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# Energy Efficient Integrated Protection System for Photovoltaic Microgrids

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***Abstract*-Microgrids have proven to be a promising solution for the integration and management of intermittent renewable energy production. This article focuses on the main issues surrounding microgrid management and protection. It proposes an integrated control and protection system with a hierarchically coordinated control strategy. The strategy includes independent operating mode, grid-connected operating mode and microgrid conversion between these two modes. To improve the system's faulty operating capacity, a comprehensive three - tier hierarchical protection system is also proposed, which fully adopts various protection schemes, such as relay protection, hybrid energy storage system (HESS) rules and emergency control. . The efficiency, feasibility and applicability of the proposed system are verified on the actual photovoltaic (PV) microgrid. It is expected that the research will provide general theoretical guidance and technical design experience for microgrids.**

***Keywords*-solar, MPPT, grid, HESS, Battery**

## I.INTRODUCTION

PV technologies years owing have received to their ability to reduce fossil energy use and provide positive impacts to the environment. Photovoltaic generation in the form of distributed photovoltaic microgrids that are integrated into the power system rely on efficient use of solar energy. When compared to traditional distribution networks, photovoltaic microgrids are distinctly different in terms of their control strategies and protection methods. Specifically, when Photovoltaic microgrids operate in isolation mode, and the improved peer-to-peer control strategy is considered a key factor supporting the operation of island microgrids.

The author proposes a coordinated voltage / frequency (V / F) and active power and reactive power (PQ) control system for island and mains connected states in the photovoltaic microgrid The system shows the inverter V / F (or PQ)) Effective coordination between. Several other strategies have been proposed for seamless transfer between different microgrid operation modes.

They include a seamless control methodology for a PV-diesel generator microgrid that can operate both in the grid-connected and islanded modes, and at the same time does not require any islanding detection mechanism. Similarly, in, a control strategy has been proposed that contains the control state/reference compensation algorithm to effectively reduce the impact caused by microgrid operation mode transitions on critical loads and distributed generators (DGs). The control strategies mentioned above provide excellent solutions for microgrid operational control. However, these strategies are relatively independent having poor flexibility and weak expansibility, which may lead to collapse when the microgrid contains multiple distributed generators. Therefore, there is a need to integrate microgrid operational control technologies at steady and transient states in more practical ways. In addition to advanced control technologies, microgrids also require effective protection systems. The maximum short-circuit current in a microgrid is generally limited to less than two times the rated current because of a large number of DGs configured with power electronic interface devices. Power flow and short-circuit capacity changes are significant under different microgrid operation modes.

As a consequence, conventional protection methods in large-scale power grids are not able to effectively meet the needs of an inverter-dominated microgrid. A range of advanced methodologies is available in the literature for microgrid protection. They include a simple three-phase four-wire system with differential current and zero sequence current used to detect faults in a microgrid; a protection scheme that uses both modes of operation for optimally setting direction over current relays; as well as other protection schemes with voltage restraint algorithms or inverse time characteristics.

All these systems can be adapted to address the frequent changes in a microgrid. However, the main focus of these aforementioned methods is on relay protection, and they tend to neglect regulation resources and means available in the microgrid, e.g., energy storage systems. As a result, there is a need to further explore and develop integrated microgrid protection systems.

## II RELATED WORK

The coming global energy crisis offers the car industry new opportunities to meet the growing demand for clean and fuel-efficient vehicles. This requires the development of fully or partially electric drive systems in the form of electric and plug-in hybrid cars (EV and HEV), respectively. These driving systems are collectively referred to as plug-in EVs (PEV). Compared to HEV, PEV is usually equipped with larger built-in storage and power electronics to charge or discharge the battery. The degree of PEV adoption depends largely on the nature of the charging solution used. This article conducts a comprehensive topological study of currently available PEV charging solutions.

Based on charging characteristics (conductive or inductive), the conversion stage (integrated one-stage or two-stage), power level (level 1, 2 or 3) and the type of semiconductor device (silicon, silicon carbide or gallium nitride) used in this article conducted a comprehensive review. Because grid-connected systems do not require batteries, they are more cost-effective than stand-alone systems and require less maintenance and reinvestment. This concept releases the power of sunlight along with cost reduction, technology development, environmental awareness and the right incentives and rules. Photovoltaic (PV) stand-alone systems require battery chargers to store energy. This article introduces modeling and controller design of a PV charging system implemented with a single-ended primary inductance converter (SEPIC). The designed SEPIC uses peak current state control in combination with the current command generated by the input PV voltage control loop.

