Isolated Operation of PMSG Based Wind Power Generating System with Hybrid Energy Storage and Fuzzy Controlled Converters

[1]. GV Apparao, [2].M.Rama Prasad Reddy

[1]. PG Scholar, Dept of EEE, Sri Vasavi Engineering College, Tadepalli gudem, A.P

[2]. Associate Professor, Dept of EEE, Sri Vasavi Engineering College, Tadepalli gudem, A.P

Abstract: Over the past 25 years the electrical power generation through renewable energy resources especially with wind energy is increasing due to the limited conventional resources and increased environmental pollution. In India, about 13.32% of power is contributed by wind energy and with the technological advances there is a good scope of increasing the power contributed by this wind energy. But in case of a Remote Area Power Supply (RAPS) system it is very difficult to operate a wind turbine generating system due to the fluctuating wind and variable load conditions.A Proposed RAPS system consisting of Permanent Magnet Synchronous Generator (PMSG), Fuzzy controlled Rectifier-Inverter arrangement, Hybrid Energy Storage (HES) system, Main load and Dump load is considered in this paper. HES system consists of a Battery storage and a Super capacitor, both are connected to the DC bus of the RAPS system. An Energy Management Algorithm (EMA) is considered for the HES system to improve the performance of battery storage. A Synchronous condenser is also considered for Reactive power support. A coordinated control approach is developed to manage both Active and Reactive power flows, and individual controllers for each RAPS component are also developedfor better performance.This Proposed system is capable of achieving the following objectives: 1) Robust voltage and frequency regulation, b) Effective management of HES system, 3) reactive power support. This entire system is implemented in MATLAB simulink software.

Key Words: Remote Area Power Supply system, Hybrid Energy Storage system, Battery storage, Super Capacitor, Synchronous condenser & Fuzzy logic controllers.

I. INTRODUCTION

Wind energy is one of the best renewable source for Power generation in Remote areas. This energy is very clean and pollution free and very much suited for Distributed generation in remote places for which it is difficult to transmit the power through the transmission system. In this Remote Area Power Supply systemsthe operation of wind based power systems becomes more challenging, particularly when they are operate in standalone mode,due to the nature of fluctuating wind and variable load profiles. The random variation of wind speed leads to fluctuating torque of the wind turbine generator resulting in voltage and frequency excursions in the Remote Area Power Supply (RAPS) system. Integration of an Energy Storage System (ESS) into a wind based power system provides an opportunity for better voltage and frequency response, specially during wind and load demand variations. The application of energy storage to a standalone power system can be used to fulfill one or more of the following requirements: (1) to improve the efficiency of the entire RAPS system, (2) to reduce the primary fuel (e.g., diesel)usage by energy conversion, and (3) to provide better security of energy supply. An ideal ESS should be able to provide high energy storage capability to handle some worst situations such as wind gust or sudden load variations which may exist for a few seconds or even longer. However a single storage device doesn'tsatisfy the power and energy requirements of RAPS system, so we are going to Hybrid energy storage(HES) system by integrating two or more storage devices. Integration two energy storage devices for HES system requires good understanding of its operational characteristics. In general, battery and supercapacitor are seen to provide high energy and power requirements respectively. Therefore, the integration of a supercapacitor ensures a healthy operation of the battery storage by preventing it to operate in high Depth of Discharge (DOD) regions and to operate at low frequency power regions. And the super capacitor operates at high frequency power regions.

