

ENHANCE THE TRANSIENT STABILITY AND REDUCE FLUCTUATIONS OF WIND POWER BY USING BATTERY AND FUEL CELL

¹ MS. G. NAGAVARDHANI M.TECH, POWER ELECTRONICS, ST.MARY'S GROUP OF INSTITUTIONS GUNTUR CHEBROLU

² Mr. Ch PARDHASARADHI, ASSOC PROFF ELECTRICAL & ELECTRONICS ENGINEERING, St.MARY'S GROUP OF INSTITUTIONS GUNTUR CHEBROLU

ABSTRACT

The paper emphasizes on the application of hybrid energy storage systems to mitigate the effect of wind speed fluctuations, thereby ensuring smooth power output as well as improving the power quality at the PCC. To achieve this a control strategy is designed for managing the demand - generation fluctuations using a hybrid energy storage system in a wind dominated remote area power supply system consisting of a DFIG, fuel cell, a super capacitor, a dump load and main loads. Operation of fuel cell is coordinated with a super capacitor with a view to improving the performance of the fuel cell. In this model, the fuel cell storage system is connected to the load side of the RAPS system, whereas the super capacitor is connected to the dc bus of the back - to - back converter of the DFIG. The models are simulated in Matlab/Simulink environment.

1. INTRODUCTION

Electricity is identified as one key commodity which can be used as a medium for economic growth in rural and regional areas. According to ministry of new and renewable energy, country's present installed power generation capacity has more than doubled to 2, 34,600 MW in the past 10 years. Renewable energy contributes to nearly **34351.39 MW to the total generating capacity and in which wind energy contributes 20149.5 MW**. Even though we have 20149.5 MW of installed capacity, India faces an outage of more than 30000 MW due to increase in demand. This shortage can be reduced by use of renewable energy, since renewable energy is reliable, abundant and will potentially be very cheap once the technology improves.

1.1 HYBRID ENERGY STORAGE SYSTEM

Ideal energy storage in a standalone wind energy conversion system should be able to provide both high energy and power capacities to handle situations such as wind gusts and load step changes, which may exist for seconds or minutes or even longer. At present, various types of storage technologies are available to full fill either power or energy requirements of a RAPS system. Widely used energy storage technologies that currently employ in wind farms are batteries, super capacitors, fly wheels, compressed-air energy storage, hydro pumped storage, superconducting magnetic energy storage, fuel cells, etc. Hybrid energy storage system is a system which consists of a battery and a super capacitor which are comparatively best when compared other storing device. Among all energy storage systems, batteries are seen to have one of the highest energy density levels i.e., it is able to store for longer periods, whereas the supercapacitors seem to have the highest power density i.e., they are able to handle transients that occur over short period of time. At present, battery storage systems are widely employed in most real life RAPS applications. To further improve the performance of the battery energy storage systems, a supercapacitor can be incorporated to perform a hybrid operation. In this way, the combined energy storage system is able to satisfy both power and energy requirements of the RAPS system. A power management algorithm is designed in such a way that the supercapacitor should be able to absorb the ripple component of demand - generation mismatch leaving the steady component for the battery storage system. In this paper design and development of wind dominated RAPS system to maintain the load side voltage and frequency within acceptable limits during over - generation and under - generation. To achieve this main objective, it is important to manage the active and reactive power contribution of the components of the RAPS system. In this regard, control coordinated strategies are developed and implemented among the components present within the RAPS system. In addition, individual control is developed based on an appropriate coordinated control approach with a view to regulate the magnitude of the voltage and frequency on the load side. In this thesis, RAPS system consisting of battery storage, super capacitor and dump load along with wind turbine generator as the main component are considered.

