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GSC Controlled Micro Grid with WECS System equipped With BESS

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***Abstract*— The places which are far from Grid connection equip micro grid by using Renewable Energy sources. In this paper Remote area places depends on Renewable energy sources like wind power which is capable of supply for local loads. But loads are varying with respect to time; to meet the power demand of this varying local load can be handled by WECS with battery enabled system. Grid side converter connected with Wind generation and BESS are capable of handling the variable load in the system, which can act as static synchronous compensator. This STATCOM is responsible for providing necessary active, reactive power to the grid. The Grid side converter is also responsible for maintaining the quality of power, constant frequency, voltage levels. In this paper different loads are considered like Linear, Non linear and dynamic loads. The system is capable for handling the any type of load demand. Simulation is also gives the results regarding different load demands.**

Keywords— Wind Energy Conversion System (WECS), Self Excited Induction Generator (SEIG); Doubly Fed Induction Generator (DFIG), Static Synchronous Compensator (STATCOM), Decoupled Control, Battery Energy Storage System (BESS), Linear Load, Non-Linear Load, Dynamic Load

I. INTRODUCTION

Wind mills which are equipping Induction Generator specially type of Self Excited Induction Generators SEIG based micro grid systems are having drawback is they are very sensitive and not suitable for variable load conditions, which are operate improperly causes severe damages. If any variations are done in load which may result damage of induction generator mode of operations, as they work in the saturated magnetization region. These load disturbances results in severe oscillations in both voltages, frequency of the system which further collapses the operation of system. To make system stable these self excited induction generators should maintain the voltage, frequency which was done many researches.

To mitigate fluctuation produced in voltage, frequency in SEIG system may application are there, which can be efficient by using FACTS devices. To maintain the required voltage to be constant [8] Static Synchronous Compensator (STATCOM) is used which supplies reactive power. This paper gives the details of a STATCOM equipped with BESS and maintains constant voltage, frequency in SEIG system equipped. A hybrid wind-micro-hydro micro grid system is mentioned in [4], where the micro-hydro generation system houses a 22KW SEIG and the wind system uses a SCIG to generate power. The DC link of the wind system houses a BESS which stores/supplies the required amount of active power from/to the system. In many articles such as [5] electronic load controllers are also used for active power management in SEIG based micro grids.

In this paper a hybrid SEIG-DFIG based micro grid system is considered. The SEIG is fed from a constant power source. The DFIG is controlled by two back to back bidirectional converters. The Rotor side converter (RSC) controls the power flow of the stator side of the DFIG where as the grid side converter (GSC) controls the rotor side power flow as well as maintains the system voltage and frequency by compensating the required amount of reactive and active power respectively. The DC link of the DFIG has a BESS connected to it which serves as an active power storage system. The system is subjected to different types of loads such as Linear R-L Load, Non-linear load and Dynamic load and the performance of the system is evaluated using MATLAB/Simulink environment.

II. SYSTEM CONFIGURATION

The micro grid consists of two generating units i.e. a constant power fed SEIG system and a DFIG based wind system as given in Fig.1.

