Fuzzy based Unified Control and Power Management Scheme for PV Battery Based Hybrid Micro grids for Both Grid Connected and Islanded Modes

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Abstract: ***This paper proposes a power management and control system for laboratory scale micro-grid based on hybrid energy resources such as solar and battery. Control schemes for PV-battery systems must be able to stabilize the bus voltages as well as to control the power flows flexibly. This paper proposes a comprehensive control and power management system (CAPMS) with Fuzzy Logic for PV battery based hybrid micro grids with both AC and DC buses, for both grid-connected and islanded modes. Power converters and control algorithms have been used along with dedicated energy resources for the efficient operation of the microgrid. The control algorithms with Fuzzy Logic controller (FLC) are developed to provide power compatibility and power management between different resources in the microgrid. It provides stable operation of the control in all microgrid subsystems under various power generation and load conditions. The proposed microgrid, based on hybrid energy resources, operates in autonomous mode and has an open architecture platform for testing multiple different control configurations. The proposed CAPMS is successful in regulating the DC and AC bus voltages and frequency stably, controlling the voltage and power of each unit flexibly, and balancing the power flows in the systems automatically under different operating circumstances, regard less of disturbances from switching operating modes, fluctuations of irradiance and temperature, and change of loads. Both simulation case studies are carried out to verify the performance of the proposed method.***

Index Terms—Solar PV System, Fuzzy Logic Control, Battery, Control and Power Management System, Distributed Energy Resource, Microgrid, Power Electronics.

I INTRODUCTION

Distributed energy generation systems predicated on renewable energy sources, such as solar photovoltaic (PV) and wind energy are playing a major role in the immaculate energy engenderment. Due to the intermittence of the solar and wind energy, energy storage system (ESS) is integrated to provide sustainable energy, especially, when operating in standalone mode. Such hybrid energy system requires multiple control strategies to ascertain smooth and efficient power transfer [1], [2]. Continually incrementing demand for energy and concerns of environmental deterioration have been spurring electric power experts to find sustainable methods of potency generation. Distributed generations (DG) in the form of renewable resources, such as solar energy, are believed to provide an efficacious solution to reduce the dependency on conventional power generation and to enhance the reliability and quality of puissance systems [1]. However, due to the nature of solar energy and PV panels, instantaneous power output of a PV system depends largelyon its operating environment, such as solar irradiance and circumventing temperature, resulting in constant fluctuations in the output power [2], [3]. Ergo, to maintain a reliable output puissance, battery storage systems are customarily integrated with PV systems to address the variability issue. A typical configuration of PV-battery system is illustrated in Fig. 1, which is a hybrid micro-grid system consisting of a PV array that contains a number of PV panels, battery bank for power storage, and a centralized bidirectional inverter that interfaces the DC to AC power system [4], [5].

The PV-battery system can be working in either grid-connected or islanded modes by transmuting the breaker status at the PCC, subject to the condition of the system and the grid, e.g., an earnest fault on the AC bus may require opening the breaker to obviate the back-victualing current from the grid [6]. Since PV output power and load demand may change perpetually during a day, the puissance management algorithms for PV-battery system are required to manage the puissance flow and promptly respond to any vicissitude to maintain the balance between power engenderment's and consumptions. Further more, both DC bus and AC bus voltages must be stabilized regardless of vicissitudes in the system to ascertain a reliable power supply. A number of potency management methods for PV-battery systems have been proposed in the literature. An energy management and control system is introduced in [7] which provide stable operation for a wind-PV-battery system. Both [8] and [9] fixate on size optimization in lieu of detailed control methods for individual power source. A puissance management strategy for a PV-battery unit is discussed in [10] predicated on droop control for load sharing between the PV-battery unit and another power source. An amended version, which considers multiple power units, has been presented in Ref. [11]. Albeit these strategies prosperously manage the potency demand and engenderment, both of them mainly fixate on the potency management between the PV-battery unit and other generation units. Supplementally, these methods do not consider systems with DC bus and loads. This method aims at solving load sharing in system configurations with multiple PV and battery units. Ref.[15] introduces a kindred method which only aims at single phase low voltage islanded microgrids.