2.DFIG OPERATION AND CONTROLLING

2.1 OPERATING OF THE DFIG

In this thesis, DFIG is given much importance because it feeds ac currents into both the stator and the rotor windings. The primary advantage of DFIG when compared to other generators is that when used in wind turbines they allow the amplitude and frequency of their output voltage to be maintained at a constant value, no matter the speed of wind blowing on the wind turbine rotor. A typical configuration of a DFIG based wind turbine generator system is shown in Fig.2.1

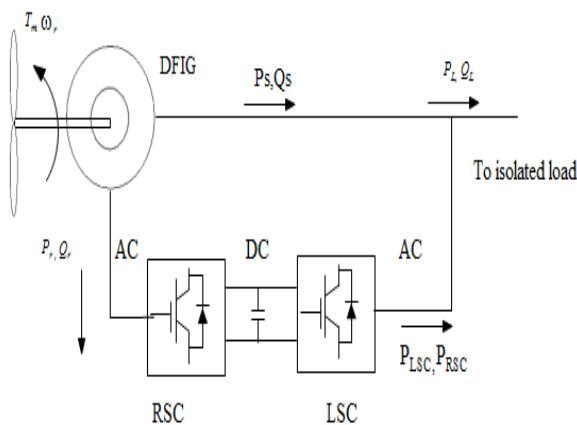


Figure 2.1: DFIG based wind turbine generator system

The operation of which can be categorized into two modes: (a) super synchronous and (b) sub synchronous. The difference between operations of these two modes can be determined from the rotor speed ω_r , compared to the synchronous speed ω_s , and the direction of power flowing through the back to back converter.

In the super – synchronous mode, the rotor speed of the DFIG is kept above synchronous speed leading to a negative slip $s < 0$, as evident from Eq. (2.1). During the super – synchronous mode, the generated wind power passes to the load through the stator, as well as through the rotor, of the DFIG which is given by Eq.(2.2) and (2.3) respectively (i.e., $P_r > 0$) as shown in Fig.2.2

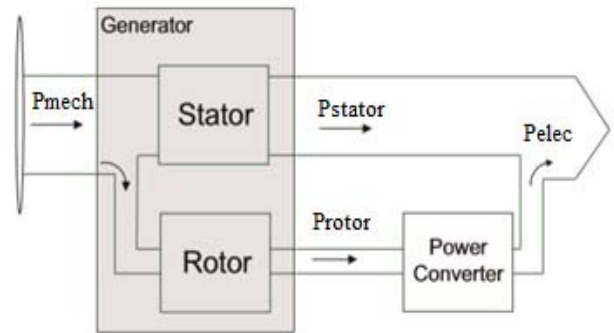


Figure 2.2: Super – synchronous mode of operation

$$s = \frac{\omega_s - \omega_r}{\omega_s} \quad (2.1)$$

$$P_s = \frac{P_m}{(1-s)} \quad (2.2)$$

$$P_r = -sP_s \quad (2.3)$$

In contrast, during the sub synchronous mode of operation, the rotor speed is kept below the synchronous speed. The generated wind power is supplied to the load by the stator while slip power is absorbed through the rotor (i.e., $P_r < 0$) as shown in Fig.2.3.

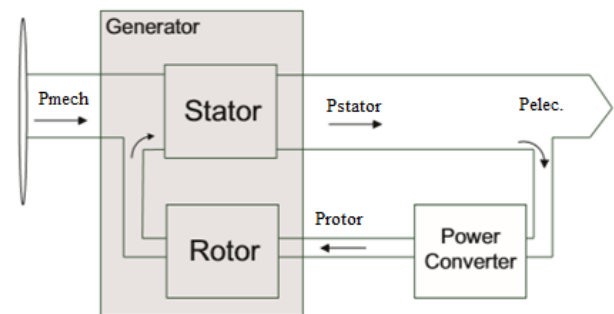


Figure 2.3: Sub – synchronous mode of operation

by developing the control strategies for each component of the RAPS system.

4. Fuzzy Logic Controller

Fuzzy logic is a new control approach with great potential for real time applications Fig 4.1 shows the

structure of the fuzzy logic controller (FIS-Fuzzy inference system) in MATLAB Fuzzy logic toolbox. Load voltage and load current taken as input to fuzzy system. For a closed loop control, error input can be selected as current, voltage or impedance, according to control type. To get the linearity triangular membership function is taken with 50% overlap. The output of fuzzy controller taken as the control signal and the pulse generator provides synchronous firing pulses to thyristors as shown in fig 4.2 The Fuzzy Logic is a rule based controller, where a set of rules represents a control decision mechanism to correct the effect of certain causes coming from power system. In fuzzy logic, the five linguistic variables expressed by fuzzy sets defined on their respective universes of discourse. Table-I shows the suggested membership function rules of FC-TCR controller. The rule of this table can be chosen based on practical experience and simulation results observed from the behavior of the system around its stable equilibrium points.