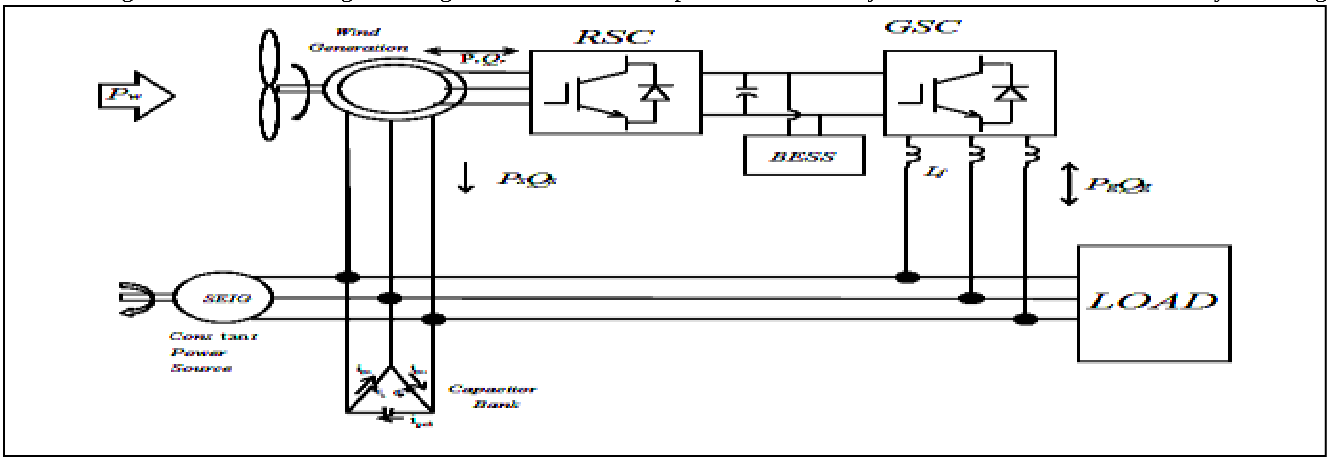

Fig.1 System Diagram of Hybrid Micro grid

Both the system forms a hybrid microgrid which feeds power to a TVL (Time-Varying-Load). The SEIG is greatly affected by the fluctuating load which causes fluctuations in system voltage and frequency.

The DFIG system houses a BESS which stores/supplies the required amount of active power from/to the system. The GSC of the DFIG works as a compensator which compensates the active and reactive power to keep the system voltage and frequency constant. The GSC is controlled by a decoupled control strategy [6], where as the RSC of the wind system controls the stator side power flow of the DFIG and employs a SF (Stator Flux) oriented vector control strategy for that purpose [7]. In this work the stator side power factor is maintained at Unity.

III. CONTROL SCHEMES

A. Control Scheme for RSC (Rotor Side Converter)

The RSC is employed to control the stator side power flow of the DFIG based WECS. The RSC utilizes a stator flux oriented vector control strategy which achieves decoupled control of stator active and reactive power. The control structure of the RSC is given in Fig.2. The RSC is set for unity power factor operation which makes the stator side reactive power zero. The quadrature axis control loop controls the active power.

