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A novel approach on hybrid AC/DC microgrid with energy storage and super capacitor control strategy optimization

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Abstract
This research presents a hybrid grid system that contains a photovoltaic panel, wind turbine, electrolyzer, supercapacitor, power convertor, and a three-phase variation load. In order to maximize the strengths of each energy storage technology, enhance the technical and economic benefits, in the hybrid energy storage unit, how to combine and coordinated control has become one of the research hotspots at an instant. For the fundamental problem of the hybrid energy storage system, academics have different technical features based on the energy storage unit, uses the changing average filter such as low -pass & high pass filtering classification to internal energy distribution of the hybrid energy storage system, play the advantages of energy storage medium respectively, Based on the system energy storage unit within their respective overcharge discharge and the limit of power, control, direct adjustment or indirect methods, such as to separate the energy storage unit output power adjustment, protect the hybrid energy storage components of the system.

Keywords: super capacitor, wind energy, hybrid microgrid, solar photovoltaic

1. Introduction

Now-a-days efficient energy storage plays an essential role in automobile. Renewable energy sources are known to support system hydrogen generation. Therefore, the newly developed idea is the ability to supply the load without any compensation by the wind turbine or PV panels sold in the offing. Although photovoltaic panels are used as accessible renewable energy sources, two major problems they encounter depending on power production are with solar irradiation and surplus energy storage. These problems are can be solved by using other renewable energy sources and storage systems such as electrolyzer, hydrogen storage tank, fuel cell, supercapacitor, and battery [2]. Due to high efficiency, fast response, flexibility and modular structures, a combination of supercapacitor with a fuel cell is the best choice for a hybrid system that uses photovoltaic panels and wind turbines. Batteries are the conventional and most promising energy storage element in the Hybrid Electrical system (HEV) and EV as it has the advantage of high energy density, which is desired for range extension of the electrical grid. But no single element (Battery) can fulfill all desirable characteristics like low power density alone. Increasing battery pack size will cause an increase in weight and cost. The midway is that Hybrid Energy Storage (Hybridization), which allows a combination of small battery for low power (average power) and supercapacitor to supply very high power (Peak power) during power generation. The designed Hybrid grid can be balanced to the Utility grid using an Intelligent Transfer Switch at point of universal coupling as in conventional AC grids. In the grid-tied mode of operation, surplus energy in the internal sub-grids, if any, can be inserted into the utility grid without breaking the local utility rules. The supercapacitor is a high power density energy storage device that can convey top short term discharging current and achieve a barrage of charging current. The supercapacitor has at least 500 times [4] number of cycles than any standard battery and is also superior to it in terms of durability. It overcomes the demerits of cells such as charging and discharging cycles, critical charging current, and reduced temperature coefficient.

The paper aims to study the storage system of DC system in sub-station, take the lithium-iron phosphate battery and super capacitor hybrid energy storage as the example. Where super capacitor will be discharged as first priority so as to buffer the impact on batteries amongst original DC system. In addition, test setup can be established based on circuit design. Parameters should be designed and simulation model for typical substation DC system will be established in MATLAB.

2. Literature Survey

Now-a-days a lot of control procedures are raised to designate the respective power of supercapacitor and battery. Reference [5] focuses on the control of hybrid SC-battery energy storage for standalone PV system. A SC-battery power allocation method based on voltage outer loop and current inner loop is proposed in [6]. In reference [7, 10], a low-pass filter has been used to make sure that the high frequency power is accorded with the SC and the low frequency power is shared with battery. A sliding average power allocation control strategy is presented in [11]. Additionally, smooth control and fuzzy control [12, 14] are also introduced to control SC-battery energy storage. Reference [12, 13], based on smooth control, corrects the SC and battery power according to the SC remaining capacity and charge state. Fuzzy control, as the most popular method, is used to smooth the revised SC and battery power [14]. In order to create full use of the respective characteristics of SC and battery, the high frequency renewable energy output power is shared with SC and the low frequency power is shared with the battery. The SC and battery power improvement is used when the SC remaining capacity is close to limit capacity. However these control strategies still remain problems. These control strategies cannot keep SC away from limit capacity effectively. In this paper, a novel control strategy of SC-battery is proposed to solve the above problems. This control strategy can adjust the reference power of SC and battery according the charge state and remaining SC capacity. DC component power which is called is proposed to keep SC away from limit capacity. By using the novel controller strategy, the high frequency energy injected into battery is almost avoided and the super capacitor is prevented from reaching the capacity limit and quit run. In small electric grid, power from renewable energy sources have the potential to change the frequency. According to [7, 8], distribution networks with huge R/X ratio growth of solar PV penetration has the potential that can lead to unpre dictability in the network-voltage and frequency [9]. Modelled and designed battery energy management system for solar PV. While a few studies aimed at minimizing solar PV fluctuation has also been recommended by some researchers using Hybrid Energy Storage System (HESS) together with solar PV [11]. In this paper, the authors proposed a battery (Lithium Ion) storage system capable of frequency regulation of grid connected solar PV system.