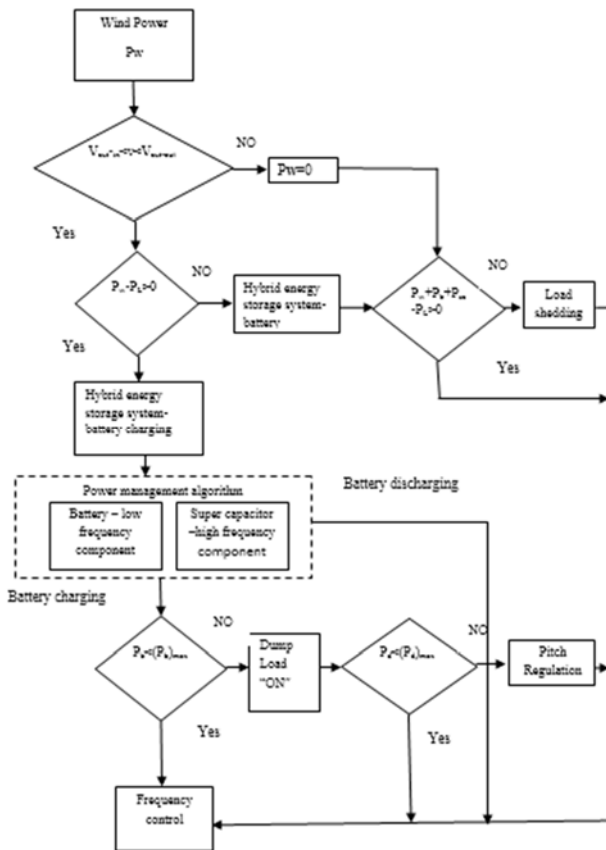


Figure 3.1: A Coordinated control approach for hybrid energy storage based RAPS system

During over generation condition where the power output from the wind turbine generator P_w is greater than the load demand P_L , the hybrid energy storage P_b (i.e., battery storage and super capacitor) absorbs the excess power ($P_w - P_L$) and is shared between the battery storage system and super capacitor according to the power management algorithm. If the capacity of the hybrid energy storage system reaches the maximum limit or $(P_b)_{max}$, the dump load needs to absorb the excess power. However, if the dump load power P_d reaches its maximum limit rating $(P_d)_{max}$, the pitch angle control has to be activated in order to reduce the power output of the wind turbine generator.

During under generation situations where the power output of the wind turbine generator is less than the load demand, i.e., $(P_w - P_L) < 0$, it is assumed that the hybrid energy storage P_b is able to supply the required power deficit $(P_L - P_w)$.

During emergency situations such as no power output from wind turbine generator due to wind speed being below cut - in level or above cut - out level, a load shedding scheme can be implemented. Moreover, the proposed control coordination concept has been realized

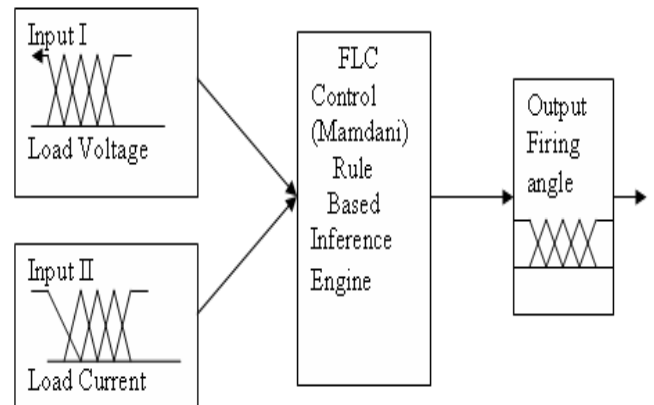


Fig 4.1 Structure of fuzzy logic controller

Table I Membership function rules

	e	Load voltag				
		NL	N M	P	PM	PB
Load current	NL	PB	PB	N M	N M	NL
	NM	PB	PB	N M	P	NL
	P	P	PM	N M	N M	P
	PM	N M	P	N M	N M	P M
	PB	NL	N M	N M	NL	NL