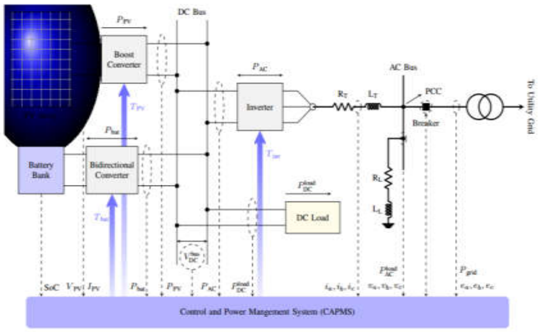


Fig.1: Proposed control and power management system

The topology of the studied system, where PV and battery bank are interfaced with the grid utilizing decentralized inverters, is different from the system configuration of this study. Homogeneous methods utilizing day ahead data for power presage of a PV-battery system are proposed in [17] and [18], All these four methods mainly fixate on forecasting the potency generation and authoritatively mandate, and scheduling the puissance flow of PV or battery, in lieu of categorical control algorithms. Supplementally, there are withal works endeavoring to manage the puissance more efficaciously by utilizing incipient topologies of converters [20]–[22] in lieu of modifying controlling methods. None of the works in there viewed literature takes into account the stabilization of the DC bus voltage, which is of great consequentiality for reliable power supply for DC loads. In an endeavor to address the issues discussed above, this paper proposes a control and power management system(CAPMS) for PV-battery systems, which is a centralized control system that flexibly and efficaciously controls power flows among the potency sources, loads, and utility grid. The proposed method prospers in regulating the voltage on both DC and AC buses, transferring between grid-connected and islanded operating modes smoothly, and balancing power expeditiously in the hybrid PV-battery system. The rest of the paper is organized as follows: Section II and III expound the proposed CAPMS with Fuzzy Logic controllers, after which the proposed method is verified in the case studies of Section IV; Section V concludes the paper.

II THE PROPOSED CONTROL AND POWER MANAGEMENT SYSTEM

The Fig. 1 illustrates the configuration of a typical PV-battery system with the proposed CAPMS. In this topology, the PV array is interfaced with the DC bus by a DC/DC boost converter while the battery bank uses a bidirectional DC/DC converter to control the charging and discharging processes.

A centralized inverter is installed to interconnect the DC and AC networks. DC load block generally represents the loads that are connecting at the DC bus, which can be multiple types of loads such as electric conveyances or office buildings. There are withal AC loads consuming power at the AC bus. This is a typical PV battery microgrid system and homogeneous or same configurations have been widely used and investigated [23]–[26].The proposed CAPMS is a centralized power management system consisting of a supervisory module that monitors the required authentic-time parameters (dashed lines in Fig. 1) from the PV-battery system and multiple controllers for each of the potency converters.

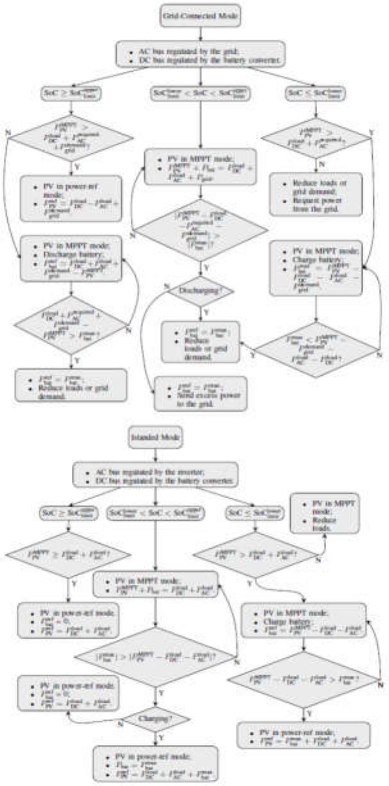


Fig.2: The power management schemes for grid-connected and islanded modes.