3. Proposed Methodology

The electrochemical battery is one of the most cost-effective energy storage technologies and has a high power density (50–130 Wh/kg for lithium (Li)-ion batteries and 30–80Wh/kg for nickel-metal hydride (NiMH) batteries).However, it is reduced in power density [3]. Super-Capacitor has a higher power density of 300–500 W/kg, and a long cycle-life surpassing 500,000 cycles [4]. Hybrid systems of these two technologies can produce excellent system performance. Battery/Super-Capacitor hybrid system has been presented in a stand-alone renewable energy power system. Such as Battery/Super-Capacitor the hybrid system has also been examined in grid-tied renewable energy applications to increase system stability. Typically, these hybrid systems consist of two bidirectional DC/DC converters, which are attached to battery and super-capacitor.

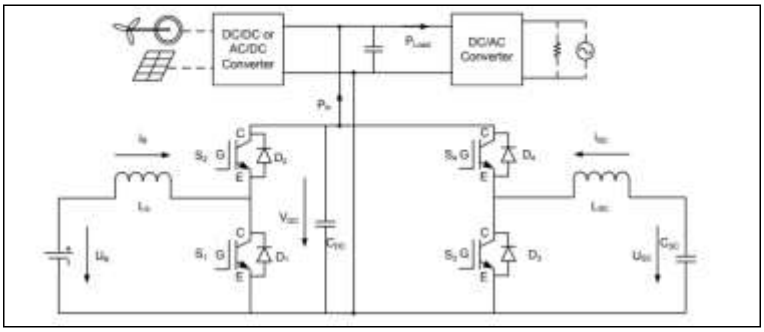

Fig 1: Proposed Super-Capacitor Hybrid System

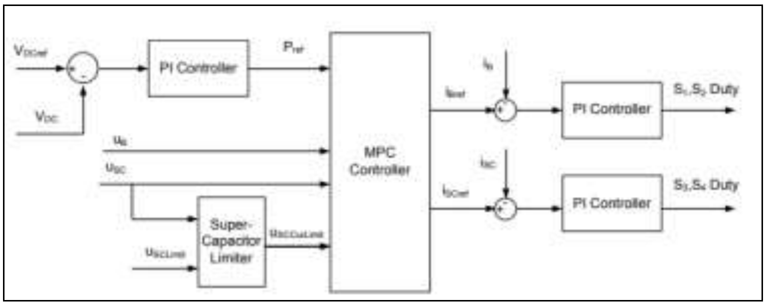

Fig 2: Battery and Super-Capacitor Banks

The proposed Battery or Super-Capacitor hybrid system is presented in Figure 1, while the similar control diagram is shown in Figure 2. Battery and Super-Capacitor banks are connected to DC-Link into two bidirectional DC/DC converters, respectively. Four controllers are included in the system. The first controller is used to provide a constant DC-Link Voltage; the second controller is the MPC controller, which is used to get the current source for both of the bidirectional DC/DC converters. The last two PI controllers are used to track the current referral from the MPC controller.

Distribution smart solar

Distributed Smart Solar (DSS) technology combines an advanced panel-level inverter with the smart grid sensors and communication technologies (Figure 3).Solar cells generate dc power when presented to the sun. The amount of dc power generated by the solar cell depends on the strength of the solar irradiance. In a single solar cell, it is the value of the diode that controls the performance of the solar cell in a manner that assures that both for short and open circuits, the current will flow or stopped. This is a single diode model in the above cell circuit. However, a maximum power point tracker is needed to secure maximum power is extracted because of the relationship between the solar panel's current and voltage in non-linear. A typical configuration is to provide each solar panel with a Smart Energy Module (SEM) connected to the low voltage utility network. All the SEMs form a secure meshed communication network that uploads their information to a data center via communication aggregators. Command and control centers and distribution management systems (DMS) access the data center to manage the solar portfolio as a virtual power plant and also to implement several smart grid functions.

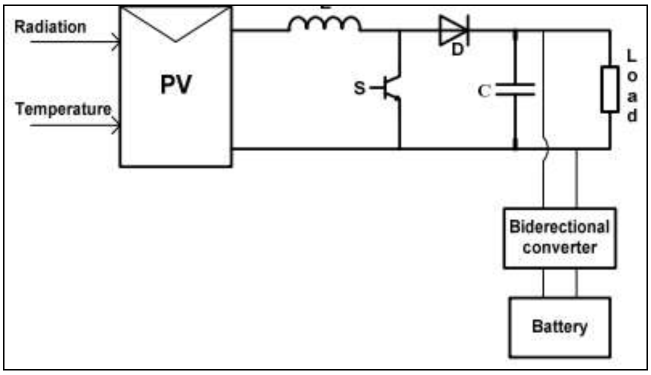

Fig 3: Typical configuration of satand-alone PV system

This technology enables each solar panel to become a node in a smart grid and thus facilitates the implementation of many utility applications such as demand response, conservation voltage reduction (CVR) [6], Volt/VAR loss minimization, predictive maintenance, outage notification, theft detection, and street lighting controls. The financial benefits of this technology go beyond those of solar energy generation to The Economic Opportunity of Distributed Smart Solar Systems Hisham A. Othman, Ruba A. Amarin those of the smart grid, and thus allow the utility to optimize the generation, the load, and the distribution assets in between.