II. PROPOSED RAPS SYSTEM COMPONENTS AND THEIR CONTROL

The schematic of the proposed RAPS system is shown in Fig. 1

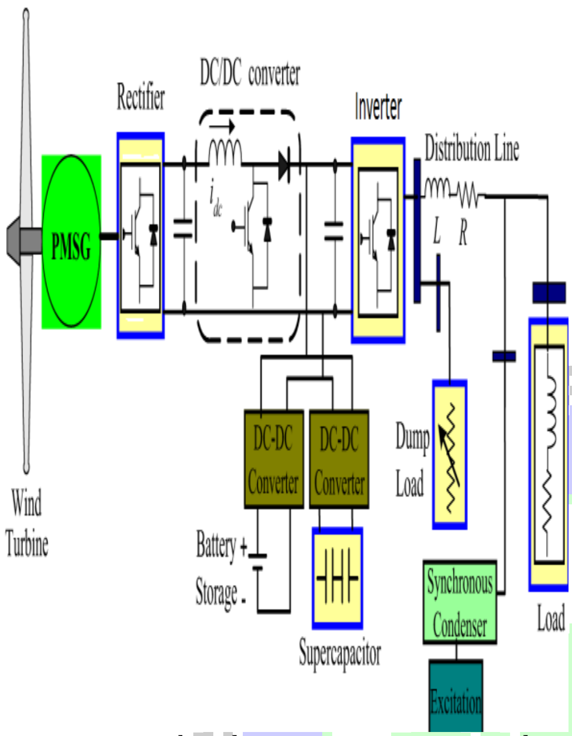

Fig. 1. PMSG based Remote Area Power Supply system with a Hybrid Energy storage

The proposed model consist of wind turbine, pitch angle control, permanent magnet synchronous generator (PMSG), Fuzzy controlled Rectifier-Inverter arrangement, DC-DC converters, Hybrid Energy Storage system, Mains load, Dump load & Synchronous condenser.

A. Wind Turbine: A wind turbine converts the kinetic energy of the wind into electrical energy. Wind turbines come in different sizes and types, depending on power generating capacity and the rotor design deployed. Small wind turbines with output capacities below 10 kW are used primarily for residences, telecommunication dishes, and irrigation water pumping applications.Utility-scale wind turbines have high power ratingsranging from 100 kW to 5 MW sufficient to provide power supply given to 10 to 500 homes. Present wind farms with large capacity wind turbine installations have sprung up in rural areas and offshore regions and are capable of generating electricity in excess of 500 MW for utility companies, they present much lower generating costs and zero maintenance and operating costs, thereby realizing significant reductions in electricity generation costs, greenhouse gas emissions, and atmospheric pollution.

B. PMSG- Permanent Magnet Synchronous Generator:

The general types of generators are induction generator (IG), synchronous generator (SG), doubly fed induction generator (DFIG), squirrel-cage rotorinduction generator (SCIG), wound rotor induction generator (WRIG), and permanent magnet synchronous generator (PMSG). The PMSG is used for small power generation and DFIG is used for large power generation. Hence PMSG is used for standalone systems and DFIG is used for grid connected WECS system. Mostly PMSG based systems are usedwithout the gear box.

Thus cost and weight of the system isreduced. PMSG offersmany advantages but not limited to self excitation capabilitywhich allows operation at a high power factor and improved efficiency, gear-less transmission, high reliability, good control performance, Maximum Power Point Tracking (MPPT) capability, low noise emissions, etc.

C. Fuzzy controlled converters: The control objective of the rectifier-inverter arrangement is to regulate the magnitude and frequency of the load side voltage. In this regard, vector control has been employed to develop the control associated with the inverter. The voltage balance across the filter of the Inverter is expressed using the following equation(1).

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \mathrm{R}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + L\frac{d}{dt}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} v_{a1} \\ v_{b1} \\ v_{c1} \end{bmatrix} \qquad (1)$$

where , v_{a1} , $v_{b1,} v_{c1}$ – voltages at the inverter output voltages at load side, i_a, i_b, i_c- current through the filter circuit,and L & R - filter inductance and resistance respectively. Analytical techniques may fail to give a precise solution in a controlling process. Where as an expert or a skilled human operator, without the knowledge of their underlying dynamics of a system can control a system more successfully. So it is worth simulating the controlling strategy based upon intuition and experience can be considered a heuristic decision or rule of thumb decision. This can be possible through the Fuzzy logic controller. In Fuzzy logic system the linguistic variables are used instead of numerical variables. The process of converting a numerical variable (real number or crisp variables) in to a linguistic variable (fuzzy number or fuzzy variable) is called fuzzification. Five linguistic variables are used for the input variables that are negative big (NB), negative small (NS), zero (Z), positive small (PS) and positive big (PB).

Error

Change in Error	NB	NS	Z	PS	PB
NB	NB	NB	NB	NS	Z
NS	NB	NB	NS	Z	PS
Z	NB	NS	Z	PS	PB
PS	NS	Z	PS	PB	PB
PB	Z	PS	PB	PB	PB

Table 1: Fuzzy Rule

The rule table for the designed fuzzy controller is given in the Table 1. The element in the first row and first column means that if error is NB, and change in error is NB then output is NB.

