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An Integrated Control and Protection System for Photovoltaic Application

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Abstract- **The microgrid has shown to be a promising solution for the integration and management of intermittent renewable energy generation. This paper looks at critical issues surrounding microgrid control and protection. It proposes an integrated control and protection system with a hierarchical coordination control strategy consisting of a stand-alone operation mode, a grid-connected operation mode, and transitions between these two modes for a microgrid. To enhance the fault ride-through capability of the system, a comprehensive three-layer hierarchical protection system is also proposed, which fully adopts different protection schemes, such as relay protection, a hybrid energy storage system (HESS) regulation, and an emergency control. The effectiveness, feasibility, and practicality of the proposed systems are validated on a practical photovoltaic (PV) microgrid. This study is expected to provide some theoretical guidance and engineering construction experience for microgrids in general.**

Keywords- **Hybrid Energy Storage System, Solar, MPPT, Batttery, Microgrid.**

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 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. LITERATURE SURVEY

Solar power is more and more attractive due to the severer environmental protection regulation and the predictable shortage of conventional energy sources. As a result, many research works have addressed the development of solar power system in recent years. Many types of photovoltaic (PV) power conversion systems have been developed including the grid-connected system for reducing the power from the utility and the stand-alone system for providing the load power without the utility. The stand-alone system requires battery for energy

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storage to supply the load power during the period without or shortage of solar power. Because the P −V characteristic of the PV module is varied with the insolation level as well as the temperature, if the peak power voltage of the PV module does not match with the battery voltage, the energy conversion efficiency of the PV module will be reduced using the direct connection of the PV module and the battery. Therefore, a battery charger is required to track the peak power of the PV module in all operation conditions. In addition, the battery charging needs control for achieving high state of charge (SOC) and, consequently, longer lifetime of the battery., it is only applicable for cases where the battery voltage is higher than the PV module voltage. The buck–boost feature of the SEPIC widens the applicable PV voltage and thus increases the adopted PV module flexibility. The battery current cannot reach its current command (Ib∗), the signal generated by the battery current controller that is a proportional and integral (PI) controller will go positive and be limited to be zero.

F. Blaabjerg, & 2017: The photovoltaic (PV) stand-alone system requires a battery charger for energy storage. This paper presents the modeling and controller design of the PV charger system implemented with the single-ended primary inductance converter (SEPIC). The designed SEPIC employs the peak-current-mode control with the current command generated from the input PV voltage regulating loop, where the voltage command is determined by both the PV module maximum power point tracking (MPPT) control loop and the battery charging loop. The control objective is to balance the power flow from the PV module to the battery and the load such that the PV power is utilized effectively and the battery is charged with three charging stages. This paper gives a detailed modeling of the SEPIC with the PV module input and peak-current-mode control first. Accordingly, the PV voltage controller, as well as the adaptive MPPT controller, is designed. An 80-W prototype system is built. The effectiveness of the proposed methods is proved with some simulation and experimental results.

III. PROPSOED SYSTEM

Grid-connected and stand-alone operations are the two typical operation modes in a microgrid. The requirements of PV microgrid operation modes include: The microgrid 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. The P&O based MPPT technique is a most popular technique because of its simplicity and is implemented by using easy mathematical equations. It is based on a slope of power (Ppv) vs. voltage (Vpv) curves of a PV array. For achieving MPP, derivative of slope of PV curve is zero. In P&O based MPPT algorithm, the power change is observed when an operating point is moved in a single direction. If change in its power, is positive then the perturbation direction is true otherwise it has to be reversed to generate reference DC link voltage V*dc. The proposed MINF based adaptive control algorithm is used to estimate reference grid currents, which generates switching pulses for VSC as shown The MINF control algorithm is described as follows.

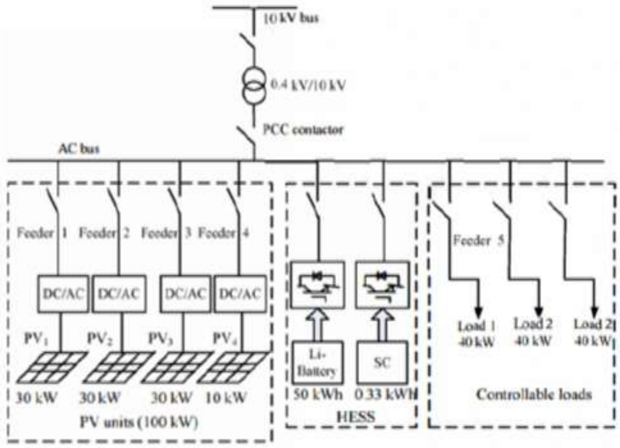

Fig 1. proposed block diagram.