According to the situation of the monitored parameters, CAPMS decides the scenarios and cull concrete control schemes to be applied to the converters to ascertain reliably power environment. Albeit the proposed CAPMS is designed predicated on the PV-battery system configuration shown in Fig. 1, for other configurations, such as systems with decentralized inverters or multiple battery banks, homogeneous approach may be applicable with opportune modifications. Detailed schemes of the CAPMS, taking into account both grid connected and islanded modes, are depicted in Fig. 2, which denotes the possible operating scenarios of the PV-battery. microgrid and how CAPMS responds to control and balance the system. As presented in the flowcharts, the PV-battery system, which connects to the grid via a circuit breaker, can operate either in islanded or grid-connected mode, depending on the conditions and plans of both the microgrid and main grid. Firstly, the CAPMS monitors the status of circuit breaker and determines different voltage and power control schemes to be applied to corresponding converters or inverter. In particular, in grid connected mode, the inverter controls the DC bus voltage (V bus DC) and reactive power (QAC) that is exchanged with the AC side; the PV converter controls the potency output of the PV array (PPV); and the battery converter manages the charging or discharging of the battery bank. In islanded mode, where the breaker is open, CAPMS has to ascertain the reliability of electric power supplied to the loads, i.e., DC and AC bus voltages and AC frequency have to be maintained around set points within acceptable limits, to avert damaging the loads during transitions. Consequently, upon transferring from grid-connected to islanded mode, the inverter switches to regulate the AC bus voltage (va, vb, and vc) and frequency (f), while V bus DC is regulated by the battery converter. Secondly, state of charge(SoC) of the battery bank is always monitored in both modes. Ergo, CAPMS is cognizant of the available energy storage that can be utilized in the battery. The upper and lower limits of the SoC (SoC upper limit and SoC lower limit) are set up to ascertain the battery is not over-charged or discharged and to increment its cycle life [27]. Depending on the PV output puissance, SoC and power limit of the battery, DC and AC loads, and the grid demand, CAPMS decides the operation modes of the PV array(MPPT or power-reference mode) and the battery (charging or discharge mode) and provides opportune reference values to the controllers, if applicable. Ergo, power flows in the hybrid microgrid are always balanced. The puissance management criteria are predicated on

$$\text{Grid connected: } P_{PV} + P_{bat} = P_{DC}^{Load} + P_{Grid} \quad (1)$$

$$\text{Islanded: } P_{PV} + P_{bat} = P_{DC}^{Load} + P_{AC}^{Load} \quad (2)$$

where P_{PV} is the output power of the PV array, P_{bat} is the power flows in the battery converter ($P_{bat} < 0$ in charging mode and $P_{bat} > 0$ in discharging mode), P_{load}^{DC} and P_{load} AC are DC and AC loads, respectively, and P_{grid} generally represents the power exchanging between the main grid and the microgrid through the breaker ($P_{grid} < 0$ when receiving power and $P_{grid} > 0$ when sending power). Note that the power demand from the main grid is denoted as P_{demand} grid (Fig. 2), which might be obtained by forecasting data. Before switching from islanded to grid-connected mode, CAPMS will synchronize the AC voltages at the PCC of the microgrid to follow the grid-side voltages to ensure a smooth transition.

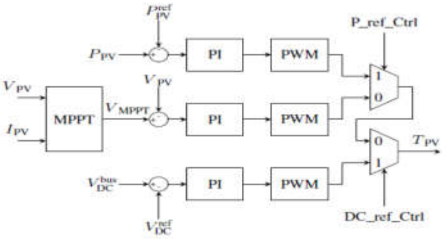


Fig.3: PV array controller.

With well-balanced power and regulated voltages, CAPMS ensures an uninterrupted power on both DC and AC buses and allows loads to plug and play in the PV-battery system, regardless of disturbances from switching operating modes. Additionally, since the DC bus voltage is controlled, as long as voltage level matches, DC loads will be able to connect to the DC bus without additional converters. When necessary, the PV-battery system can also provide reactive power to the grid. Detailed controlling schemes for each part of the system will be elaborated in the next section.

III PROPOSED CONTROL DESIGN WITH FUZZY LOGIC CONTROLLER

The PV array converts solar energy into DC puissance, and is connected to the DC bus via a boost DC/DC converter. However, due to nonlinear characteristics of PV panels and the stochastic fluctuations of solar irradiance, there is always maximum power point (MPP) for every categorical operating situation of a PV array. Consequently, maximum power point tracking (MPPT) algorithms are typically implemented in PV system to extract the maximum power a PV array can provide [28]. The proposed CAPMS employs one of the most popular methods, the Incremental Conductance MPPT, which provides a reference voltage V MPPT that the PV array will track to engender the maximum power under sundry operation conditions (different cumulations of irradiance and temperature).There are three possible control schemes for the PV array: MPPT control, power-reference control, and DC bus voltage control, depending on the situation of the PV-battery system. For example, in islanded mode, when PMPPTPV is more preponderant than the total load demand (DC and AC), and the battery is plenarily charged or the charging rate Pbat reaches its upper limit, the CAPMS will engender control commands P ref Ctrl = 1 and DC ref Ctrl = 0 to set the PV array to work in power-reference control mode by sending PWM streams, TPV, to the DC/DC converter accordingly. In this case, to balance the puissance flows, CAPMS will decide felicitous power references for the PV array, Pref PV, according to the value of which the operating voltage of the PV array, VPV, will be moving between its VMPPT and the open-circuit voltage, VOC.