D. DC/DC Converter: The DC link voltage of the RAPS system is regulated using a DC/DC converter. The rectified voltage output, $(V_{dc})_{unreg}$ presents at the full converter diode bridge is a function of the generator speed, ω_g. The outer control loop measures the DC link voltage, V_{dc} which is compared with the reference DC link voltage, $(V_{dc})_{ref}$ and the error is compensated using a fuzzy logic controller to generate the reference current through the inductor of the boost converter. The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. In a boost converter, the output voltage is always higher than the input voltage.When the switch is turned-ON, the current flows through the inductor and energy is stored in it. When the switch is turned-OFF, the stored energy in the inductor tends to collapse and its polarity changes such that it adds to the input voltage. Thus, the voltage across the inductor and the input voltage are in series and together charge the output capacitor to a voltage higher than the input voltage.

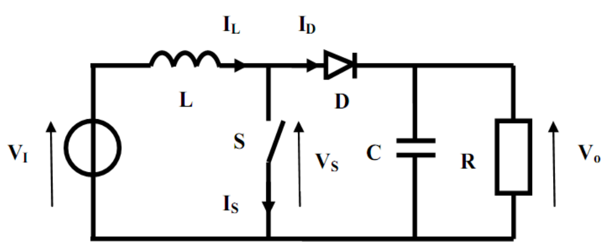

Fig 2. Circuit Diagram of a Boost Converter

E. Battery Storage and Super Capacitor:

Nickel-metal hydride battery model is employed in this paper. The capacity of the battery storage system reduces dramatically under high DODs. Therefore, in real life situations, it is vital to regulate the State Of Charge(SOC) of the battery within the safe limits $SOC_{min} \leq SOC \leq SOC_{max}$. The battery storage capacity is estimated using (eqn2) which is able to provide a fraction (or ϒ) of rated current of the load demand.

$$\Upsilon * I_{rated} * (t/60) = (\text{Ah Rating}) * k \qquad (2)$$

where

ϒ — fraction of the rated current of the load demand,

I_{rated} — rated current of the load demand,

t — time duration that battery provides power into thesystem and

k — a fraction that defines the average discharge/charge current of the battery.

It is assumed that battery storage is used to supply 40 percent of the rated load current (i.e., ϒ =0.45) for the time-duration of 30 min (i.e., t =30 sec). To demonstrate how the size of the battery can be estimated, assume that the rated power of PMSG,(P_{PMSG})rated is 100 kW and the rated AC voltage, V_{rated} is 400 V. The rated current of the PMSG can be calculated as follows:

$$I_{rated} = \frac{(PPMSG\ )rated}{\sqrt{3}Vrated} \approx 144.51 \text{ A.} \qquad (3)$$

For this condition, the Amphere-hour (Ah) rating of the battery storage system can be estimated using (eqn 4) as below:

$$\text{Ah rating} = \frac{144.51*30*0.4}{0.4*60} \approx 72 \text{ Ah.} \qquad (4)$$

The size of the super capacitor can be estimated using (eqn 5)–(eqn 7).

$$E_{sc} = \frac{1}{2} C_{sup} V_{sc}^2 \qquad (5)$$

$$E\ sc = \frac{1}{2} C_{sup} (V_{sc})_{max}^2 - \frac{1}{2} C_{sup} (V_{sc})_{min}^2 \qquad (6)$$

$$C_{sup} = \frac{2E_{SC}}{[(V_{sc})_{max}^2 - (V_{sc})_{min}^2\ ]} \qquad (7)$$

where,

E_{sc} - Energy rating of the super capacitor

$(V_{sc})_{max}$ and $(V_{sc})_{min}$ - maximum and minimum operatingvoltages of super capacitor respectively.

To demonstrate how the size of the supercapacitor can be calculated, let us assume that the safe voltage operating limits of the supercapacitor is

$$275V < V_{sc} < 375V \quad (8)$$

The size of the supercapacitor is estimated in the absence ofwind power where the supercapacitor provides the rated power of PMSG, (i.e., 100 kW) to mains load for a time duration, say t = 20s. For this condition, the capacitance value of the supercapacitor will be as below:

$$C_{sup} = \frac{2(P_{PMSG})_{rated} * t}{[(V_{sc})^2_{max} - (V_{sc})^2_{min}]} \quad (9)$$

$$C_{sup} = \frac{2*100*1000*10}{375^2 - 275^2} \approx 30F \quad (10)$$

F. Synchronous Condenser:

In Remote area power supply systems it is very difficult to the rectifier-inverter control system to provide robust voltage control, especially when it needs to serve the reactive power loads.This is mainly due to the limited reactive power capability of inverter. Moreover, the PMSG is fully decoupled from the power electronic arrangement (i.e., through rectifier and inverter arrangement). Therefore, the PMSG has no inertia contribution towards the inertial requirement of the entire RAPS system. In this regard, to provide enhanced reactive power together with inertial support, a synchronous condenser can be incorporated into the RAPS system.In this paper, the synchronous condenser is intended to operate at leading power factor region in order to supply the required reactive power into the RAPS system. For the simulation purpose a battery with a converter is used to supply the reactive power.

