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An Optimal Energy Managing Stratagem for DC Micro Grids

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Abstract— **In this project, due to substantial generation and demand fluctuations in green micro grids, energy management strategies are becoming essential for the power sharing and voltage regulation purposes. The classical energy management strategies employ the maximum power point tracking (MPPT) algorithms and rely on batteries in case of possible excess or deficit of energy. However in order to realize constant current-constant voltage (IU) charging regime and increase the life span of batteries, energy management strategies require being more flexible with the power curtailment feature.**

In this project a coordinated and multi variable energy management strategy is proposed that employs a wind turbine and a photo voltaic array of a DC micro grid as controllable generators by adjusting the pitch angle and the switching duty cycles. The proposed strategy is developed as an online nonlinear model predictive control (NMPC) algorithm. Applying to a sample standalone dc microgrid, the developed controller realizes the (IU) regime for charging the battery bank. The variable load demands are also shared accurately between generators in proportion to their ratings. More over the DC bus voltage is regulated within a predefined range, as a design parameter.

Index Terms— **Energy Management System(EMS), Hybrid System, Maximum Power Point Tracking(MPPT) Control ,Non-Linear Model Predictive Control(NMPC).**

1) Introduction

The not so distant future dissemination systems will comprise of a few interconnected micrgrids that will locally produce, expend, and Store vitality. A micro grid may work as augmentation of primary matrix, ie., lattice associated network. DC Micro grids have some particular applications in flying car, marine business and in addition remote provincial regions.

While air conditioning frameworks experience the ill effects of the need of synchronization of a few generators, dc microgrids are more productive because of the way that dc generators and stockpiles needn't bother with air conditioning dc converters for being associated with dc microgrids. The three understood issues with respect to voltage direction, power sharing, and battery administration, are more extreme in standalone green microgrids, which comprise of just irregular sun based and wind vitality sources, and prompt to the need of more complex control procedures.

The solidness of a dc microgrid is measured as far as the steadiness of its dc transport voltage level, which is one of the fundamental control destinations. The network voltage source converters (G-VSCs) are the essential slack terminals to control the voltage level of lattice associated microgrids. Battery banks, then again, are compelling slack terminals for microgrids; in any case, their vitality retaining limits are restricted with respect to various operational limitations, as clarified later in this segment. With a specific end goal to direct the voltage level of dc microgrids, the works in and exhibit stack shedding systems for the cases in which there is deficient power era or vitality stockpiling. The works in, then again, exhibit procedures that shorten the renewable power eras of dc microgrids if the battery bank can't ingest the overabundance era. The works in and develop the traditional hang control strategy for dc slack terminals by supplanting the customary bends with either a dc power-dc voltage or a dc voltage-yield current bend. Be that as it may, dc microgrids are normally situated in little scale territories where the power sharing between DGs can be overseen by brought together calculations which are less influenced by two issues:

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1) Batteries in charging mode are nonlinear burdens making bends the framework voltage; and

2) The total voltage level of a standalone micro grid is moved as the after effect of the heap request variety.

Various wonders influence the batteries operation amid the charging mode:

1) Applying high charging currents, the batteries voltages rapidly reach to the gassing limit;

2) The interior resistor and consequently power misfortunes and warm impacts increment at high SOC levels; and

3) Batteries can't be completely accused of a consistent high charging current.

2) LITERATURE STUDY

Contingent upon the extent of the power era to the heap request proportion inside standalone DC microgrids, three cases are visualized:

1) Power era and load request are adjusted;

2) Load request surpasses power era causes dc transport voltage to drop without any heap shedding; and

3) Power era is higher than load request drives batteries to be cheated and transport voltage to climb.

This study concentrates on case in which the created power must be diminished on the off chance that it abuses the batteries charging rates or if batteries are completely charged. A novel vitality administration technique (EMS) is proposed to address, as its control destinations, three previously mentioned issues relating standalone dc microgrids; i.e., dc transport voltage direction, corresponding power sharing, and battery administration. As opposed to the methodologies accessible in writing in which renewable vitality frameworks (RESs) dependably work in their MPPT mode, the proposed multivariable technique utilizes a wind turbine and a PV exhibit as controllable generators and abridges their eras on the off chance that it is essential. The proposed EMS is produced as an online novel NMPC procedure that consistently takes care of an ideal control issue (OCP) and finds the ideal estimations of the pitch point and three exchanging obligation cycles.

