

Power management strategy in a DC microgrid with hybrid storage system

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ABSTRACT

The concept of integration of distributed energy resources for formation of microgrid will be most significant in near future. It shows a broad overview on the worldwide research trend on microgrid which is most significant topic at present. This literature survey reveals that integration of distributed energy resources, operation, control, power quality issues and stability of microgrid system should be explored to implement microgrid successfully in real power scenario. In addition, DC micro grids diverted the attention of researchers and power electronics industry in recent years to stimulate renewable energy technologies (RETs) and distributed energy resources (DERs) deployment and encouraging technological innovation to reduce green house gas (GHG) emission and achieve energy security and independence to meet the growing electricity demand. So, for many studies have been done on successful integration of RETs and DERs, operation and control, protection and stability issues, simultaneously and satisfactorily implemented during feasible operation of microgrid. Studies show that DC transmittable power can increase the system efficiency up as compared to AC. But still DC bus voltage fluctuation, power quality and flow during the transition between grid connected mode to islanded mode or transient load insertion which intend to DC microgrid instability are the problems which need to be investigated and resolved for the effective use of DC microgrid generation. In this concept DC microgrid voltage, power flow, power quality and energy management different controls and techniques are reviewed. This concept can be extended as induction motor drive power management for DC microgrid application.

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1. INTRODUCTION

Nowadays, the issue of vitality emergency has been progressively tense, while low carbon vitality should be created. In this specific situation, dispersed sustainable power source has been given careful consideration and grew incredibly, particularly wind control and photovoltaic (PV) age, because of their inexhaustible accessibility and less effect on the earth. Yet, hypothesis and practice have demonstrated that these disseminated sustainable power source have some intrinsic issues, for example, its irregularity, which has some negative effect on the security, dependability and power nature of utility framework [1]. On this premise, the idea of microgrid exhibited by Robert Lasseter and different researchers is thought to be a doable plan to take care of the issue. The microgrid is a nearby vitality organize that incorporates sustainable power sources and capacity frameworks. It can be associated with the mains network or works separated when there is a power outage at the primary matrix, and keeps on providing their nearby loads in "islanded mode" [2], [3].

A microgrid can be intended to help substituting current (AC) or direct present (DC). Contrasted and AC shapes, DC microgrid can stay away from the thought of responsive power and recurrence synchronization [4]. In the meantime, some DC sources and DC loads, for example, photovoltaic, supercapacitor, EV and LED, give chances to DC microgrid. Additionally, DC microgrid will have the capacity to expand the general framework proficiency contrasted with AC system.

On the other hand, storage systems are usually installed to alleviate system power mismatch between generation and consumption in DC microgrid, and they can improve the stability, power quality, reliability of supply and overall performance of microgrid. Capacity frameworks can be described in view of energy thickness, vitality thickness, incline rate, life cycle et cetera, however none of the capacity frameworks satisfy every normal component. The normal vitality stockpiling in reasonable building is lead corrosive batteries, which have high vitality thickness however low power thickness, low charge/release rates and life expectancy of under 1,000 full cycle. So batteries can't react quickly under regular load vacillations. Contrasted with battery, super-capacitor has high power thickness yet low vitality thickness, high charge/release rates and life expectancy of around 500,000 cycles. Hence, super-capacitor can be utilized to coordinate the snappy load vacillations [5], [6]. The mix of the two sorts is essential for differing vitality stockpiling needs of both quick and moderate fluctuating force and it has turned into an exploration hotspot, and the structure of two-sorts stockpiling frameworks have been the subject of more research programs, for example, the mix of batteries and super-capacitors.

The researcher [5], [7] demonstrated the hybrid energy storage systems lowers the battery cost and improves the overall system efficiency. The framework reconciliation of PV cluster, batteries, and super-capacitors has been contemplated in a few writings, yet this framework still has a few inadequacies [8]–[10]. Right off the bat, when it is an islanding mode, power deficiencies happen now and again. Furthermore, PV excess vitality will be squandered when capacity frameworks have been completely charged. From the above, we consider how the DC microgrid in view of PV cluster with a half and half stockpiling framework associated with utility network works. We exhibit a novel power administration of DC microgrid to acknowledge framework solidness, low voltage direction and equivalent load partaking in every unit. It is affirmed that the relentless state and transient state transformation of various operation mode through MATLAB/SIMULINK reenactment stage. The paper is sorted out as takes after. In section 2, framework design of this microgrid and its displaying are talked about. Section 3 portrays the control technique and operation methods of this microgrid. The simulation results of the proposed system are given in section 4. Finally, the conclusions of the paper are summarized in section 5.

