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AN INNOVATIVE AND AMALGAMATED CONTROLLER FOR GRID-CONNECTED CONTINENT MANAGEMENT OF PV-FED SINGLE-STAGE INVERTER

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ABSTRACT

The growing demand for renewable energy integration into power grids has spurred the development of advanced control mechanisms for photovoltaic (PV)-fed inverters. This paper presents an innovative and amalgamated controller designed for efficient grid-connected continent management of a PV-fed single-stage inverter. The proposed controller combines advanced control strategies, such as Maximum Power Point Tracking (MPPT), voltage and frequency regulation, and grid-support functionalities, to ensure optimal energy conversion and seamless grid integration. The controller's unique feature lies in its amalgamation of adaptive and predictive control algorithms, allowing for real-time adjustments in response to fluctuations in solar irradiance, load demand, and grid conditions. By managing both active and reactive power, the controller enhances the inverter's performance, improving energy efficiency and stability while supporting the grid's operational requirements. Additionally, the proposed system addresses issues related to power quality, such as harmonics and voltage sags, through dynamic compensation techniques. Simulation and experimental results validate the effectiveness of the innovative controller, demonstrating significant improvements in power conversion efficiency, grid stability, and overall system reliability. The findings of this study provide a viable solution for enhancing the performance of PV-fed single-stage inverters in grid-connected applications, contributing to the sustainable integration of renewable energy into power systems..

Keywords: *Photovoltaic (PV) systems, Single-stage inverter, Grid-connected inverters, Amalgamated controller, Continent management, Maximum Power Point Tracking (MPPT), Predictive control.*

INTRODUCTION:

Parallel operation of inverter-based photovoltaic (PV) distributed generator (DG) requires three main control functions. Maximum power point tracking (MPPT) and DC link voltage regulation, mainly used while operating in a grid connected mode (GCM). Power sharing, primarily employed while operating in an islanded mode (ISM). Active synchronization with the main grid. For maximum power point tracking, the control system should manipulate the power circuit output impedance till matching with the PV internal resistance at the point of maximum power. For this purpose, many MPPT algorithms have been presented for conditioning the control system aiming the extraction of the maximum power point (MPP) belonged to the P-V and I-V characteristics of a PV module. This tracking should be addressed automatically by the local controller of the voltage source inverter (VSI) depending on various techniques, which can be divided into three major categories [1].

The first category continuously monitors the PV current and/or voltage, thus achieving precise MPPT independently of empirical data related to the PV module characteristics. The main methods imputable to this category are the incremental conductance, perturb and observe (P&O), hill climbing (HC), BJTT uned MPPT, in addition to optimization and fuzzy logic (FLC) based techniques The second category embraces several methods that determine the MPP at different irradiances and temperatures relying on apriorism data belonged to the typical I-V curves of the PV array, such as fractional open circuit voltage (FOCV), fractional short circuit current (FSCC), constant reference voltage (CRV) , curve fitting, look-up tables- based method, and current sweep. With the use of these methods, the total number of required voltage and/or current sensors is reduced, but at the expense of compromising the tracking accuracy, which is the main disadvantage of such approach, particularly under anomalous changes in ambient insolation and temperature. P&O algorithm not only has relatively simple control algorithm, but also offers high tracking precision for the MPP without prior knowledge of the mathematical PV model, besides granting satisfactory dynamic response. Therefore, P&O has been widely employed for MPPT using only two set of sensors for measuring the PV current and voltage. However, this method still holds few disadvantages as follows. Firstly, the P&O algorithm causes an inherent oscillation in the output of the PV system during the tracking process. In addition, the time elapsed while oscillating around the MPP results in energy waste until convergence is achieved [2]. Moreover, the convergence time can be further increased under rapidly changing atmospheric conditions leading to higher energy losses, variations are not very common. Therefore, a compromise between MPPT sampling rate and incremental step voltage should be considered with DC voltage regulation in order to achieve an optimized performance with minimal oscillations. Regarding the second objective related to the power sharing, droop-based control-methods have been broadly used in voltage control mode (VCM) to support the dual mode of operation for parallel inverters in micro-grids (MGs). DGs, poor dynamic response owing to the bandwidth limitation influenced by the dual voltage-current loop architecture, the lack of adaptability with load variations considering the inertia-less nature of VSIs, and the indirect control of line currents since P-Q are used as the main control variable resulting in poor power quality. Therefore, to enhance power quality, a fast-islanding detection (ID) and transient mitigation strategies are needed for switching over between voltage-controlled mode (VCM) and current controlled mode (CCM) subsequent to MG operating mode changes from ISM to GCM, and vice versa [3]. Attractively, all these issues have been obviated through a hybrid scheme reported. Finally, concerning the active synchronization with the main grid. The simulation results presented in have relied on synchronous reference frame phase-locked loop (SRF-PLL) to detect the frequency in the MG; meanwhile, a simple zero-cross detection (ZCD) method has been adopted for the active synchronization to clear any phase shift between the inverter and the main grid voltages [4].