Establishing the right solar energy policies and regulations in a country is crucial to the proper expansion of the various forms of solar energy technologies. In this respect, it is essential to understand who, along the electricity value chain, benefits from the solar energy investments in order to allocate the costs to these beneficiaries in a proper fashion. The beneficiaries of a solar energy investment depend on the market structure and subsidy system in a country.

Super capacitance optimization technique

Voltage indicates the energy in the Super-Capacitor. At any time, for any power demand, and a particular battery current, energy stored in the Super-Capacitor should verify the output power without making battery current rate of change surpasses its maximum limit. These can be represented in equation. U_{CurMax}, U_{CurMin}, are the voltage limits, U_{Max}, U_{Min}, are the limits of complete working range of Super-Capacitor, P_{Max}, P_{Min} are the maximum power commands. Consider $P_{Min} = -P_{Max}$.

$$\begin{cases} \frac{1}{2}\cdot C_{sc}\cdot U_{curMin}^2 \geq \frac{1}{2}\cdot C_{sc}\cdot U_{curMin}^2 + \frac{(P_{Max} - i_B\cdot U_B)^2}{2\cdot k_B\cdot i_B\cdot U_B} \\ \frac{1}{2}\cdot C_{sc}\cdot U_{curMax}^2 \leq \frac{1}{2}\cdot C_{sc}\cdot U_{curMax}^2 - \frac{(P_{Min} - i_B\cdot U_B)^2}{2\cdot k_B\cdot i_B\cdot U_B} \end{cases}$$

For avoiding violation, equation (15) must be satisfied.

$$\frac{1}{2}\cdot C_{sc}\cdot U_{curMax}^2 - \frac{1}{2}\cdot C_{sc}\cdot U_{curMin}^2 \geq 0$$

That means:

$$\frac{1}{2}\cdot C_{sc}(U_{curMax}^2 - U_{curMin}^2) \geq \frac{P_{Max}^2 + i_B\cdot U_B^2}{k_B\cdot i_B\cdot U_B}$$

To charge and discharge the battery bidirectional converter is used in this paper, where the PV output power should be greater than the load power and the SOC (state of charge) of battery should be less than the maximum value in order to charge the battery. On the other hand, in case of battery discharge, the power output from PV should be less than load power and the SOC should be greater than a minimum value.

$$SOC = 1 - \frac{\int I_b\, dt}{Q}$$

Where, Ib: Battery current (A). Q: Maximum capacity of battery (65 Ah).

The power electronics are capable of taking independent control signals for real and reactive power on the AC side of the PCS, which enables the BESS to provide power factor and voltage support functions. I-V characteristics of a solar PV module are non-linear and continuously changes due to temperature and solar irradiance, which means that the power output delivered by the solar PV module depends on the weather condition at that material time. However, MPPT is used to control the power output of the PV and to ensure that the PV module delivers maximum power output at all times, thereby increasing its efficiency. An appropriate duty cycle value is set at the gate of the Insulated-gate bipolar transistor (IGBT) switch used in the DC-DC converter to ensure maximum power is achieved.This function is referred to as a four-quadrant operation and can eliminate the need for such system components as capacitor banks at the point of inter-connection of the wind plant and the grid.

3. Expectred Outcome

In this paper, the proposed solar grid system with supercapacitor will be modeled and simulated in MATLAB. Mini-grids and hybrid systems have demonstrated their efficiency in very different applicability and with different renewable energy sources. The modifications and improvements from the very fast-growing world for grid-connected PV technology can be used in improve system with a power-range from the 3kW to 100kW or more, and it can efficiently be developed, established, and administered with standard components. Since the outcomes of this paper is a hybrid system with renewable energy sources, Industrial evaluation shows that production has been significantly improved by the hybrid system and according to research hybrid systems are more effective than using solar panels or a wind turbine individual in an order can be a most essential advantage of this work.

4. Conclusion

This paper explores the relationship between DC bus voltage and system efficiency in a hybrid photovoltaic-grid power system. An optimal efficiency bus voltage value can be found by loss analysis within a specific voltage range. A new method of optimizing the efficiency of the hybrid photovoltaic-grid power system by changing the dc bus voltage is proposed. It provides an idea to improve the effectiveness of the hybrid photovoltaic-grid Power system. The optimal efficiency point of the system is different under different power states. So this paper proposes a new method to optimize the efficiency in a hybrid photovoltaic-grid power system by changing dc bus voltage.The objective of

MPC controller is to get current references for both of the battery and the super-capacitor converters. For simplicity, consider voltage of battery and capacitance of Super-Capacitor as constants.

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