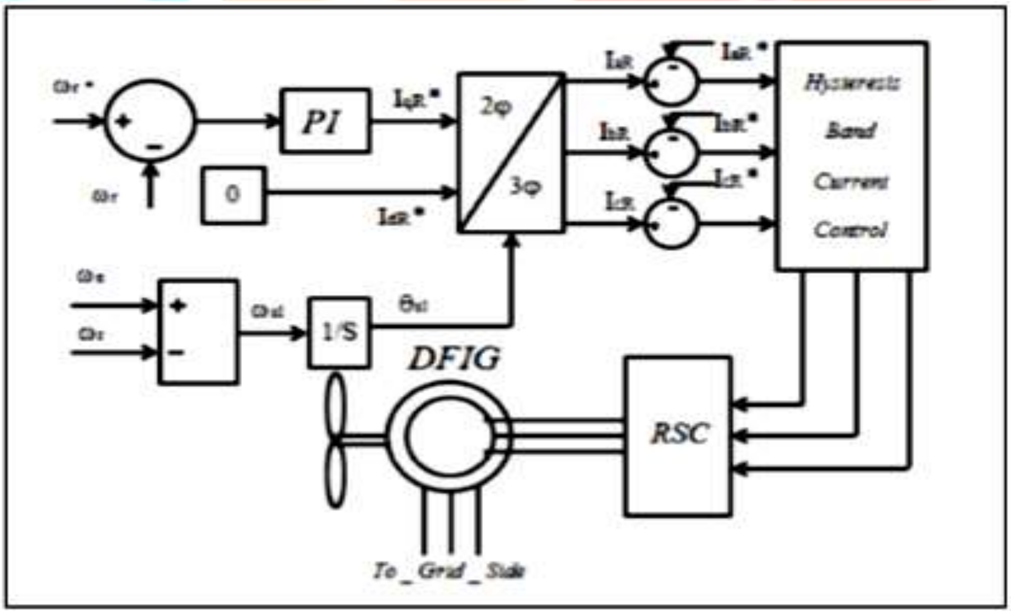

Fig.2. Control Scheme of RSC

B. Control Scheme for GSC-II (Grid Side Converter-II)

GSC-II manages the power of the whole micro grid system. It stores the surplus active power in BESS during light load conditions and feeds power during power deficit. Other than that GSC-II also compensates the required amount of reactive power to keep the system voltage constant during load fluctuation. The control structure of GSC-II is given in Fig.2. The three phase voltage ($V_{a,}V_b, V_c$) of the SEIG system are sensed along with the frequency of the system. This actual frequency needs to be compared with the reference frequency, the frequency error is fed to the PI controller and give the amplitude of the active component of the current (I_{m_P}). From the 3 phase sinusoidal voltage their amplitude can be calculated as

$$V_t = \left\{(2/3) * \left(V_a{}^2 + V_b{}^2 + V_c{}^2\right)\right\}^{1/2} \quad (1)$$

This voltage amplitude t V or voltage of the terminal is compared with the reference-voltage amplitude and produces the amplitude of the reactive current component (I_{m_Q}). The two components i.e. in-phase components and quadrature voltage components of the SEIG voltage are calculated to derive the active and reactive component of the compensating current. The in-phase unit vector are derived as

$$u_a = \frac{V_a}{V_t}, u_b = \frac{V_b}{V_t}, u_c = \frac{V_c}{V_t} \qquad (2)$$

The quadrature unit vectors are derived from the in-phase vectors by the given relation

$$\begin{bmatrix} w_a \\ w_b \\ w_c \end{bmatrix} = \begin{bmatrix} 0 & -\frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{\sqrt{3}}{2} & \frac{1}{2\sqrt{3}} & -\frac{1}{2\sqrt{3}} \\ -\frac{\sqrt{3}}{2} & \frac{1}{2\sqrt{3}} & -\frac{1}{2\sqrt{3}} \end{bmatrix} \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} \quad (3)$$

The three phase active current can be estimated by multiplying the in phase component (u_a, u_b, u_c) with the active current component (I_{m_p}). So

$$i_{a_p} = I_{m_p} * u_a \quad (4)$$
$$i_{b_p} = I_{m_p} * u_b \quad (5)$$
$$i_{c_p} = I_{m_p} * u_c \quad (6)$$

Where I_{m_p} is the active current component of the compensating current Similarly the three phase reactive current can be calculated by multiplying the reactive current component (I_{m_Q}). with the quadrature component w_a, w_b, w_c.

$$i_{a_Q} = I_{m_Q} * w_a \quad (7)$$
$$i_{b_Q} = I_{m_Q} * u_b \quad (8)$$
$$i_{c_Q} = I_{m_Q} * u_c \quad (9)$$

Compensating current of STATCOM is the sum of active current & reactive current which can be expressed as

$$I_{c_a} = I_{a_p} + I_{a_Q} \quad (10)$$
$$I_{c_b} = I_{b_p} + I_{b_Q} \quad (11)$$
$$I_{c_a} = I_{c_p} + I_{c_Q} \quad (12)$$

The $I_{c_a}, I_{c_b}, I_{c_c}$ are the actual value of compensation current which are compared with the reference compensation currents $I_{c_a}{}^*, I_{c_b}{}^*, I_{c_c}{}^*$ and the current errors are compared with a 12.5KHz Triangular Signal to generate switching signals which are fed to the converter.

IV. RESULTS & DISCUSSIONS

In this work the Micro grid system is subjected to different loads and the performance of the system is evaluated. Three different types of loads are considered in this work i.e. linear load, non-linear load and dynamic load. The non-linear load taken into consideration is nothing but a three phase diode rectifier feeding a 'RL' load. The dynamic load is taken as a three phase 7.5 KW squirrel cage induction motor.