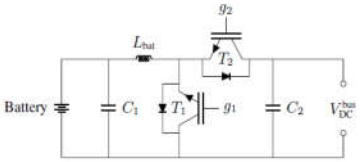


Fig.4: Bidirectional DC/DC converter for the battery bank.

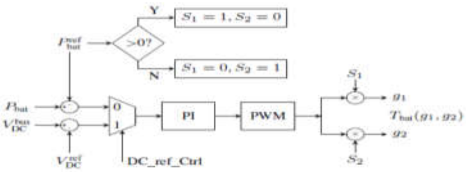


Fig.5: Battery charging/discharging controller.

Since the DC bus voltage is regulated by the battery converter in this situation, there will be a stable voltage at the DC bus in spite of the fluctuations in VPV. In MPPT mode (P ref Ctrl = 0 and DC ref Ctrl =0), real-time PV current, IPV, and V PV are measured and sent to the MPPT module, which then provides V MPPT as the voltage reference for the PV array. Additionally, in islanded mode, when the battery is not available, e.g., due to faults, the PV converter has to switch to control the DC bus voltage to ensure a stable power supply to the loads on the DC bus(P ref Ctrl = 0 and DC ref Ctrl = 1). Fig. 3 illustrates the controller for these three modes. Note that the situation where both P ref Ctrl = 1 and DC ref Ctrl = 1 is not applicable.

As an energy buffer, battery bank is indispensable in PV systems for power balancing. The battery bank of this system is connected to the DC bus and is controlled by a bidirectional DC/DC converter (Fig. 4) which includes two switches, T1and T2, that control the charging/discharging process. Fig. 5explains the detailed control process. In grid-connected mode, with the command DC ref

Ctrl = 0, the converter controls theer flow (Pbat) in or out of the battery, where in discharging mode Pbat > 0, and in charging mode Pbat < 0. The final output of the battery controller is a two-dimensional switching signal Tbat(g1; g2). In Islanded mode, the control command DC ref Ctrl is set to "1" by the CAPMS, which switches the converter to work in voltage reference mode. The output voltage of converter, which is withal the DC bus voltage, is regulated to follow the reference so that the DC load voltage is stabilized. The CAPMS monitors the SoC of the battery and enforces its upper and lower limits (SoC upperlimit = 90% and SoC lowerlimit = 10% in this study) in order to increment the lifecycle. Note that the culls of the SoC limits do not affect the performance of the controller.

A three-phase inverter is used to convert DC to AC power, interfacing the DC and AC sides. Similar to the converters discussed above, the control scheme of inverter depends on the operating (grid-connected or islanded) mode of the system. During islanded mode, the signal"Sync" is set to 0 so that CAPMS has full control of theAC bus voltage by adjusting the references, V_{refd} and V refq .However, to ensure a smooth transition upon switching to grid connected mode, "Sync" will be set to 1 to synchronize theAC bus and grid side voltages right before closing the breaker. To this end, _ will be synchronized to follow the output angle of PLL, and the AC voltages after the breaker in d-q frame,E_d and E_q, will be chosen as the references for V_d and V_q(Fig. 6), respectively. In grid-connected mode (Islanded = 0),the inverter is responsible for regulating the DC bus voltage V_{DC} and controlling the reactive power transferring from DCto AC side. Additionally, in both operating modes, the current references of inner loop of the controller (I^{ref}_d and I^{ref}_q) can been forced to proper limits to prevent overloading of the inverter.

FUZZY LOGIC CONTROLLER

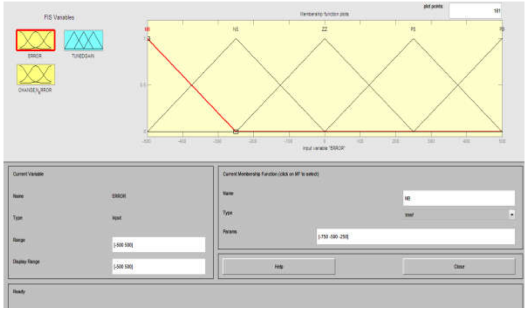
Fuzzy logic uses fuzzy set theory, in which a variable is member of one or more sets, with a specified degree of membership. Fuzzy logic allow us to emulate the human reasoning process in computers, quantify imprecise information, make decision based on vague and in complete data, yet by applying a "defuzzification" process, arrive at definite conclusions.