3) PROBLEM IDENTIFICATION

The three understood issues with respect to voltage direction, power sharing, and battery administration, are more serious in microgrids that comprise of just discontinuous sun based and wind vitality sources, and prompt to the need of more complex control systems. So as to counteract over-focusing on conditions and circling currents between generators, stack requests should be shared between every slack Dg in extent to their appraisals.

The power sharing between DGs can be overseen by incorporated calculations which are less influenced by two issues:

1) Batteries in charging mode are nonlinear burdens making bends the lattice voltage; and

2) The outright voltage level of a standalone micro grid is moved as the after effect of the heap request variety.

Various wonders influence the batteries operation amid the charging mode:

1) Applying high charging currents, the batteries voltages rapidly reach to the gassing edge;

2) The inner resistor and henceforth power misfortunes and warm impacts increment at high SOC levels; and

3) Batteries can't be completely accused of a consistent high charging current.

4) OUT LINE OF DC MICRO GRID

A schematic of the dc microgrid with the conventions employed for power is given in fig: 4.1

. The dc bus connects wind energy conversion system (WECS), PV panels, multilevel energy storage comprising battery energy storage system (BESS) and super capacitor, EV smart charging points, EV fast charging station, and grid interface.

The WECS is connected to the dc bus via an ac–dc converter. PV panels are connected to the dc bus via a dc–dc converter.

The BESS can be realized through flow battery technology connected to the dc bus via a dc–dc converter.

The super capacitor has much less energy capacity than the BESS. Rather, it is aimed at compensating for fast fluctuations of power and so provides cache control as detailed in below fig 4.1

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Giving uninterruptible power supply (UPS) administration to burdens when required is a center obligation of the urban microgrid. EV quick charging acquaints a stochastic load with the microgrid.

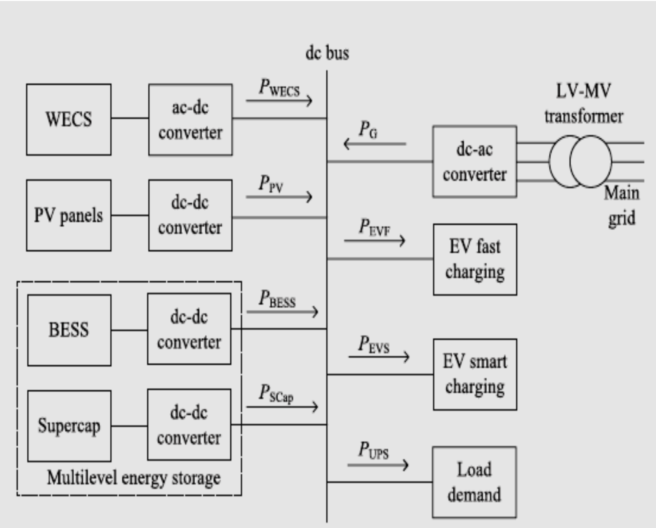

Fig. 4.1 Layout of the DC Microgrid.

The multilevel vitality stockpiling mitigates potential effects on the primary lattice. In building coordination, a vertical pivot wind turbine might be introduced on the housetop co-situated on the housetop and the veneer of the building. Such or comparable designs advantage from a neighborhood accessibility of rich wind and sun based vitality. The quick charging station is acknowledged for free at the ground level. It is associated near the LV–MV transformer to diminish misfortunes and voltage drop. EVs stopped in the building are offered savvy charging inside client characterized requirements.

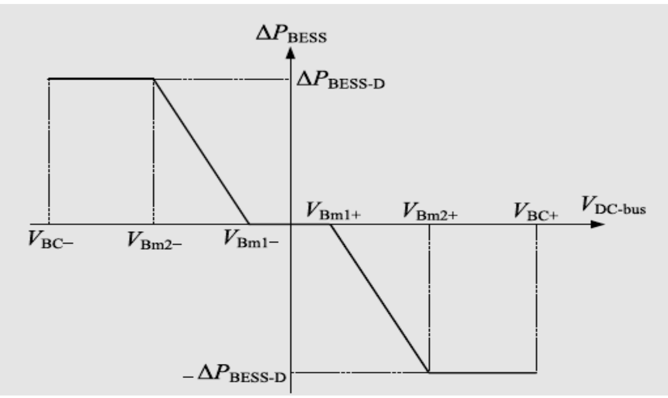

Fig. 4.2 Droop control of BESS power electronic converter to mitigate power deviations of dc microgrid in normal SOC of the BESS.