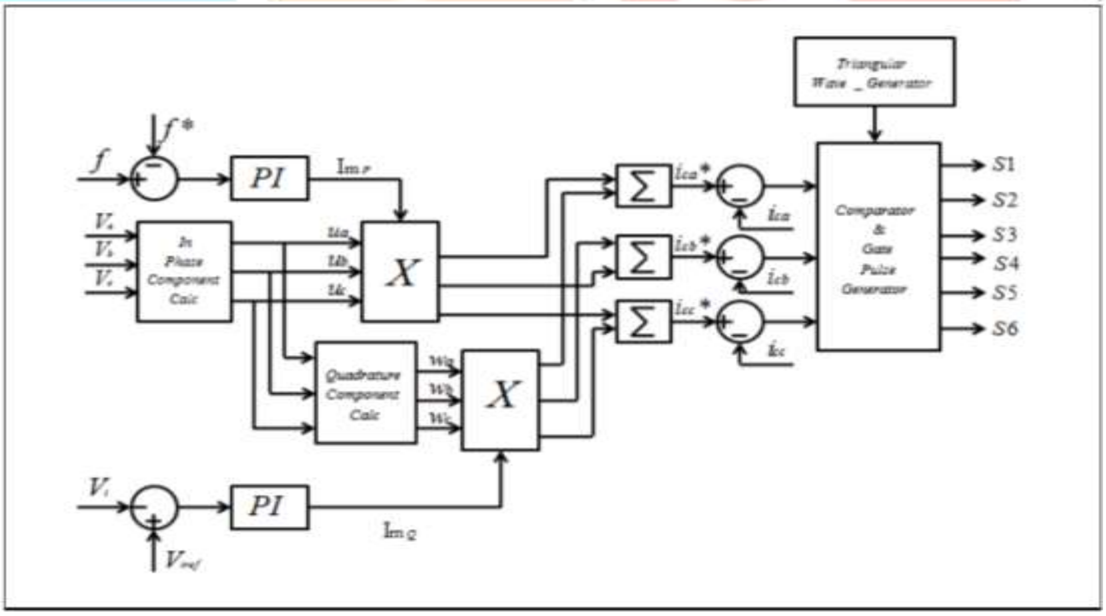

Fig.3 Control Structure of GSC

A. Linear Time Varying RL Load In the first case the system is subjected to a time varying RL type load. The load is changed in steps at time 2.1 sec and 2.2 sec. Fig.4 shows the different response of the system when subjected to linear RL load. It can be clearly seen from the figure that due to the consumption done by the GSC of the wind system the SEIG current and the voltage of the system can be kept unaltered. The active power compensated by GSC is stored or supplied from the BESS as can be seen from the figure. The battery current becomes negative during storage and positive when the BESS supplies power to the system. Due to the appropriate consumption of P and Q by the GSC the F (Frequency) and V (Voltage) are maintained at a constant level. Initially the system was supplying power to a linear RL type load.

B. Non-Linear Load In the second case the system is subjected to a nonlinear load. At time 3 sec a three phase diode rectifier load is switched on. Switching on the non-linear load leads to distorted load current. The GSC in this case acts as a compensator as well as a active filter which eliminates the harmonics from the load current and makes the SEIG current sinusoidal. In this case also appropriate active and reactive power consumption is done by the GSC which helps in achieving constant system voltage and frequency.

C. Dynamic Load Lastly the system is lead to a Dynamic load. Initially the power is supplied to a R-L type load. At time 3 sec a 7.5 KW induction motor was stored direct on line. During starting, the above mentioned load draws a huge amount of VAr from the system which results in a large load current. The GSC compensates the sudden load demand and makes the voltage as well as frequency constant. The sudden Active power(P) demand is supplied by the BESS. Fig. 6 shows the different response of the system when subjected to dynamic load. The P and Q consumption improves the (VP) Voltage profile and (FP) Frequency profile of the system as well as improves its stability.

