



INNOVATIVE MODELLING OF RENEWABLE ENERGY DG MICROGRID USING CLASS TOPPER OPTIMIZED PI CONTROLLER AND HIGH GAIN CONVERTER

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Abstract: In modern energy systems, the pursuit of sustainable and efficient energy solutions has driven the development of renewable energy sources and microgrid systems. Traditionally, power grids have relied heavily on centralized power generation, which poses challenges related to energy efficiency, reliability, and environmental impact. This system incorporates dual photovoltaic (PV) arrays to ensure maximum power extraction and efficient energy conversion. The high-gain Cuk converters boost voltage levels, allowing for effective integration of renewable energy into the grid. The Class Topper Optimized PI controller dynamically regulates voltage and power, maintaining stability and minimizing fluctuations. The single-phase VSI facilitates the conversion of DC power from the PV arrays into AC power compatible with the grid, while the LC filter smoothens the output waveforms by mitigating harmonics and ensuring high-quality power delivery. A pulse width modulation (PWM) generator is used to control the switching of both the VSI and the converters, enhancing overall system efficiency. This integrated approach significantly improves power quality, reduces response time, and enhances the reliability of the microgrid. This model effectively addresses challenges in voltage regulation, power quality, and stability in renewable energy-based microgrids. This is implemented by Matlab Simulation 2021a.

Index Terms – Renewable Energy, DG Microgrid, Class Topper Optimized PI Controller and Energy Management Systems

I. INTRODUCTION

Integrating renewable energy into distributed (DG) microgrids is an important step in the quest for sustainable energy. As the world grapples with climate change, climate and energy security, harnessing the potential of renewable energy sources such as solar, wind and hydropower has become increasingly important. Microgrids are local networks that operate independently or in conjunction with larger projects and have the potential to improve the quality and use of energy in society. However, effective management of microgrids, especially in ensuring stability, reliability and performance, requires new management and energy conversion equipment. Recommendation. Among various control techniques, Proportional-Integral (PI) controllers are widely recognized for their simplicity and effectiveness in managing dynamic systems. However, traditional PI controllers may fall short in scenarios requiring rapid response and high precision, particularly in systems with significant variations in load and generation.

This limitation has prompted the exploration of more advanced control strategies, such as the Class Topper Optimized PI Controller. This innovative approach enhances the performance of conventional PI controllers by optimizing their parameters using advanced algorithms, ensuring improved response times and system stability. By employing such optimized controllers, microgrids are better adapt to fluctuating renewable energy inputs, thereby maximizing efficiency and minimizing energy waste.

Additionally, the role of electrical converters in renewable energy systems cannot be ignored. High Gain Converters (HGCs) are particularly advantageous in renewable applications due to their ability to step up low voltages generated by renewable sources to the higher levels required for grid connection or local consumption. These converters are crucial for integrating various energy sources into a microgrid, enabling seamless energy flow and efficient power management. The combination of Class Topper Optimized PI Controllers with HGCs presents a unique opportunity to enhance the operational capabilities of DG microgrids. By enabling efficient conversion and distribution of renewable energy, these technologies increase the overall efficiency and reliability of microgrid systems.

II. LITERATURE SURVEY

In recent years, today's world is increasingly concerned about population growth and environmental change. Population growth and industrialization demand more energy from the grid. Traditional energy sources are not enough to meet the demand and also affect the environment.

Zhaodi Shiet al [2022] described to simultaneously optimize the capacity of RE generation and energy storage systems. Time series simulation technology is used to determine all the characteristics of renewable energy in the region to establish a reliable model. A low-level optimization is developed for ESS capacity measurement. The golden section Fibonacci tree optimization algorithm is used to improve efficiency and solve accuracy.

Fahad R. Albogamyet al [2022] exploited to minimize overall average energy cost and thermal discomfort cost over a long time horizon for sustainable smart homes, accounting for changes in home occupancy state, the most comfortable temperature setting, electrical consumption, renewable generation output, outdoor temperature, and electricity costs.