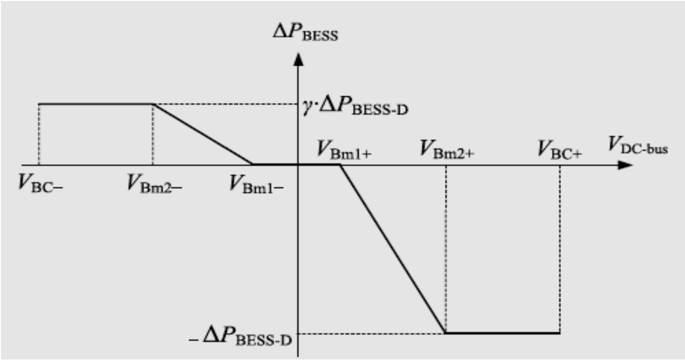

Fig. 4.3 Droop Control of BESS Power Electronic Converter to Mitigate Power

4.1) ADAPTIVE DROOP CONTROL OF BESS

In this section, the real-time operation of the microgrid in the interconnected and autonomous modes is studied. In the interconnected mode of operation, an adaptive droop control is devised for the BESS. The adaptive droop characteristic of the BESS power electronic converter is selected on the basis of the deviation between the optimized and real-time SOC of the BESS, as calculated. In autonomous mode of operation, the BESS is responsible for keeping the voltage of the dc bus in a defined acceptable range for providing UPS service.

4.1.1) DC Voltage Droop Control in Interconnected Mode

The devised droop controls of the BESS are depicted in figs: 4.2– 4.4. The change of the battery power _P_{BESS} is deviations of dc microgrid in higher than the scheduled SOC of the BESS. It can be noted that two of the three devised droop characteristics are asymmetric.

The first droop curve, as shown in fig: 4.2, is devised for a case where the real-time SOC of the BESS. The acceptable real-time SOC is determined through definition of upper and lower boundaries around the optimized SOC. If the real-time SOC is within these boundaries, the droop control of the BESS power electronic converter is selected as shown in fig: 4.2 to support the dc voltage. In this case, the upper boundary and the lower boundary lead to a symmetrical droop response. In the voltage range between V_{Bm1-} and V_{Bm1+}, battery storage does not react to the voltage deviations of the dc bus. In the voltage range from V_{Bm1-} to V_{Bm2-} and also from V_{Bm1+} to V_{Bm2+}, the droop control of the BESS reacts.

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The second droop curve as shown in fig: 4.3 is devised for a situation where the real-time SOC of the BESS is lower than the optimized and scheduled SOC of the BESS. Therefore, the BESS contributes to stabilizing the dc bus voltage by charging at the same power as shown in fig: 4.2. However, the upper boundary of the BESS droop response is reduced by the factor γ, and it is equal to $\gamma \cdot \Delta P_{BESS\text{-}D}$. This way, the SOC can come closer to the optimized and scheduled SOC.

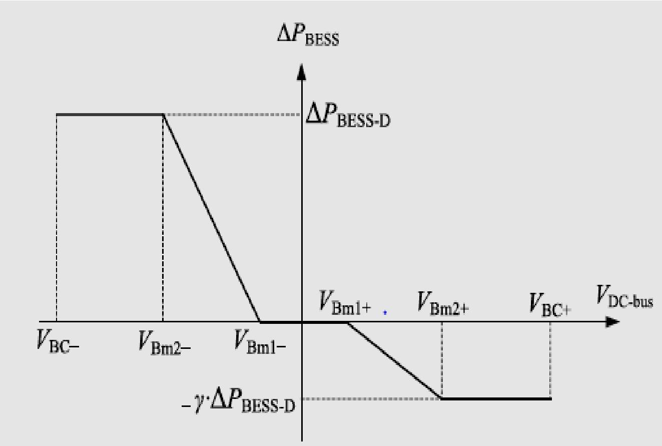

Fig. 4.4 Droop Control of BESS Power Electronic Converter to Mitigate Power

The third droop curve as shown in fig: 4.4 is devised for a situation where the real-time SOC of the BESS is higher than the optimized and scheduled SOC of the BESS. The BESS contributes to stabilizing the dc bus voltage by discharging at the same power as shown in fig: 4.2. However, the lower boundary of the BESS droop response is modified by the factor γ, and it is equal to $-\gamma. \ \Delta P_{BESS\text{-}D}$. The dc–ac converter connected to the main grid is also controlled by a droop. The droop parameters are adjusted to support the droop control of the storage.