G. Dump load:

In this RAPS system a Dump load is also used in conjunction with the main load. This is coordinated with the hybrid energy storage system in order to maintain the active power balance in the system. The operation of this dump load is only limited to the case where excess power is available in the system. Also, the dump load will start absorbing the additional power only after battery storage reaches its rated capacity. A simplified control schematic diagram of the dump load controller is shown in Fig.(3)

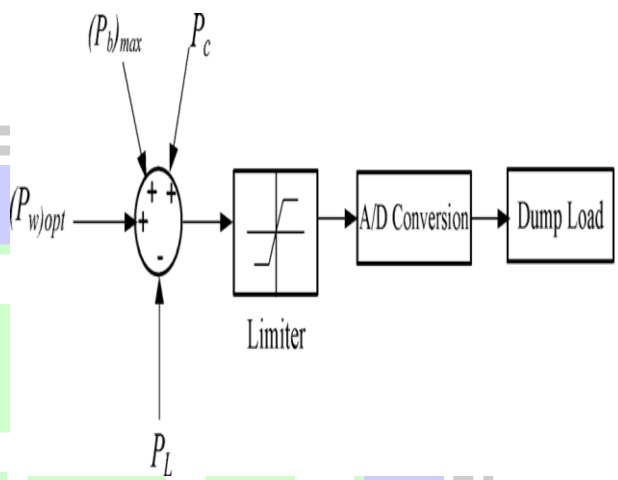

Fig. 3. Dump load controller.

In practical RAPS systems, a dump load can be a space-heating or water-heating system. In this paper, the dump load is represented by a dynamic load of active power 25 kw, with zero reactive power.

III. COORDINATED CONTROL APPROACH FOR THE RAPS SYSTEM

In any power system it is very imported to maintain active and reactive power balance given by the following equations (eqn11&12), in order to achieve robust voltage and frequency regulation.

$$\Sigma P_{sources} - \Sigma P_{sinks} = 0 \quad (11)$$

$$\Sigma Q_{sources} - \Sigma Q_{sinks} = 0 \quad (12)$$

where P—active power and Q—reactive power.

In relevance to the RAPS system shown in Fig. 1, the active power flow has to be coordinated among the wind turbine generator, battery storage, supercapacitor, main load and dump load which is given by the following equation(13).

$$P_w \pm P_b \pm P_c = P_L + P_d \quad (13)$$

Where, P_w —wind power output, P_b—battery storage output, P_c —supercapacitor output, P_d —dump load power and P_L—active power demand.