2. SYSTEM CONFIGURATION

A lattice associated DC microgrid explored in this paper is appeared in Figure 1. It comprises of PV-board, half and half stockpiling unit, utility matrix, DC/DC converters, DC/AC converter and DC stack. The PV board is related with the DC transport through a lift DC/DC converter which expels the most outrageous power from PV board using most noteworthy power point following (MPPT) figuring. The cream imperativeness amassing unit is made out of lead-destructive batteries and super-capacitors. The batteries and the super-capacitors are related with the DC transport through two bi-directional half-interface DC/DC converters. The utility structure is related with the DC transport through a three-arrange bi-directional full-interface AC/DC converter.

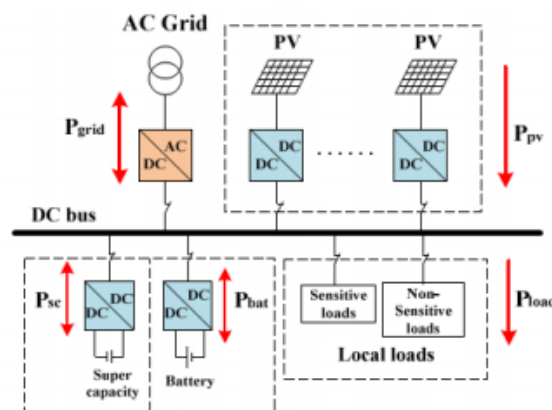


Figure 1. DC microgrid with hybrid storage system

2.1. MPPT control of PV module

The PV cells are connected in series to form a module that gives a standard dc voltage. Modules are connected into an array to produce sufficient current and voltage to meet a demand for a grid-connected application [11]. Normally, the PV modules are first connected in series into strings and then in parallel into an array. The PV model can be portrayed by nitty gritty condition. The power delivered by a PV exhibit is reliant on the irradiance and temperature. There is a most extreme power point (MPP) which ought to be followed in the power-voltage (P-V) bend. It can be expert through DC/DC converter connecting the PV exhibit to the DC transport as appeared in Figure 2.

Average MPPT control techniques incorporate open-circuit voltage strategy, short-current circuit current strategy, irritate and watch strategy (P&Q) and incremental conductance strategy (INC). By and large, P&Q technique and INC strategy are the broadly utilized methodologies for MPPT control. Be that as it may, those customary MPPT calculations have weaknesses, for example, flimsiness, poor flexibility to outer condition. Now and again, they may neglect to track the MPP when the climatic conditions change quickly. The progression estimate is naturally tuned by the intrinsic PV cluster qualities. On the off chance that the working point is a long way from MPP, it builds the progression measure which empowers an optimizing capacity. On the off chance that the working point is close to the MPP, the progression measure turns out to be little that the wavering is all around diminished adding to a higher effectiveness. The stream diagram of the variable advance size INC MPPT calculation is appeared in Figure 3 and the variable advance size &V is naturally tuned.

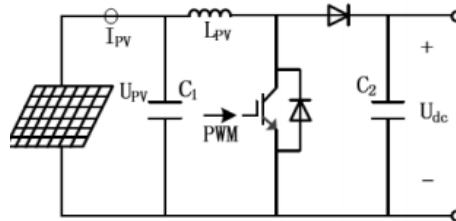


Figure 2. DC/DC converter of PV module with MPPT function

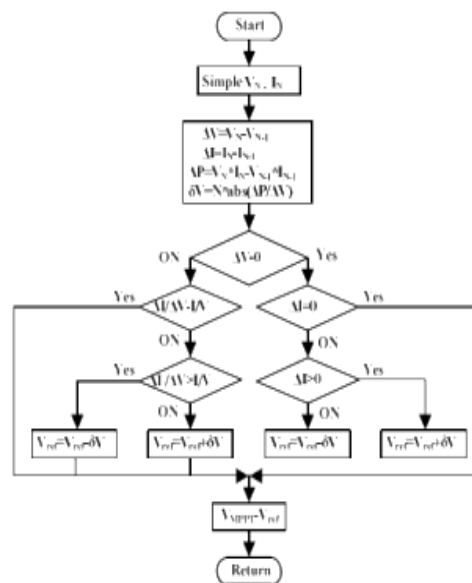


Figure 3. Flowchart of the variable step size INC MPPT algorithm

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

Battery has high vitality thickness though it has moderately moderate charging and releasing velocity. Then again, super-capacitor has high power thickness and quick reaction [12]. The super-capacitor as a transient vitality stockpiling gadget is used to make up for quick changes in the yield control, while the battery

as a long haul vitality stockpiling gadget is connected to take care of the vitality demand [13]. The battery is demonstrated utilizing a straightforward controlled voltage source in arrangement with a steady protection. The SC is displayed as a consistent capacitor in arrangement with a steady protection. The bi-directional buck/help converter is utilized as a part of the paper to interface the SC or battery with the DC transport. The structure of the two converters is a parallel association. This converter fills in as a lift converter amid capacity unit release mode and a buck converter amid charge mode. The control method is a conventional double loop, including an inner current loop and an outer voltage loop, which is shown in Figure 4.

