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Energy Management and Power Control of Islanded Microgrid with RES and Energy Storage System

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ABSTRACT

This paper proposes an alternative strategy to control the generated power within an isolated ac microgrid with distributed RES. The proposal is to control the terminal voltage of the existing battery banks below or equal its maximum allowable value. This is done by limiting the amount of power that each energy source can generate at each instant. The microgrid frequency is used to characterize the state of charge of the battery bank and quantify to the converters' control systems how much power they need or can generate to maintain under control the internal power balance of the microgrid. The control of the battery banks' terminal voltage implies indirectly the control of their SOC.

KEYWORDS: *Battery banks, isolated microgrids, parallel inverters, power control, renewable energy sources (RESs), state of charge (SOC).*

I. Introduction

Micro grids are turning into famous of assignment structures because she be able enhance the monitoring quality or reliability on control resources or limit the environmental impact. Micro grid act be able remain classified in twain modes: gridconnected or islanded modes. In general, micro grids are comprised about distributed energy sources (DERs) inclusive of renewable power sources, distributed power tankage systems (ESSs), or partial hundreds [1–3]. However, the usage on renewable energy sources such as breeze then photo voltaic control of micro grids motives monitoring go with the flow versions due in imitation of uncertainties among theirs monitoring outputs. These editions have to remain decreased to forgather power-quality requirements [4,5]. This discipline focuses about coping with the issues as are added by means of air power. To compensate because of fluctuations into breeze power, various ESSs have been implemented between micro grids. Short-term ESSs such as much superconducting magnetic energy storage (SMES) structures [6], electrical double-layer capacitors (EDLCs) [7], then flywheel energy storage systems (FESSs) as like nicely as much long-term ESSs certain as like battery strength tankage systems (BESSs) [8-9] are utilized after micro grid control. ESSs perform additionally remain back after limit the rule glide at factor about frequent merger among the grid-connected passion namely properly namely in accordance with modify the frequency and voltage about a micro grid within the islanded mode. Among this ESSs, BESSs have been implemented extensively due in accordance with their versatility, excessive strength density, and efficiency. Moreover, their charge has decreased inasmuch as their performance or breath has increased. In practice, BESSs along excessive overall performance such as much clean and quickly strong answer throughout charging then discharging are required for Microgrid control. This overall performance depends on the government overall performance concerning the government electronic converter. Proportional-integral (PI) control is a realistic yet popular control method because BESS monitoring systems. However, PI rule may exhibit unsatisfactory consequences because nonlinear or discontinuous systems [10]. When proper applied, these new, allotted technology gadgets (DG) offer great advantage in conformity with the grid then in imitation of cease users. However, merging DGs between the regular grid is no longer barring empirical challenges. The typical electrical grid was now not designed for power generation sources dispensed close to the ends concerning the T&D grid. The successful integration over DG government sources requires the single-direction grid structure about the previous transit after a smarter then greater agile bi-directional grid [11]. As DGs proceed after obtain drawing among the electric market, instant wondering yet recent strategies round power generation, parcelling then bad desire proceed after emerge. One over the an increasing number of frequent techniques because merging DGs into the large electric grid is a new twist over an ancient electrical architecture recognized so the Microgrid. Micro grids are areas about the grid so much do function as like section on the larger macro grid then operate autonomously as like a standalone system. The micro grid systems help facilitate the integration of DG belongings within the large electric grid. Further, when true implemented, micro grids execute unbolt a large adjust regarding stacked values for grid operators and electrified customers toughness [12].

II. System Description

A grid-connected DC microgrid investigated in this paper is shown in Fig.1. It consists of PV-panel, hybrid storage unit, utility grid, DC/DC converters, DC/AC converter and DC load. The PV panel is connected to the DC bus through a boost DC/DC converter which extracts the maximum power from PV panel using maximum power point tracking (MPPT) algorithm. The hybrid energy storage unit is composed of lead-acid batteries and super-capacitors. The batteries and the super-capacitors are connected with the DC bus through two bi-directional half-bridge DC/DC converters. The utility grid is connected to the DC bus through a three-phase bi-directional full-bridge AC/DC converter.