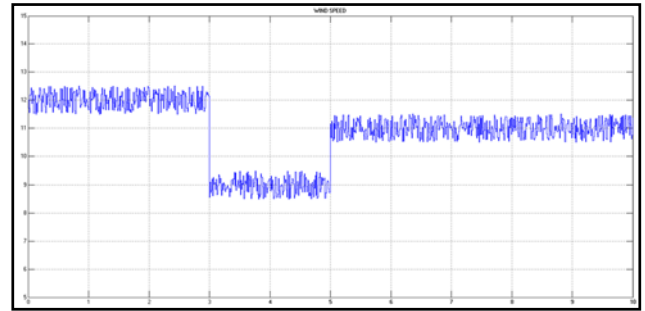


Figure 5.3: Wind speed (battery)

The voltage on load side is shown in Fig.4.4 which not to be affected by the wind speed or load changes. This proves that the DFIG controllers are able to maintain voltage constant. The load voltage of the system stays 1 Pu ($\pm 2\%$ of its rated value) throughout the operation.

5. SIMULATION MODELS AND RESULTS

5.1 BATTERY AND SUPER CAPACITOR RESULTS

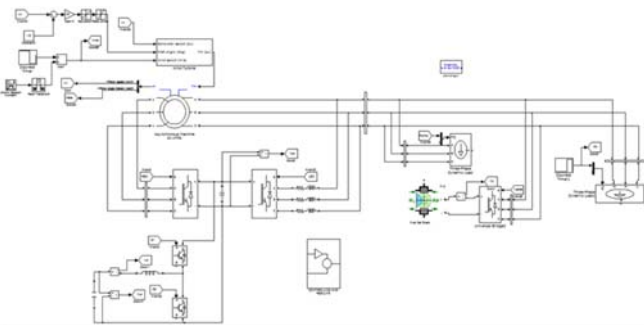


Figure 5.1: Simulation circuit with battery and super capacitor

The simulation model with Battery and super capacitor is designed presented above in fig 4.1.

The system response of the DFIG based RAPS system with battery and super capacitor as hybrid storage system is shown in below. The FFT analysis of the battery current is shown to be free from ripples or high-frequency component which is presented in Fig 5.6. The operating frequency of the RAPS system is shown in Fig.5.5. The operating frequency is closely regulated at its rated value of 50Hz and is seen not to be influenced by the wind speed or load step changes. Furthermore, it can be seen that the frequency of the system is maintained within 0.2% of its rated value.

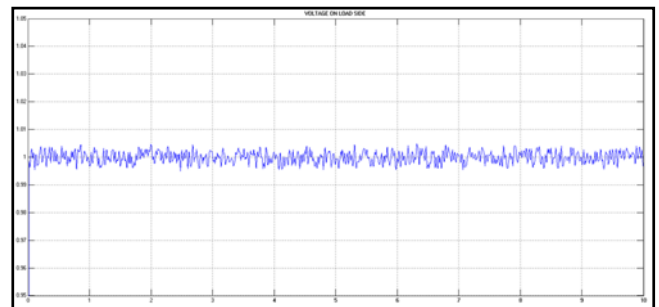


Figure 5.4: Voltage on load side (battery)

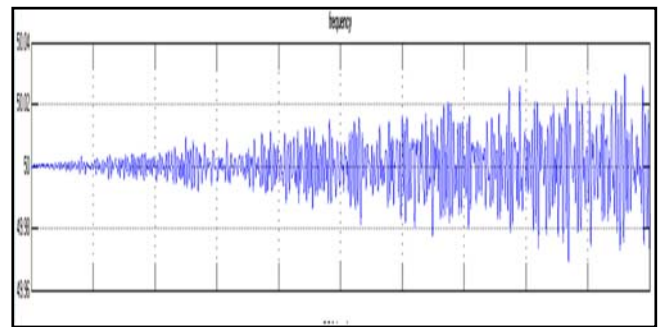


Figure 5.5: Frequency on load side (battery)