2.3. The control 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 Figure 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.

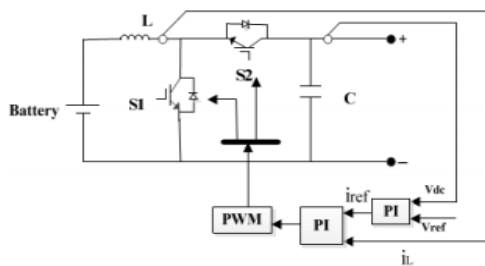


Figure 4. Control strategy of the bi-directional DC/DC converter

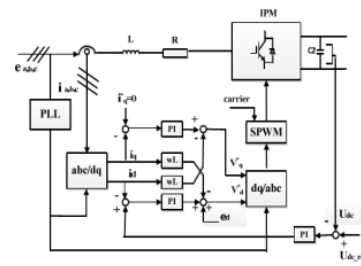


Figure 5. Control strategy of the bi-directional DC/AC converter

3. CONTROL STRATEGY

A novel power administration system of DC microgrid is proposed in this paper. The key purpose of energy administration conspire in DC microgrid is to keep the power adjust among PV module, stockpiling frameworks, utility network and loads constantly, which is showed by DC transport voltage [14]–[16]. The super-capacitor is the optional power supply as assistant energy of PV power and it works when there are surges or vitality rushes in the framework. The utility framework is the following spot of the power supply needs when there is mass vitality befuddle over a more drawn-out day and age. The structure can bring down the loss of lifetime of the battery in the contingent microgrid. At long last, when the primary matrix blames, the accessorial batteries will charge or release to keep the DC transport voltage enduring.

At the same time, the system also has several abnormal cases drawn by blue arrow lines, as shown in Figure 6. These abnormal cases will happen when certain source or certain converter is in trouble. For example, the case 15 and case 16 between mode I and mode IV will happen in the situation that the utility grid or grid-connected converter breaks down and super-capacitor is full. Actually, it has twenty abnormal cases in unexpected situations. In Table 1, we have summarized each mode and its characteristic. In general, the switching between different modes and the changes of control methods for converters can be achieved through bus voltage changes without communication links. These modes are analyzed in the following paragraphs.

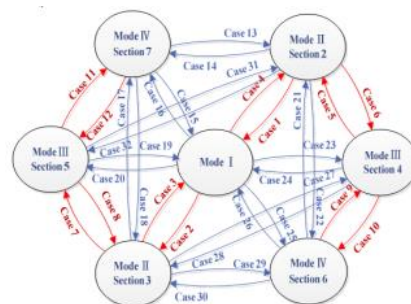


Figure 6. Mode transition mechanism

Mode-I: $U_{low1} < U_{dc} < U_{high1}$. In this mode, the DC bus voltage is regulated only by the PV generation, which means the generated PV power just matches the demands. The bus voltage fluctuates at the reference value in a small range. At the same time, the other converters are in the standby state. The power flow is shown in Figure 7.

Table 1. Summary of each mode and its characteristics

Mode Name	Power Characteristic	Bus Voltage Range	Bus Regulation	Power Supply
Mode I (section 1)	$P_{pv} = P_{load}$	$U_{low1} < U_{dc} < U_{high1}$	PV Unit	PV
Mode II (section 2)	$P_{pv} + P_{sc} = P_{load}$	$U_{low2} < U_{dc} < U_{high2}$	Super-capacitor Unit	PV, Super-capacitor
Mode II (section 3)	$P_{pv} + P_{sc} = P_{load}$	$U_{high1} < U_{dc} < U_{high2}$	Super-capacitor Unit	PV, Super-capacitor
Mode III (section 4)	$P_{pv} + P_{sc} = P_{load}$	$U_{low2} < U_{dc} < U_{high2}$	Utility Unit	PV, Utility grid
Mode III (section 5)	$P_{pv} + P_{sc} = P_{load}$	$U_{high1} < U_{dc} < U_{high2}$	Utility Unit	PV, Utility grid
Mode IV (section 6)	$P_{pv} + P_{load} = P_{load}$	$U_{dc} < U_{low0}$	Battery Unit	PV, Battery
Mode IV (section 7)	$P_{pv} + P_{load} = P_{load}$	$U_{high0} < U_{dc}$	Battery Unit	PV, Battery

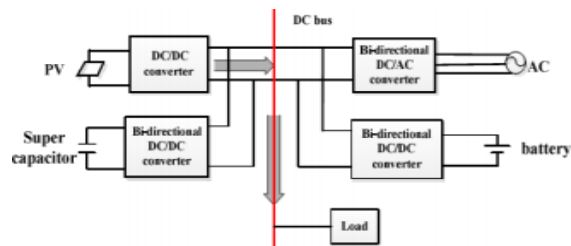


Figure 7. Power flow of mode-I

4. SIMULATION RESULTS

MATLAB/Simulink model of DC microgrid in this research is shown in Figure 8. Transition process between mode-I and mode-II, transition process between mode-I and mode-III, transition process between mode-II and mode-IV are shown in Figures 9, 10 and 11, respectively.