The FLC mainly consists of three blocks

- Fuzzification
- Inference
- Defuzzification

RULES:

If input is NEGATIVE then output is POSITIVE
If input is ZERO then output is ZERO
If input is POSITIVE then output is NEGATIVE



Current Variable
Name ERROR
Type input
Range [-500 500]
Display Range [-500 500]

Current Membership Function (click on MF to select)
Name NB
Type trimf
Params [-750 -500 -250]

Fig.6: Fuzzy Inputs and Outputs

V SIMULATION RESULTS

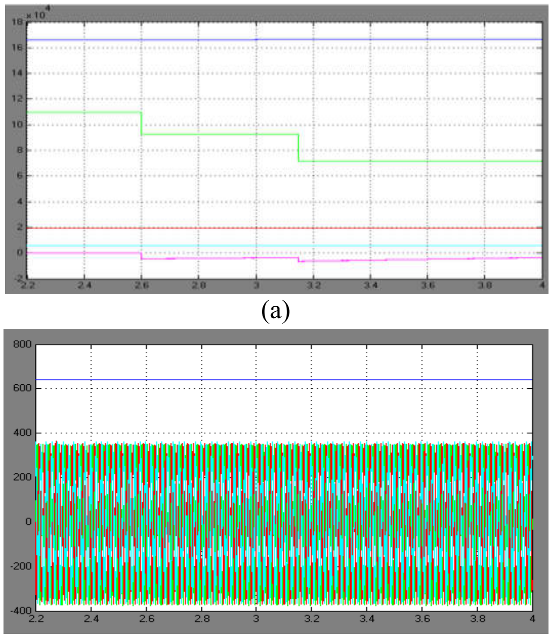
In order to verify the performance of the proposed CAPMS, numerous simulation and experimental case studies are carried out in this section using the PSCAD/EMTDC and Matlab/ Simulink software package. A PV-battery system is constructed with the configuration presented in Fig. 1, with the parameters listed in Table I. Note that the parameters for the PV array are under standard testing condition (STC, irradiance = 1000W/m2, temperature = 25_C).

The battery bank uses a general Ni-Cd characteristic model whose capacity is sized according to the IEEE Standard 1562-2007 [29] to support 5 days of autonomy operation (for 150kW loads) under low irradiance conditions. The proposed CAPMS monitors the required variables out of the PV-battery system mentioned in the above sections, process the data following the schemes in Fig. 2, and, according to the situation observed, switches the control schemes automatically. The case studies test the CAPMS's responses for multiple scenarios that the PV-battery system is working in or switching to.

Results are analyzed individually in each case. A.

Simulation Verification: Grid-Connected Mode

1) Case A-1: The first case is the normal operation situation of the PV-battery system in grid-connected mode, when the battery is fully available for power balancing (10% < SoC < 90%). PV array is working in MPPT mode, tracking the voltage reference (V_{MPPT}) estimated by the MPPT module. DC and AC loads are supplied by the buses. Depending on the amount of generation, load, and demand requested by the grid (P_{grid}), the battery is balancing the power by absorbing or releasing power.



(a)

(b)

Fig.7: (a) power flows and (b) voltage values of the PV-battery system.

The Fig. 7 presents the power flows and voltages of the PV-battery system under the control of CAPMS in Case A-1. Before 2.6 s, the PV array power P_{PV} is around 170kW in MPPT mode, which is shared by the DC load (P_{loadDC} =50 kW), AC load ($P_{load\ AC}$ = 10 kW), and the utility grid (P_{grid} = 110 kW). The power flow in or out of the battery during this period is about 0 since no extra power is available. At about 2.6 s, as the grid demand decreases to around 85kW, 15kW extra power is sent to charge the battery (P_{bat} = 15 kW). Later at 3.15 s, the grid demand drops again, and the battery power continues to increase. As long as the battery SoC and P_{bat} are within the limits, the battery is able to balance the power as an energy buffer. During these changes, the DC and AC bus voltages are controlled (Fig. 7).

2) Case A-2: As the battery is charged, the SoC will keep increasing. When the battery SoC is greater than 90 %, CAPMS will stop charging the battery and send the surplus power to the grid. Whenever the demand increases, the energy stored in the battery will be released to complement the change. Fig. 8 illustrates these processes. At 2 s, the battery is fully charged and the CAPMS sets P^{ref}_{bat} to 0. Thereby, P_{bat} follows the reference and the excess power of the system is delivered to the grid (P_{grid} increases to 50kW at 2 s). At 3 s, the demand from grid (P^{demand}_{grid}) increases to about 95kW. Since the PV array is working in MPPT mode (P_{PV} = 170 kW), and the DC and AC loads require 125kW totally (P_{LoadDC} = 103kW and load AC = 22 kW), the battery has to be controlled to provide 50kW to balance the power.