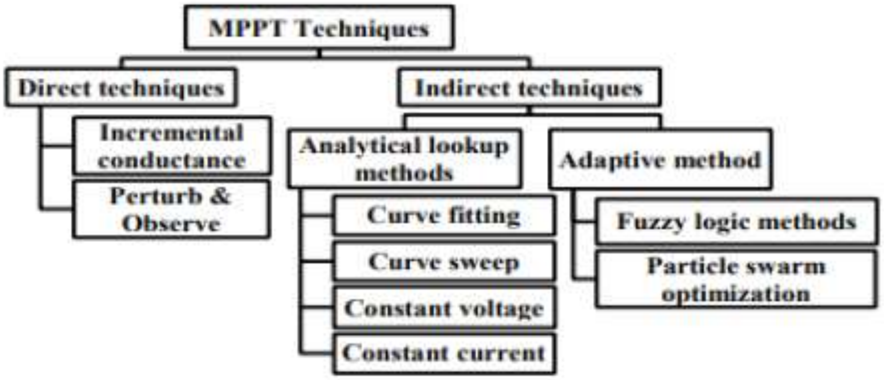

Figure1: classification of maximum power point tracking techniques

LITERATURE SERVEY

The electric power grid forms the foundation for several other critical infrastructures of national importance such as public health, transportation and telecommunication systems, to thrive. The current power grid runs on the century-old technology and faces serious challenges of the 21st century - Ever-increasing demand and the need to provide a sustainable way to meet the growing demand, increased requirement of resilience against man-made and natural disasters, ability to defend against cyber-attacks, increasing demand for reliable power, requirement to integrate with alternate energy generation and storage technologies [5]. Several countries, including the United States, have realized the immediate need to modernize the grid and to pursue the goal of a smart grid. Majority of recent grid modernization efforts are directed towards the distribution systems to be able to meet these new challenges. One of the key enablers of a fully functional Smart Grid are microgrids – subsystems of the grid, utilizing small generation capacities at the distribution system level to increase the overall reliability and power quality of the local grid [6]. It is one of the key directions recommended by national electric delivery technologies roadmap in United States as well as policy makers for electricity delivery in many countries. Microgrids have witnessed serious research activity in the past few years, especially in areas such as multi-agent system (MAS) architectures for microgrid control and auction algorithms for microgrid electricity transaction. However, most of the prior research on electricity transaction in microgrids fails to recognize and represent the true nature of the microgrid electricity market [7]. In this research, a comprehensive microgrid electricity market has been designed, taking into account several unique characteristics of this new market place. This thesis establishes economic rationale to\ the vision of wide-scale deployment of microgrids serving residential communities in near future and develops a comprehensive understanding of microgrid electricity market. A precise model helps the electric utility to make unit commitment decisions and to reduce operating costs and emission level properly. Besides playing a key role in meeting the load demand, it is also essential to the reliability of the MG. The central controller uses the modelling result as a basis of off-line network analysis to determine if the system might be costly and have high emissions. If so, corrective actions should be prepared, such as power sales, power purchases and bringing units on line. This thesis focuses on the modeling of MGs and discusses new management approaches for reducing the operating costs and emission level [8].