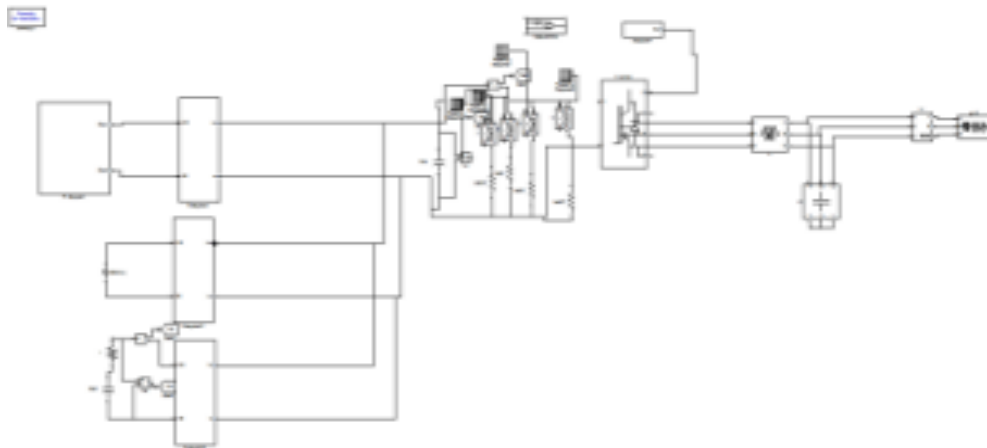


Figure 8. MATLAB/Simulink model of DC microgrid

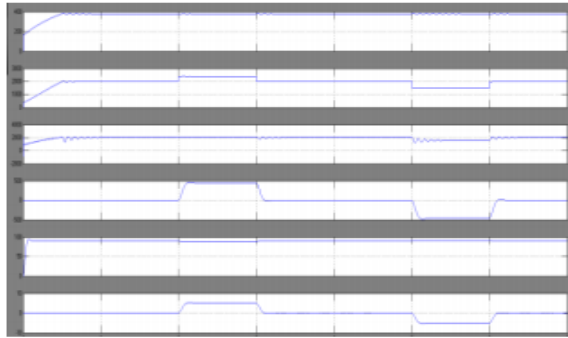


Figure 9. Transition process between mode-I and mode-II

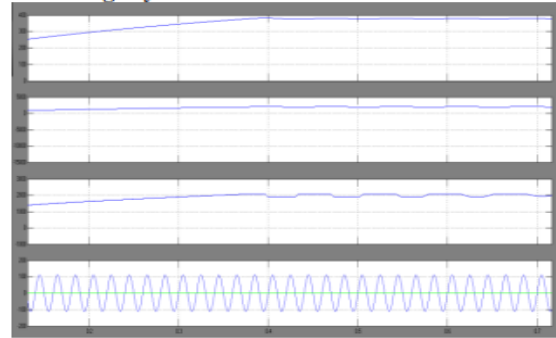


Figure 10. Transition process between mode-I and mode-III

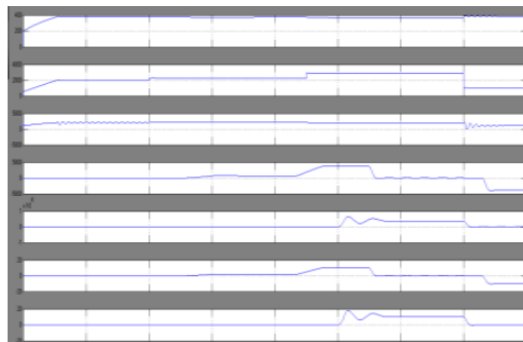


Figure 11. Transition process between mode-II and mode-IV

5. CONCLUSION

In the paper, a DC microgrid with hybrid storage system is investigated. A power management strategy for this DC microgrid is proposed, in which the bus voltage is employed as a carrier to represent different operation modes. The hybrid energy storage system in this microgrid that contains two complementary type storage elements-battery and super-capacitor, can enhance the reliability and flexibility of the system based on their special supply logical. Different from the previous studies, the ac grid has a new supply status in the system. The practical feasibility and the effectiveness of the proposed control strategies have been validated by the induction motor drive application simulation of MATLAB model.

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