4.1. 2 DC Voltage Droop Control in Autonomous Mode

In the autonomous mode, the main grid is disconnected. Then, the fast charging service has less priority compared with the supply of other loads. The control of the BESS converter is also defined by the voltage–power droop as discussed. The BESS so supports the voltage of the dc bus.

5) MPPT CONTROL

Numerous MPPT calculations have been proposed in the writing, for example, incremental conductance (INC), consistent voltage (CV), and bother and perception (P&O). The two calculations regularly used to accomplish most extreme power point following are the P&O and INC techniques. The INC strategy offers great execution under quickly changing barometrical conditions. In the event that the sensors require more transformation time, then the MPPT procedure will take more time to track the greatest power point. This implies the more drawn out the transformation time is, the bigger measure of power misfortune will be despite what might be expected, if the execution speed of the P&O strategy builds, then the framework misfortune will diminish.

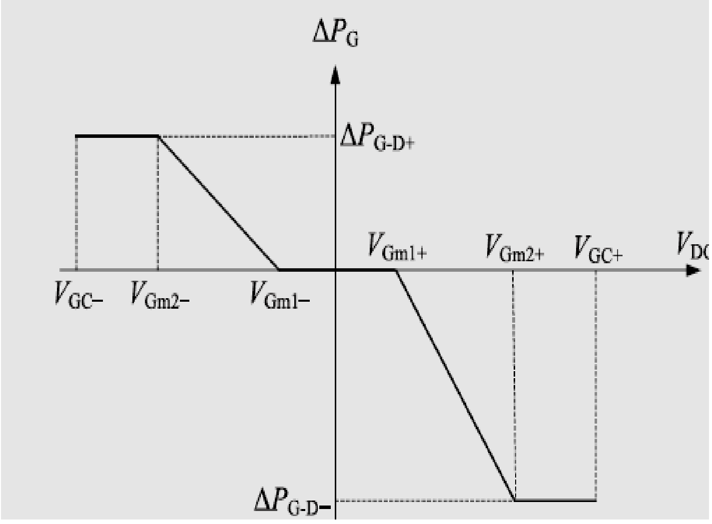

Fig. 4.5 Droop Control of the Grid Power Electronic Converter in Interconnected Operation Mode of DC Microgrid.

Also, this strategy just requires two sensors, which brings about a lessening of equipment prerequisites and cost. Thusly, the P&O strategy is utilized to control the MPPT procedure. The downside of the voltage-input control is its disregard of the impact of light and cell temperature. In this manner, the power-criticism control is utilized to accomplish most extreme power.

The P&O MPPT calculation with a power-criticism control is appeared in fig: 5.1. As PV voltage and current are resolved, the power is figured. At the greatest power point, the subordinate ($\frac{dP}{dV}$) is equivalent to zero. The most extreme power point can be accomplished by changing the reference voltage by the measure of ΔV_{ref}. So as to actualize the MPPT calculation, a buck-help dc/dc converter is utilized as portrayed as a part of fig: 5.2. The parameters L and C in the buck-support converter must fulfil the accompanying conditions:

$$L > \frac{(1-D)^2 R}{2f} \ ; \qquad C > \frac{D}{Rf\,(^{\Delta V}/_{V_{out}})}. \qquad (1)$$

The buck-help converter comprises of one exchanging gadget (GTO) that empowers it to turn on and off contingent upon the connected door flag D. The door motion for the GTO can be gotten by contrasting the saw tooth waveform and the control voltage.

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6) CONTROL OF THE HYBRID SYSTEM

The control modes in the microgrid incorporate unit power control, feeder stream control, and blended control mode. The two control modes were initially proposed by Lasserter. In the UPC mode, the DGs (the crossover source in this framework) direct the voltage extent at the association point and the power that source is infusing. In this mode if a heap increments anyplace in the microgrid, the additional power originates from the framework, since the half source manages to a consistent power.