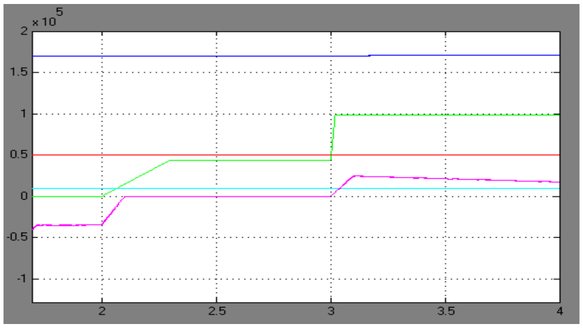


Fig.8: Grid-connected mode Case A-2: power flows of the PV-battery system.

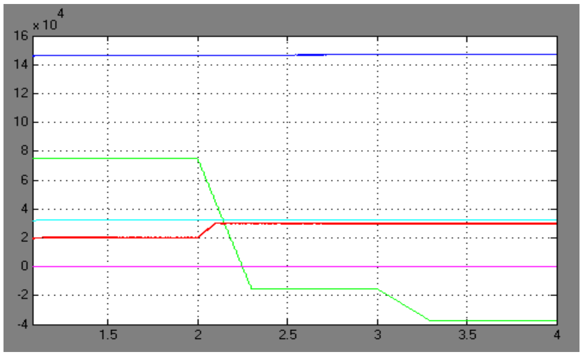


Fig.9: Grid-connected mode Case A-3-1: PV array in power-reference mode.

3) Case A-3: There is also situation where the SoC of battery has reached the upper limits (90 %), however, the maximum power provided by the PV array is more than the demands and loads. In this case, since the battery has been fully charged, and if the grid cannot absorb the excess power from PV array, CAPMS will switch the operating mode of PV from

MPPT to power-reference mode to balance the system, as is presented in Fig. 9 (Case A-3-1). Before 2 s, PPV is set to 150kW, and Pbat is set to 0. Therefore, besides the DC and AC load, (50 and 25kW, respectively), excess power is sent to the grid (Pgrid = 75 kW). As the reference of PV power changes at 2 s and 3 s, the power sent to grid adapts accordingly, keeping the power balanced in the PV-battery system. Fig. 10 (Case A-3-2) shows the smooth changes of PV voltage (blue curve) and the stable DC bus voltage (red curve) during the transitions between MPPT and power-reference modes. Note that VPV is greater than VMPPT but less than VOC in power-reference mode, and the PV operating point depends on the value of Pref PV.

4) Case A-4: The power flow in the inverter is bidirectional, i.e., when necessary, the PV-battery system can request power from the grid. For instance, when there is available power from the grid and the PV-battery system has more demand than generation, the CAPMS can reverse the power through the inverter to supply the system. Fig.11 gives an example of this situation. The battery SoC is less than 10% which hits the lower limit and stops releasing power for battery protection. The PV array is supplying power to the DC and AC loads Fig. 10. Grid-connected mode Case A-3-2: DC bus and PV array voltages during transitions between MPPT and power-reference modes. And the grid. However, DC load increases suddenly at 2 s, which causes the DC system to request power from the grid.

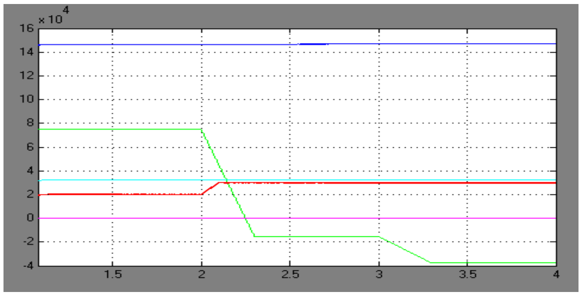


Fig.10: Grid-connected mode Case A-4: the PV-battery system is receiving power from the grid after 2.2 s.

Hence, Pgrid becomes negative, delivering reversed power in the inverter from the grid to the DC load. Immediately after that, at 3 s, the AC load increases. Since the battery bank is still not available, power from the grid increases to balance the system. Case study A-4 shows the proposed CAPMS rapidly responds to this situation.

5) Case A-5: In grid-connected mode, since the inverter has full control of the DC bus voltage as well as the reactive power, it is able to provide reactive power to the grid if necessary. The waveforms associated with this case are plotted in Fig.12, where the blue and red curves are the active and reactive power, Pgrid and Qgrid, respectively, that are being transferred from the PV-battery system to the grid. The inverter controls the reactive power flexibly. Regardless of changes of Qgrid, Pgrid is stabilized at its value.