The voltage command is determined by the maximum power point tracking (MPPT) control loop of the PV module and the battery charging loop. The control objective is to balance the current from the PV module to the battery and the load to efficiently use the PV current and charge the battery through three charging steps. This article first provides SEPIC modeling of PV module input and peak current state control. Therefore, a PV voltage controller and an adaptive MPPT controller are designed. Designed an 80W prototype system. Simulation and experimental results prove the effectiveness of the proposed method.

**K. Chaudhari, (2018)** Energy storage system (ESS) is generally used to manage the intermittency of the renewable energy sources (RESs). The proper control strategy is needed to effectively maintain the power balance between the RESs, load demand, and ESS. The conventional control strategy for the hybrid energy storage system (HESS) uses the high-/low-pass filter method for system net power decomposition and the ESS power dispatch. In this paper, a new joint control strategy is proposed for photovoltaic-based dc grid system, with battery and super capacitor (SC) as a HESS. The new joint control strategy utilizes the uncompensated power from the battery system to increase the performance of the overall HESS. The advantages of the proposed control strategy over the conventional control strategy are faster dc-link voltage restoration and effective power sharing between the battery and the SC. The detailed stability analysis of the proposed control strategy is also presented. The increased concern about fossil fuel based energy usage, the design of electrical power system focuses on increasing the utilization of renewable energy sources (RESs). Solar photovoltaic (PV) and the wind are the two commonly known RESs.

PV is preferred in terms of sustainability and reliability, but its generation and stability are easily affected by intermittent operating conditions such as change in irradiance, temperature, humidity, and partial shadings effects. In real-life scenario, both the generation of RESs and the load demand are intermittent in nature. To solve the above mentioned issues, battery energy storage system (BESS) is generally used. Among different types of energy storage systems (ESSs), the BESS is easiest to implement. The BESS has relatively less impact from environmental variations. The problem with the BESS is low power density and relatively high overall system cost to meet the peak load demand. Hybrid energy storage system (HESS) is generally implemented to manage such issues. The advantages of HESS over single ESS are that it can effectively utilize the properties of the different types of energy storages. The combination of battery and supercapacitor (SC) is one of the popular HESS configurations. Battery with high energy density is used to compensate the slow average power demand. However, its lifetime is decreased if subjected to frequent transient power fluctuations.

The SC is used to smoothen the transient power fluctuations in the HESS. This combination can effectively and efficiently solve the varying power fluctuations, with less stress in the battery storage system. Thus, the effective control method is essential for the optimal operation of the HESS with varying load demand

**H. B. Gooi,(2017)** The power generation from renewable power sources is variable in nature, and may contain unacceptable fluctuations in case of the wind power generation. High fluctuations in power generation may negatively impact the voltage stability of the microgrid. This problem can be alleviated by using hybrid energy storage system consisting of batteries and supercapacitors (SCs) at DC grid. A new control scheme is proposed to control the power sharing between batteries and SCs to match the generation-demand mismatch and hence to regulate the grid voltage. In the proposed control strategy, the SC supplies error component of the battery current in addition to the fast transient power demand. This added feature not only improves the DC grid voltage regulation capability but also reduces the stress levels on the battery and hence increases the life span of the battery. The main advantage of the scheme is that, the uncompensated power due to slow dynamics of the battery is diverted to the SC and keeps the state of charge within the limits for longer durations compared to the conventional strategy. Solar and wind power sources are considered as economically viable renewable sources in remote area power systems(RAPS).

Usually in remote areas, the load demand is quite low. Therefore, considering the transmission and daily maintenance costs, it is not recommended to supply power from the grid. Hence, the standalone power system serves as most suitable power source in the remote area and offers the advantages like reduction in running and maintenance costs. Due to the variable nature of renewable power sources and load demand in RAPS, renewable generation alone cannot supply the load demand. To ensure the continuity of power supply to load with an intermittent power source such as wind and solar, standalone power systems are significantly dependent on energy storage systems (ESSs).In the authors proposed battery based energy storage system to balance the intermittency of wind power.

