# A Hybrid AC/DC Micro grid

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***Abstract*—**This paper proposes a hybrid ac/dc grid to minimize the processes of a multiple dc–ac–dc or ac–dc–ac conversions in an isolated dc/ac grid. The hybrid grid consists of both the ac and dc networks which are connected by multi-bidirectional converters. The AC sources and the loads are connected to the ac network, whereas the dc sources and the loads are to the dc network. The energy storage systems to either dc or ac links. In this paper, the proposed hybrid grid can be considered to operate in a grid-tied mode or an autonomous mode. It is modeled and simulated using the MATLAB-Simulink Environment. The proposed control schemes are obtained in simulation even when the grid is switched between different operating conditions.

***Index Terms*—** PV system micro grid Energy management, grid control and operation, wind energy.

## I. INTRODUCTION

Three phase ac power systems have been existing for over 100 years mainly due to their transformation at different voltage levels, efficient long-distance transformation and the inherent characteristic from the fossil energy driven rotating machines. In the current trend, the renewable power conversion systems are either connected in low voltage ac distribution systems as distributed generators or as ac micro grids due to the environmental issues caused by the conventional fossil fueled power plants. On other hand, many dc loads such as light-emitting diode (LED) lights and the electric vehicles (EVs) are connected to the ac power systems to save energy as well as reduce the $CO_2$ emission. When the power can be fully supplied by the local renewable power sources, long distance high voltage transmission is no longer necessary [1]. The AC micro grids [2]–[5] have been proposed to facilitate the connection of the renewable power sources to the conventional ac systems. However, the dc power from photovoltaic (PV) panels or the fuel cells must be converted into ac using dc/dc boosters and dc/ac inverters in order to connect to the ac grid. In an ac grid, the embedded ac/dc and dc/dc converters are required for various home and office facilities to supply the different dc voltages. The AC-DC-AC converters are commonly used in order to control the speed of ac motors in industrial plants.

Recently, dc grids are gaining importance due to the development and the deployment of the renewable dc power sources and their inherent advantage of dc loads in wide range of applications such as commercial, industrial and residential. The dc micro grid has been proposed in [6]–[10] to integrate different distributed generators. However, ac sources must be converted into dc before connecting to a dc grid and dc/ac inverters are required for the conventional ac loads.

Since in a hybrid grid, energy management, control, and operation are more complicated than that of an individual ac or dc grid. Also, different operating modes of a hybrid ac/dc grid. The coordination of control schemes among various converters have been proposed to harness the maximum power from the renewable power sources to minimize the power transfer between ac and dc networks. The advanced power electronics and the control technologies used in this paper will make a smarter future power grid.

## II. SYSTEM CONFIGURATION AND MODELING

### A. Grid Configuration

Fig. 1 shows the conceptual hybrid system configuration where the two transformers and two four-quadrant operating the three phase converters.

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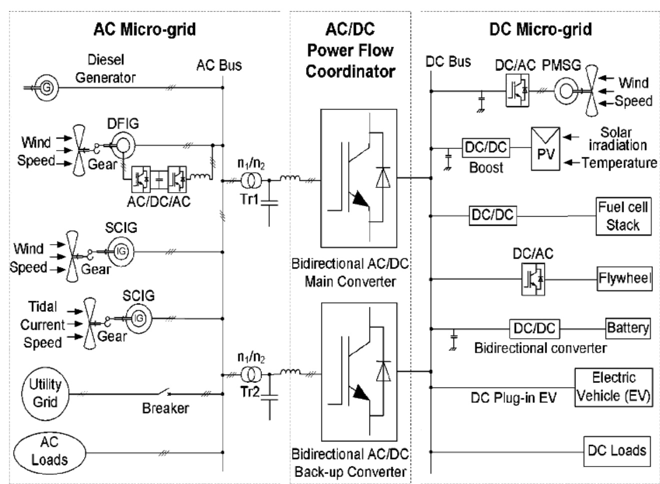



Fig. 1. A hybrid AC/DC grid system

p

A DC-DC boost converter is used to simulate the dc sources of sources. A $C_v$ is used to suppress the ripples of the PV output voltage. A 50-kW wind turbine generator (WTG) with the doubly fed induction generator (DFIG) is connected to an ac bus to simulate the ac sources. A 65 Ah battery used as energy storage is connected to the dc bus through a bidirectional dc/dc converter. The variable dc load (20 kW–40 kW) and ac load (20 kW–40 kW) are connected to the dc bus and the ac bus respectively. The rated voltages for the dc and ac buses are 400 V and 400 Vrms respectively.