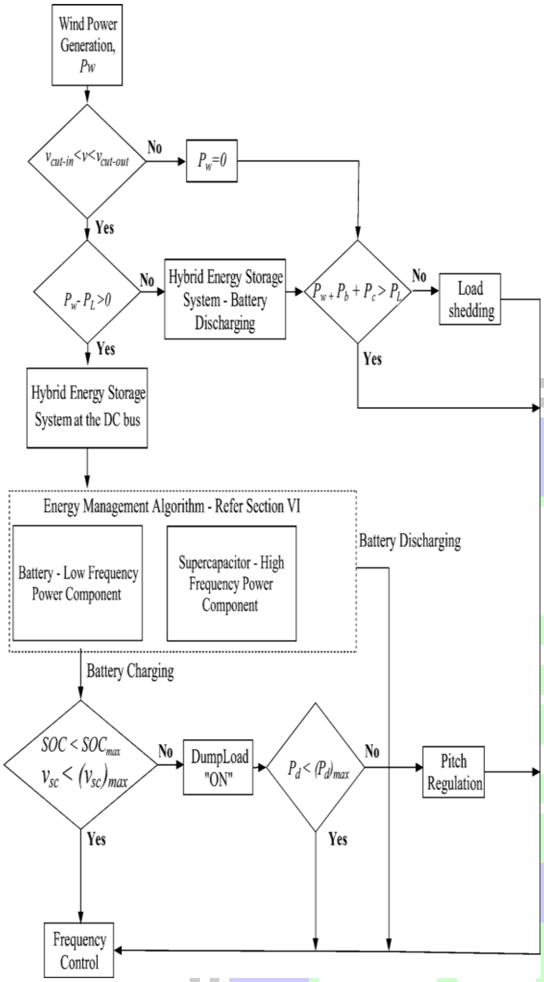

Fig.4 . Control coordination methodology

In this RAPS system It is assumed that the power outputs of wind system and hybrid energy storage system are sufficient to supply the load demand at all time. In other words, emergency situations such as wind turbine generator operation below cut-in speed, v_{cut-in} or above cut-out speed, $v_{cut-out}$ have not been considered. In practical RAPS systems, a load shedding scheme can be implemented during an emergency situation where the reduced load is then supplied by the hybrid energy storage system. If the power generation is more than the load demand, the excessive power is stored by the hybrid energy storage system, where high frequency power component is stored by the super capacitor and the low frequency power component is stored by the battery. If the battery reaches its maximum storage capability then dump load absorbs the excessive power. If the dump load is also not sufficient to utilize that excessive power then pitch angle control of wind turbine generator has to be activated. During under power generation conditions, hybrid energy storage system will supplies the required power to meet the load demand.

IV. SIMULATION MODEL AND RESULTS

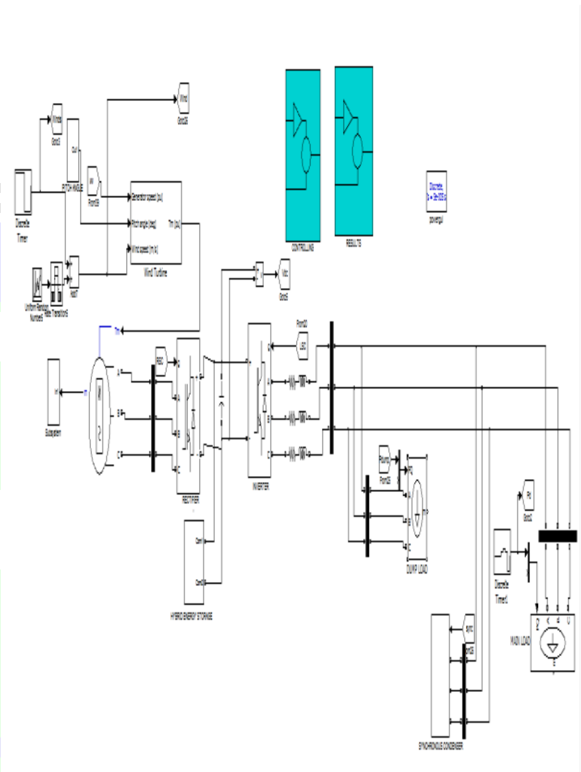

Fig.5. Simulation model of PMSG based RAPS system with Hybrid Energy storage

The proposed RAPS system was implemented with the detailed model of the MATLAB Simulink Sim Power systems and also with the highly accurate models of the system components as shown in fig 5. The simulation time step used was 5 micro-seconds to capture the true behavior of the system components. To prove the robustness of the proposed method, wind gusts and load step changes in wind profile and load profile respectively are used to synthesize the worst system conditions in a RAPS system. Such worst case scenarios are used to show how well the proposed control strategy behaves in relation to the voltage and frequency regulation.

The responses of RAPS system components have been tested under variable wind and load condition. Fig.6a. shows the wave form fluctuating wind input conditions. Initially wind speed input is set at 12m/s, after t=3 seconds it drops to 9m/s and then it is increased to 11m/s at time t=5sec. fig.6b. shows the per unit load voltage, it can be seen that it is always maintained at 1pu irrespective of fluctuating wind and variable load conditions.

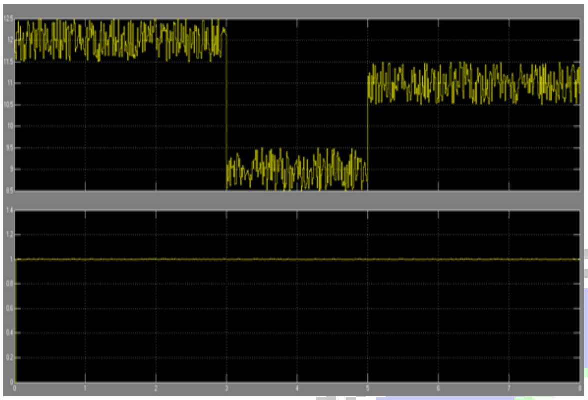

Fig .6. (a) Wind Speed&(b) Voltage at load side

Fig.7.a. shows the waveform of frequency at load side, even though it having some minute fluctuations but still it maintained at 1pu only. And fig.7.b.shows the waveform of DC link voltage.