Christian Breyeret al [2022] described on the challenges and opportunities around the grid, energy storage, interconnection, transport and business electricity (meaning electricity for X and hydrogen for X), and participation in natural and technological CO2 removal techniques. Advanced concepts and methods now allow the field to deliver real, cost or resource optimized, sustainable changes without the use of fossil fuels. In most transitions, solar and wind energy have become the pillars of sustainable energy, along with energy efficiency.

Feifei Bai et al [2022] explained the dynamic response of small photovoltaic inverters dominates the distribution network and affects the energy of the entire grid. Some important cases in Australia have shown that the dynamic response of small inverters does not always follow the inverter model. There is no detailed research in the existing literature on the effective response of small photovoltaic inverters to grid disturbances.

Chuan Yue Li et al [2022] demonstrated a Voltage Source Inverters (VSIs) with vector control based on Phase-Locked Loops (PLL) suffer instability when connecting to a very weak AC grid. The normal inductive grid impedance compensation of the PLL actually stabilizes the connection by reducing the grid impedance. The improved grid impedance compensation in the PLL improves the stability and performance of VSIs connected to low-power lines (where the grid impedance is high and highly variable).

Muhammad F. Umar et al [2022] developed an effective resonance suppression control for grid-interactive inverters with LCL filters in weak grid conditions. The resonance suppression mechanism is based on an adaptive model of predictive control. The adaptive predictive control technique effectively suppresses resonance issues that arise in single-phase grid-interactive inverters, particularly when connected to a weak grid with high impedance.

Xin Ding et al [2022] explained a Capacitor-current-feedback active damping has been widely adopted in digitally controlled LCL-type Grid-Connected Inverters (GCI). However, digital delay control weakens the stability of the system in the negative damping range. Especially in weak grids, such GCIs are prone to instability due to changes in grid impedance.

Gedeon Rusatiraet al [2023] presented an optimal grid-supporting power-to-gas (GS-P2G) control scheme that coordinates the operation of a Grid-Forming Inverter (GFMI), Battery Energy Storage (BES), and Hydrogen Energy Storage (HES) in a Power-To-Gas (P2G) system. The model aims to provide a stable energy flow in critical situations by smoothing out the fluctuating energy flows from renewable energy sources (RES) to the grid.

Zhanlong Li et al [2023] proposed a grid-side transient fault ride-through problem seriously affects the stable operation of the grid-connected wind turbine. At present, the grid-connected adaptability analysis of DC wind turbines (DCWT) under grid-side transient faults is still vacant. Adaptive control strategies improve the fault recovery capacity of DC wind turbines, allowing them to remain operational and continue operating during and after grid-side faults such as voltage sags or outages.

Md Ismail Hossain et al [2023] proposed a photovoltaic-wind-MMC-HVDC system flywheel energy storage energy control strategy to control HVDC connection electricity during AC grid connection power outage and solve electricity problem. Electricity transmission and instantaneous transmission from RER junction. The scheme eliminates the competition stoppage in HVDC line and connects RER without the need for renewable energy during low power periods.

Huan Zhu et al [2023] explained Tips for planning energy storage to convert renewable energy into generators. Energy storage technology is adapted to the understanding of different renewable energy sources. Then, the role of energy storage in the production, transmission, distribution and efficient use of renewable energy sources is analyzed. Integrating different renewable energy sources is one of the best ways to achieve low-carbon energy.

III. MODELING AND CONFIGURATION OF RENEWABLE ENERGY DG MICROGRID

Traditional fossil fuels such as coal and oil contribute to global climate deterioration and air pollution. Global environmental concerns and the reduction of fossil fuels have triggered further advances in renewable energy technologies. Renewable energy (RES), such as wind energy, solar energy, hydropower, geothermal energy and biomass energy, are considered the preferred energy of the 21st century.

Today, many countries and regions are actively exploring the potential of renewable energy to support their economic development and social development. As the world's largest developing country, China has made renewable energy an important pillar of the

government's strategy to reduce the impact of economic power on the country's environment. As the country commits to spreading high-tech technologies, China has announced an ambitious plan: In its National Decision Making (NDC) project, China has pledged to increase the use of non-fossil fuels, including renewable and nuclear energy. By 2020. For 20%.

