Chapter 68
Hybrid Power System Based Load Sharing and Maintaining the DC Voltage in UPS System

R. Jaiganesh and S. Sharmila

Abstract Power interruption is the major problem in many sectors, to overcome this issue Uninterruptible Power Supply is used. During emergency situation it is a reliable source. During backup time batteries are more efficient when supplied to low load. In case of connecting to heavy load, Pulsated power is extracted. This greatly reduces the lifetime of the battery and alters the battery cycle due to frequent charging and discharging. To overcome this issue ultra capacitors are used. The proposed method has a variable speed wind turbine using a permanent magnet synchronous generator (PMSG), integrated with the grid system. This combination will be reducing the wind turbine fluctuation and voltage variation. The design is simulated by using MATLAB Simulink. Results show that this method efficiently eliminates the battery stress and improve the power quality.

Keywords Permanent magnet synchronous generator (PMSG) · Load sharing · Uninterruptible power supply · Grid system

68.1 Introduction

In recent years, power variations and frequent power out have been the main reason behind developing Uninterruptible Power Supply (UPS) system [1, 2]. In many sectors, high reliability power supply is required for heavy loads. Uninterruptible Power Supplies (UPS) improve the power quality and guarantee the reliability of backup power [3, 4].

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However, there are disadvantages associated with batteries such as limited charge/discharge cycles. Moreover, extracting pulsed power instead of average power from the battery can alter the cycle and decrease the lifespan.

In this paper, ultracapacitor (UC) is used to overcome the disadvantage. Ultracapacitors represent one of the newest innovations in the field of electrical energy storage and will find their place in many applications where energy storage can help to the smoothing of strong and short time power interruption of a distribution network.

An ultracapacitor [5] is a double-layer electrochemical capacitor which can store thousand times more energy than an ordinary capacitor. It has both the characteristics of batteries and conventional capacitors and has more energy density than a battery. Moreover, they have almost negligible losses and long lifespan. They possess a large number of charge and discharge cycles compared to few thousand cycles for lead-acid batteries and can supply much higher currents than batteries.

Batteries are mostly efficient when used to supply low power levels. Ultracapacitor leakage rate and series resistance are quite small. The power sharing between ultracapacitors, and batteries is a promising solution for improving system performance due to the dynamic behavior of the SCs and their long life. Renewable Energy Systems (RES) are also an independent power producer.

Bi-directional converters are used in connecting energy storage systems like ultracapacitors and battery banks to wind power systems. Permanent-magnet synchronous generator is coupled with the wind turbine, with this interfacing RES based output is controlled, load shared and maintained in the UPS system. An applications of ultracapacitor and battery tie is used in pure battery powered electric vehicle, hybrid electric vehicle [6] and in escalators. Simulation results are provided for maintaining the load and sharing the DC voltage to UPS system and reducing the stress in battery to show the effectiveness of the proposed system.

68.2 Proposed Topology

The proposed topology is shown in Fig. 68.1. The rectifier is connected to the wind generator, it converts AC to DC and its output is variable. The load is connected to the grid, the battery and supercapacitor tie is connected to bi-directional converter and it is controlled by PI controller. Normally when there is a demand power and wind generator doesn't meet the demand, the battery acts as a backup. But when heavy load acts, the battery backup power is greatly reduced and it's under heavy stress. To overcome this issue UC is used, it reduces the high drawing power from the battery at start by instantly giving the demanded power. The UC is charged by battery when UC gets discharged.

In the proposed method, permanent magnet synchronous generator is coupled with wind generator, which is the renewable energy source. The output is filtered by