*B. Operation of the grid*

Grid is capable of operating in two modes. In grid-connected mode, the converter is used to provide the stable dc bus voltage and the required reactive power along with power between the ac and dc buses. When the total power generation is less than that load. In grid, when the total power generation is than that of the load, it will inject power to the utility grid. Otherwise, the hybrid grid will receive the required power from the utility grid. In the mode, the battery converter is not very important in the system operation Voltage can be maintained stable by a battery converter or a boost converter according to the different operating conditions. The main converter is controlled in order to provide a high-quality and stable ac bus voltage. Both PV and WTG can operate on the maximum power point tracking (MPPT) mode or the off-MPPT mode based on the system operating requirements. The variable wind speed and solar irradiation are applied to the WTG and PV arrays respectively for simulating the variation of power of ac and dc sources and test the MPPT control algorithm.

*C. Modeling of PV Panel*

Fig. 3 represents the equivalent circuit of a PV panel connected with a load. The current output of the shown PV panel is modeled by the three equations below [11], [12]. All the parameters are given in Table I:

$$I_{pv} = n_p I_{ph} - n_p I_{\text{sat}} \times \left[\exp\left(\left(\frac{q}{AkT}\right)\left(\frac{V_{pv}}{n_s} + I_{pv}R_s\right)\right) - 1\right] \quad (1)$$

$$I_{ph} = (I_{sso} + k_i(T - T_r)) \cdot \frac{S}{1000} \quad (2)$$

$$I_{\text{sat}} = I_{rr}\left(\frac{T}{T_r}\right)^3 \exp\left(\left(\frac{qE_{\text{gap}}}{kA}\right) \cdot \left(\frac{1}{T_r} - \frac{1}{T}\right)\right). \quad (3)$$

*D. Battery*

In the grid connected mode, the hybrid grid operates such that the control objective of the boost converter is to regulate The back-to-back ac/dc/ac converter of the DFIG is then to The dc/dc converter of the battery can be controlled as an energy buffer using the technique proposed in [15]. The main converter is designed to incorporate complementary characteristic of wind and solar sources and operate bidirectional [16], [17].

Equations of Power flow for both ac and dc is as follows:

$$P_{pv} + P_{\text{ac}} = P_{dcL} + P_b \quad (14)$$

$$P_s = P_w - P_{acL} - P_{\text{ac}} \quad (15)$$

## III. COORDINATION CONTROL OF THE CONVERTERS

There are different types of converters in the hybrid grid. Those converters must be controlled and coordinated with the utility grid to supply a uninterrupted power to the variable dc and ac loads under variable conditions such as solar irradiation and wind speed which should operate in both isolated and connected modes. The control algorithms for all those converters are presented in this section.

*A. Grid-Connected Mode*

pv

PQ control scheme is implemented using a current controlled voltage source for the converter. When the resource conditions or the load capacities change, the dc bus voltage is to desired constant value through PI regulation. The PI controller is set by controlled.

When a sudden dc load drop causes the power surplus at the dc side, the converter is modulated. The dc load causes the power shortage and the $V_d$ drop at the dc grid. The main converter is controlled to supply the power from the ac to the dc side. Therefore, the power is transferred from the ac grid to the dc side.

## IV. SIMULATION RESULTS

The operations of the hybrid grid under the various source and load conditions are simulated to verify the proposed control algorithms.

**Analysis:** Maximum power is 2000W the MPPT voltage is 180V (Temperature=25oC Irradiance S=1KW/m2). The value of the utility grid is 110V. The nominal voltage of the battery is 90V, while its rated capacity is 90Ah. The capacitance value of super-capacitor is 12.5F in series with a 0.01Ω resistance. The sample time of the simulation has to 2e-6.