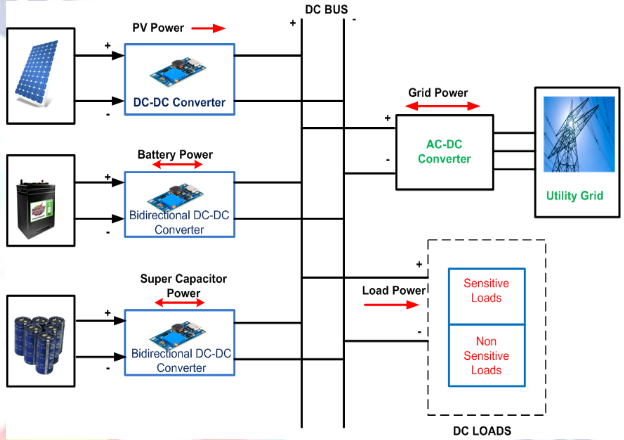

Fig. 1. Block Diagram for power management strategy in a hybrid DC microgrid

III. Energy Management System

Generally, the objectives of HESS implementation in standalone micro-grid can be grouped into three main categories: (1) optimising micro-grid performance, (2) enhancing system reliability and (3) lowering set-up and operating cost. Fig. 2 summarizes the objectives. Active HESS topology enables each ESS elements to be optimized through an energy management system (EMS).

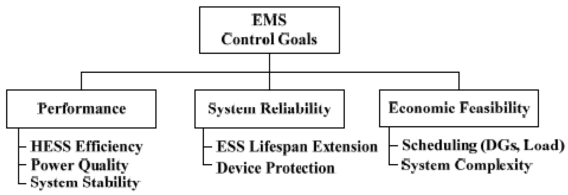

Fig. 2. EMS control goals.

The role of EMS is to maximise the benefits of HESS. Volumetric and coulombic efficiencies have to be maximized while maintaining system stability and power quality at the DC bus. In terms of system reliability, EMS must ensure robust system operation in all possible loading conditions, protect the ESSs from extreme conditions and extend the useful lifetime of the ESS elements. EMS also needs to ensure that cost of implementation, operation and maintenance are kept low. For instance, scheduling of diesel generator and load can be integrated into the EMS to lower the operating cost. In general, the EMS can be divided into two levels: (1) the low-level control system regulates the DC bus voltage and controls the current flowing in and out of ESS elements based on the reference signal generated by high level control system. (2) The high-level control system performs power allocation strategy, SoC monitoring and control, and other sophisticated energy management strategies to achieve the set control goals.

Zhou et. al. adopted the parallel active topology and proposed a modular HESS scheme that splits the single battery bank into multiple smaller battery modules [154]. The supercapacitor module and battery bank modules are interfaced to DC bus using dual-active-bridge bidirectional DC/DC converters. The authors employed a linear filtering approach to remove high frequency power fluctuations and distribute the smooth power demands to each battery modules based on their SoC level. The supercapacitor module will respond the high frequency power exchange through cascaded inner current control loop and outer voltage control loop. A simple SoC management scheme for supercapacitor module is implemented where the battery modules will charge the supercapacitor when the SoC level is lower than a pre-set threshold. The EMS mainly focuses on balancing the charge/discharge current among different battery modules. However, it does not consider the impacts of battery SoC variation in long-term operation, which may affect the system stability and longevity of the battery. Moreover, the proposed modular HESS topology requires a large number of DC/DC converters, leading to significant increase in power loss and set-up cost.

IV. Proposed Strategy To Control The Generated Power In The Microgrid

A. MPPT control of PV module

The power produced by a PV array is dependent on the irradiance and temperature. There is a maximum power point (MPP) which should be tracked in the power-voltage (P-V) curve. It can be accomplished through DC/DC converter linking the PV array to the DC bus as shown in fig.2 Typical MPPT control strategies include open-circuit voltage method, short-current circuit current method, perturb and observe method (P&Q) and incremental conductance method (INC). In general, P&Q method and INC method are the widely used approaches for MPPT control. However, those conventional MPPT algorithms have disadvantages such as instability, poor adaptability to external environment. Sometimes they may fail to track the MPP when the atmospheric conditions change rapidly. To solve the tradeoff between the accuracy of the dynamic and steady state, a variable-step size INC method is utilized to realize MPPT of PV panel. The step size is automatically tuned according to the inherent PV array characteristics. If the operating point is far from MPP, it increases the step size which enables a fast tracking ability. If the operating point is near to the MPP, the step size becomes very small that the oscillation is well reduced contributing to a higher efficiency. The flow chart of the variable step size INC MPPT algorithm is shown in fig.3 and the variable step size &V is automatically tuned