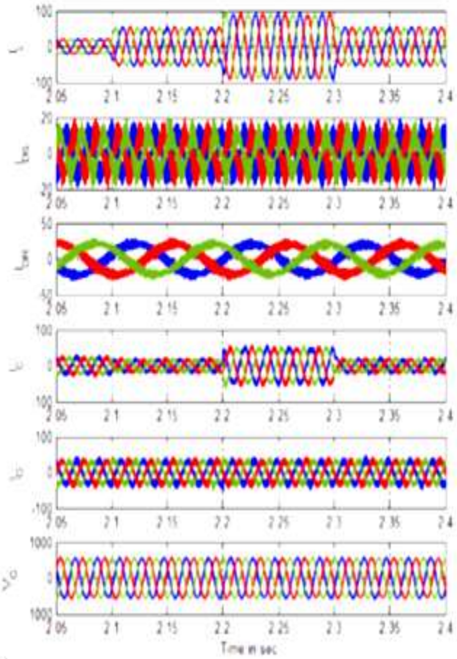

Fig.4 Response of Linear Time Varying Load

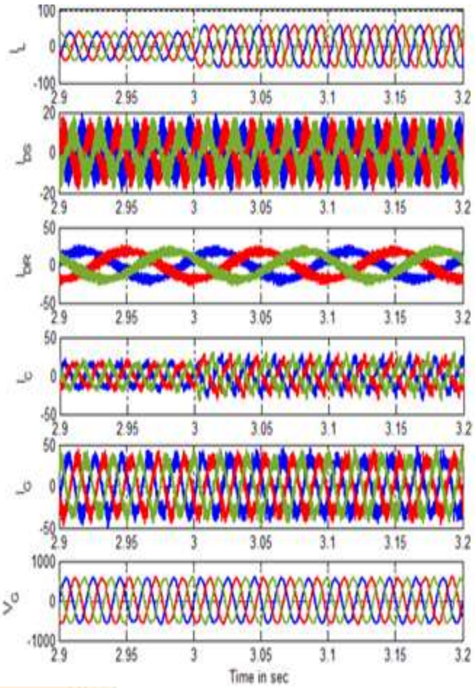

Fig. 5 Non Linear Load

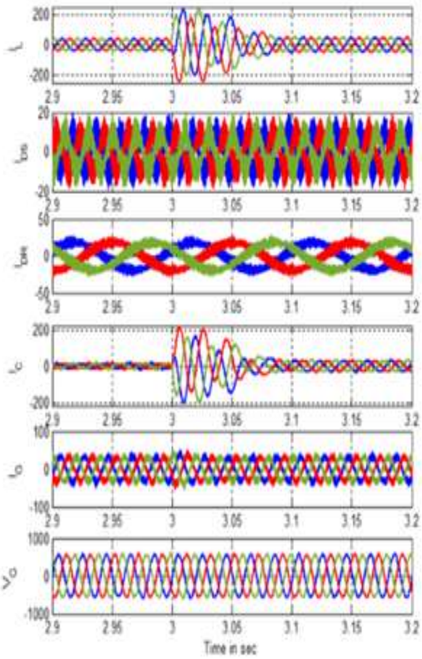

Fig. 6 Dynamic Load

V. CONCLUSIONS

Here a hybrid micro-grid system is taken into consideration. The power flow in the system is controlled by the different converters i.e. rotor side converter and grid side converter. The BESS supplies or stores the power according to the loading conditions. The GSC acts as a robust controller during the dynamic loading condition. It restores the system parameters back to its original value. In non linear loading the GSC compensates the unbalanced load current by supplying the compensating current and makes the SEIG current balanced. It supplies the required active power by the BESS. Moreover the RSC controls the stator side power. As the GSC acts like a STATCOM in the hybrid micro-grid system as it supplies both the active and reactive power as demanded by the load.

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