METHODOLOGY:

The proposed fuzzy control is to optimize energy distribution and to set up battery state of charge (SOC) parameters. The control algorithm takes the priority of selling electricity as the premise of energy distribution to allow remaining power generated by the renewable energy of the electrical grid sold through the connected mains grid.

System Configuration Of The Micro-Grid Case Study

The case study considers a low voltage (LV) MG system as shown in Fig. 2. Two three phase VSIs fed by multi-string PV array are interfaced through an output LC filter and coupling lines with parallel linkage at the PCC. The adopted PV module parameters are extracted from the Sun power (SPR-315E-WHTD) module data encompassed within the library of MATLAB/Simulink software.

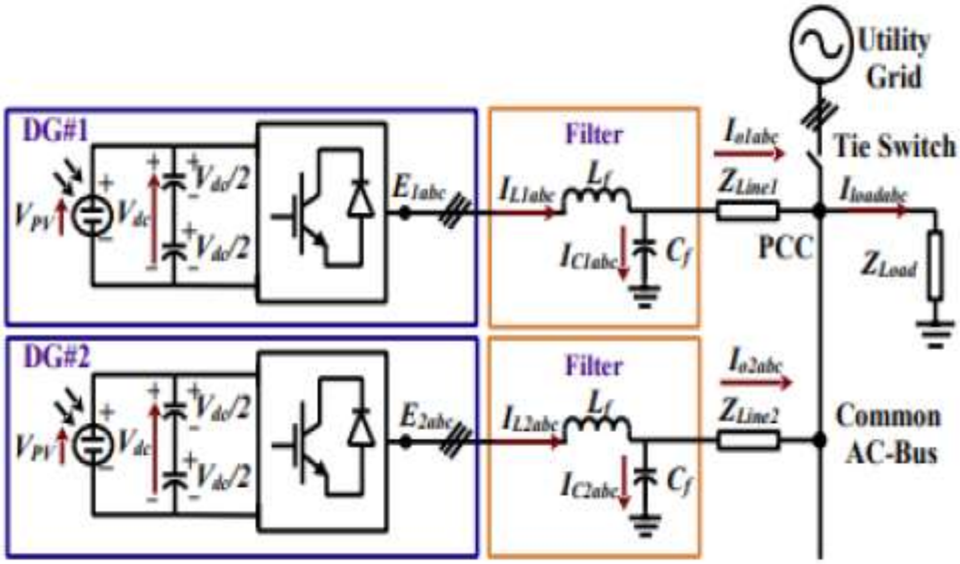

Figure2: Standard block diagram of the MG under examine

Photovoltaic Inverter

The inverter is the heart of the PV system and is the focus of all utility-interconnection codes and standards. A Solar inverter or PV inverter is a type of electrical inverter that is made to change the direct current (DC) electricity from a photovoltaic array into alternating current (AC) for use with home appliances and possibly a utility grid.

Since the PV array is a dc source, an inverter is required to convert the dc power to normal ac power that is used in our homes and offices. To save energy they run only when the sun is up and should be located in cool locations away from direct sunlight..