In this paper, a coordination of the UPC mode and the FFC mode was researched to decide when each of the two control modes was connected and to decide reference esteem for every mode. The proposed operation procedure exhibited in the following segment is additionally in light of the minimization of mode change. This proposed working methodology will have the capacity to enhance execution of the framework's operation and improve framework solidness.

6.1) Overall Operating Strategy for the Grid-Connected Hybrid System

It is outstanding that in the microgrid, every DG and additionally the crossover source have two control modes:

1) The UPC mode and

2) The FFC mode.

The motivation behind the calculation is to choose when every control mode is connected and to decide the reference estimation of the feeder stream when the FFC mode is utilized.

This working procedure must empower the PV to work at its greatest power point, FC yield, and feeder stream to fulfill their imperatives. On the off chance that the half breed source works in the UPC mode, the cross breed yield is managed to reference esteem and the varieties in load are coordinated by feeder power.

Table – 6.1 System Parameters

Parameter	Value	Unit
P_{FC}^{low}	0.01	MW
P_{FC}^{up}	0.07	MW
P_{Feeder}^{max}	0.01	MW
ΔP_{MS}	0.03	MW

In summary, in a light-load condition, the hybrid source works in UPC mode, the hybrid source regulates output power to the reference value P_{MS}^{ref}, and the main grid compensates for load variations. P_{MS}^{ref} is determined by the algorithm and, thus, the PV always works at its maximum power point and the PEMFC always works within the high efficiency band ($P_{Fc}^{low} \div P_{Fc}^{up}$). In heavy load conditions, the control mode changes to FFC, and the variation of load will be matched by the hybrid source.

In this mode, PV still works with the MPPT control, and PEMFC operates within its efficiency band until load increases to a very high point.

Hence, FC only works outside the high efficiency band ($P_{Fc}^{up} \div P_{Fc}^{max}$) in severe conditions. With an installed power of FC and load demand satisfying (18), load shedding will not occur. Besides, to reduce the number of mode changes, must be increased and, hence, the number of mode changes is minimized when is maximized.

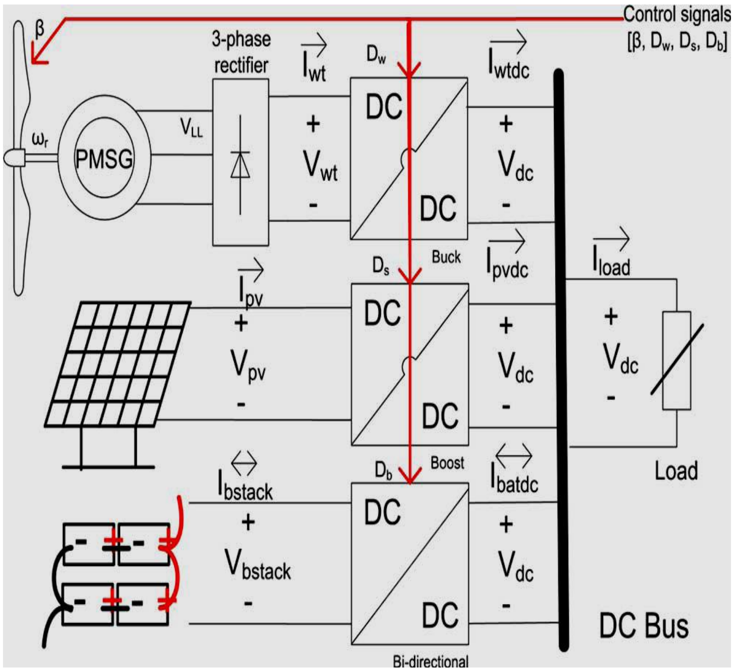

Fig. 6.1 Topology of a Small-Scale DC Microgrid.

The following notations are used to model the dc microgrid in fig: 6.1 as DAEs: where F is a set of implicit differential and algebraic functional for. The first two constraints and are due to the fact that in standalone dc microgrids the sum of the generated, stored, and consumed powers is always zero:

