A FLYWHEEL ENERGY STORAGE SYSTEM INTEGRATED WITH PV FOR FRT SUPPORT OF GRID CONNECTED HVDC –BASED OFFSHORE WIND FARMS

[1]E.Damodar Reddy, PG Scholar, EEE, lakireddy Balireddy College of Engineering,

Email Id: erugala.damodarreddy@gmail.com

[2]Mr. J.V .Pavan Chand, Sr. Asst. Professor, EEE, lakireddy Balireddy College of Engineering ,

Email Id: pavanchand217@gmail.com

Abstract— For the sake of uninterrupted power supply (UPS) to the loads, here in this paper we are using the renewable energy source (RES).Among the RES, Photovoltaic and wind energy are most familiar and hence we are using both the energy source which comes under hybrid system or integrated system. The cause of using both the system is to meet the loads demand during off set of any one of the energy source where the balancing of power takes place. In addition to this we are also using a flywheel energy place storage system which is of large capacity and of low speed. It is a connected in shunt along with a VSC-HVDC which is present at grid side circuit based on squirrel cage induction motor. The VSC-HVDC transmission is chosen for the offshore wind farms. The main property of FESS is to absorb the excess amount of energy that reaches the load and also provision of the stored energy to the grid when there is a fault (or) when there insufficient amount of energy to meet the load demand at grid. From the above discussion it is clear that FESS is accomplished for monitoring of power (or) even out through normal and fault operating conditions. The outcomes for the projected system are attained by means of Matlab /Simulink during the normal and abnormal conditions.

Keywords— FESS, HVDC, Off Shore wind energy system integrated with PV, fault ride through system.

INTRODUCTION

Due to the random increase in population there is a greater degree of demand for electrical energy which tuned our interest towards the RES, Which are clean, pollution free and non-exhaustible. Generally there are three forms of RES. Among them solar and wind are very much familiar to the research and also to the power generator. The solar energy depends upon the temperature and irradiation of sun .Depending up on those two factors the energy will be generated. The solar cells are exposed to the sun for the generation of solar energy. Moving on to the wind energy the wind farms are installed onshore and off shore .The utilization of offshore wind farms is generally high because of high wind speed [1] when compared to on shore wind farms. The installation cost and maintenance of offshore wind farms is high when compared to the on shore wind farms and hence it is considered to be its limitation. Higher power transmission from offshore wind farms is a essential task. The transmission of higher voltage i.e. Dc (HVDC) for long distance from offshore wind farms is an substitute to ac communication. In general the HVDC system uses line-commutated converter (LCC) [2] which are appropriate for large power control request [3]. The LCC generates a large amount of harmonic and the conduction angle is dependent on non-unity displacement factor as there is large amount of harmonics, it requires filters at the ac side. The study of VSC based HVDC [2] was started by the developers in 1990. Moving on to the comparison between LCC HVDC, VSC-HVDC transmission has more and more benefits [3]-[4]. The VSC plays an vital role became the system stability depends upon the control of VSC ,which is a difficult task .the system stability in turn depends upon the transients and variations of ac systems. The deportment of ac system is considered as one of the vitiation under fault condition Even during(or) after the short circuit fault the wind farms need to be associated to meet the demand of grid [5]. Finally to make this clear FRT in VSC –HVDC for wind farms is necessary. There are many policies that takes place for FRT in VSC-HVDC in case of offshore wind system [4]-[5].

