Energy Management Using Battery And Ultra Capacitor Of Wind Turbine Generating System

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***Abstract*— Wind is the world's fastest growing energy source today. During normal operation, the wind generating systems have large fluctuations due to sudden wind speed changes. The Possible solution for this problem is to use hybrid energy storage management. Thus the performance of this system can be improved by using battery as well as super capacitor which is integrated with wind turbine generators. It provides an opportunity for better voltage and frequency response. During wind and load demand variations the use of super capacitors helps to prevent the applications from over voltages during short circuit condition and also it avoids the battery operation in high rate of depth discharge regions. Thus this system meets the need by absorbing or delivering the required power to the load. The performance and the analysis are done in a user friendly MATLAB/Simulink environment and Hardware results are compared.**

Keywords—Ultracapacitor, Battery, Energy Management, DC link capacitor.

I. INTRODUCTION

Wind power is the fast growing renewable energy source because of its improving technologies and economic competitiveness. Air acts as a prime mover to the generator of Wind turbine. Mechanical energy is converted into electrical energy by Induction generator. Random variations of wind speed leads to fluctuating torque for wind turbine generator resulting in voltage and frequency deviation. To resolve this problem, we are going for Energy Management System. A single type of storage doesn't satisfy the requirements of Remote Area Power Supply. Thus, it requires two or more energy storage to perform in a hybrid manner. Nowadays there are different types of storage technologies, but unfortunately all of them cannot satisfy the requirements when operating as an integrated unit. The selection of an energy storage system requires good understanding of its operational characteristics. The integration of Battery and Super capacitor ensures the perfect operation of the system.

Battery storage is used to mitigate low frequency fluctuation and the super capacitor is to mitigate high frequency fluctuation.

The main objective of introducing this system is to maintain the constant DC voltage to the inverter circuit connected to the load and to improve the efficiency of the entire Remote Area Power Supply system.

II. PROPOSED SYSTEM

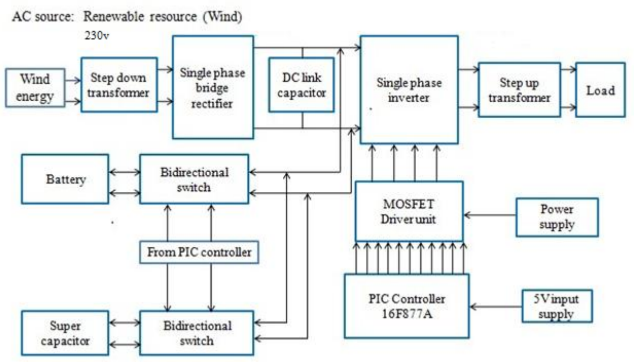

Fig1. Block diagram of proposed system

Integration of an Energy Storage System is the one of the main objective of this paper. Input voltage is obtained from wind turbine generating system. The voltage is stepped down to 18V AC supply using step down transformer. Time varying output voltage of 18V AC supply is given as input for the single phase diode bridge rectifier unit. A pulsating DC voltage is obtained as an output from the rectifier unit, which is stabilized by DC link capacitor.

The stabilized DC voltage is given as an input for the single phase PWM inverter unit. The firing pulse for the switches is provided by the micro controller. The output voltage of the inverter unit is stepped up to 230V for the resistive load requirement.

The hybrid storage system, battery and super capacitor start to charge when the input is provided. When the supply voltage is less than the required output voltage, the hybrid storage systems starts to discharge. Battery and super capacitor provides high energy and power requirement. The battery has linear charging and discharging properties and super capacitor has sudden charging and discharging properties.

The integration of a super capacitor with the battery ensures a healthy operation of the battery, by preventing it to operate in a high DOD region and to operate at low frequency power. In this project, an entire RAPS system is modeled to evaluate the complete system performance as well as the

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performance of the individual components in relation to the voltage and power sharing among the system-components.

III. ULTRACAPACITOR WORKING PRINCIPLE

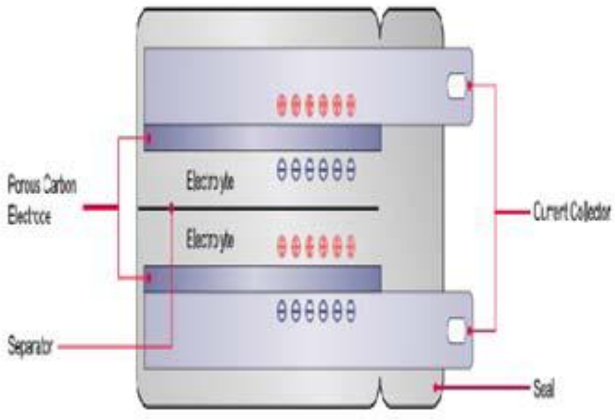

Fig.2 shows the construction of ultracapacitor [1].

