Review of MPPT and Control Strategies in a Solar-Diesel Hybrid Power System

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Abstract: The integration of solar-diesel hybrid power systems offers a reliable and sustainable energy solution, particularly for off-grid and remote locations. This paper presents a comprehensive review of Maximum Power Point Tracking (MPPT) and control strategies employed in solar-diesel hybrid systems. It discusses various MPPT techniques, including Perturb and Observe (P&O), Incremental Conductance (IC), and advanced algorithms like fuzzy logic and neural network controllers, focusing on their effectiveness in optimizing photovoltaic (PV) energy extraction. Additionally, the paper explores control strategies for system components such as diesel generators, battery storage, and inverters. Techniques like Proportional-Integral-Derivative (PID) controllers, adaptive controllers, and multi-input converters are analyzed for maintaining system stability, minimizing Total Harmonic Distortion (THD), and ensuring efficient energy management. This review underscores the potential of hybrid solar-diesel systems for sustainable energy deployment, emphasizing the need for advanced control mechanisms. Future research directions include real-world implementation, large-scale system optimization, and development of next-generation intelligent controllers for enhanced system performance and resilience.

Keywords- Renewable Energy, Solar system, Diesel System, Hybrid System, Maximum Power Point Tracking.

Introduction

Microgrids are decentralised groups of electrical sources and loads. However, when necessary, they can operate independently in "island mode" and disconnect from the interconnected grid. A microgrid is an independent energy system that supplies power to a specific area, such a neighborhood, hospital complex, college campus, or corporate centre.

A microgrid is described as a collection of distributed energy resources (DERs) and associated loads that operate as a single, controlled entity inside well-defined electrical boundaries and are connected to the grid by the US Department of Energy Microgrid Exchange Group. A microgrid may function in both connected and island mode by connecting and disconnecting from the grid. A microgrid is defined as a combination of Low-Voltage (LV) distribution systems, energy storage systems, storage devices (flywheels, batteries), distributed energy resources (DERs) (micro turbines, fuel cells, photo voltaic (PV), etc.), and flexible loads in an EU research project. These systems may function with or without a connection to the main grid.

One benefit of connecting PV power generating systems to the grid is that the generated electricity may be used more practically. To ensure the security of the PV installer and the utility grid's accountability, however, the technical requirements from both the PV system and the utility installation grid aspect must be satisfied. For PV systems to be widely used, it is crucial to understand the technical requirements for grid [30]. PV systems may be connected to the grid by means of an electrical converter, which transforms the DC power produced by the modules into AC power, which is utilised to supply standard power to electrical appliances. The need of an electrical converter system for grid-connected.Desegregating renewable energy sources-electricity (RES-E) production technologies into an established electrical network requires careful consideration of grid affiliation associated extension charges.

Different Technology for Grid Connected Solar PV System

The goal of [10] is to maximise the performance of a grid-connected PV-fuel cell hybrid system by the use of a two-loop controller. A neural network controller for the best electric receptacle chase might be one loop that maximises solar energy extraction from PV arrays under a range of isolation, temperature, and system load circumstances. The other loop is controlled by a genuine reactive power controller (RRPC). By controlling the inflow of fuel to cell stacks and sending shift management signals to an influence learning system, the RRFT satisfies the system's requirements for real and reactive powers. The majority of the PV array's power points are monitored by a neural network-based controller, as their nonlinear I-V characteristics make them a good fit for NN applications. Examine the simulations that show the intended method is capable of producing a PV array that can precisely follow the height power circumstances, including sporadic instances of rapid dynamic isolation. The electric cell powerhouse is designed with a PI-type controller to meet the actual and reactive power requirements of the system.

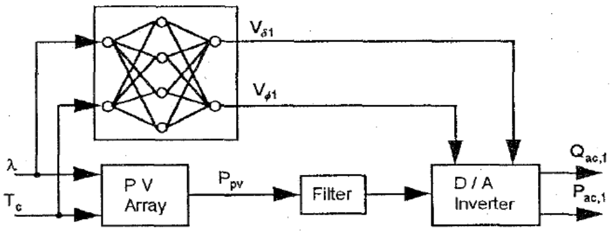

Figure1: NN Controller for PV Arrey [11]

For the grid-connected hybrid PV/wind power grid, a unique multi-input electrical converter was proposed in order to change the ability system and reduce the value. A full-bridge dc/ac electrical converter and a buck/buck-boost amalgamated multi-input dc/dc converter make up the intended multi-input device. Utilising the perturbation and observation approach, the most electrical outlet pursuit rule for input sources is achieved. An explanation of the intended multi-input electrical converter's working concept is provided.