The utmost and the primary step is that, diminish the energy generated since by wind turbines. Basically here are two sorts of conditions to diminish the power that is produced by the wind turbine. Among them the first condition is to lower the torque of generator by controlling the frequency to be constant and useful active current component to be lower for the off shore converter [5]. Under this circumstance the diminishing of power generated by wind turbines is very slow and it's not adequate. The second condition is to obtain the grid frequency under that fault condition. The second strategy that exist for FRT VSC—HVDC is by creating or provision of short circuit at the offshore HVDC circuit in despite to stop the happening of onshore side near power spread. This can be done by diminishing the value of modulation index which in turn used to decrease the terminal voltage of offshore converter .even through there is a flow of high currents [6] across the converter which is consider to be its limitation. Ac side faults uses dc chopper along with the breaking resistor for avowing the igniting and power dissipation on dc side [6]-[7],which comes under third strategy. Among the mentioned strategies this is advantageous as it is reliable , but in accumulation to this the system price and energy losses increases. The above study is made to obtain new fault ride through technique which is used to preserve the power during abnormal condition and also leveling of wind energy during and normal operation. The flywheel is nothing but the storage element which stores the energy in the form of kinetic energy resisting on the rotational speed and its mass. Therefore, from the above discussion we can say that FESS is surviving two basic needs which is nothing but balance of power during normal condition .from the above discussion we can say FESS acts as storage elements in addition to batteries and super capacitors . The performance of fess is similar to that of super capacitor .the life time and density of energy for charging and discharging is relatively high [8] to overcome the limitation of super capacitor [i.e. the cost for the energy stored in fess per kwh is less compared to super capacitor] we are going ahead for Fess. The foremost aim of the this report is employing a FESS for ac side faults ride through system, at grid side converter of VSC-HVDC transmission system. The Integration of FESS with PV for leveling and tracking of power during normal and abnormal conditions can be obtained through Matlab/Simulink software.

I. ILLUSTRATION OF THE PROPOSED SYSTEM

Despite of balancing the power during normal operation and tracking of the power during conditions the fess have high efficiency, low maintenance, simple in structure with high energy and power mass [9]. A fess eventually consists of flywheel, bearings, power convention system and an electrical machine [10]. As we know that kinetic energy is the products of mass and volume here the flywheel acts as a mass where the kinetic power is preserved to drive the electrical system. Hence the machine behave like a motorized during incriminating and as generator during discriminating. Generally the high speed flywheel are incorporated in permanent magnet machine [11] but Whereas the induction motor are incorporated with low speed flywheels [12]. For the sake of power conversion, the power electric circuits are employed at wind farms known as wind side converter along with flywheel in parallel to the system. Moving on to bearings they are used in all the machines for the free rotation of the motor. Basically here we are have two sorts of bearings such as conventional mechanical bearings and magnetic bearings. In conventional mechanical bearings the rotor is made up of steel which used for low speed application to increases the inertia which finally results in abundant fess but where as in the magnetic the rotor is composed of composite material [11] which is applied in high speed requirements.

II. OPERATION OF PROPOSED SYSTEM

Here in this proposed project flywheel energy storage of large capacity is used for little speed induction machine which is associated in shunt to the grid side circuit .The single line diagram of FESS integrated with PV and VSC-HVDC transmission system is represented in Figure 1. The operation of the single line diagram is as follows her the power production by wind farms is offshore power which uses the ac generators like double fed induction generators (DFIG) and permanent magnet synchronous generator (PMSG) which in turn this ac power is transformed to dc through the converter present at wind side. The dc energy produced by the offshore wind farms is conveyed to onshore system by converting that high dc level power into ac power by efficiently utilizing the grid side converter. The converted power can stay sustainable for high power applications, losses in power and the harmonic content present in the output [13]. The above discussed operation is similar to that of the batteries that were used in case of FESS [14].