However, in the battery based energy storage system (BESS) ,power density and charge/discharge rates are not high enoughto meet the peak/pulse load demand. Therefore, to stabilize thepowerfluctuations ina standalone renewable power system, super capacitors (SCs) with high power density have been proposed [5], [6]. But, a SC has low energy density, thus it cannot support the load demand for long duration. Different energy storages with their power and energy densities [7], [8]are shown in Fig. 1. From the chart, it is clear that the battery has high energy density but low power density compared to those of a super capacitor. In contrast, asupercapacitorhas high power density but low energy density compared to those of a battery. Therefore, in order to harness the advantages of both high power and energy densities, a hybrid energy storage system is reported in this literature

## III. PROPOSED SYSTEM

Grid-connected and independent operation are two typical operating modes in microgrid. The requirements for operation of photovoltaic microgrid include: the voltage and frequency of the microgrid must be stable and the power current must be balanced to achieve independent operation in different conditions. The two modes can be switched smoothly from one to the other, which helps to avoid short-term overvoltage’s in the microgrid network. The P&O-based MPPT technology has become the most popular technology due to its simplicity and is implemented using simple mathematical equations. It is based on the slope of power (Ppv) and voltage (Vpv) curve for the photovoltaic group. To reach MPP, the pour derivative of the PV curve is zero. In P&O-based MPPT algorithm, when the operating point moves in a single direction, power changes are observed. If the power change is positive, the disturbance direction is true, otherwise it must be reversed to generate the reference DC bus voltage V * dc. The proposed MNF-based adaptive control algorithm is used to estimate the reference current flow generating the switching pulse to VSC, as shown in the figure. The MINF control algorithm is described as follows.

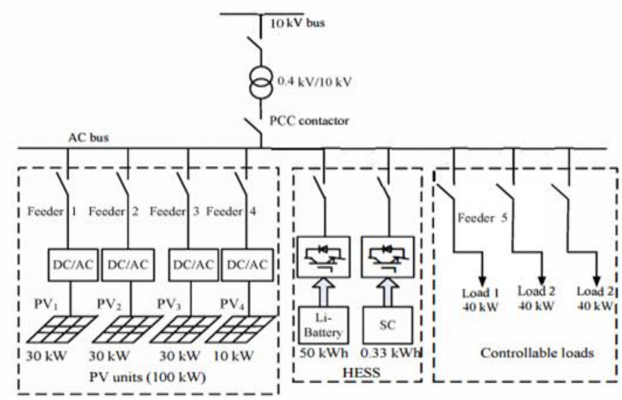


Fig.1 proposed simulink model

The power at the MPP (Pmpp) is the product of the MPP voltage (Vmpp) and MPP current (Impp).

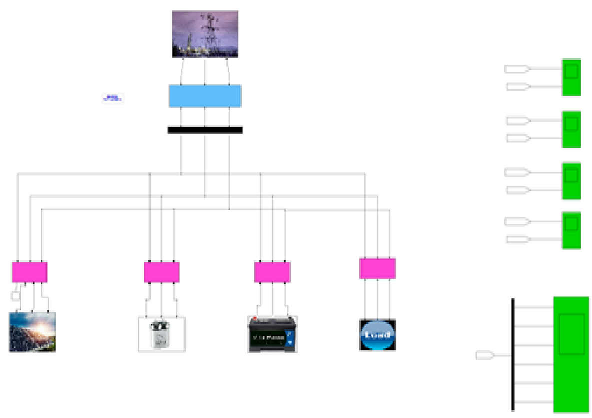

Fig.2 proposed simulink model.

The details of the PV microgrid configuration are depicted as follows: 1) renewable sources: 60 kW PV shed and 40 kW PV roofs; 2) HESS: 50 kWh Li-batteries and 0.33 kWh super capacitors; 3) loads: 120 kW controllable loads with three different priority levels. It should be noted that different types of inverters, including single-phase inverter, three-phase inverter, and micro-inverter are installed in the PV microgrid.

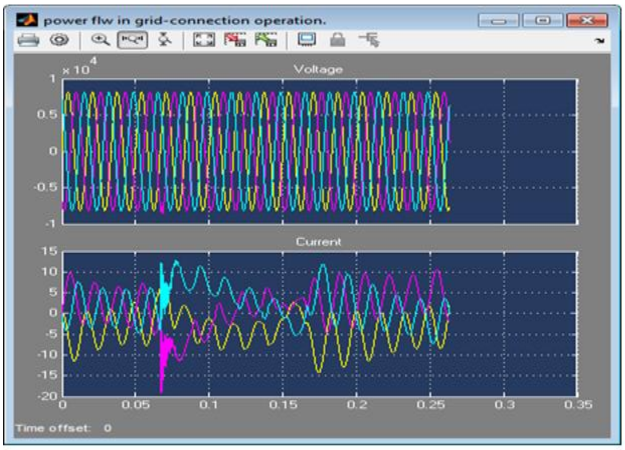


Fig.3 power flow in grid connection operation

The proposed protection system has been integrated into the built microgrid, and the simulations are carried out to validate the effectiveness and feasibility of the protection schemes.