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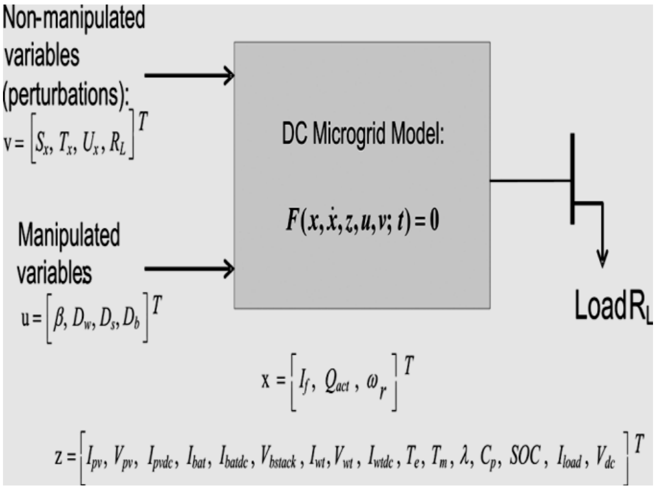

Fig. 6.2 Modified Version of the System Model.

7) 5.3 NMPC

Show prescient control (MPC) is a propelled technique for process control that has been being used in the process businesses in compound plants and oil refineries since the 1980s. As of late it has likewise been utilized as a part of power framework adjusting models. Display prescient controllers depend on element models of the procedure, regularly direct observational models got by framework ID. The principle preferred standpoint of MPC is the way that it permits the current timeslot to be enhanced, while keeping future timeslots in record.

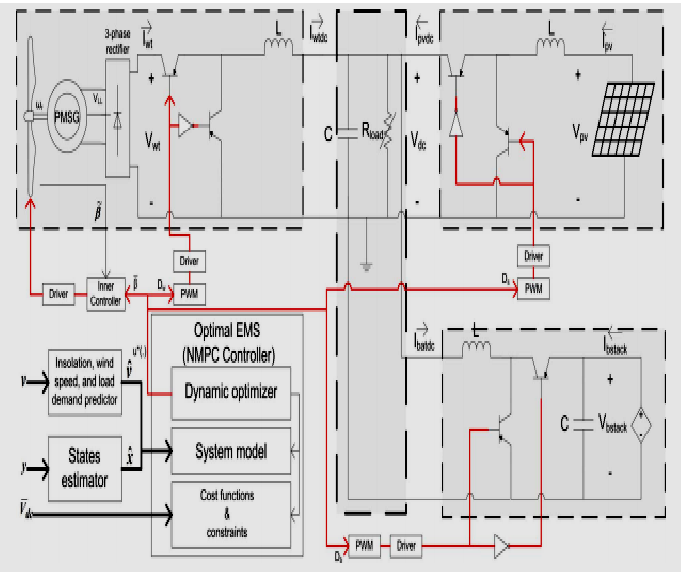

Fig. 7.1 Simplified view of the DC Microgrid and the Developed NMPC controller. The Battery Bank is assumed to Work in Charging Mode.

This is accomplished by advancing a limited time-skyline, however just actualizing the current timeslot. MPC can envision future occasions and can take control activities accordingly.PID and LQR controllers don't have this prescient capacity. MPC is almost generally actualized as an advanced control, in spite of the fact that there is research into accomplishing speedier reaction times with exceptionally outlined simple hardware.

OCPs are open-circle techniques and are wrapped by a criticism circle to build NMPC procedures. NMPC techniques, which are additionally called as the subsiding skyline control. At that point the main ideal esteem is connected as the following control flag. Contrasting and the ordinary techniques, NMPCs are intrinsically nonlinear and multivariable systems that handle requirements and deferrals. There are three distinct systems to discretize and fathom OCPs of

1) Dynamic programming strategy in view of the Bellman's optimality rule;

2) Indirect strategy in view of the Pontryagin least rule; and

3) Direct strategies that change over OCPs into nonlinear streamlining issues (NLPs) which are then settled by NLP solvers.