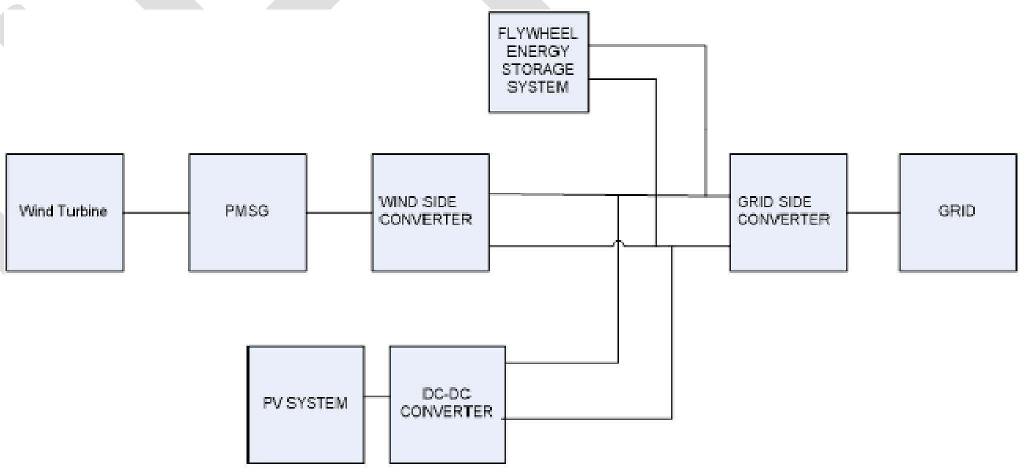


Fig 1. Single line strategy of planned system

The justification of the project is that both the wind energy and photovoltaic energy system are integrated with FESS. The integration of wind energy and Photovoltaic energy is to meet the demand at grid. For example if we consider only the wind energy (or) PV energy sometimes it is impossible to meet the demand at grid side even during the presence of flywheel In order to overcome that problem we are integrating both the energy system to meet the demand. If the generated energy by integrated systems is more (or) excess than the required demand at grid then the excess amount of energy is stored in fess which is connected in parallel with the wind side circuit. Apart from this the fess is also well known for leveling (or) balancing of power during normal condition. As discussed earlier that fess stores the energy , stored energy is utilized during the fault condition in order to meet the demand at grid as it is necessary. During phase to ground short circuit faults which is considered to be a worst fault will takes place at the ac side will tend the energy to zero. Taking this circumstance into account it is important to design the fess converter as that of the ratings of wind farm to store , store the wind energy for the fault at ac side. Here a high power flywheel is direct through an induction machine for balancing of power conditioning applications even there is a presence of variation in the operating mode.

The induction machine and fess modeling is done using direct and quadrature frame is as follows

A) Modeling of induction machine and FESS using direct and quadrature frame:

The design of induction machine in d-q frame [7], and for FESS converter is illustrated in (1-7) mathematical equations.

The voltages at stator side are as follows.

$$v_{ds} = r_s i_{ds} + p\lambda_{ds} - w_e \lambda_{qs} \quad (1)$$

$$.v_{qs} = r_s i_{qs} + p\lambda_{qs} + w_e \lambda_{ds} \quad (2)$$

Since the overhead basic equation (1) and (2) we can obtain the torque and flux of stator as follows

$$P_s = \frac{3}{2}(v_{ds} i_{ds} + v_{qs} i_{qs})$$

$$= Pcu_{stator} + Pcu_{rotor} + Tm_{wm} \quad (3)$$

$$Q_S = \frac{3}{2}\left(v_{ds} i_{qs} - v_{qs} i_{ds}\right) = L_m w_e i^2{}_{ds} \quad (4)$$

$$T_m = \frac{3}{2}\frac{PL^2}{L_r} i_{qs} i_{ds} \quad (5)$$

$$P_{fw} = P_S \quad (6)$$

$$\lambda_s = L_m i_{ds} \approx \frac{V}{Ws} \quad (7)$$

B) Converter at grid side

The ac voltage of d-q frame which are fed to grid via grid side converter and power were as depicted below (8-10).

$$v_{dinv} = v_{dg} - r_g i_{dg} - L_g p i_{dg} - wL_g p i_{qg} \quad (8)$$

$$v_{qinv} = v_{qg} - r_g i_{qg} - L_g p i_{qg} + wL_g p i_{dg} \quad (9)$$

$$P_g = \frac{3}{2}(v_{dg} i_{dg} + v_{qg} i_{qg}) \quad (10)$$

Where, v_{inv}= Voltage across inverter

v_g= Grid voltage

δ =Grid angle

The total power that flows through the system is illustrated as

$$P_{fw} = P_s = P_{dc} - P_g \quad (11)$$

As there is a change in the energy that was stored in flywheel, it can be obtained as

$$\Delta E = \frac{1}{2} J(W^2{}_2 - W^2{}_1) = P_{fw} t_{disch} \qquad (12)$$

Where,

J = Moment of inertia for flywheel

W1,W2 =Initial and final speeds

t_{disch}=Discharging time of stored energy

We are well familiar to the power deposited in the capacitor as

$$E=\frac{1}{2} CV^2 \qquad (13)$$

Thus, From the equation (13) the voltage across the dc link is obtain as

$$V_{dc}(t) = \sqrt{\frac{2}{C}\int\left(P_{dc} - P_g - P_{fw}\right)dt + c} \qquad (14)$$