The US wind energy capacity reached 61.1 GW in 2013, up 26.5% from the previous year. The following year, wind energy produced 181.1 TWh, accounting for about 4.33% of the country's total electricity generation. The US Department of Energy (DOE) estimates that wind energy will account for 20% of US electricity by 2030, while renewables will account for 4%. Due to technical, environmental and economic reasons, the energy sector is interested in the use of micro-electric systems and smart plans to increase efficiency and ensure future plans. Microgrid is a small grid that solves energy problems, increases local comfort and operate in grid or control mode.

Compared with AC microgrids, DC microgrids have the advantages of better performance, lower cost, easy control and higher reliability. Against this background, scientists have proposed various management systems such as centralized management, decentralized management and hierarchical management to meet the communication needs in real projects and ensure the efficient operation of microgrids. Among the advanced control methods, predictive control model is considered one of the most advanced control methods for DC microgrids.

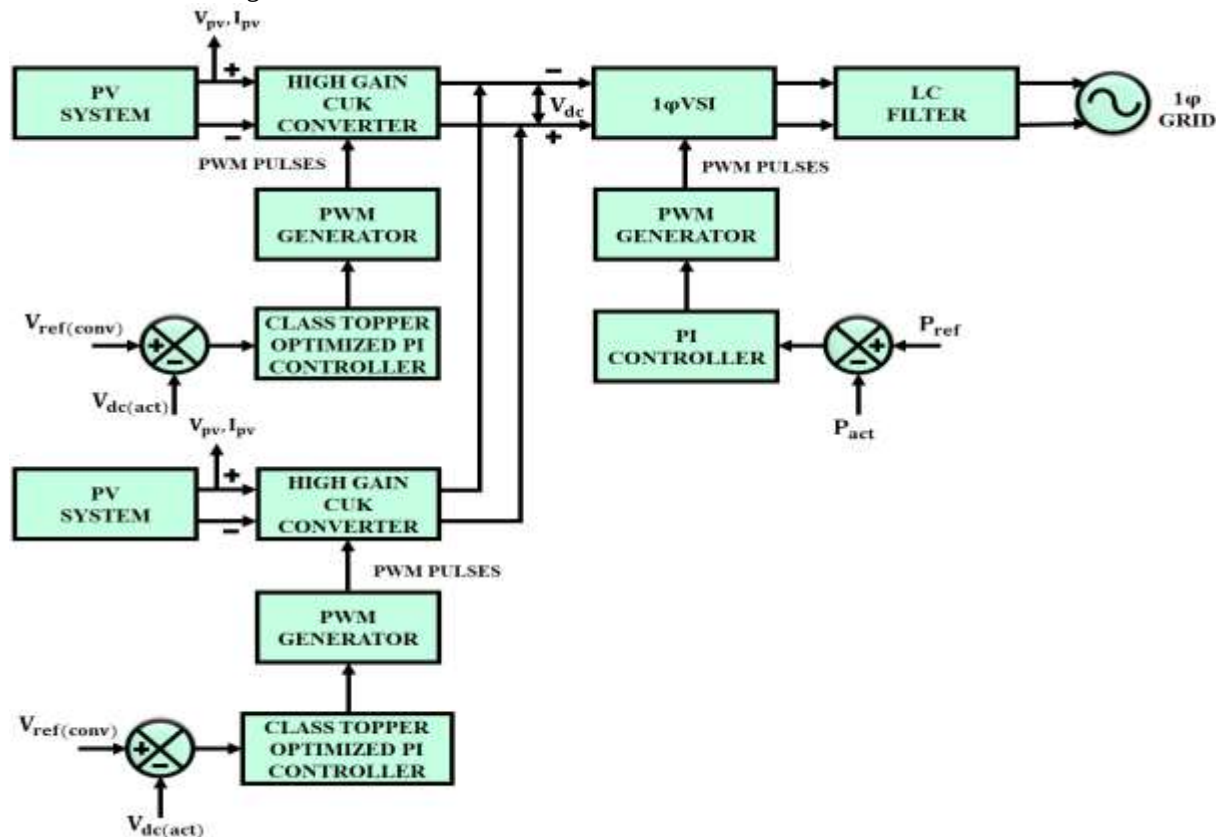


Figure 1: Block Diagram of renewable energy distributed generation

In this project, the modelling of renewable energy distributed generation (DG) microgrids by integrating a Class Topper Optimized PI Controller with a high-gain converter is proposed. This system enhances the integration of renewable energy distributed generation (DG) microgrids by using a Class Topper Optimized PI Controller and a high-gain Cuk converter. Dual photovoltaic (PV) arrays are used to maximize power extraction and boost voltage levels for efficient grid connectivity. The high-gain Cuk converters play a vital role in improving energy transfer by increasing the voltage from the PV arrays. A Class Topper Optimized PI Controller is implemented to dynamically regulate voltage and power, ensuring stable microgrid operation despite fluctuations in supply and demand.

IV. RESULTS AND DISCUSSIONS

The proposed work is implemented in MATLAB simulation and the following results are obtained.