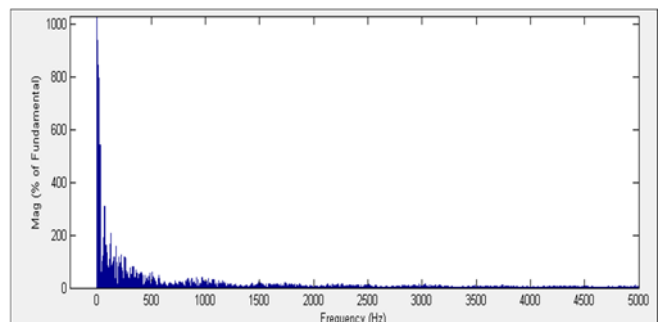


Figure 5.6:FFT analysis of the battery system

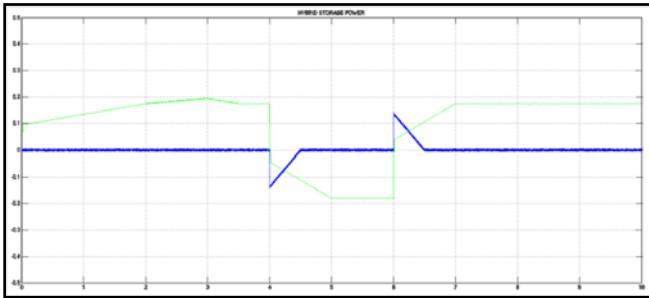


Figure 4.7:Hybrid energy storage power

4.2 FUEL CELL AND SUPER CAPACITOR RESULTS

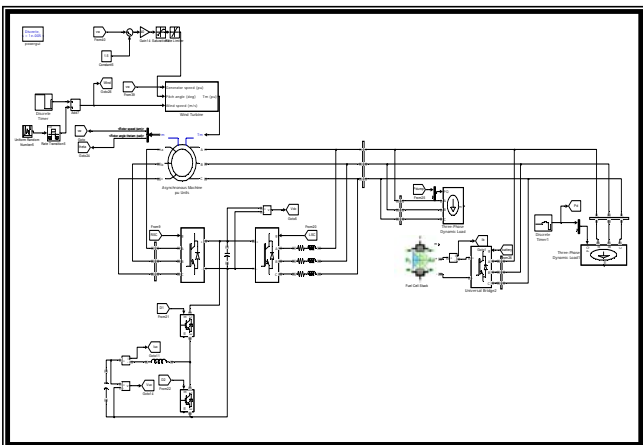


Figure 5.8:Simulation model with fuel cell and super capacitor

Since fuel cell are more efficient and has life cycle more than batteries, so batteries are replaced by fuel cell. The function of fuel cell is same as that of battery, so controlling is designed same as battery controlling. The simulation model is shown in Fig.5.2

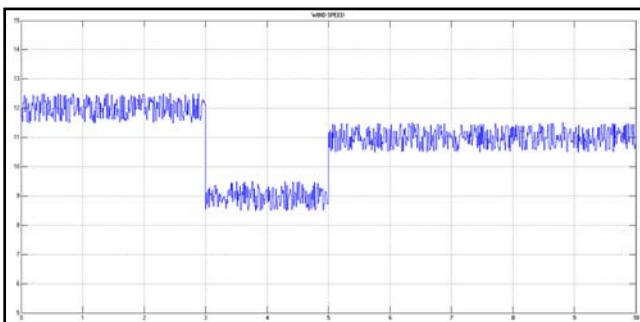


Figure 5.9:Wind Speed (Fuel cell)

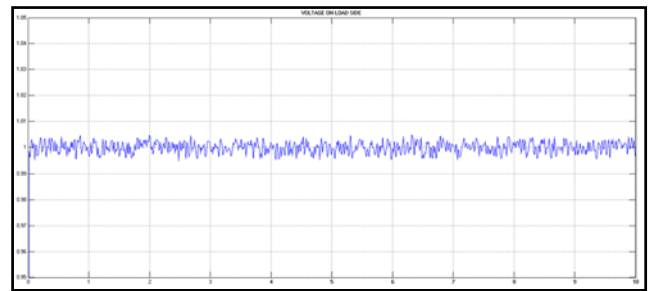


Figure 5.10:Voltage on load side (fuel cell)