The controlling of flywheel dc link power depends on the controlling of dc link voltage. Hence it is maintained constant

III. CONCEPT OF FAULT-RIDE THROUGH SYSTEM

Faults ride through system [FRT] is nothing but the system used to control the flywheel to operate during normal and fault condition. The flywheel drives the induction machine which depends up on the control indirect feed forward control [IFOC] [15].The basic sketch for the proposed fess based on IFOC is shown in Figure 2.

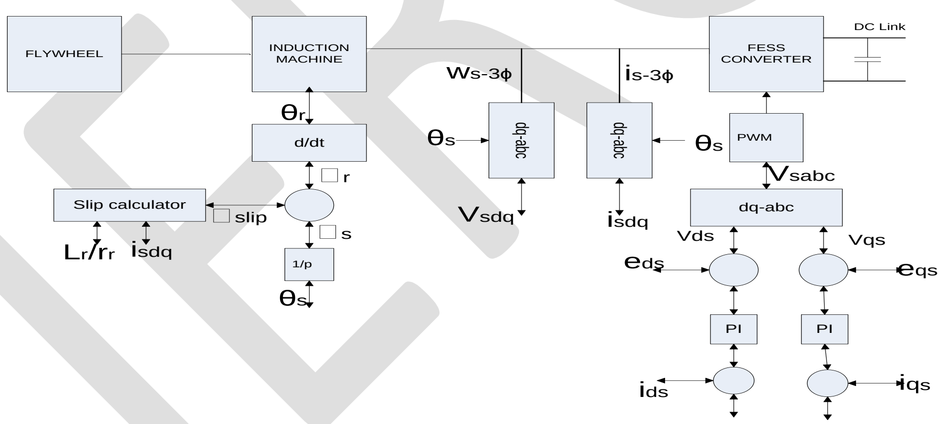


Fig.2 Sketch for proposed FESS based on IFOC

Figure 2 we can say that the dc link power sustains on the wind farm where in turn the fess control and grid side converter under normal operating condition control depends on dc link [16]. As we know that the flywheel has two conditions to be satisfied i.e balancing of power during normal operating conditions and control of dc voltage during faults conditions. The voltage control represents the controlling of torque component for quadrature axis current. The rating of machine [i.e voltage and current]are compared with the integrated power (PV, wind)and grid power to obtain the error which is applied controller in order to get the power across fess .The controller is PI controller as shown in Figure 3.