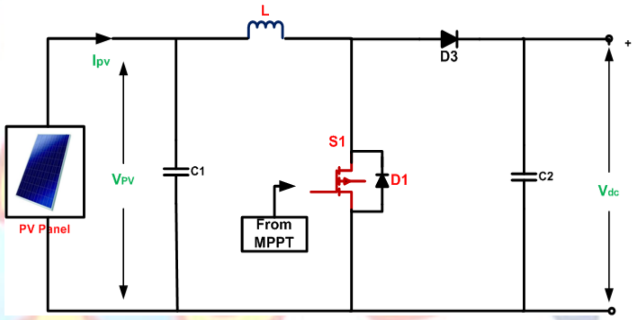

Fig 2: DC/DC converter of PV module with MPPT function

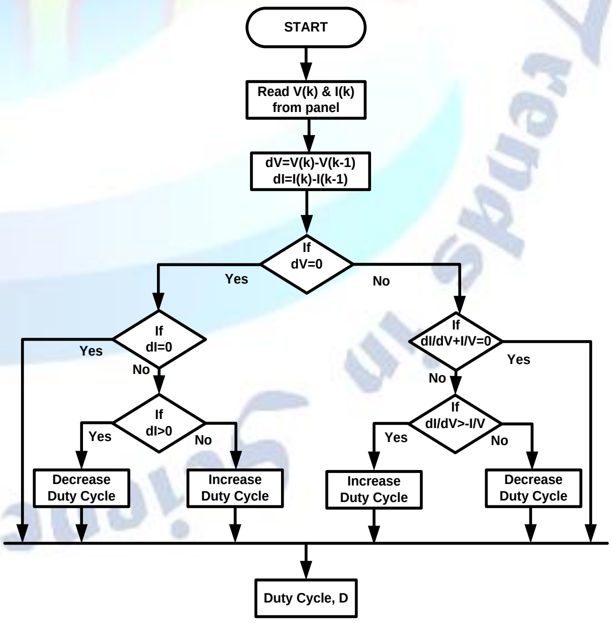

Fig.3 Flowchart of the variable step size INC MPPT algorithm

B. Control of bi-directional DC/DC converter for hybrid energy-storage

Battery has high energy density whereas it has relatively slow charging and discharging speed. On the other hand, super-capacitor has high power density and fast response. The super-capacitor as a short-term energy storage device is utilized to compensate for fast changes in the output power, while the battery as a long-term energy storage device is applied to meet the energy demand. The battery is modelled using a simple controlled voltage source in series with a constant resistance. The SC is modelled as a regular capacitor in series with a constant resistance. The bi-directional buck/boost converter is used in the paper to link the SC or battery with the DC bus. The structure of the two converters is a parallel connection. This converter works as a boost converter during storage unit discharge mode and a buck converter during charge mode. The control method is a conventional double loop, including an inner current loop and an outer voltage loop, which is shown in Fig.4.

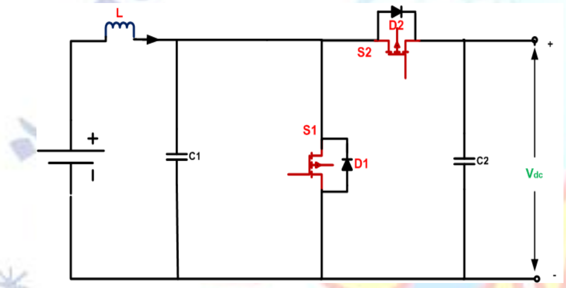

Fig 4: Bidirectional DC/DC converter of Battery and Super capacitor

C. Control strategy of three phase bi-directional AC/DC converter

The utility grid is connected to the DC bus through a three-phase bi-directional full-bridge AC/DC converter. The control strategy is a direct-quadrature (DQ) current controller together with an outer voltage control loop as illustrated in fig.7.5. When utility grid works normally, the DC bus will be connected to utility grid through the bi-directional converter and the power will be transmitted mutually; otherwise it will be disconnected with utility grid to avoid faults.