An additional analogue circuit and a digital signal processor are used to complete the feedback loop. The protection area unit's soft-start logic gate functionalities are enforced for reasonable uses.

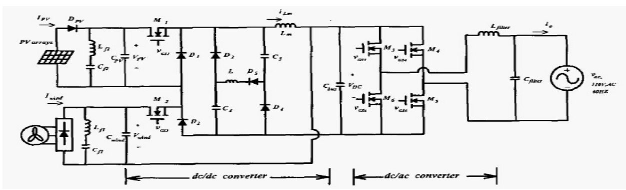

Figure 2: Multi-Input Inverter

A revolutionary grid-connected multi-input electrical converter. A hybrid PV and wind grid is anticipated. it's the following benefits: Power from the turbine and PV array is frequently delivered to the utility grid either simultaneously or separately;2) most PV and wind energy systems achieve maximum power point tracking (MPPT) features;3) an excessive variation in input voltage is often caused by varying isolation and wind speed is suitable; and4) the power rating of the electrical converter is frequently lowered. For grid-connected photovoltaic systems, a high-performance, single-stage electrical converter architecture was anticipated. In addition to potentially increasing the normally low voltage of photovoltaic (PV) arrays, the proposed design has the potential to transform stellar dc power into high-quality ac power that may be sent into the grid while maximising PV array output. According to IEEE-519 standard, the total harmonic distortion of this feed into the grid is limited. Numerous intriguing possibilities, including increased PV array utilisation, potency, affordability, and small size, are offered by the proposed topology. Furthermore, the PV array seems to be a floating supply to the grid because of the terrible nature of the predicted topology, which increases system safety.An extensive comparison between the current topologies and the predicted topology is provided, along with a study of the current topologies suitable for single-stage, grid-connected PV applications. Included is a complete steady-state analysis along with the lookup process and peak device stress expressions. For discontinuous conductivity mode operation.

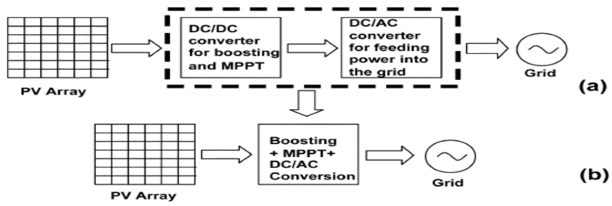

Figure3. Grid Connected PV System Topologies: Single Stage and Multistage

For the first time, a three section line commutated electrical converter will be used to interface a PV array with the utility grid via a symbolic logic controller [42]. Most electricity is fed into and tracked by the electrical grid via the controller. The language variables are chosen appropriately to adjust the electrical converter's firing angle in order to maximise power. Using MATLAB/PSB, the Simulink model of the intended theme with a symbolic logic controller has been created. It is programmed to fire pulses to the thyristors in the electrical converter using a PIC microcontroller. The intended theme has been experimentally built up, and as a consequence, the outcomes on a PV array with a fifty-four V, twelve A rating square measure granted. The results of the simulation and experiment compare horribly, indicating that the controller's design was supported.

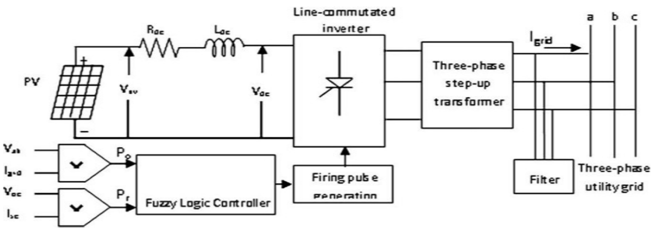

Figure 4. Basic PV System with Using Fuzzy Logic Controller [43]

Through the use of a transformer and line-commutated electrical converter, a straightforward power electronic controller has been devised to interface electrical phenomena arrays with the three-phase grid. The closed-loop system topic is studied through simulation using a mathematical logic controller. When the findings from the simulation studies and the experimental investigation of the projected theme are compared, it is discovered that the simulation results closely resemble the results from the experiments, supporting the experimental power circuit and management circuits of the electrical converter. Thus, the most effective method for tracking and extracting electricity from the grid is mathematical logic management.

Components and Techniques

Figure 1 depicts the whole block design of the army's intended 1-MW microgrid system. It has several sub-systems, of which PV, battery, and inverter are only a few. The details of each component system are provided below.