6) Case A-6: As is mentioned in previous sections, the PVbattery system may work in either grid-connected or islanded modes. For example, when the utility grid is unstable or there are severe faults at the AC bus, to prevent drawing back feeding current from the grid, the circuit breaker at PCC will open, switching the system to work in islanded mode. After operating the breaker, the inverter is switched to control the AC bus voltage and frequency (Fig. 6), while the DC bus voltage is controlled by the battery converter (Fig. 5). Fig. 13 presents the dynamics of the DC and AC bus voltages (operating mode is changed at 1.4 s), where the voltages take less than 0.05 s to settle.

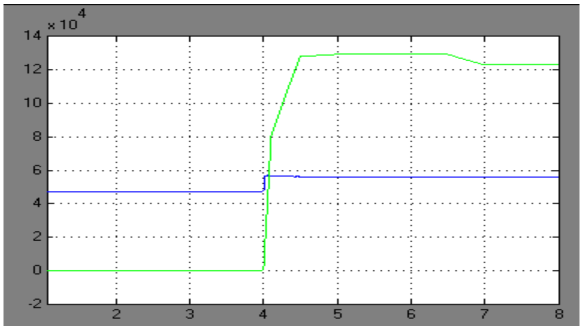


Fig.11: Grid-connected mode Case A-5: Reactive power control of the inverter.

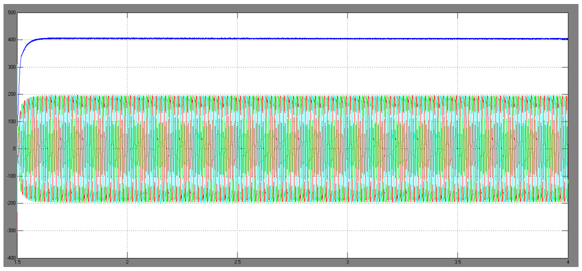


Fig.12: Grid-connected mode Case A-6: transition from grid-connected to islanded mode.

B. Simulation Verification: Islanded Mode

1) Case B-1: When the PV-battery system works in islanded mode, the available power is provided by PV or battery only, and the power balance criterion follows equation PPV + Pbat = Pload DC + PloadAC . Under normal operation conditions, where the battery SoC is within the lower (10%) and upper (90%) limits, PV array tracks VMPPT provided by the MPPT module and provides power to the DC and AC loads. Power going through the battery converter might be in either direction, depending on the load demand and PV output. Fig.14 shows an example of power sharing between PV and the battery bank: a 20kW increase of AC bus load (Pload AC) at 1.2 s results in a decrease of battery charging power (Pbat) from 50kW to 30kW; and another precipitous increase of DC load at 2.5 s poses the battery to discharge power in order to fulfill the system demand. It is verified in this case that the proposed CAPMS successfully responds to manage these changes.

2) Case B-2: Solar irradiance may change in seconds, resulting in PV power oscillations that will influence the load in both DC and AC buses. With the help of battery bank and the proposed CAPMS, the change of PV power can be compensated effectively by adapting the power flow in the battery converter. Fig. 15 shows how the battery power (red solid curve) responds to the decline of PV power due to reducing solar irradiance. Case study B-2 proves that CAPMS is capable of controlling the battery to balance the power quickly and precisely.

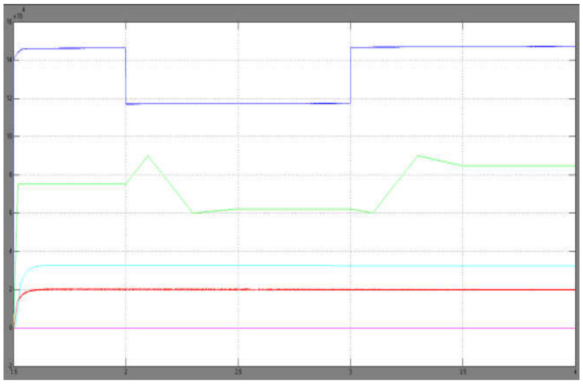


Fig.13: Islanded mode Case B-1: power flows of the PV-battery system with changing loads.

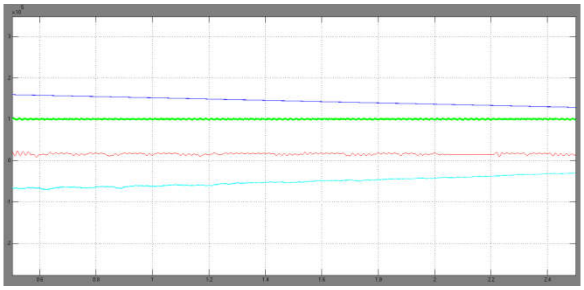


Fig.14: Islanded mode Case B-2: battery power changes with PV generation.

