Management of Low and High Frequency Components in Generation and Reduce Fluctuations Fed by DFIG Based WIND System with Battery and Fuel Cell

1.J.Rajesh Reddy & 2.P.Sivakrishna

Email: rajeshreddy.jetty@gmail.com
Email:sivakrishna915@gmail.com

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 improve.

1.1 HYBRID ENERGY STORAGE SYSTEM

An 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 startor 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

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 $\omega_r$, compared to the synchronous speed $\omega_s$, 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

$$s = \frac{\omega_s - \omega_r}{\omega_s}$$  \hspace{1cm} (2.1)

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

$$P_r = -sP_s$$  \hspace{1cm} (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.
2.2. ROTOR SIDE CONVERTER CONTROL

As shown in Fig. 3.5, the RSC controller consists of inner – loops which have fast field oriented current control and the slow outer – loops that generate the reference currents forth inner loops.

Figure 2.4: RSC control scheme

The voltage controller of the DFIG is developed in gareactive power based control approach. In this regard, the total stator reactive power output Q_{S,s} of DFIG given in Eq. (2.4)

\[ Q_s = \frac{3}{2} \left[ -\frac{V_s^2}{\omega L_s} + V_s \frac{L_m}{L_s} i_{dr} \right] \]

(2.4)

Therotord – axis current \( i_{dr} \), consists of two components, namely: magnetizing current \( i_{drmag} \), which is mainly used for magnetization. The purpose of the DFIG and \( i_{dgen} \), which is used to satisfy the reactive power requirements of the loads. The corresponding reactive power components of the set currents, namely: \( Q_{mag} \) and \( Q_{gen} \) are given by Eq. (2.5) and Eq. (2.6) respectively.

\[ Q_{mag} = \frac{3}{2} \left[ -\frac{V_s^2}{\omega L_s} + V_s \frac{L_m}{L_s} i_{drmag} \right] \]

(2.5)

\[ Q_{gen} = \frac{3}{2} V_s \frac{L_m}{L_s} i_{dgen} \] (2.6)

2.3 LINESIDE CONVERTER CONTROL

The LSC is used to control the DC bus voltage of the back – to – back converter system and to supply any reactive power to the loads if needed.

Available online: http://internationaljournalofresearch.org/
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 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.
Fig 4.1 Structure of fuzzy logic controller

Table I Membership function rules

<table>
<thead>
<tr>
<th>Load voltage</th>
<th>Load current</th>
</tr>
</thead>
<tbody>
<tr>
<td>NL</td>
<td>N M</td>
</tr>
<tr>
<td>NL</td>
<td>PB</td>
</tr>
<tr>
<td>NM</td>
<td>PB</td>
</tr>
<tr>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>PM</td>
<td>N M</td>
</tr>
<tr>
<td>PB</td>
<td>NL</td>
</tr>
</tbody>
</table>

5. SIMULATION MODELS AND RESULTS

5.1 BATTERY AND SUPER CAPACITOR RESULTS

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 Fig. 4.4. 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 50 Hz 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 with in 0.2% of its rated value.

Figure 5.3: Wind speed (battery)

The voltage on load side is shown in Fig. 4.4 which is not 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 (±2% of its rated value) throughout the operation.

Figure 5.4: Voltage on load side (battery)

Figure 5.5: Frequency on load side (battery)
4.2 FUEL CELL AND SUPER CAPACITOR RESULTS

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.4.2

The fuel cell current consists of high frequency fluctuating component and exhibits steep 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.

REFERENCES


sustainable-energy/introduction-to-the-doubly-fed-inductiongenerator-for-wind-power-applications

[10] Literature review paper on doubly fed induction generator wind turbine technology Ajay Kushwahal, Inderpreet Singh2 1,2EIED, Thapar University, Patiala, Punjab, IndiaISSN: 2319-7463 Vol. 2 Issue 9, September-2013.


Mr. JETTY RAJESH REDDY was born in India in the year of 1990. He received B. Tech degree in Electrical and Electronics Engineering in the year 2013 (AUDISANKARA COLLEGE OF ENGINEERING AND TECHNOLOGY , JNTUA) IN NELLORE . and PURSUING M. Tech in Power Electronics EEE Department from Brahmaiah College of Engineering, A.P, India,

MAIL ID: rajeshreddy.jetty@gmail.com

P.SIVA KRISHNA received his B.Tech Degree in Electrical and Electronics Engineering from Narayana engineering college, Nellore affiliated to jntuananthapur. He received his M.Tech from sreevenkataperumalu engineering college puttur, chitter dist. He has 1 years teaching experience, presently working as Asst.Professor of EEE, Brahmaiahcollegeof engineering Affiliated to JNTU, Anantpur. Andhra Pradesh, India.

Mail Id:- Email:sivakrishna915@gmail.com