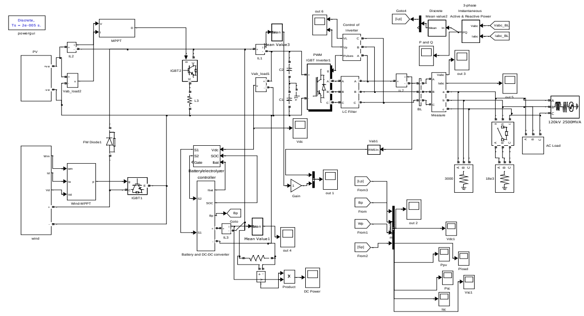


**Fig 2: Simulation Model for Transition process between Mode Ⅰ and Mode Ⅱ**

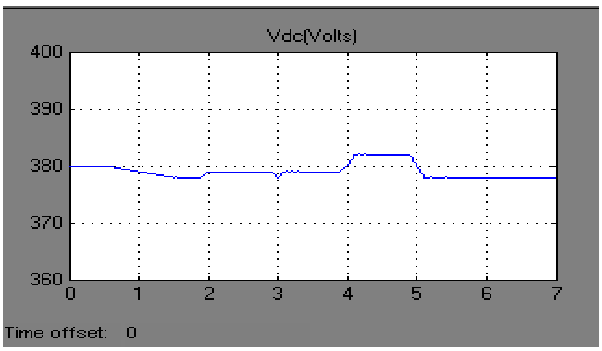



**Fig 3: DC voltage Versus Time (secs)**

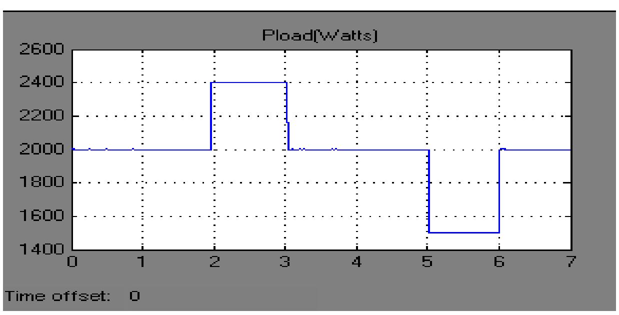



**Fig 4: Load Power Versus Time (secs)**

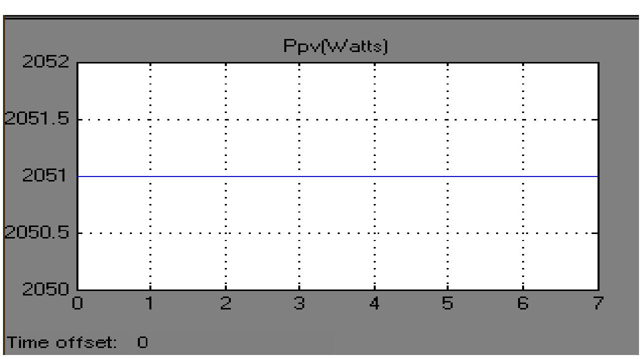



**Fig 5: Solar Power (watts) versus Time(secs)**

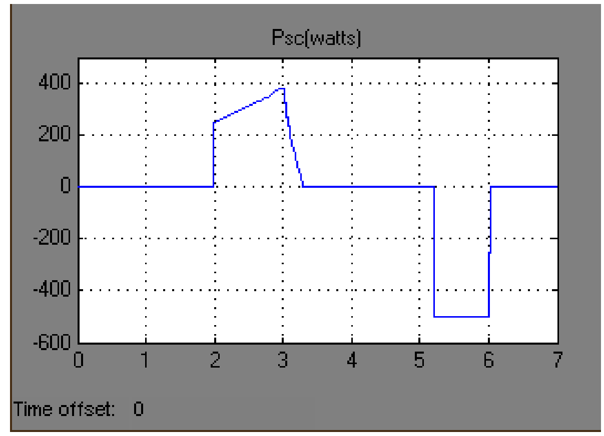



**Fig 6: Power of capacitor Verus Time (Secs)**

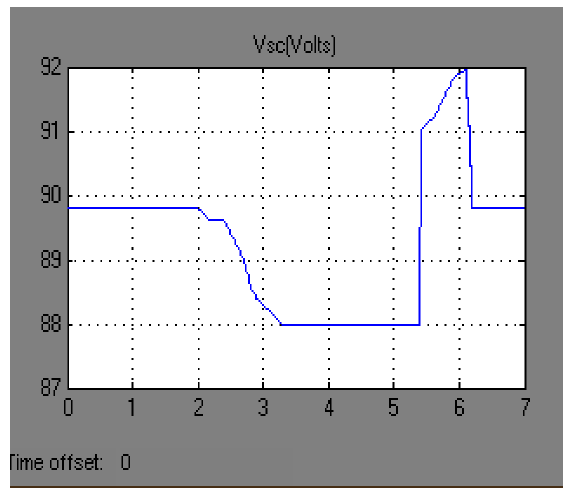
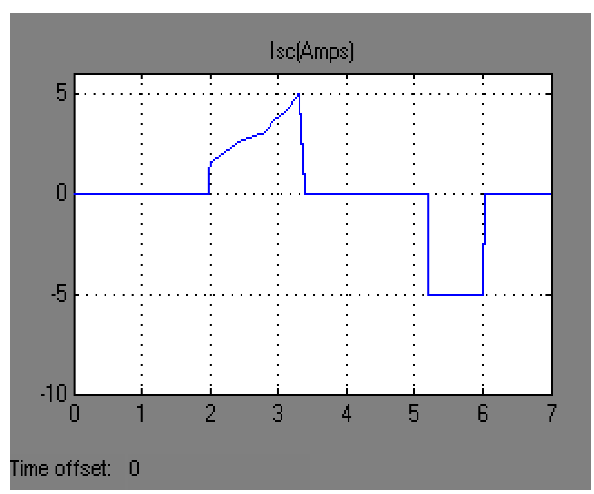
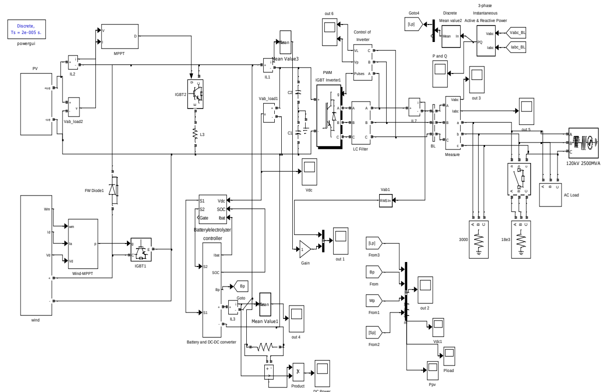



**Fig 7: Voltage of Super Capacitor Versus Time(Secs)**

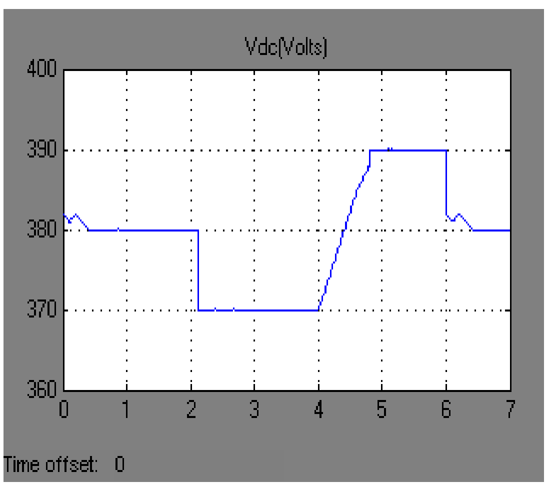