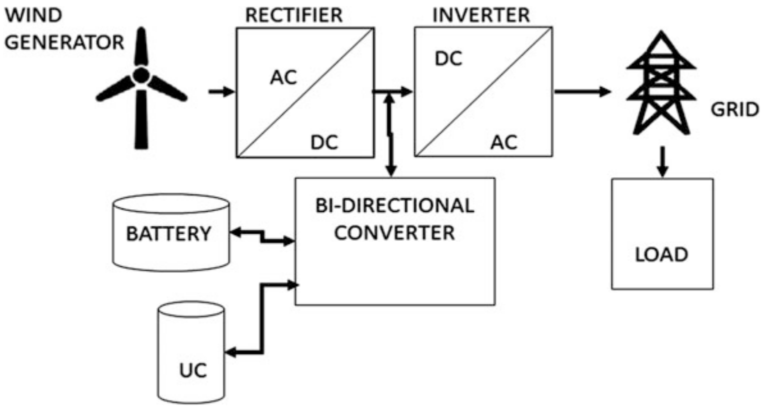

Fig. 68.1 Topology of the UPS system

RLC filter, they are rectified and DC voltage is given to the bidirectional converter. The battery and ultracapacitor is integrated with bi-directional converter and IGBT inverter. Overall it is controlled by the current control system and DC voltage to UPS system is maintained, load sharing between heavy load and low load is controlled and reduces the stress in battery. The switching between heavy load and low load is controlled using circuit breaker. When the demand is high and heavy load acts, the ultracapacitor produces the pulsated power for a short period of time, then the battery gives the backup power until the interruption is rectified. Then supercapacitor gets charged from the battery. The effectiveness of the proposed system is clearly analyzed.

68.3 System Description

68.3.1 Permanent Magnet Synchronous Generator

Permanent magnet synchronous generator (PMSG) belongs to Horizontal-axis wind turbines (HAWT) and they are the major commercial energy source [7]. Excitation to the generator is provided by excitation field instead of coil. The mechanical output energy of turbine like steam, hydro, gas and wind energy are converted into electrical power using this generator for the grid. The induced voltage, frequency (f) in the rotor and armature conductors, is directly proportional to the number of permanent magnet stator poles (p), so they are called synchronous generators. The constant of proportionality is $\frac{P}{120}$ and P is magnetic poles and RPM is the revolutions per minute of the rotor (or angular speed) $f = \frac{RPM}{120} P$.

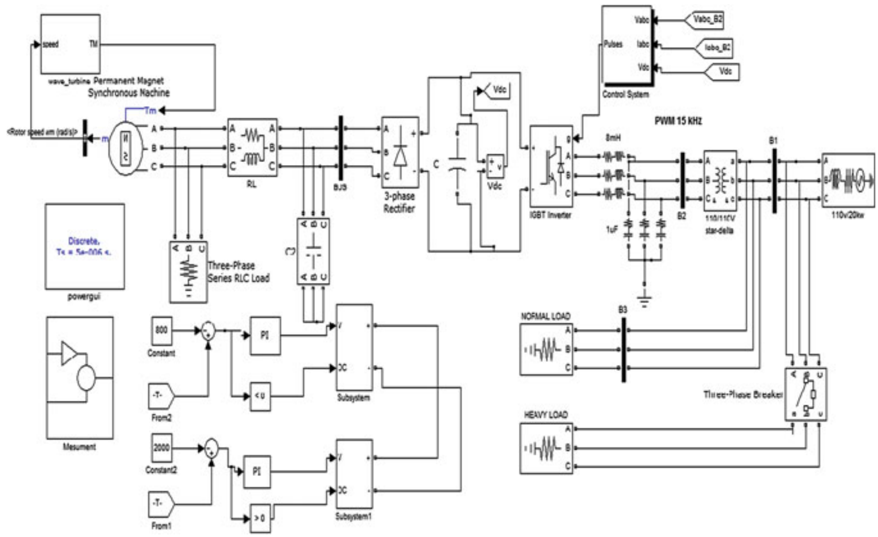

Fig. 68.2 MATLAB simulation for RES based control of load sharing and maintaining the dc voltage to UPS system

68.3.2 Uninterruptible Power Supply

The integrated ultracapacitor and battery is the Uninterruptible Power Supply used in the proposed system shown in Fig. 68.2.

The ultracapacitor produces the necessary pulsated power when heavy load acts, this increases the lifetime of the battery and its stress are greatly reduced. The ultracapacitor works purely on physical phenomena rather than through a chemical reaction and a highly reversible process, which result in high power life cycle, shelf life and maintenance issues are low [6]. Modeling of ultracapacitor and battery is same while the control system slightly varies (Figs. 68.3 and 68.4).

68.4 Performance Analysis of Proposed System

The proposed system is designed with MATLAB, Simulink environment. Efficient control of the proposed circuit is analyzed by using a circuit breaker for load controlling when heavy load acts the ultracapacitor gives the necessary pulsated power to the load. The simulation parameters are showed in Table 68.1.