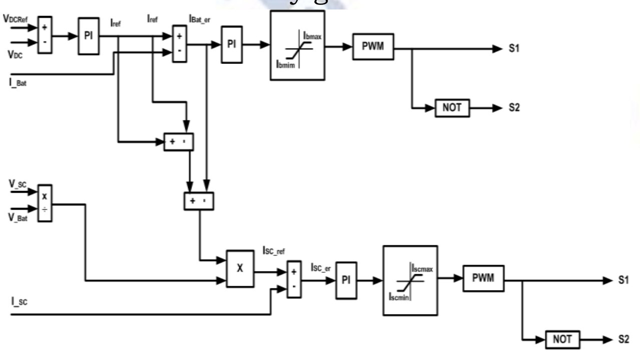

Fig 5: Control Circuits of parallel operation of ESS

Battery

Batteries have already been widely used and are still a favourite energy storage device up until today. There are many variants of batteries existing nowadays, either non-rechargeable or rechargeable, with different types such as lithium-ion, leadacid, nickel-metal-hydride and plenty more.

Overall, batteries have high power densities, low self-discharge rate and cost much less when compared to supercapacitors. Though extensively used, there are nevertheless many inferior elements affecting the batteries. These are temperature, slow charging time, high energy density and short life cycle.

A battery contains chemicals which can convert chemical energy to electrical energy and vice-versa. Batteries are typically rated in terms of energy and power capacities.

There are some essential elements that need to be taken into account when

Purchasing batteries:

- Battery efficiency
- Lifespan
- Operating temperature
- Depth of discharge
- Self-discharge rate
- Energy density

When the high load demands cause high surge current, in a short duration, it will be very disadvantageous to the lifetime of the battery because the battery is high in energy density but not suitable for high power density [117]. The stress factor on the battery such as variable discharging rate and extensive time at the low state-of-charge (SOC) could increase the rate of damage to the battery.

In certain applications of batteries such as motor starting, portable power systems, electric vehicles and digital communication systems, the batteries were sized to meet

the requirements of peak currents spanning a short duration, causing unnecessary expenses which are hardly justified [112]. An oversized battery system is suggested to provide the peak power and also to extend the battery lifespan. Lead acid batteries, which offer deep cycles, large capacity and wide availability, are typically the choice for these applications. It has a relatively high energy density, but it does not have the capability of instantaneous charging and discharging [118].

Supercapacitor

General Electronics developed the first supercapacitor in 1957. This supercapacitor was based on a double layer mechanism in the clear using a porous carbon electrode. These devices can charge and discharge extremely fast compared to batteries, while having much higher load capacity compared to conventional capacitors. Supercapacitors can be recharged hundred thousand times compared with only a few thousand recharge cycles for conventional batteries.

The rate of self-discharge is higher compared with batteries, but the power generated by a supercapacitor is for a short duration only. There are no chemical reactions when supercapacitors charged, while batteries undergo an internal chemical reaction while charged. This chemical reaction will be reversed during discharge to deliver the absorbed energy. Examples of applications that use supercapacitors are uninterruptible power supplies and hybrid electric vehicles [121].

V. MATLAB/SIMULATION RESULTS

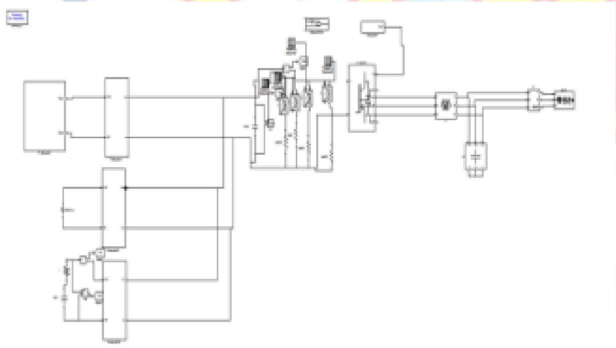

Fig.7. Matlab/Simulation Circuit of Simplified Diagram of the Studied Microgrid

The simulation in the mutual transition from standalone mode to grid connected mode is shown in Fig.7.The transitions will happen in the situation that the super-capacitors' converter breaks down or the energy of super-capacitors is full or insufficient. In the initial state, the DC bus voltage is regulated by the PV converter at 380V. In the 2s, a 1000W load is connected with the system, then, the grid-connected AC/DC converter starts and works in rectification mode. The instantaneous transform is shown in fig.7.7 (d). The current and voltage of the AC grid is synchronous. The voltage is regulated by the gird converter at the 370V. In the 4s, the 2000W load is cut off from the system, and the DC bus voltage is up to 390V in 4.8s. The current and voltage is antiphase as shown in fig.7.7 (e). The results have proved that the transitions between the modes and the both modes are successful and stable.