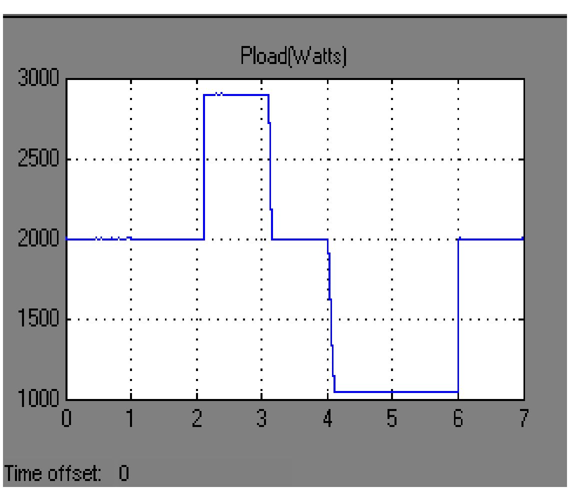

The system is working in two modes like mode I and mode II in six seconds. It includes from 1 to 4 operations. The transitions will happen in the situation that temperature and irradiance changes obviously or light load is derived. Firstly, the micro grid operates in 1-2s the value of the DC bus is near 380V in above figures, which means that the generated PV power matches the demand. Then, a 400W load in the system in 2s the DC bus drops to 377V. The bus is regulated by the bi-directional DC/DC converter of the super-capacitor in this period. In 3s, the 400W load is cut off from the system the DC bus voltage is up to 380V.