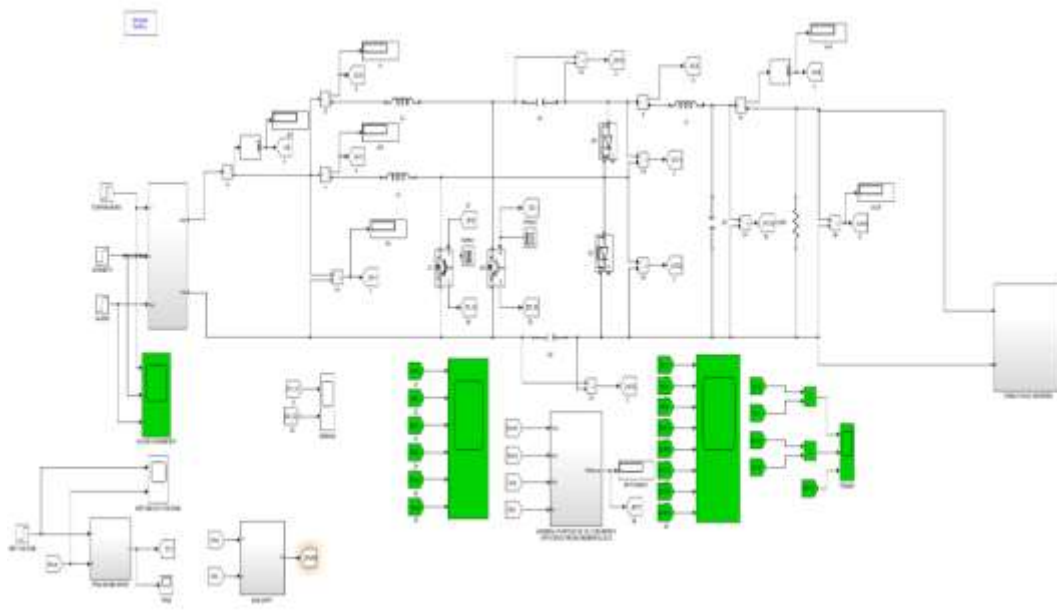


Figure 2: Overall Simulation Block Diagram

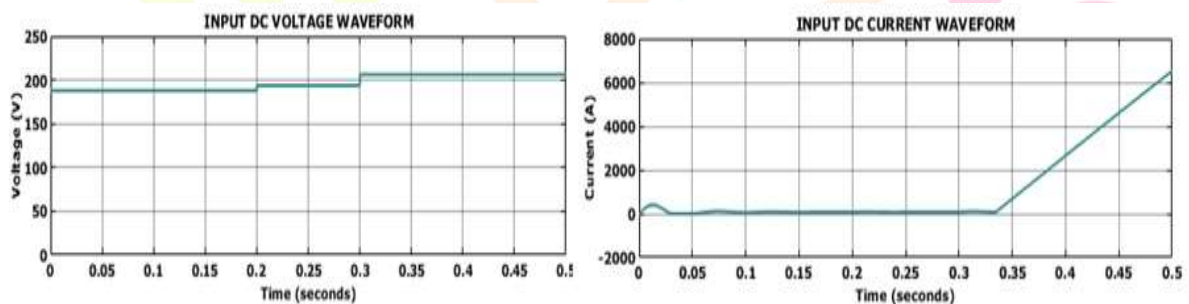


Figure 4: Input DC Voltage & Current Waveform

The input DC voltage and current waveforms are shown in figure 4. The input DC voltage waveform shows that the voltage stabilizes at 200V in 0.5 seconds, indicating that the power supply voltage is stable. In comparison, the input DC current waveform starts from 0 A and increases to 6000 A considering the current increase in the same period.

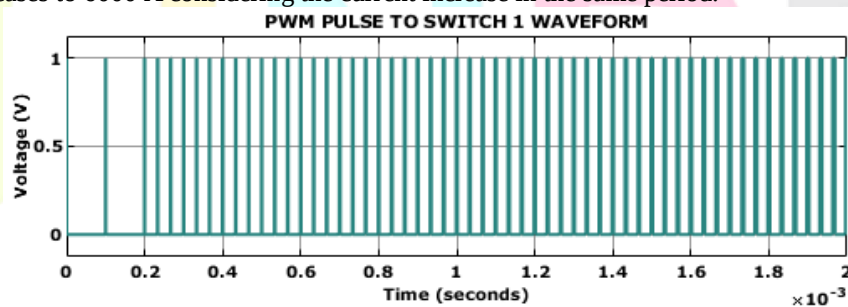


Figure 5 : Zoom View PWM Pulse to Switch 1 Waveform

Figure 5 shows that zoom view PWM pulse to switch 1 waveform. The PWM pulse to Switch 1 waveform shows a voltage alternating between 1 V and 0 V, creating a repetitive pattern over the 2 milliseconds. The pulse width modulation occurs at a frequency indicating quick switching, with high voltage lasting for brief intervals followed by low voltage.