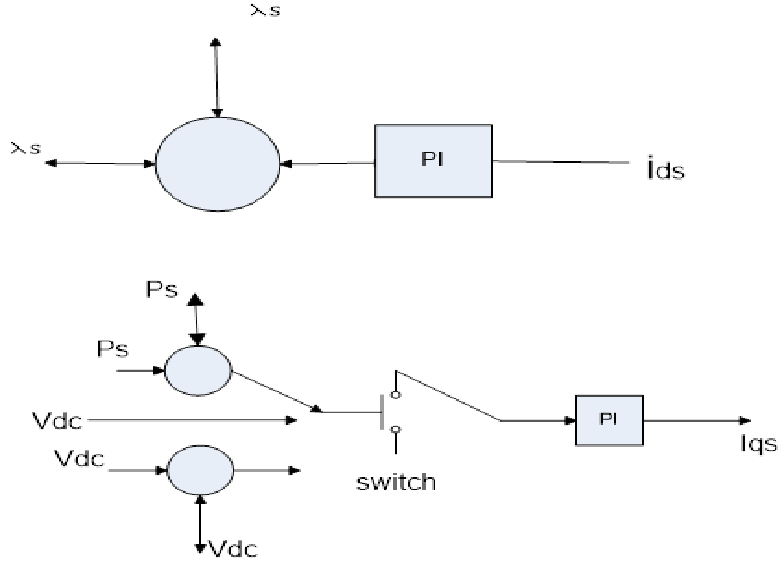
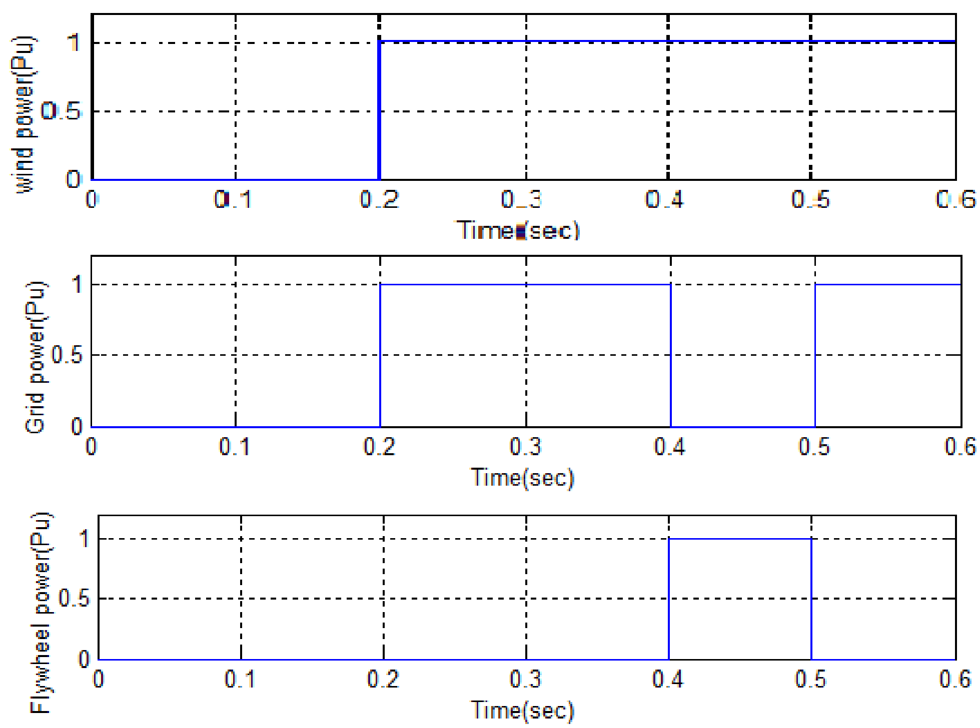


Fig. 3 Based on dc link voltage the switching between normal and abnormal conditions