A. Technical Details of the Setup

An isolated, one-MW microgrid system is recommended for military usage by the writers of this paper. The system is designed to have a 400V rms phase-phase AC voltage output. The output AC voltage of 400V rms necessitates a dc link voltage of about 665V at the inverter's input after taking voltage loss across the output LC filter into consideration. The authors of this work are able to maintain a constant dc-link voltage of 665V by using a dc-dc bidirectional converter to charge and discharge the battery system. The portions that follow provide a description of the same.

B. Photovoltaics

The intended islanded microgrid, fueled by solar power, would mostly use sustainable energy sources. A microgrid with a 1 MW total solar capacity is suggested by the authors. The PV system block in Fig. 1 shows the same thing. PV systems employ PV panel layouts in series and parallel to satisfy the necessary system characteristics. Because of the way the PV system is built, MPPT may be achieved without the need for a separate converter and controller.

A single Soltech 15TH-215-P solar panel module was utilised in the suggested microgrid concept. At its maximum power point (MPP), a single solar panel can generate 213.15 watts of electricity from a 29-volt open circuit.

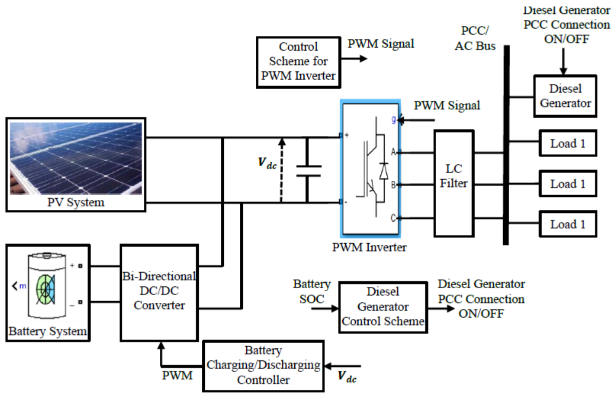

Figure 5. Block diagram of the proposed 1-MW microgrid

By serially connecting 23 solar panel modules, the MPPT is achieved without the requirement for a controller or converter. The open circuit maximum power point voltage is 667V given an output phase-phase voltage of 400 V rms. Furthermore, the PV system does not require an extra MPPT controller since the battery-powered dc-dc bidirectional converter maintains the dc link voltage. The PV panel will always run at its maximum power point voltage thanks to the battery controller's guarantee.

One of the most common energy sources historically, a micro grid is a dispersed network of dispersed energy sources (like solar or wind turbines). Furthermore included in energy and load storage systems are microgrids (e.g., residential and industrial). Based on ecologically friendly renewable energies and safe, secure, friendly, and sustainable electrical energy, microgrids provide practical solutions to today's electrical energy problems. By rebuilding the microgrid, it helps with energy efficiency, stability measures, and organisation and administration of energy.

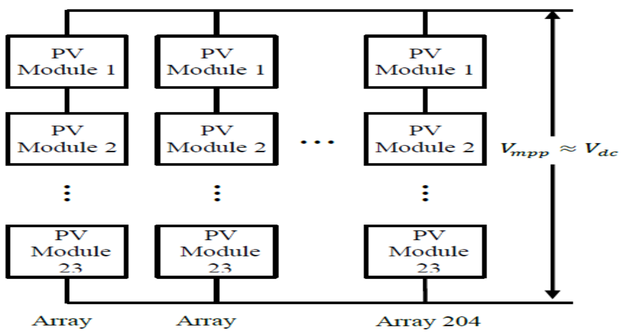

Figure 6: PV Array Module

Conclusion and Future Scope

Evaluation of Maximum Power Point Tracking (MPPT) and Control Strategies in Solar and Diesel Hybrid Power Systems Various MPPT algorithms, including Perturb and Observe (P&O), highlight the potential of such systems to provide energy solutions reliable, efficient, sustainable will provide. Incremental Conductance (IC), fuzzy logic, in neural network-based controllers Available, proven effective in extracting energy from photovoltaic (PV) systems under different environmental conditions Similarly also advanced such as proportional integral derivative (PID) . controllers, adaptive controllers and many inputs. The control methods include optimal system performance, total harmonic distortion (THD); Ensure reduced energy consumption and efficiency Combining solar and diesel energy sources supported by energy storage systems increases system reliability, reduces reliance on fossil fuels That way these two reduce operating costs and environmental impact and ensure a constant supply of electricity to remote off grid areas However, challenges remain in real time in terms of design efficiency, complexity, and cost. Future research will focus on developing intelligent, adaptive strategies capable of learning and optimization. Large-scale system implementation, real-world testing, and next-generation deployments will dramatically improve system performance, scalability, and flexibility, enabling solar, diesel, and hybrid electricity has been a viable solution to meet sustainable energy needs.

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