a promising solution for modern distributed renewable energy systems.

## II. LITERATURE SURVEY

The integration of photovoltaic (PV) systems with the utility grid has attracted considerable research interest in recent years due to the growing emphasis on renewable energy and sustainable power generation. Several studies have been conducted on grid-connected PV systems, particularly focusing on converter topologies, control strategies, and power regulation techniques to enhance system performance and reliability. Dual-stage conversion systems have been extensively explored in the literature as an effective configuration for grid-connected PV applications. In these systems, a DC-DC converter is used in the first stage to boost and regulate the PV array's output voltage, followed by a DC-AC inverter that interfaces with the grid. According to Kumar et al. (2021), dual- stage systems offer improved control over voltage and power flow, enhancing the overall stability and efficiency of the PV grid integration.

Recent investigations have also focused on enhancing **power regulation** in PV systems to mitigate the effects of environmental fluctuations and ensure stable grid operation.

Techniques such as Perturb and Observe (P&O), Incremental Conductance (INC), and Fuzzy Logic Control (FLC) have been widely applied for Maximum Power Point Tracking (MPPT) and dynamic power control.

As reported by Singh et al. (2020), the integration of simple yet effective power regulation strategies ensures optimal PV performance while maintaining grid code compliance.

Furthermore, hybrid control approaches combining MPPT algorithms with advanced converter Topologies have been proposed to improve system responsiveness and power quality. Patel and Desai (2022) implemented a dual-stage PV system with a Luo converter and adaptive MPPT control, achieving enhanced voltage stability and reduced power fluctuations under rapidly changing irradiance conditions.

## III. LUO CONVERTER

The Luo converter is a type of DC-DC converter that belongs to the family of positive output super-lift converters, introduced by Fang Lin Luo. It is designed to step up (boost) the input DC voltage to a higher DC output voltage with improved performance characteristics compared to conventional boost converters.

Unlike simple boost converters, the Luo converter uses a combination of inductors, capacitors, and switching devices arranged to produce higher voltage gain, continuous input current, and reduced output ripple making it highly suitable for renewable energy systems like PV systems.

There are several configurations of Luo converters, categorized based on voltage polarity and conversion type:

**Positive Output Luo Converter:** Both input and output are positive.

**Negative Output Luo Converter**: Output voltage is negative relative to the input.

**Super-Lift Luo Converter:** Provides even higher voltage gain through additional capacitors.

**Ultra-Lift Luo Converter**: Further enhanced version for extremely high voltage boosting applications.

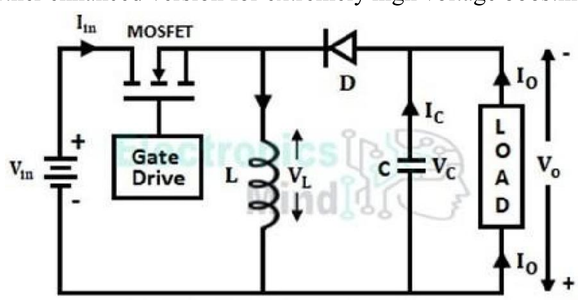


Fig: Luo Converter

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## IV. MPPT TECHNIQUES

MPPT stands for Maximum Power Point Tracking.

It's a technique used in solar photovoltaic (PV) systems to ensure the system operates at its maximum power point (MPP) — the point on the current-voltage (I-V) curve of a solar panel where the product of current (I) and voltage (V) is maximum. The output power of a solar panel varies with irradiance (sunlight) and temperature. To get the maximum available power at any given time, an MPPT controller continuously adjusts the electrical operating point of the modules.

Without MPPT, a solar system might operate away from its optimum point, wasting potential energy.

A DC-DC converter (like a buck, boost, or buck-boost converter) is controlled by an MPPT algorithm, which varies its duty cycle to change the operating voltage/current of the PV panel.

The algorithm continuously monitors the power output and adjusts until it finds the point where power is maximized.

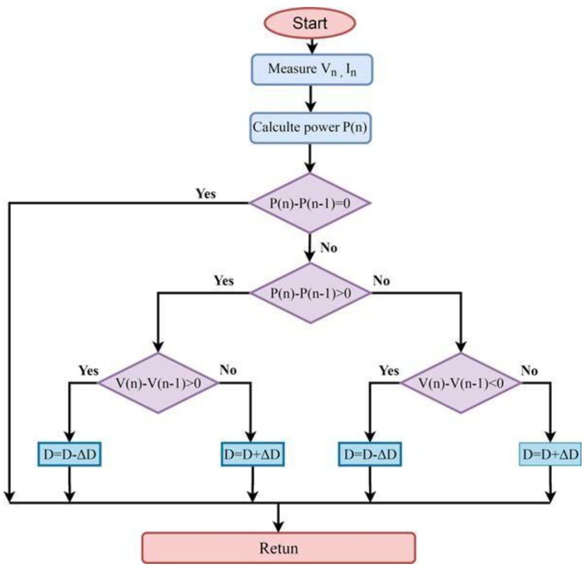


Fig: Flowchart Of P&O Algorithm

The controller perturbs (changes) the PV voltage slightly and observes the change in power. If power increases, it continues in the same direction; if it decreases, it reverses the direction.

Algorithm Steps:

- Measure current power.
- Slightly change the voltage.
- Measure new power.
- If power increased → continue.
- If power decreased → reverse.