Inverter Classification

Solar inverters may be classified into three broad types:

Stand-alone inverters, used in isolated systems where the inverter draws its DC energy from batteries charged by photovoltaic arrays and/or other sources, such as wind turbines, hydro turbines, or engine generators. Many stand-alone inverters also incorporate integral battery chargers to replenish the battery from an AC source, when available. Normally these do not interface in any way with the utility grid, and as such, are not required to have anti-islanding protection. Grid tie inverters, which match phase with a utility-supplied sine wave. Grid-tie inverters are designed to shut down automatically upon loss of utility supply, for safety reasons. They do not provide backup power during utility outages. Battery backup inverters. These are special inverters which are designed to draw energy from a battery, manage the battery charge via an onboard charger, and export excess energy to the utility grid. These inverters are capable of supplying AC energy to selected loads during a utility outage, and are required to have anti-islanding protection. Normally, grid-tied inverters will shut off if they do not detect the presence of the utility grid. If, however, there are load circuits in the electrical system that happen to resonate at the frequency of the utility grid, the inverter may be fooled into thinking that the grid is still active even after it had been shut down.

RESULT ANALYSIS:

An inverter designed for grid-tie operation will have anti-islanding protection built in; it will inject small pulses that are slightly out of phase with the AC electrical system in order to cancel any stray resonances that may be present when the grid shuts down. Maximum power point tracking is a technique that solar inverters use to get the most possible power from the PV array. Any given PV module or string of modules will have a maximum power point: essentially, this defines current that the inverter should draw from the PV in order to get the most possible power (power is equal to voltage times current). At night, an off-grid PV power system uses batteries to supply its loads. Although the battery pack voltage when fully charged may be close to the PV array's peak power point, this is unlikely to be true at sunrise when the battery is partially discharged. Charging may begin at a voltage considerably below the array peak power point, and a MPPT can resolve this mismatch. The MPPT must then shift the array operating point away from the peak power point until production exactly matches demand. (An alternative approach commonly used in spacecraft is to divert surplus PV power into a resistive load, allowing the array to operate continuously at its peak power point.)

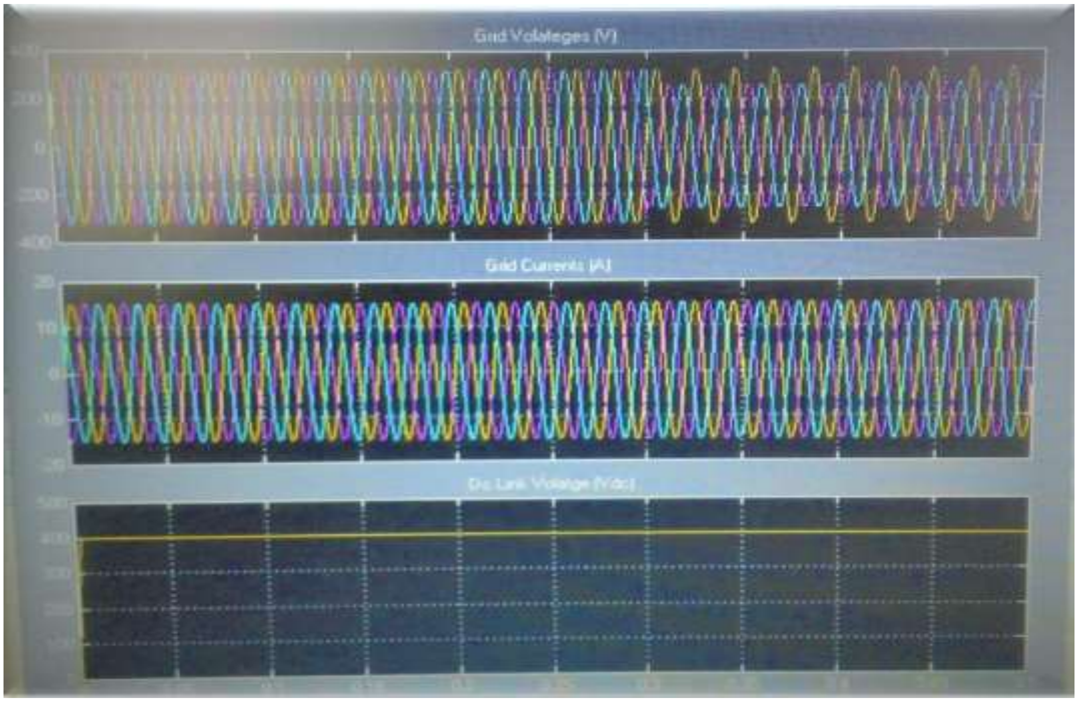

Figure3: voltage at the PCC of the MG with resonance effect of single stage PV system