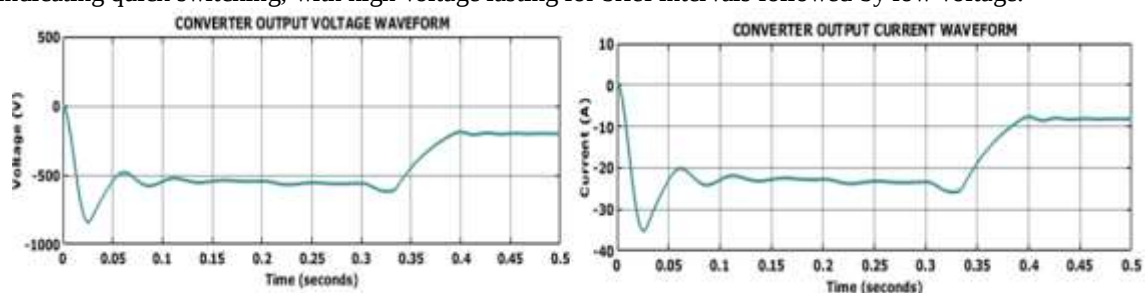
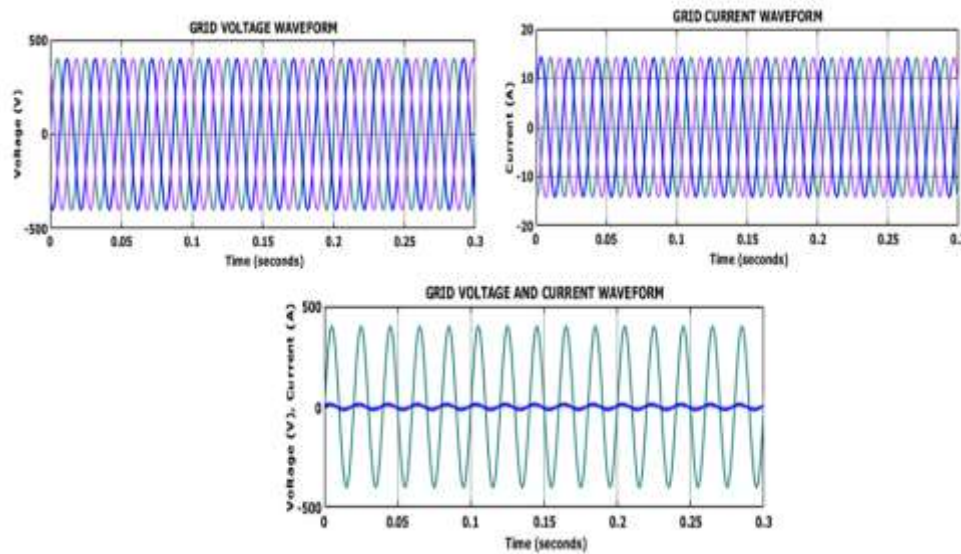
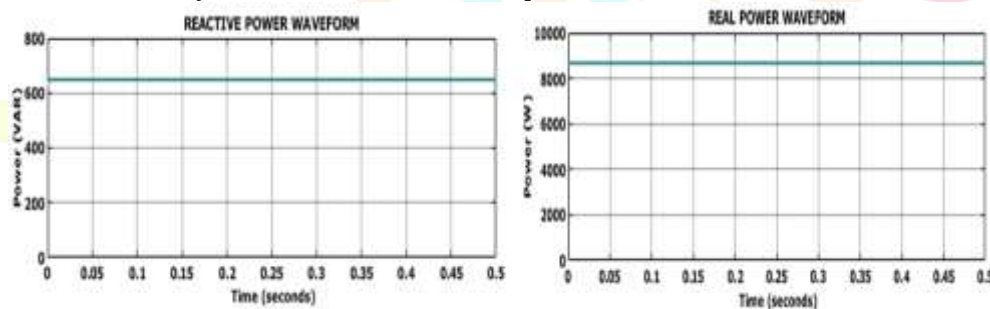


Figure 6: Converter Output Voltage & Current Waveform

The converter output voltage waveform is shown in figure 6. It is fluctuating voltage peaking at approximately 500 V and dipping to around -1000 V over 0.5 seconds. Meanwhile, the converter output current waveform ranges from about -40 A to 0 A, indicating periods of negative current flow during the operation.

**Figure 7: Grid Voltage & Current Waveform**

The grid voltage and current waveforms are shown in figure 7. The grid voltage waveform oscillates between approximately -500 V and 500 V, exhibiting a consistent sinusoidal pattern. Meanwhile, the grid current waveform varies from about -20 A to 20 A, demonstrating a similar oscillatory behavior over the same time period.

**Figure 8: Real and Reactive Power Waveforms**

Active power and reactive power waveforms are shown in figure 8. The reactive power waveform remains constant at approximately 600 VAR, indicating no fluctuations over the observed period. In contrast, the real power waveform stabilizes at around 8000 W, also showing no variations throughout the timeframe.

V. CONCLUSION

In conclusion, the innovative modelling of renewable energy DG microgrids utilizing a Class Topper Optimized PI controller and high-gain converter presents a promising solution to the challenges associated with integrating renewable energy sources into the grid. By leveraging dual PV arrays and high-gain Cuk converters, this system maximizes power extraction while ensuring efficient voltage boosting for optimal grid compatibility. The dynamic regulation capabilities of the optimized PI controller enhance stability and minimize fluctuations, thereby improving overall power quality. The inclusion of a single-phase VSI and an LC filter ensures that the converted AC power meets stringent quality standards, while PWM control further optimizes system efficiency. This integrated approach not only addresses critical issues such as voltage regulation and response time but also significantly enhances the reliability of renewable energy microgrids. The successful implementation of this model through Matlab Simulation 2021 underscores its potential impact on advancing renewable energy solutions and supporting sustainable energy systems in the future.

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