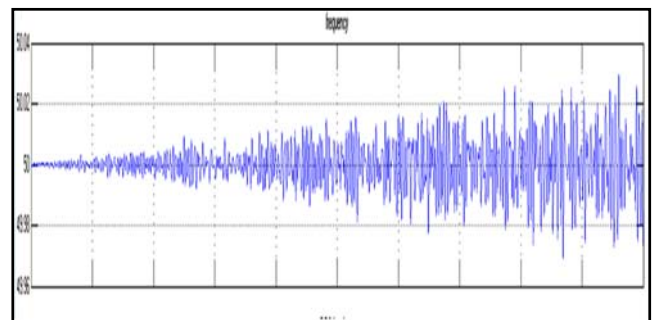


Figure 5.11:Frequency on load (fuel cell)

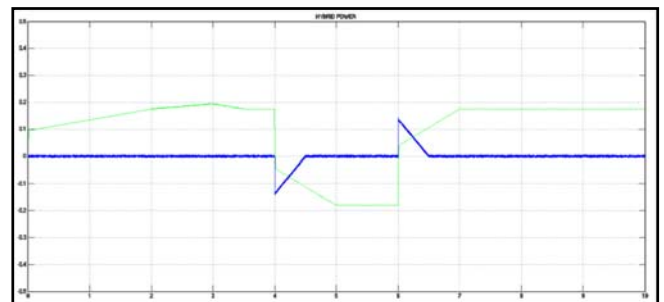


Figure 5.12:Hybrid energy storage power

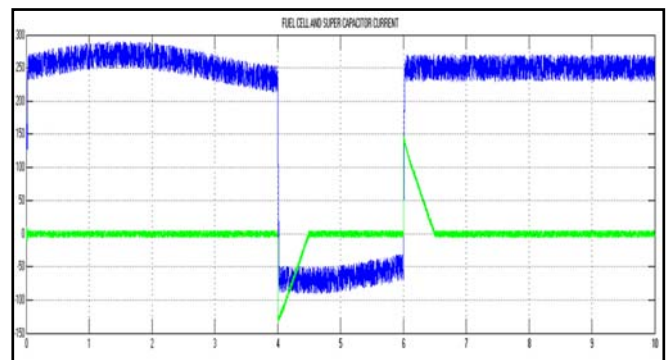


Figure 5.13:Hybrid Energy storage current

The Fuel cell current consists of high frequency fluctuating component and exhibits step DOD during load step changes. The current level of the hybrid energy storage with the super capacitor is shown in Fig.5.13. Fuel cell and super capacitor responded efficiently depending on increase in demand.

5. CONCLUSION

The paper has addressed the benefits of integrating a super capacitor to a battery storage system in a wind – based hybrid RAPS system. Through simulation studies it can be concluded that RAPS systems was capable in maintaining the constant voltage and frequency at the load end. Also, it has been noted that the power sharing between the systems components were accomplished in accordance with the proposed coordinated control methodology.

When considering the operation of battery storage systems, avoidance of heavy DOD rates and reduced ripple content in the battery current is given importance. To solve above problem, a super capacitor was integrated with the battery storage system to form the hybrid energy storage (i.e. battery and super capacitor) and improving battery's performance. Furthermore, it has also been noted that the super capacitors integrated to the DFIG was able to handle the transients caused by wind speed and load changes effectively.

Thus concluding by saying that the hybrid operation of the RAPS systems were capable in maintaining the voltage and frequency at the load end with proper power sharing between the devices

As extensions to the work presented in this paper, following is a description of further activities that can be undertaken in relation to standalone RAPS system:

- Development of the control strategies for each component of RAPS systems with a view to operate them under unbalanced load conditions.
- Providing protection to the system.
- Integration of other types of renewable energy systems (e.g. solar photovoltaic) to wind based RAPS systems.
- Further development of the existing control strategies of the RAPS systems to operate as a grid interactive micro – grid.

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Ms. G. Nagavardhani. She Pursuing M.Tech Degree In Power Electronics In EEE Department In St.MARY'S GROUP OF INSTITUTIONS GUNTUR CHEBROLU(P&M), GUNTUR(Dt), AP. Phone.7207326988
Mail.id.vardhu.naga@gmail.com



Mr. Ch PARDHASARADHI M.Tech was born in India..ASSOC PROFF OF EEE IN St.MARY'S GROUP OF INSTITUTIONS GUNTUR CHEBROLU(P&M), GUNTUR(Dt), AP Ph NO: 9951493288

Mail id: pardhu.220@gmail.com