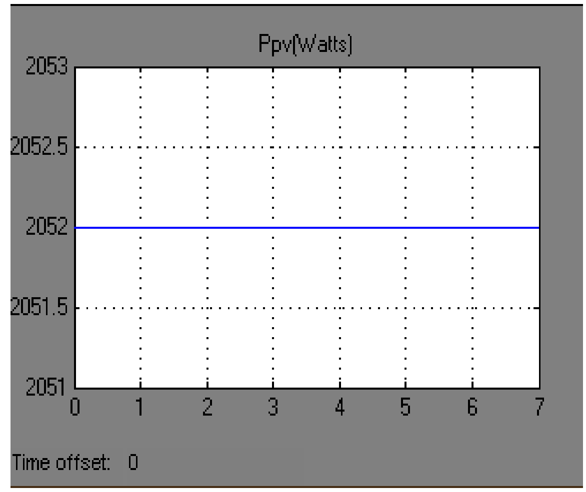
In the 5s, about 500W load is cut off from the system the DC bus voltage is up to 383V. In this period, the surplus energy is drive to super-capacitor.



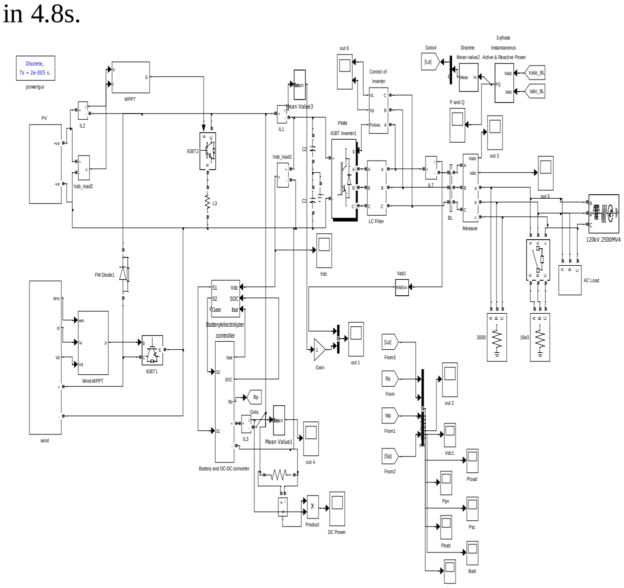
**Simulation Model for Transition process between Mode Ⅰ and Mode Ⅲ**



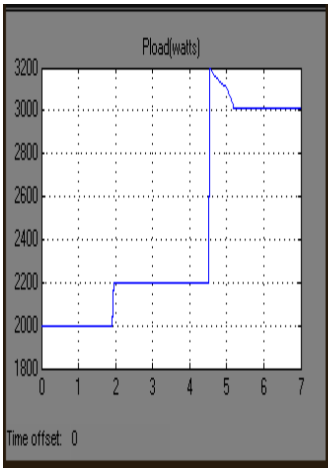



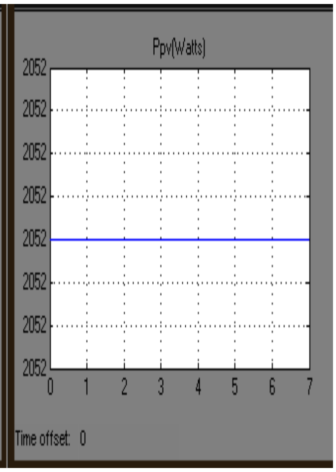



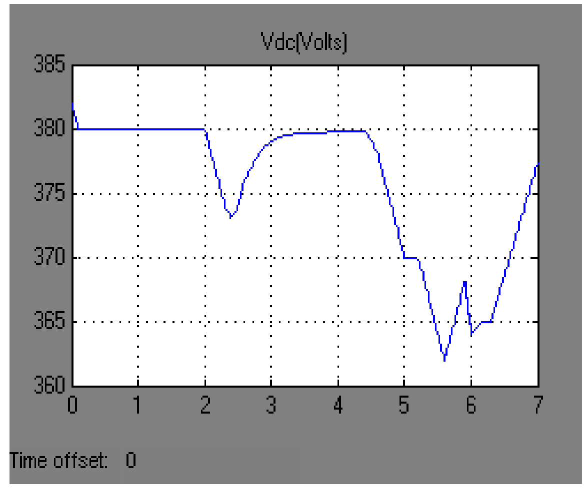

The simulation in the mutual transition from Mode I and Mode II is shown in above figure. It includes the transitions will happen in the situation that the super-capacitors' converter breaks down or the energy of super-capacitors is full or insufficient. In the initial state, the DC bus voltage is regulated 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. 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.