IV. SIMULATION RESULTS



(a)Power profiles

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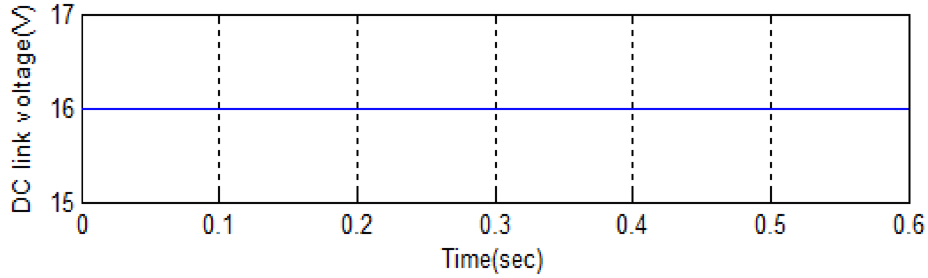
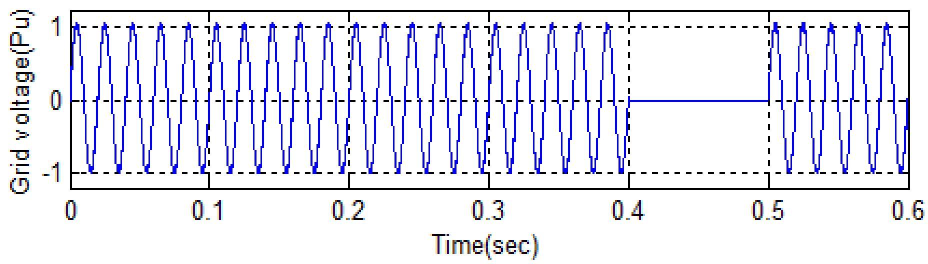
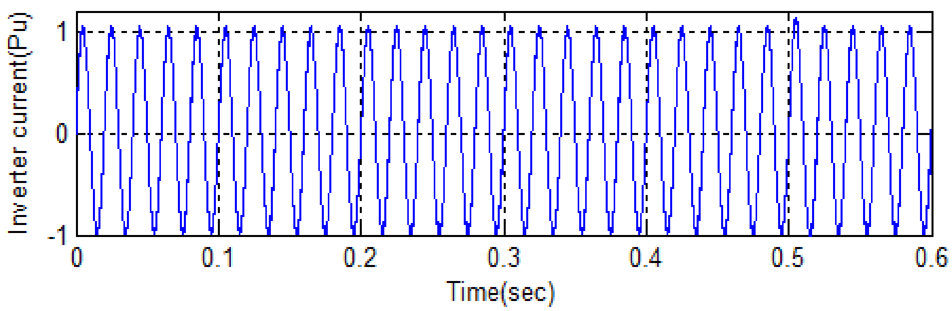


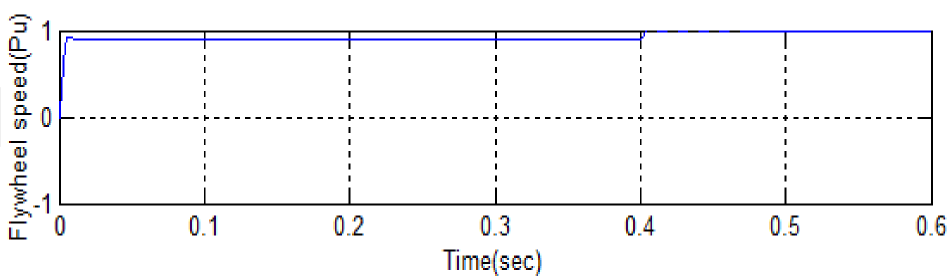
(b)DC link voltage



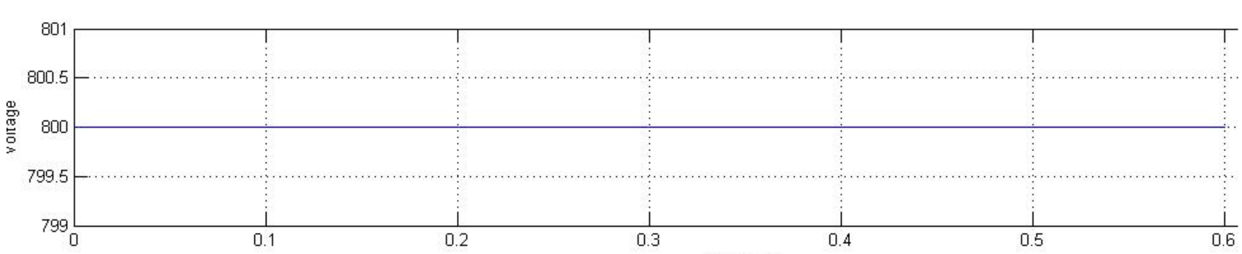
(c)Grid voltage



(d)Main inverter current



(e)Flywheel speed



(f)Photovoltaic cell input energy

Simulation results when three phase to ground fault operation were considered (a)Power profiles(b)Dc-link voltage(c)Grid voltage(d)Main current of inverter(e)Speed of flywheel(f)PV cell input

V. CONCLUSION

An integrated system is used for meeting the requirement of demand at grid. Along with this integrated system a FESS is associated in shunt by a wind side converter which is driven by induction machine. Therefore, an integrated PV system along with fess is proposed in this paper in which the fess operates during the normal condition for balancing the power and discharging of power from fess the grid which was stored during normal condition.

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