8) SIMULATION MODELING & RESULTS

8.1) PROPOSED SIMULATION DIAGRAMS

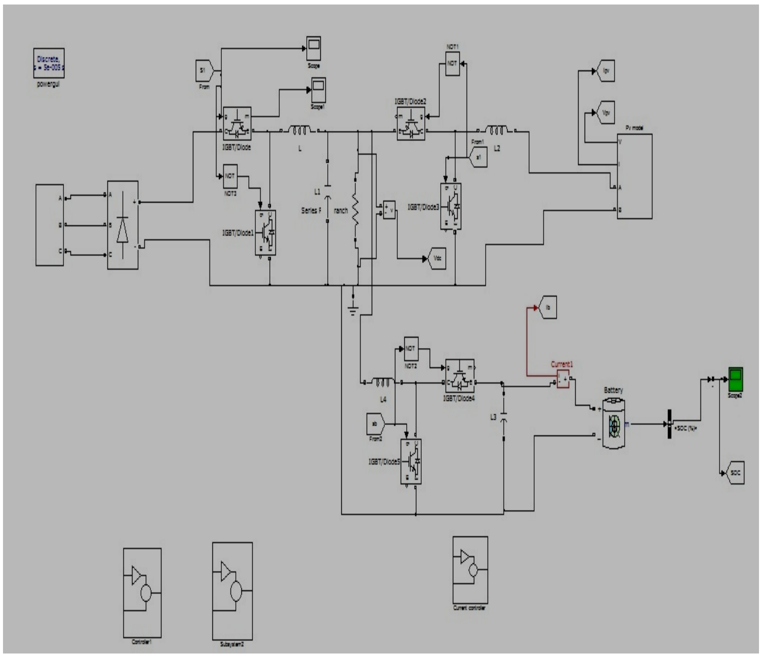

Fig. 8.1 Constant Current Charging Mode

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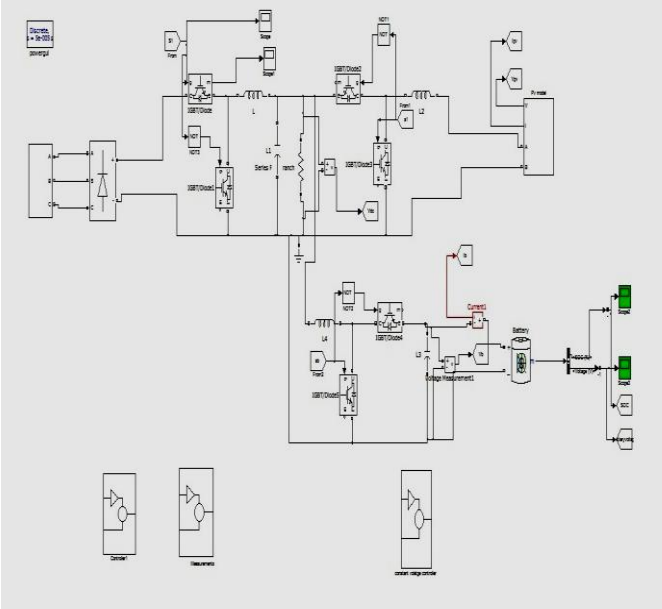