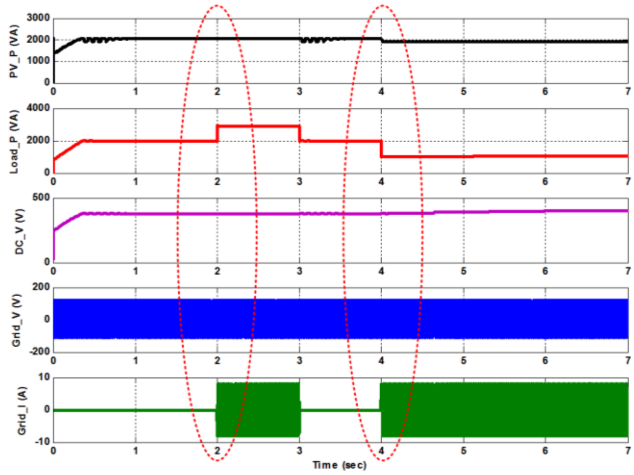

Fig 7: Transition between Mode I and Mode IV

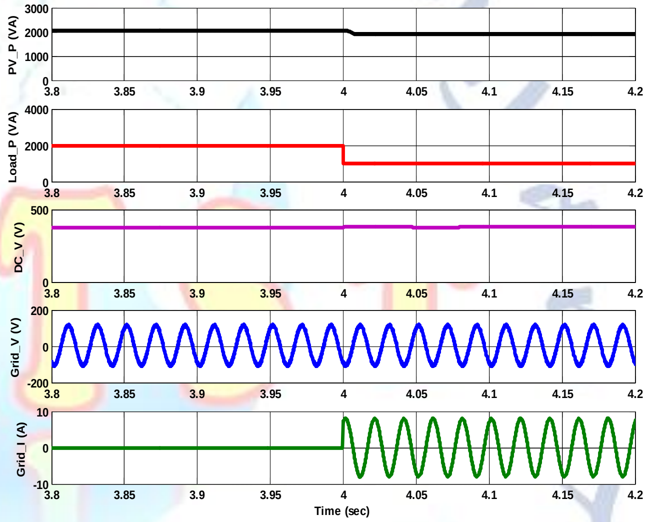

Fig 7(a): Transition between Mode I and Mode IV(a)

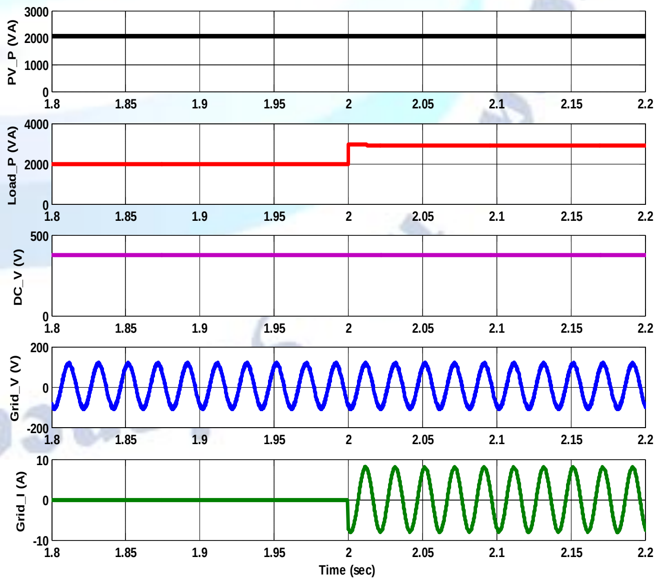

Fig 7(b): Transition between Mode I and Mode IV(b)

VI. CONCLUSION

This paper proposed controller is a procedure to fluffy rationale control the created control so as to monitor the charging voltage battery banks in remain solitary Microgrid with conveyed sustainable power sources. This system does not require wired correspondence between the conveyed sustainable sources nor dump burdens to scatter the excess of created control in the Microgrid. These specialized favorable circumstances make the proposed technique a promising instrument to build the reasonability and unwavering quality of the inexhaustible power age framework introduced in secluded and remote groups. In spite of the fact that a breeze turbine has been utilized to exhibit the legitimacy of the proposed methodology, it is additionally substantial paying little mind to the power source existing in the confined Microgrid. The proposed methodology computes the measure of energy that must be created at each time by each source with a specific end goal to keep the adjust of vitality into the Microgrid. At the end of the day, the total of the created, expended, and put away vitality should dependably be zero constantly

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