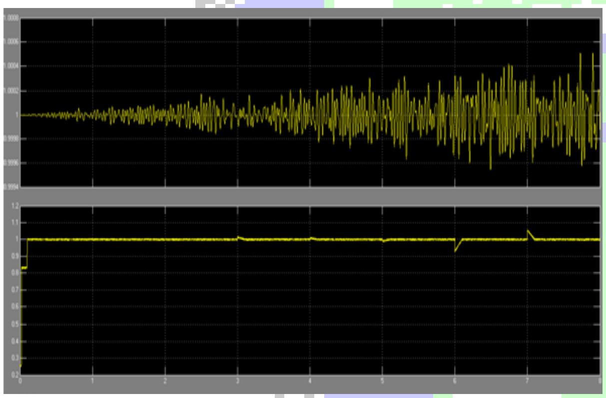

Fig.7. (a) Frequency at load side & (b) DC link Voltage .

Fig.8 shows the waveforms of power shared between various components of RAPS system. The load demand initially set at 0.5pu and after 4sec it is increased to 0.7pu, and it is again reduced to 0.45pu at time t= 6sec, this is clearly shown in fig.8(e). Initially wind power generation is more than the load demand, in this condition battery starts charging, and stores the excess energy. At time t= 3sec load demand is same, but power generation is reduced, in this condition battery starts discharging to supply the load demand. Again at time t= 4sec the battery increases its discharging to meet the additional load demand. At time t= 5sec the power generation is increased with constant load demand, in this battery again starts charging. Again from time t= 6sec onwards load is reduced with constant power generation so the battery continues in its charging mode. This battery storage operation is clearly shown in fig.8(b). Throughout the operation, the supercapacitor absorbs the high frequency power component of demand-generation mismatch during transient conditions which occur due to wind and load step changes as evident from Fig.8(c). from time t=0sec to t=3sec there is an excessive power in the RAPS system and this power is absorbed by the dump load as shown in fig.8(d).

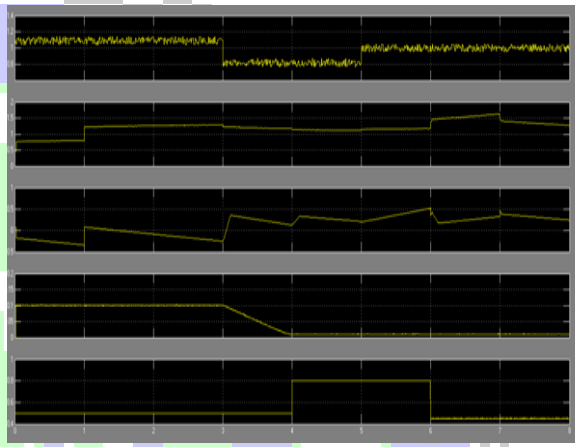

Fig.8. (a) Wind Power, (b) Battery power, (c) Super capacitor power (d) Dump load power and (e) Load demand.

Fig.9. shows the current waveforms of battery and super capacitor. It is clearly visible that the high frequency component (i.e.,above 0.5 Hz) is absorbed by the supercapacitor and provides a smoother transition from one operational mode to another with lower depth of discharge for the battery storage.

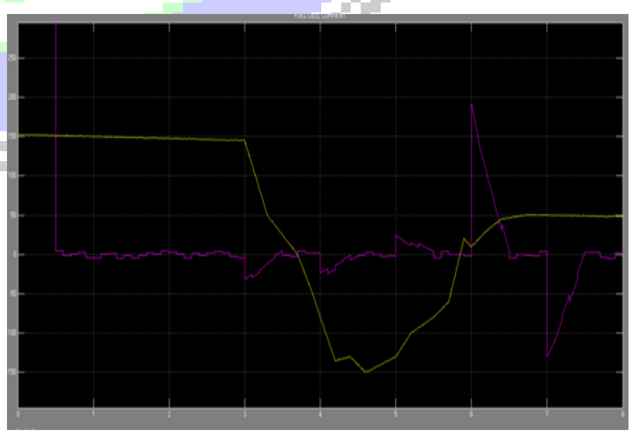

Fig.9. Currents of battery storage and supercapacitor.