Fig. 8.2 Constant Voltage Charging Mode

8.2) SIMULATION RESULTS

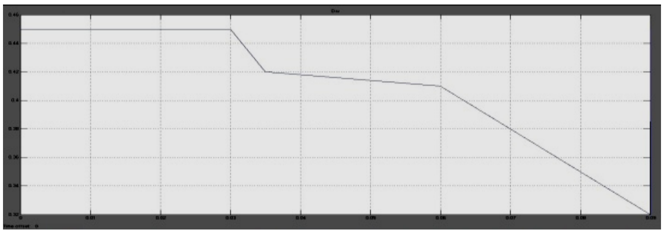

Fig. 6.3 Switching Duty Cycle of Wind

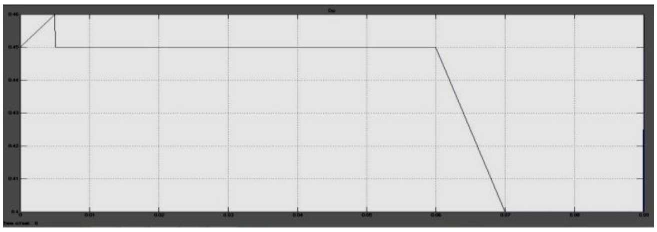

Fig. 6.4 Switching Duty Cycle of Solar

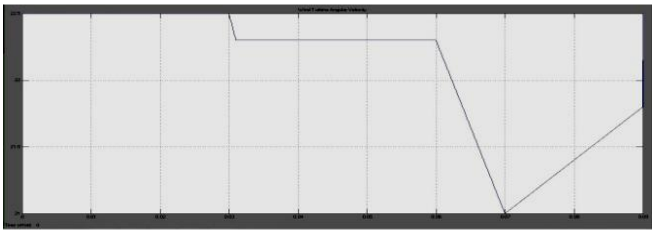

Fig. 6.5 Wind Turbine Angular Velocity

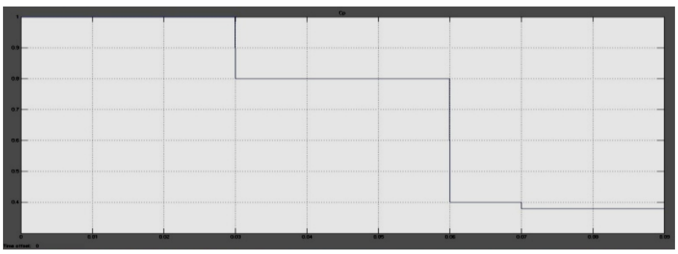

Fig. 6.6 Power Coefficient

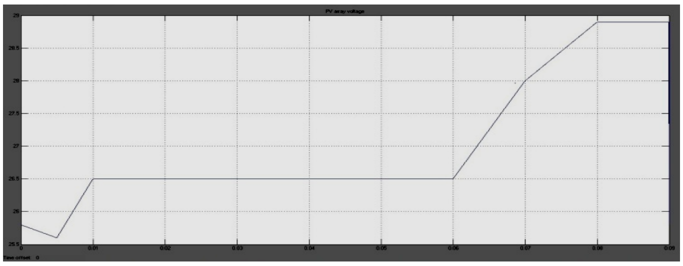

Fig. 6.7 PV Array Voltage

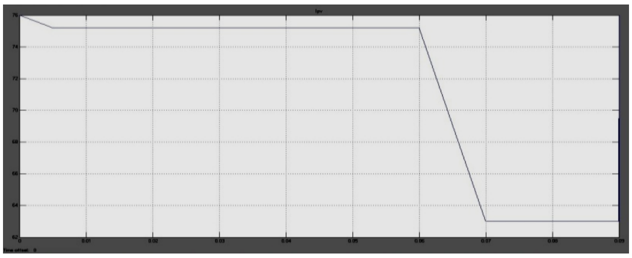

Fig. 6.8 PV Array Current

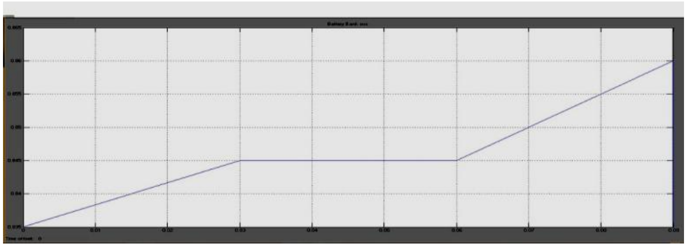

Fig. 6.12 SOC of the Battery Bank

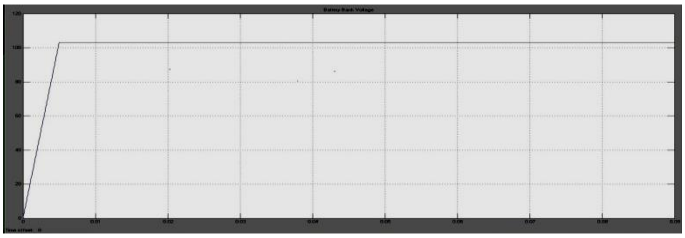

Fig. 6.13 Terminal Voltage

9) CONCLUSION AND FUTURE WORKS

In this venture, we built up a novel ideal EMS that deals with the vitality streams over a standalone green dc microgrid, comprising of the wind, sun based, and battery branches. An organized and multivariable online NMPC methodology has been created to address, as the ideal EMS, three principle control goals of standalone dc microgrids. These goals are the voltage level direction, corresponding power sharing, and battery administration. So as to address these goals, the created EMS at the same time controls the pitch point of the wind turbine and the exchanging obligation

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cycles of three dc-dc converters. It has been demonstrated that the created controller tracks the MPPs of the wind and sun powered branches inside the ordinary conditions and shortens their eras amid the under load conditions. They gave adaptable era diminishing system understands the consistent current-steady voltage charging administration that conceivably builds the life expectancy of the battery bank. Note that the proposed technique can be utilized as a unified execution of the essential and optional levels in the progressive design.

The re-enactment comes about have demonstrated its capacity to accomplish all control targets.

The issue of considering the releasing method of the battery operation, which moves the issue to the class of cross breed dynamical frameworks, is currently being examined.

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