3) Case B-3: Unlike grid-connected mode, V bus DC and AC bus voltages (va, vb and vc) are controlled by the battery converter and inverter, respectively. Normally, bus voltages have to be regulated at certain values in order to provide reliable power to loads. Nevertheless, the CAPMS also has full control of these voltages. Both DC and AC bus voltages can be scaled by changing their references (Fig. 5 and 6). A case study of changing the DC (at 1 s) and AC bus voltages (at 1.55 s and 1.97 s) is presented in Fig. 16.

4) Case B-4: Disconnecting the PV-battery system might result from accidental actions of the breaker at the PCC. However, reconnecting the system to grid is usually preplanned, i.e., before closing the breaker, the operator will have sufficient time to posture the standalone PV-battery system for a smooth reconnection. One of the most important parameters to control is the three-phase AC bus voltage, which has to be synchronized with the voltage at the grid side PCC to avoid disturbances introduced by the action of breaker. This case compares the situations where the AC bus voltage is synchronized by the CAPMS, and is not synchronized before closing the breaker. In Fig. 17 (a), waveform distortion can be observed at the inception of closing the breaker (at 1.025 s) without voltage synchronization. In contrast, Fig.17 (b) presents the synchronizing process, which takes only approximately one cycle but successfully avoids the distortion.

This greatly reduces the disturbances, ensuring a stable power supply to the loads on the AC bus when reconnecting the PV battery system to the grid.

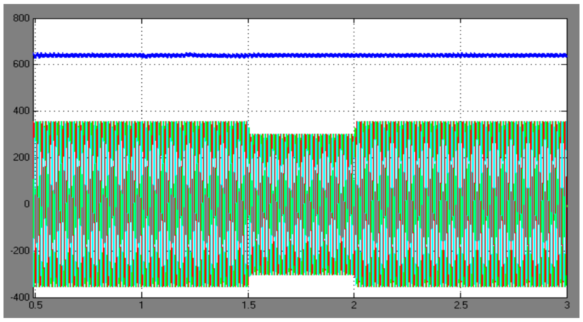


Fig.15: Islanded mode Case B-3: bus voltage control of the PV-battery system.

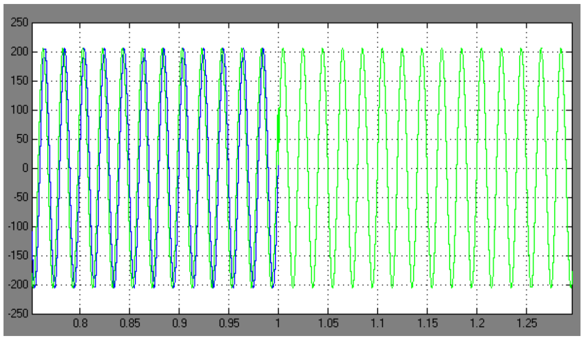


Fig. 16: Islanded mode Case B-4: (a) unsynchronized and (b) synchronized AC bus voltages (displaying phase-a) when closing the breaker at the PCC.

Table.1 : Comparison of THD values

Cases	**THD % by PI Controller**	**THD % by Fuzzy Controller**
A-1	16.67 %	2.27 %
A-2	18.97 %	2.75 %
A-3	23.92 %	9.70 %
B-2	0.23 %	0.13 %
B-3	0.15	0.03 %

VI CONCLUSION

This paper proposes a control and power management system (CAPMS) with Fuzzy Logic Controller (FLC) for hybrid PV-battery systems with both DC and AC buses and loads, in both grid-connected and islanded modes. The presented FLC-CAPMS is able to manage the puissance flows in the converters of all units flexibly and efficaciously, and ultimately to realize the potency balance between the hybrid micro grid system and the grid. Furthermore, CAPMS ascertains are liable power supply to the system when PV power fluctuates due to unstable irradiance or when the PV array is shutdown due to faults. DC and AC buses are under full control by the CAPMS in both grid-connected and islanded modes, providing a stable voltage environment for electrical loads even during transitions between these two modes. This withal sanctions supplemental loads to access the system without extra converters, reducing operation and control costs. Numerous simulation and experimental case studies are carried out in Section IV that verifies the copacetic performance of the proposed CAPMS. Fuzzy Logic Controller Reduces the THD values and improve the Voltage stability.

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