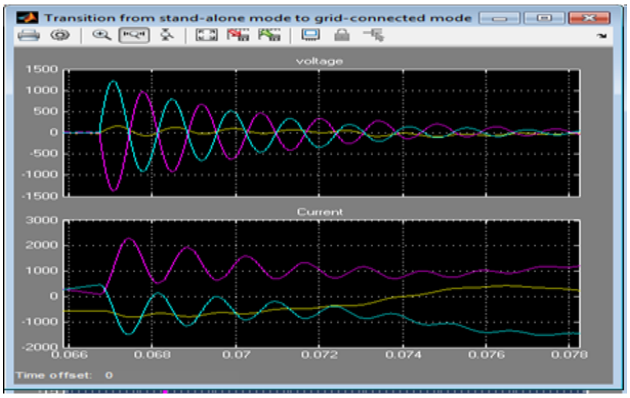


Fig.4 grid voltage and current

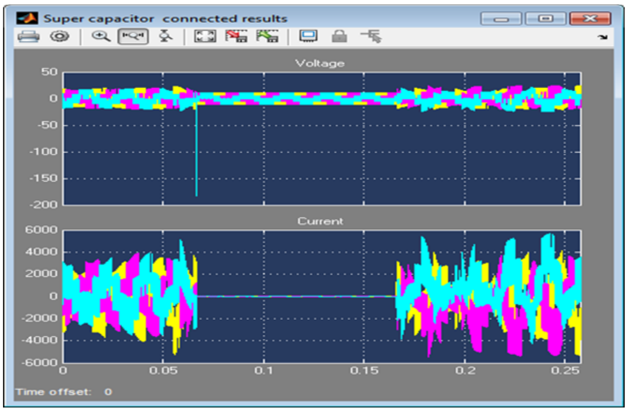


Fig.5 super capacitor voltage and current

It can be seen that the transition between stand-alone mode and grid-connected mode is smooth. The transient state of the transition

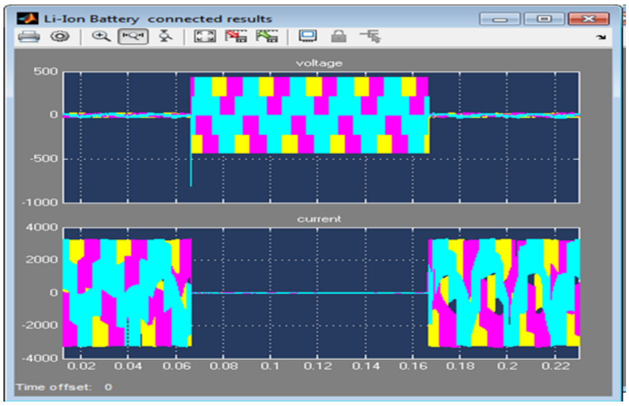


Fig.6 li-Ion Battery

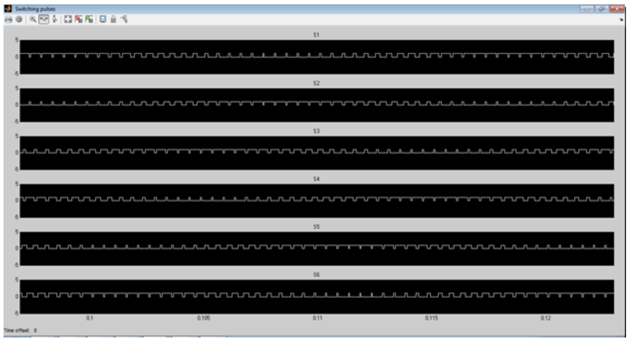

Fig.7 switching pulses

- The rnicrogrid voltage and frequency should be stable and the power flow should be balanced, so as to realize the independent operation in different modes;
- The two modes can transfer smoothly from one to the other, which can help avoid transient surge in the microgrid.

## IV. CONCLUSION

This paper proposes an integrated protection and control system with a hierarchical structure and builds a 100 kWp photovoltaic microgrid to verify the effectiveness and feasibility of the strategy. The test results show that the photovoltaic microgrid achieves a stable and flexible transition between different modes of operation, which greatly improves the survivability of the microgrid during severe failures.

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