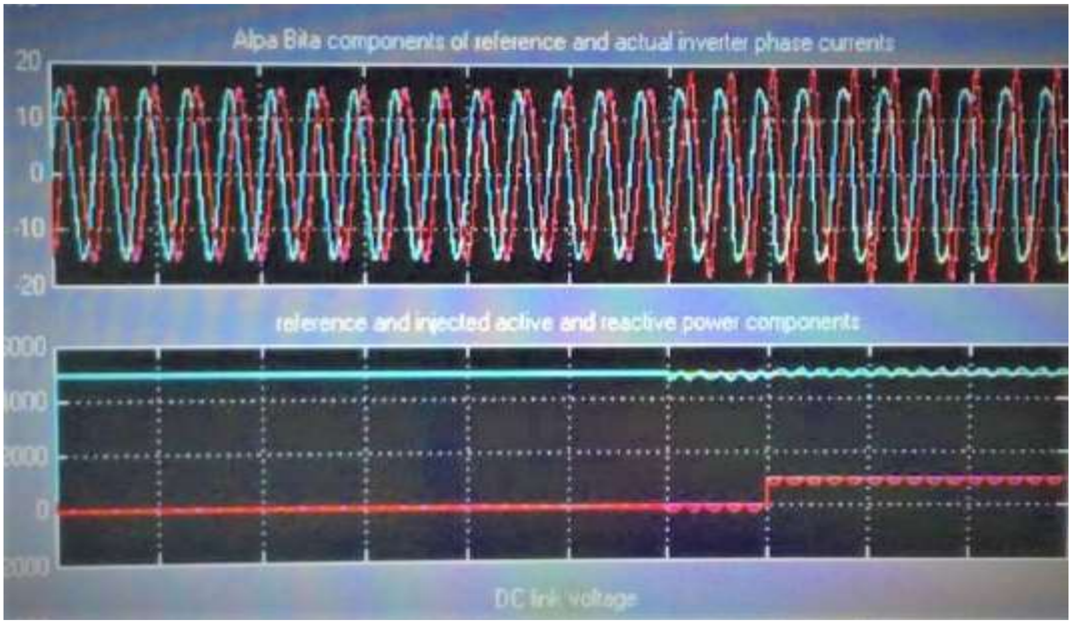

Figure4: Grid Stability in single stage PV system

CONCLUSION:

The development of an innovative and amalgamated controller for grid-connected continent management of PV-fed single-stage inverters presents a significant advancement in renewable energy integration. The controller effectively combines multiple advanced control strategies, including Maximum Power Point Tracking (MPPT), adaptive control, and predictive algorithms, to optimize the performance of PV-fed systems in real-time. By managing active and reactive power, as well as ensuring voltage and frequency stability, the controller enhances energy conversion efficiency and improves the reliability of grid-connected operations. Simulation and experimental results confirm the effectiveness of the proposed controller in handling variable solar irradiance, fluctuating grid conditions, and dynamic load demands. It not only improves the stability of the grid but also addresses power quality challenges such as harmonics and voltage sags through dynamic compensation techniques. These findings demonstrate the controller’s potential to support the widespread adoption of renewable energy by ensuring smooth and efficient grid integration of PV systems. In conclusion, the amalgamated controller offers a robust and scalable solution for the continent management of PV-fed single-stage inverters, significantly contributing to the enhancement of grid-connected renewable energy systems. Future research can explore further refinements in controller design, including real-time communication with smart grids and enhanced fault-tolerant capabilities, to address emerging challenges in modern power systems.

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