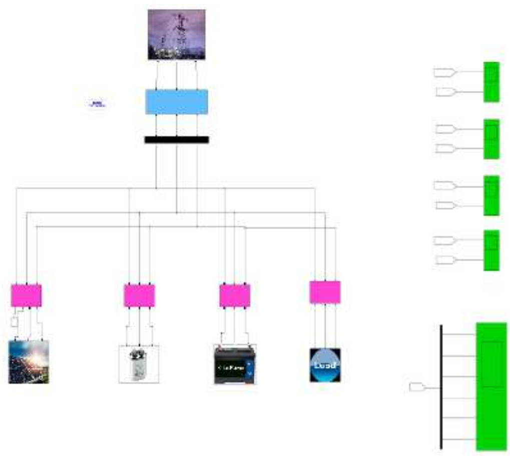

Fig 2. proposed simulink model.

MTTP ALGORITHM: Maximum power point tracking (MPPT) is an algorithm implemented in photovoltaic (PV) inverters to continuously adjust the impedance seen by the solar array to keep the PV system operating at, or close to, the peak power point of the PV panel under varying conditions, like changing solar irradiance, temperature, and load. Engineers developing solar inverters implement MPPT algorithms to maximize the power generated by PV systems. The algorithms control the voltage to ensure that the system operates at "maximum power point" (or peak voltage) on the power voltage curve, as shown below. MPPT algorithms are typically used in the controller designs for PV systems. The algorithms account for factors such as variable

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irradiance (sunlight) and temperature to ensure that the PV system generates maximum power at all times. Maximum power point tracking is a technique used commonly with wind turbines and photovoltaic (PV) solar systems to maximize power extraction under all conditions. Although solar power is mainly covered, the principle applies generally to sources with variable power: for example, optical power transmission and thermo photo voltaics. PV solar systems exist in many different configurations with regard to their relationship to inverter systems, external grids, battery banks, or other electrical loads.

BATTERY STORAGE SYSTEM (HESS) Battery Batteries.jpg Various cells and batteries (top-left to bottom-right): two AA, one D, one handheld ham radio battery, two 9-volt (PP3), two AAA, one C, one camcorder battery, one cordless phone battery Type Power source Working principle Electrochemical reactions, Electromotive force First production 1800s Electronic symbol Battery symbol2.svg The symbol for a battery in a circuit diagram. It originated as a schematic drawing of the earliest type of battery, a voltaic pile. A battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices such as flashlights, smartphones, and electric cars.

When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy. Historically the term "battery" specifically referred to a device composed of multiple cells, however the usage has evolved to include devices composed of a single cell.

DC-AC CONVERTER This chapter gives a description and overview of power electronic technologies including a description of the fundamental systems that are the building blocks of power electronic systems. Technologies that are described include: power semiconductor switching devices, converter circuits that process energy from one DC level to another DC level, converters that produce variable frequency from DC sources, principles of rectifying AC input voltage in uncontrolled DC output voltage and their extension to controlled rectifiers, converters that convert to AC from DC (inverters) or from AC with fixed or variable output frequency (AC controllers, DC–DC–AC converters, matrix converters, or cycloconverters). The chapter also covers control of power converters with focus on pulse width modulation (PWM) control techniques.

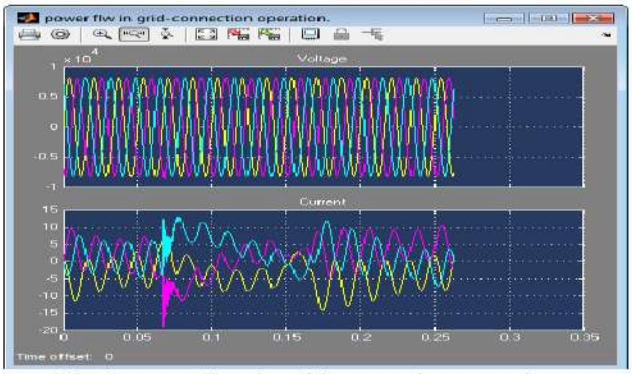

Fig 3. power flow in grid connection operation.