The reactive power sharing of synchronous condenser and inverter is shown in Fig. 10. Initially, the load reactive power is set to 0.3 pu. The highest reactive power support is provided through inverter where the rest is supplied by the synchronous condenser. During the load step change at t= 4sec , the reactive power demand is increased to 0.5 pu where the highest proportion of reactive power is now supplied through synchronous condenser while the rest is provided through inverter.

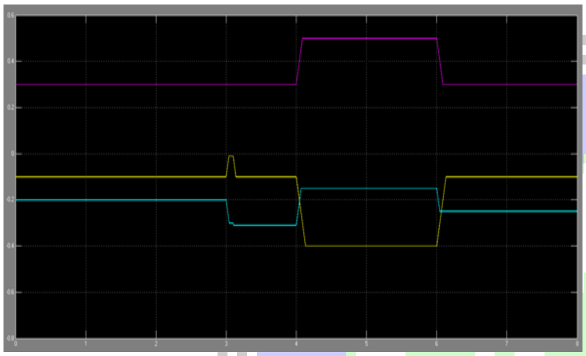

Fig.10. Reactive power sharing.

V. CONCLUSION

This paper has investigated the standalone operation of PMSG with a Fuzzy controlled rectifier-inverter arrangement, a hybrid energy storage system consisting of a battery storage and a super capacitor, a synchronous condenser, main load and a dump load. The entire RAPS system is simulated under over-generation and under-generation conditions covering the extreme operating conditions such as load step changes and wind gusts. From the simulated behavior, it is seen that the proposed approach is capable of regulating both voltage and frequency within tight limits for all conditions. The performance of the battery storage is improved with the implementation of energy management algorithm, as supercapacitor absorbs the ripple or high frequency power component of demand generation mismatch while leaving the steady component for the battery storage. The super capacitor helps in avoiding battery operation in high rate of depth of discharge regions. The proposed fuzzy control algorithm is able to manage power balance in the RAPS system while extracting the maximum power output from the wind throughout its entire operation. With the integration of the synchronous condenser it has been proven that the RAPS system is able to maintain the load voltage within acceptable limits for all conditions including the situation when reactive power demand becomes very high.

REFERENCES:

[1] Abbey. C. and Joos. G. (2005) 'Short-term energy storage for wind energy applications', In 40 th Industry Applications Conference (IAS2005),Hong Kong, volume 3, pages 2035 – 2042, Oct. 2005.

[2] Abedini. AandNikkhajoei. H.(2011) 'Dynamic modeland control of a wind-turbine generator with energy storage', IET Renewable Power Generation, 5(1):67 –78, Jan. 2011.

[3] Beaudin.M, Zareipour.H, A. Schellenberglabe, andW. Rosehart.(2010) 'Energy storage for mitigating the variability of renewable electricity sources: An updatedreview. Energy for Sustainable Development', 14(4):302 – 314, 2010.

[4] Bhuiyan.F.A. and A. Yazdani.(2009) 'Multi mode control of a DFIG-based wind-power unit for remote applications', IEEE Transactions onPower Delivery, 24(4):2079 –2089, Oct. 2009.

[5] Borowy B. S. and Salameh. Z. M.(1997) 'Dynamic response of a stand-alone wind energy conversion system with battery energy storage to a wind gust', IEEE Transactions on Energy Conversion, 12(1):73 –78, Mar. 1997.

[6] Brekken. T. K. A, Yokochi.A., A. von Jouanne, Z.Z. Yen, H. M. Hapke, and D. A. Alamay. (2011), Optimal energy storage sizing and control for wind power applications', IEEE Transactions on Sustainable Energy, 2(1):69 – 77, Jan. 2011.

[7] Corbus. D, Newcomb. C, E. I. Baring-Gould, and S. Friedly.(2002) 'Battery voltage stability effects on small wind turbine energy capture', In AWEA WINDPOWER, Portland, USA, Oct. 2002.

[8] Haque.M. E., Negnevitsky. M, and K. M. Muttaqi, (2009), A novel control strategy for a variable-speed wind turbine with a permanent-magnet synchronous generator', IEEE Trans. Ind. Appl., vol. 46, pp. 331–339, Nov. 2009.

[9] Harnefors. L and Nee. H. P., (1998), Model-based current control of ac machines using the internal model control method', IEEE Transactions on Industry Applications, 34(1):133 – 141, Jan./Feb. 1998

[10] Haruni. A.M.O,Haque. M.E., A. Gargoom, and M. Negnevitsky. (2010) 'Control of a direct drive ipm synchronous generator based variable speed wind turbine with energy storage', In 36 th Annual

Conference on IEEE Industrial Electronics Society (IECON2010), Glendale, AZ, USA, pages 457 – 563, Nov. 2010.