## V. PROJECT DESIGN

A dual-stage grid-connected PV (Photovoltaic) system typically consists of:

- DC-DC Converter Stage boosts and regulates the voltage from the PV panel.
- DC-AC Inverter Stage converts regulated DC to AC and synchronizes it with the grid.

The PV panel generates a variable DC voltage depending on sunlight. To extract maximum power, MPPT algorithm (like P&O or Incremental Conductance) is applied.

The Luo converter is a high- efficiency DC-DC converter capable of both voltage boosting and polarity inversion (if needed). It operates by switching a power MOSFET on and off at high frequency. Inductors, capacitors, and diodes

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smooth out the voltage and reduce ripple. The Luo converter steps up the fluctuating PV voltage to a stable higher DC level required by the inverter.

MPPT controller adjusts the duty cycle (D) of the Luo converter based on PV voltage and current to track the maximum power point. This ensures optimum PV utilization under different irradiance and temperature conditions. The regulated DC output from the Luo converter is fed to a voltage source inverter (VSI). The inverter converts this DC to AC.

A Phase Locked Loop (PLL) ensures the AC output matches the grid's voltage, frequency, and phase.

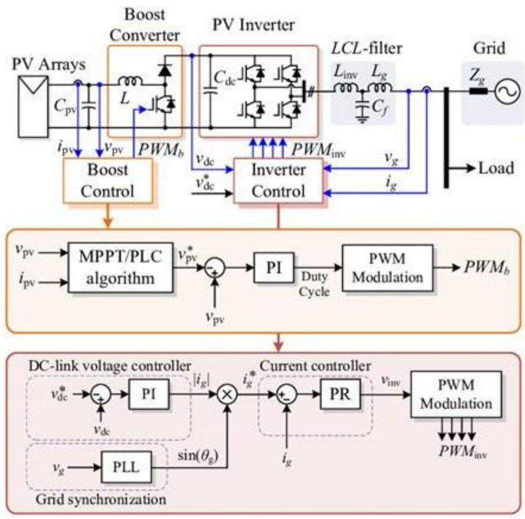


Fig: System Configuration and Control Structure

Grid Connection and Power Injection. The inverter injects synchronized AC power into the grid. Power control mechanisms regulate how much power is sent to the grid based on demand and system settings.

## VI. RESULTS AND DISCUSSIONS

The proposed dual-stage connected photovoltaic (PV) system was successfully simulated and analyzed using MATLAB/Simulink. The system architecture consists of a PV array connected to a Luo converter in the first stage for DC voltage boosting, followed by an inverter stage to interface with the AC grid. The Luo converter, known for its high voltage gain and continuous input current, was controlled using a simple and efficient regulation technique.

The PV system maintained a stable DC output voltage even under varying solar irradiance and temperature conditions, thanks to the Luo converter's superior voltage boosting capability.

The maximum power point tracking (MPPT) algorithm integrated into the regulation strategy enabled the PV array to operate consistently at its maximum power point, improving the overall efficiency of the system.

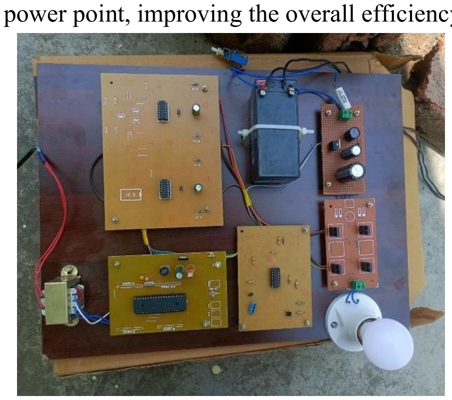

Fig: prototype

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The inverter stage successfully converted the regulated DC voltage to a sinusoidal AC output, synchronized with the grid voltage in both frequency and phase.

The total harmonic distortion (THD) of the AC output was within the permissible limits as per IEEE-519 standards, indicating high power quality.

The response time of the regulation system was fast, ensuring quick adaptation to changes in environmental conditions and load demands.


Fig: Input Voltage Measured from the module


Fig: Output Voltage Measured from the Module

| Input Voltage | Expected Output Voltage | Conventional System | Proposed LUO System |
|---|---|---|---|
| 10V | 20V | 18.33 V | 20.2V |
| 50V | 100V | 98.05V | 113.7V |
| 100V | 200V | 197.7V | 230.5V |
| 400V | 800V | 795.5V | 931.5V |
| 600V | 1200V | 1194V | 1399V |
| $V_0$ | $V_0=2V_{in}$ | $V_o<2V_{in}$ | $V_0>2V_{in}$ |

Table: Comparison of LUO converter with conventional converter

## VII. CONCLUSION

A dual-stage connected PV system employing a Luo converter with easy regulation was designed, modeled, and evaluated. The results demonstrate that the Luo converter effectively boosts and regulates the PV output voltage, ensuring a steady DC link voltage for the inverter stage. The regulation strategy, coupled with MPPT control, provided efficient and reliable system performance under dynamic environmental conditions.

The inverter stage achieved high-quality AC output with low harmonic distortion and excellent synchronization with the grid, confirming the suitability of the proposed system for grid-connected renewable energy applications. The ease of regulation and fast dynamic response make this configuration a promising solution for enhancing PV system performance in modern power systems.


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