Ultra capacitor is a high power density electrical energy storage device which could not be achieved in traditional capacitors. Ultra capacitor consists of two electrodes immersed in an electrolyte and separator prevents the charge from moving between two electrodes having different polarity. Ultra capacitor stores energy relied on electrostatic charges on opposite electrode surface of the electric double layer, which is formed between each of the electrodes and the electrolyte. Randomly distributed ions in electrolyte move toward the electrode surface of opposite polarity under electric field when charged. It is purely physical phenomena rather than through a chemical reaction and highly reversible process, which result in high power, high cycle life, long shelf life, and maintenance-free product [2, 3, 4].

Ultra capacitor is unique energy storage device to offer high power and high energy compared with conventional electrolytic capacitor and battery. The high content of energy stored by Ultra capacitor in comparison to conventional electrolytic capacitor is by activated carbon electrode material having the extremely high surface area and the short distance of charge separation created by the opposite charges in the interface between electrode and electrolyte [37].

IV. DC LINK CAPACITOR

DC-Link capacitors are used in the DC voltage intermediate circuit of wind power Units, for voltage stabilization. The DC current intermediate circuit capacitor Of a wind turbine requires a capacitance of about 3300 mF to 4700 mF and a high Rated voltage of 600 V to 1000 V. Due to the self-healing effect after an electrical Breakdown of the dielectric, their dry construction and their low sensitivity against High temperature variations film capacitors used in wind turbines offer a considerably higher reliability and a significantly longer life time than electrolytic capacitors.

V. MODELING OF ULTRACAPACITOR BANK

The parameters used in the mathematical modeling of the ultracapacitor (UC) bank are as follows [5]:

C	Capacitance [F]
C_{UC_total}	Total UC system capacitance [F]
EPR	Equivalent parallel resistance [Ω]
ESR,R	Equivalent series internal resistance [Ω]
E_{UC}	The amount of energy released or captured by the UC bank
n_s	Number of capacitors connected in series
n_p	Number of series string in parallel
R_{UC_total}	Total UC system resistance [F]
V_i	Initial voltage before discharging starts [V]
V_f	Final voltage after discharging ends [V]

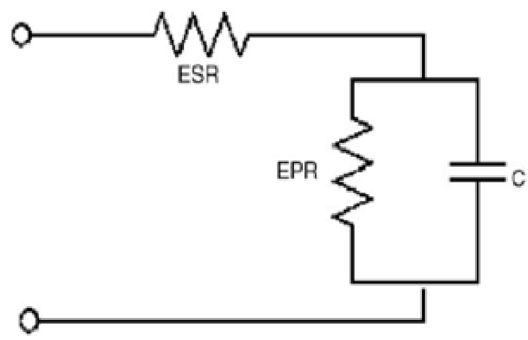

Fig3. Equivalent circuit of ultracapacitor[6]

Fig.2 shows the classical equivalent circuit of the ultracapacitor UC unit. The circuit consists of a capacitance (C), an equivalent series resistance (ESR, R) representing the charging and discharging resistance, and an equivalent parallel resistance (EPR) representing the self-discharging losses [6]. The amount of energy drawn from the UC bank is directly proportional to the capacitance and the change in the terminal voltage, given by equation 1.

$$E_{UC} = \frac{1}{2}C\left(V_i^2 - V_f^2\right) \qquad 1$$

Ultra capacitors can be defined as a energy storage device that stores energy electro statically by polarizing an electrolytic solution. Unlike batteries no chemical reaction takes place when energy is being stored or discharged and so ultra capacitors can go through hundreds of thousands of charging cycles with no degradation.