The output generated by Permanent magnet synchronous generator is shown in Fig. 68.5. Individual analysis of the battery and supercapacitor is compared in Figs. 68.6 and 68.7.

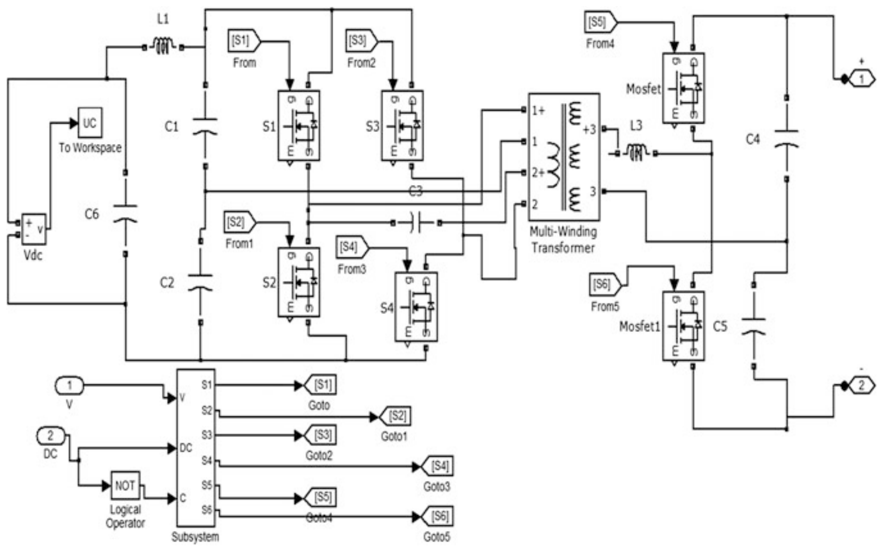

Fig. 68.3 Modelling block of ultracapacitor with bi-directional converter

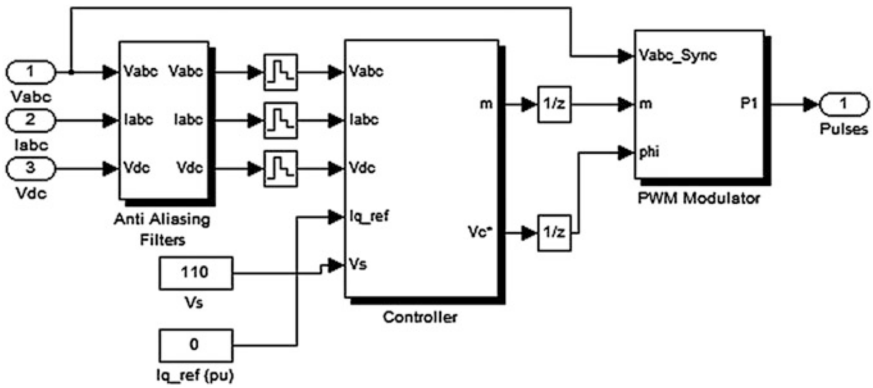

Fig. 68.4 Current control system block

The fall in signal of Fig. 68.6 shows there is demand for source power and the battery gives necessary power for the grid. The fall in signal of Fig. 68.7 shows there is demand for source power and the ultracapacitor gives necessary power for the grid, while the peak shows it gets charged from battery (Fig. 68.8).

Table 68.1 Simulation parameters

S. No	Parameters	Ratings
1	Fundamental frequency	50 Hz
2	Capacitance of super capacitor	10 F
3	Capacitor voltage	12 V
4	C1–C5	0.0495 μf
5	Battery voltage	24v
6	Rated capacity	20 Ah
7	Initial state of charge	60 V
8	Active power of normal load	1,000 W
9	Active power of heavy load	20,000 W
10	Transition time of heavy load	0.8 and 1.4 s