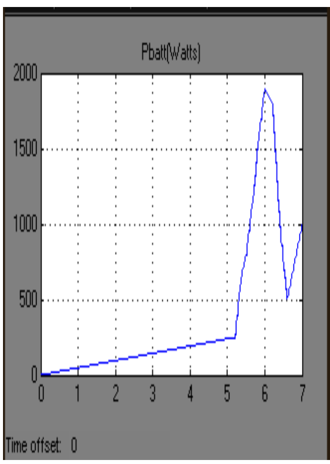


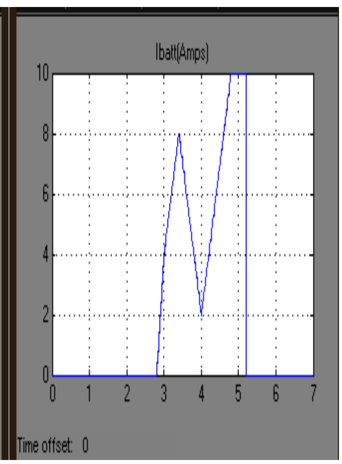
**Simulation Model for Transition process between Mode II and Mode IV**

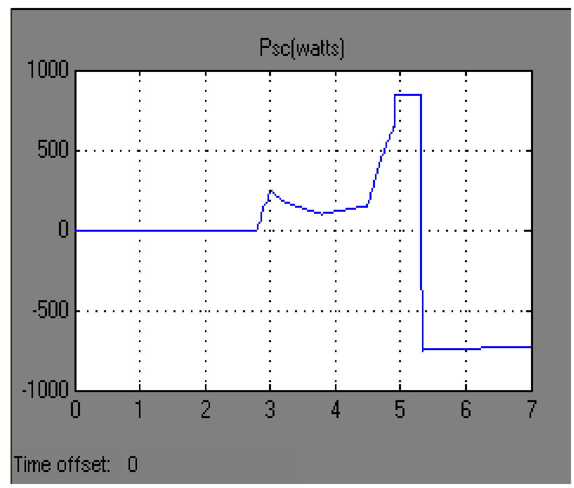


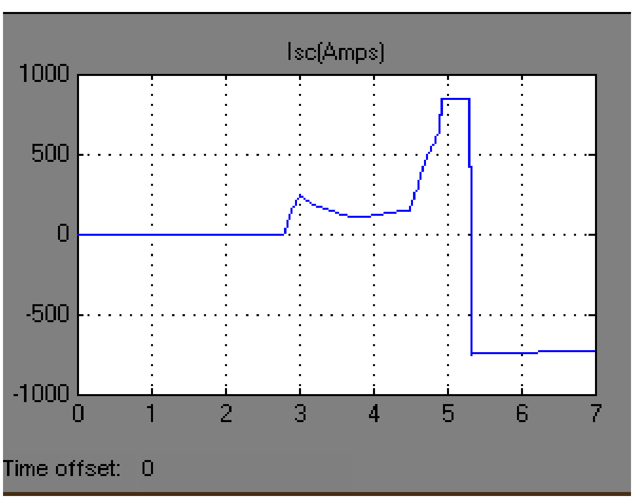




The situation that grid is power off or the grid-connected converter breaks down. Firstly, the DC bus voltage is regulated by the PV converter at 380V. In the 2s, a 300W load relates to the system, then, the bus voltage is regulated by the bi-directional DC/DC converter of the super-capacitor at 377V. In the 4.5s, an 1100W load relates to the system, and the DC bus voltage will drop to 365V which is controlled by the converter of the battery. In the 7s, a 1400W load is cut off from the system; the voltage is up to 383V.

**Equations:**

**Equation – 1 :** DC voltage and DC Current is obtained across Resistor

**Equation – 2 :** DC voltage, DC Current and DC Power is obtained across Resistor

**Equation – 3 :**To adapt to the proposed Pdc – $Vdc^2$droop strategy, the average model of the switch cycle of boost converter

**Equation – 4 :** DC voltage regulator is used in inner loop with PI Controller

**Equation – 9:** Reference frequency and voltage

**Here two DGs are used (Solar , wind sources)**

Hybrid AC/DC micro grid with multiple sub grids is proposed and a decentralized power management method is designed for this kind of hybrid micro grid.

## V. CONCLUSION

A hybrid ac/dc microgrid is proposed and briefly studied in this paper. The converter models and the coordination control schemes are proposed such that the converters maintain stable system operation even under various load and resource conditions. The coordinated control strategies are verified used the MATLAB Simulink Environment for the considered operating conditions.

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