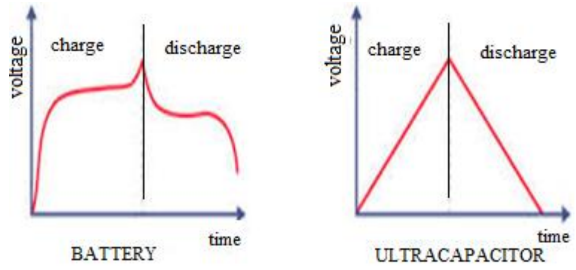

Fig4. Charging and discharging characteristics of Super capacitor and Battery

VI. MATLAB SIMULATION

The MATLAB circuit shown in Figure 4.1explains the interconnection of the components in the MATLAB application. The simulation is performed for an input voltage of 230V.

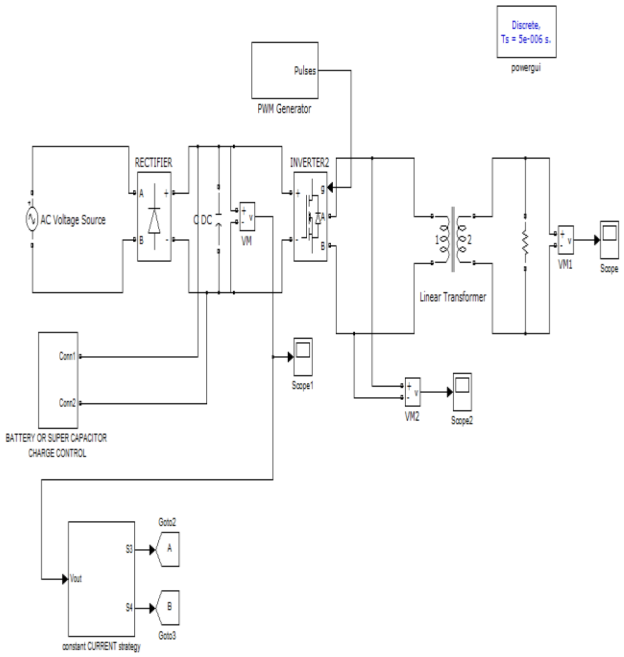

Fig 5. Simulation circuit of the modeled RAPS system

VII. SIMULATION RESULTS

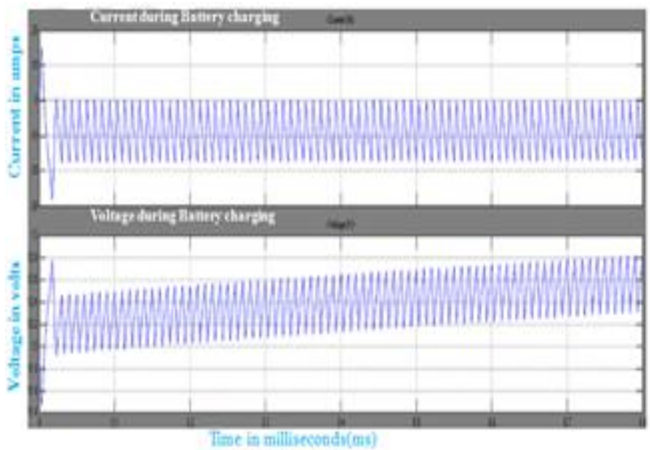

Fig 6. Simulated result of battery charging

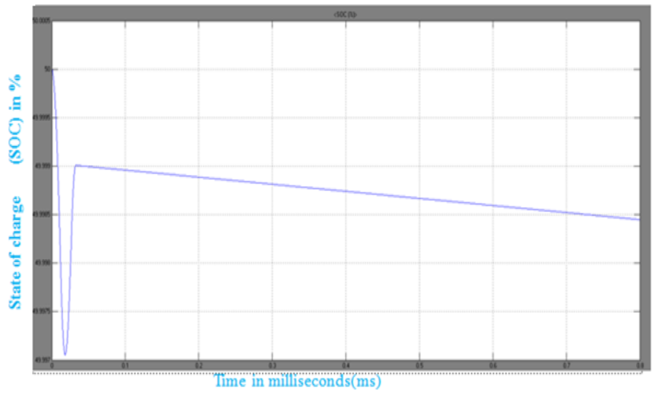

Fig 7. Simulated result SOC of ultracapacitor

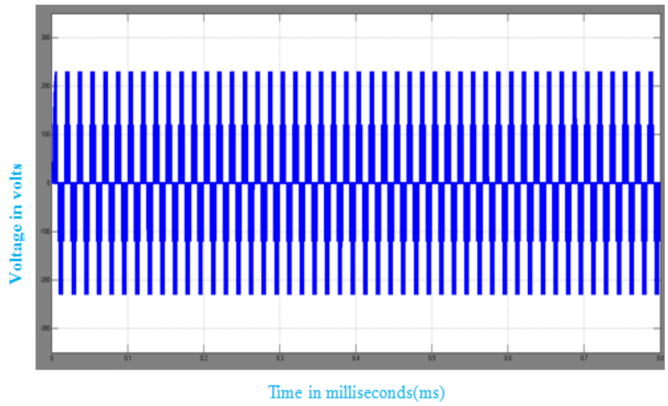

Fig 8. Simulated output voltage

VIII. HARDWARE SETUP

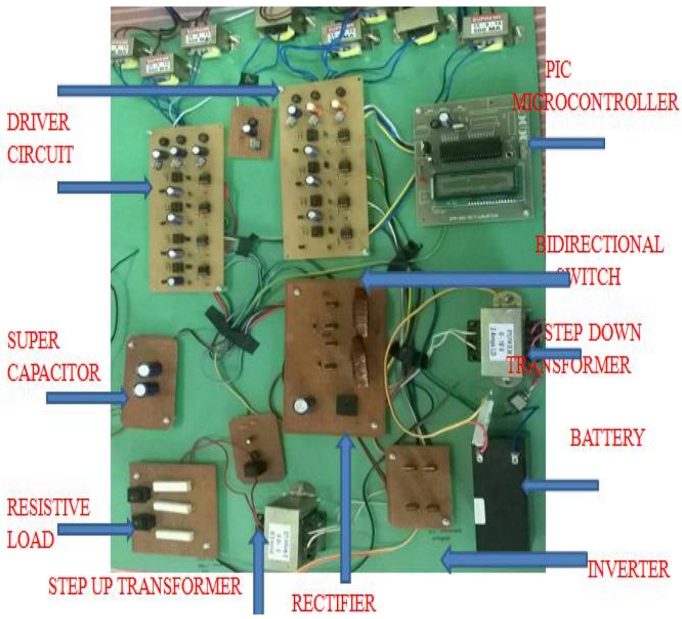

Fig 9. Hardware setup

IX. RESULTS

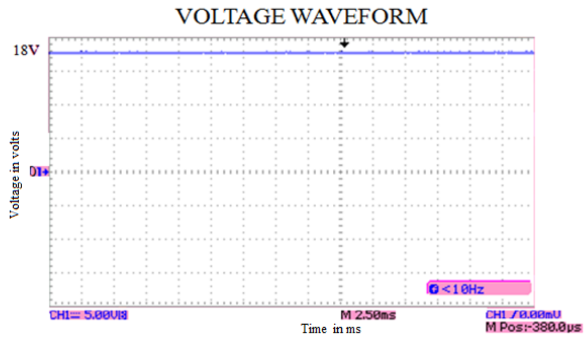

Fig 10. Charging voltage of Super capacitor

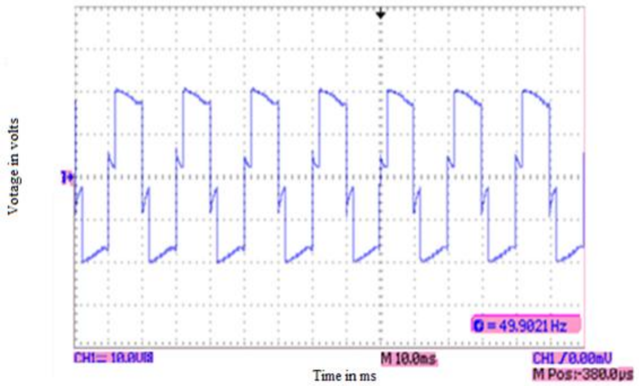

Fig 11. *Output voltage*

X. CONCLUSION

In this project, the integration of an energy storage system into wind based power system provides an opportunity for battery storage with the input voltage. Battery and super capacitor provide high energy and power requirements when there is a fluctuation in the input supply.

Therefore, the integration of a super capacitor with the battery has ensured healthy operation of the battery by preventing it to operate in high Depth of Discharge regions and to operate at low power regions.

A model of the Remote Area Power Supply system is evaluated using MATLAB simulation. The complete system performance as well as the performance of the individual components in relation to the voltage, power sharing among the system-components is evaluated in the hardware implementation.

XI. References

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