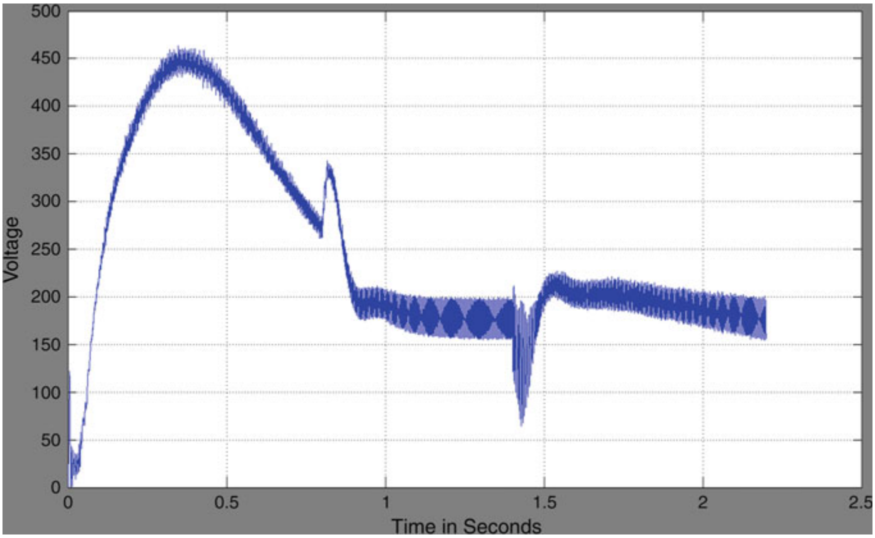

Fig. 68.5 Wind generator output

In Fig. 68.9, the peak of source power shows the demand and in inverter power the fall in peak shows the power demand is given by Uninterruptible Power Supply.