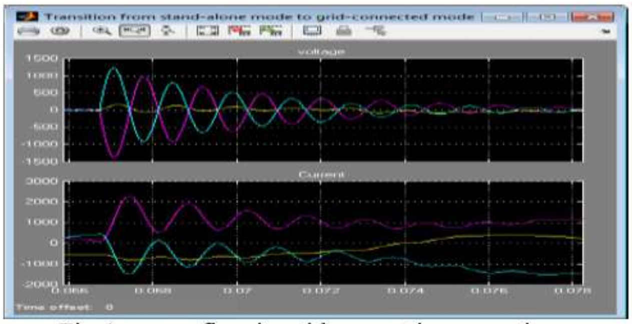

Fig 4. power flow in grid connection operation.

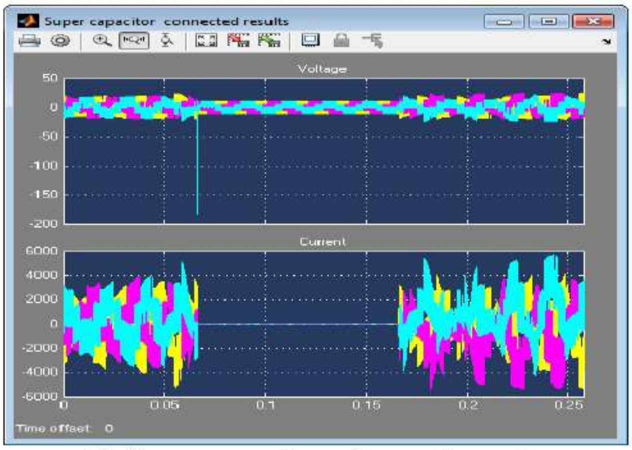

Fig 5. super capacitor voltage and current.

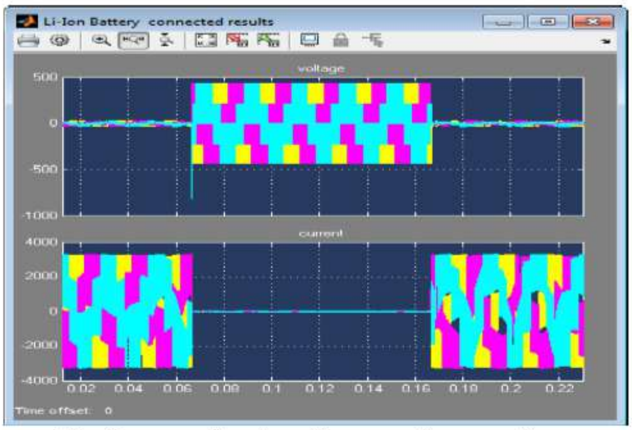

Fig .6. power flow in grid connection operation.

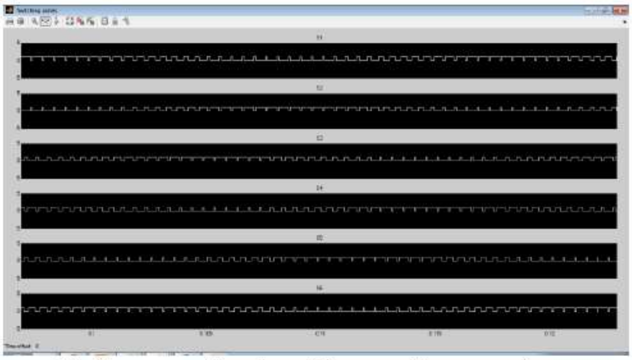

Fig 7. power flow in grid connection operation.

IV. CONCLSUION

In this Research an integrated protection and control system with a hierarchical structure is proposed and a 100 kWp photovoltaic microgrid is built to validate the effectiveness and feasibility of the proposed strategy. Test results show that stable and flexible transition between different operation modes of the PV microgrid is achieved and the viability of the micro-grid under severe fault is greatly improved. At the design stage of the microgrid ESS it is necessary to compare energy efficiency indicators before and after its implementation. The specification of the energy efficiency indicators estimation is based on comparison of daily profiles of loading and of solar insolation in the course of the calendar year. The implementation of microgrid with solar power plants allows increasing the efficiency of the ESS. The reserve for increasing the efficiency through the implementation of microgrid has two components, the first one is related to the normalization of the power consumption mode, and the second one to the optimization of the structure of the network, when the distances between energy sources and consumers are reduced, and the density of the network energy flow and trunk line decreases. Moreover, the second component makes a more significant contribution to increasing the efficiency of the energy supply system.

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