[11] Li. Q, Choi. S. S, Yuan. Y, and D. L. Yao. (2009),On the determination of battery energy storage capacity and short-term power dispatch of a wind farm‵, IEEE Transactions on Sustainable Energy, 2(2):148 –158, Aprl. 2011.

[12] Li. W and Joos. G (2008) ‗A power electronic interface for a battery supercapacitor hybrid energy storage system for wind applications‵, In IEEE Power Electronics Specialists Conference, 2008, (PESC 2008), Rhodes, Greece, pages 1762 –1768,Jun. 2008.

[13] Li. W, Joos. G, and J. Belanger.(2010) ‗Real-time simulation of a wind turbine generator coupled with a battery supercapacitor energy storage system‵, IEEE Transactions on Industrial Electronics, 57(4):1137 –1145, Apr. 2010.

[14] Liu. F, Liu. J., and L. Zhou,(2010), ―A novelcontrol strategy for hybrid energy storage system to relieve battery stress,‖ in Proc. Int. Symp. Power Electron.Distrib.Gener. Syst. (PEDG), Hefei, China, Jun. 16–18, 2010, pp. 929–934.

[15] Mercier. P, Cherkaoui.R and A. Oudalov.(2009) ‗Optimizing a battery energy storage system for frequency control application in an isolated power system‵, IEEE Transactions on Power Systems,24(3):1469 – 1477, Aug. 2009.

[16] Mohod.S. Wand Aware. M. V. (2012), ‗Micro wind power generator with battery energy storage for critical load‵,IEEE Systems Journal, 6(1):118.– 125, Mar. 2012.

[17] NishadMendis, M. Muttaqi, SarathPerera(2014), ‗Management of Battery-Super capacitor HybridEnergy Storage and Synchronous Condenser for Isolated Operation of PMSG Based Variable-Speed Wind Turbine Generating Systems‵ IEEE Transactions on smart grid, Vol. 5, No. 2, Mar 2014.

[18] Patrick. Tand Moseley. (2006) ‗Energy storage inremote area power supply (RAPS) systems‵, Journal of Power Sources, 155(1):83 – 87, 2006.

[19] Qu. L and Qiao. W (2011), ‗Constant power control of DFIG wind turbines with super capacitor energy storage‵, IEEE Transactions on Industry Applications, 47(1):359 –367, Jan.- Feb. 2011.

[20] Ramirez-Elizondo. L. M,Paap.G.C and N.Woudstra. (2008), ‗The application of a fuel cell electrolyzer arrangement as a power balancing set-up in autonomous renewable energy systems‵, In 40 th North American Power Symposium, (NAPS 08), Calgary, Canada, pages 1 – 8, Sept. 2008.

[21] Ribeiro. P. F, Johnson.B. K., M. L. Crow, A. Arsoy, and Y. Liu. (2001), ‗Energy storage systems for advanced power applications‵, Proceedings of theIEEE, 89(12):1744 – 1756, Dec. 2001.

[22] Shiao. Y. S, Lin. C. E, M. T. Tsai, and C. L. Huang. (1992) ‗Harmonic and reactive current compensation using a voltage source inverter in a battery energy storage system‵, Journal of Electric Power Systems Research, 25(1):25 – 33, 1992.

[23] Teleke. S, Baran. M. E, A. Q. Huang, S. Bhattacharya, and L. Anderson. (2009) ‗Control strategies for battery energy storage for wind farm dispatching‵, IEEE Transactions on Energy Conversion, 24(3):725 –732, Sept. 2009.

BIOGRAPHIES

Mr. G.V.Apparao completed his Diploma in Electrical & Electronics Engineering in 2009 and received his B.Tech degree in 2012. Currently he is pursuing his M.Tech from Sri Vasavi Engineering college, Tadepalli gudem, A.P. His areas of interests are in power systems and Electrical Machines.

Dr.M.Rama Prasad Reddy received the Bachelor of Engineering degree in Electrical & Electronics Engineering from Karnataka University of Dharwad in 1999 and Master's degree from JNTU Kakinada in 2007. He is completed Doctoral degree from JNTU, Hyderabad in 2015. Currently, working as an Associate Professor in Sri Vasavi Engineering College, Tadepalligudem, A.P. His areas of interests are in power systems, Power electronic control of drives.