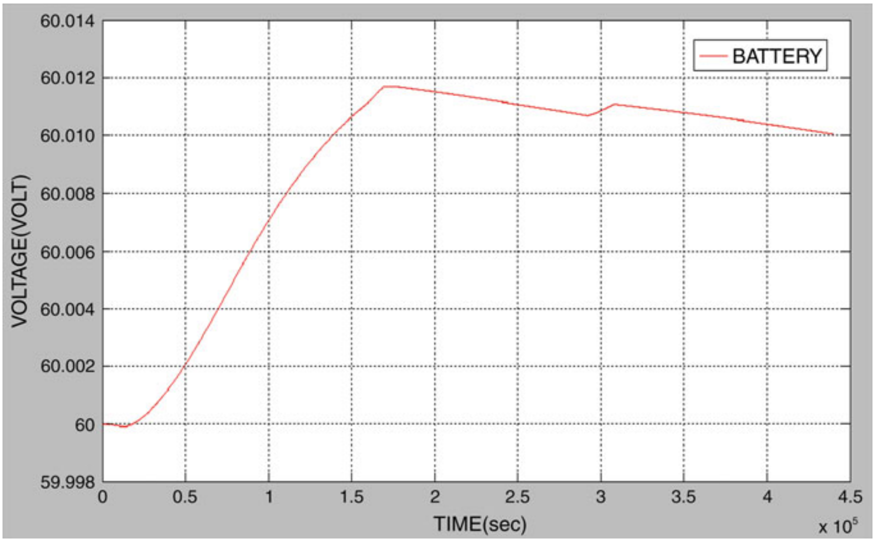

Fig. 68.6 Battery output

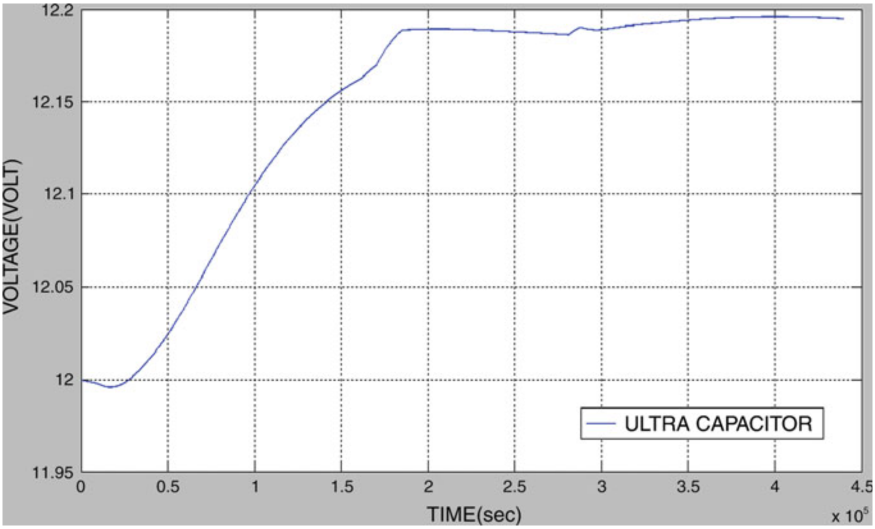

Fig. 68.7 Ultracapacitor output

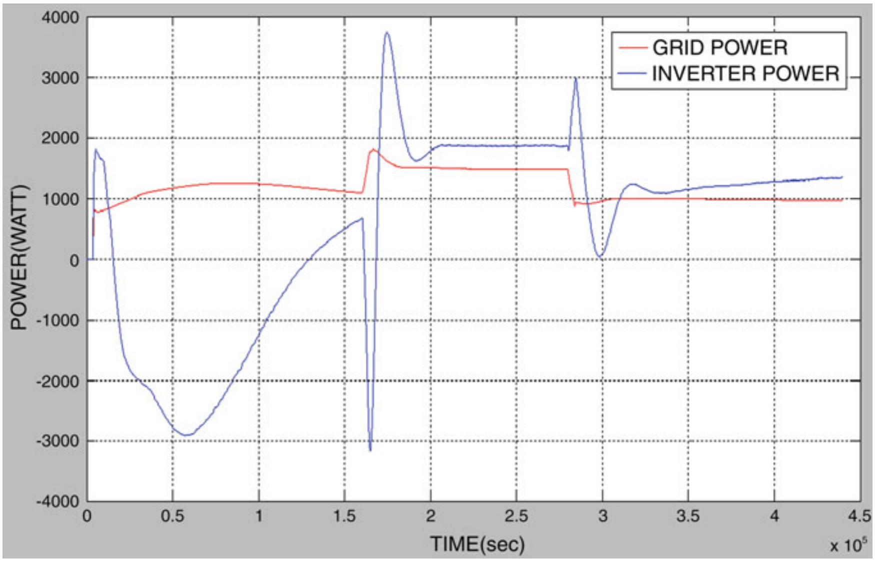

Fig. 68.8 Comparison between ultracapacitor and battery

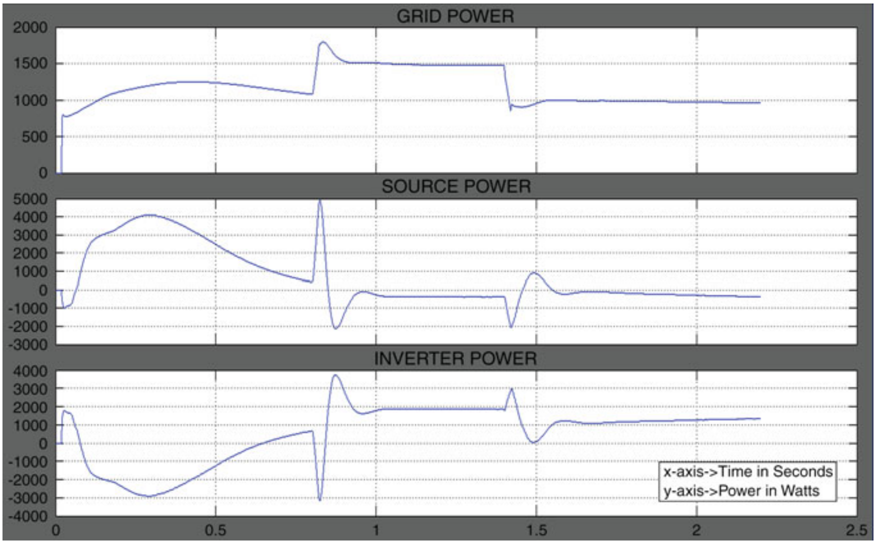

Fig. 68.9 Source power versus inverter power

68.5 Conclusion

The design of battery—supercapacitor combination has been presented. A control concept of the hybrid system is developed using normal load and heavy load. The integration of the batteries and the supercapacitor in the storage system and integration of wind generation in the grid system is explained. The reduction in battery stress has been discussed. The supercapacitor meets the high power demand and reduces the battery stress during backup time. The supercapacitor and the battery are simulated using MATLAB/Simulink system. Simulation technique shows that this technique reduces the battery stress and increases its lifetime.

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