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Control of PV-Wind-Diesel Hybrid System with BESS for Optimal Operation

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Abstract: - This work presents a proposed power system with a diesel generator (DG), wind energy conversion system and solar photo voltaic (PV) system. The proposed power system with its control techniques, regulates the loading of DG to achieve a low specific fuel consumption with the help of wind energy conversion systems (WECS) and SPV system. The doubly fed induction generator (DFIG) is used in WECS system. The WECS system consists of two voltage source converters (VSCs) for the system control. One converter is the rotor side converter (RSC), which helps in achieving maximum power point tracking of the wind turbine. Another one is the generator side converter (GSC), which helps in regulating DG generation while maintaining WECS generator as well as Diesel generator currents balanced, unbalanced and harmonics within the requirement of the IEEE-519 standard at different load conditions. The system envisages an energy storage by connecting a battery bank at the DC bus of DFIG. The battery bank provides a buffer storage. To increase optimal operation, solar PV system with MPPT technique also integrated with DG system, and SPV system with MPPT algorithm maintain DC link voltage. The proposed power system is modelled using MATLAB Sim-power-system tool box and proposed system performance results are presented under variation of linear loads, nonlinear loads, unbalanced loads.

Key Words— ***Fuel Efficient Zone, DGs, Solar PV system, Wind Energy conversion system***

I. Introduction

A hybrid of DG and WEG in an autonomous system, has been proposed by many authors. The wind-diesel hybrid system without storage as an autonomous system, has been proposed in [3-7]. WDHS has been presented with permanent magnet synchronous generator (PMSG) [4], a three phase induction generator [5] and a doubly fed induction generator (DFIG) [6-7]. These authors in their work, have important highlighted way to achieve power regulation in view of changing power output of WEG. They have not touched load regulation of DG to achieve Fuel Efficient Zone operation, which can only be achieved with an energy storage. Haruni *et al.* [4] have presented a control scheme of power sharing between PMSG and DG. However, it is without an energy storage and it uses energy dissipation through a dump load. Singh *et al.* [8-12] have presented a scheme of DG with a battery energy storage system (BESS) to achieve Fuel Efficient Zone operation of DG. Some authors have presented wind diesel hybrid system with an energy storage [9-12]. Cendoya *et al.* [12-15] have presented a wind diesel hybrid system with the mechanical storage system. The pumping system discussed may not be suitable for all places while flywheel suffers from the limitation of an energy storage capability. The authors in [10-11], have presented the scheme of load leveling through BESS, however, they have not touched the aspects of neutral and harmonic currents compensation. Geeta *et al.* [15-21] have presented BESS based wind solar hybrid system by using permanent magnet brushless DC generator.

The authors in their work for wind-PV-diesel system, have presented compatibly of the DGs to accommodate solar power, wind power and power quality issues. With the help of solar PV and battery storage, the objectives of the research have been to provide the regulated power to absorb solar and wind power fluctuations. This paper presents a wind-PV-diesel hybrid system forming a microgrid with a battery storage and load regulation to achieve (Fuel Efficient Zone).

II. Control Technique

The control of proposed system, consists of three sub-control blocks namely GSC system set (in Fig.1), RSC system set (in Fig.2), and MPPT algorithm (in Fig.3), which are described below.

A. GSC system set:

The following functions of GSC system set are

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- It maintains DFIG currents sinusoidal.
- It generates the required non-fundamental current under nonlinear loads.
- It maintains each DG voltage within limits.

I_{qr}^{*} is generated from the generator speed error, ω_{err} as,

$$I_{qr(k)}^{*} = I_{qr(k-1)}^{*} + K_{p\omega}(\omega_{err(k)} - \omega_{err(k-1)}) + K_{i\omega}\omega_{err(k)} \quad (1)$$

θ_{slip}, is as follows,

$$\theta_{slip} = \int_{0}^{t} \{\omega_e - \omega_r - (\pi/2)\} dt \quad (2)$$

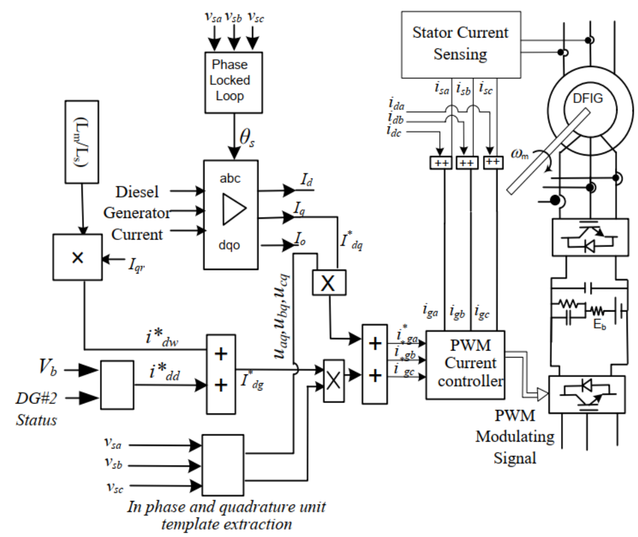

Fig.1. Control diagram of GSC system set

B. RSC System set:

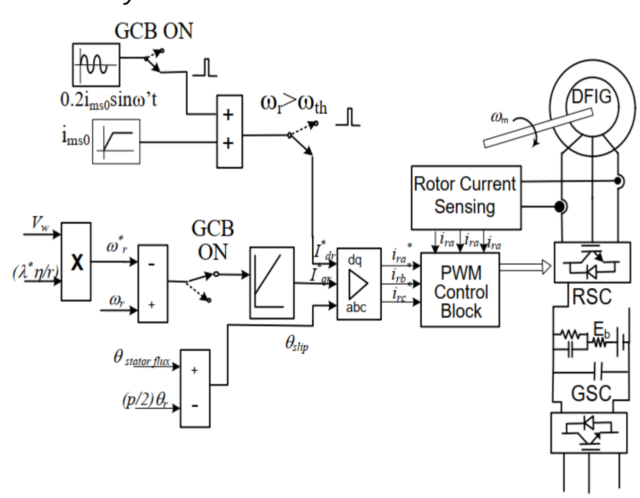

Fig.2. Control diagram of GSC system set

I_{dg}^{*} current generation: I_{dg} is the d-axis component of GSC converter at voltage angle and is computed as

$$I_{dg}^{*} = I_{dws}^{*} + I_{dd}^{*} \quad (3)$$

I_{dws}^{*} is the set-point of the WECS wind generator related to the quadrature(Q-axis) component of WECS rotor current and is calculated as,

$$I_{dws}^{*} = -L_m \times I_{qr} / L_s \quad (4)$$

P_d^{*} is the reference power from the DGs and is derived as,

$$P_d^{*} = \{0.4 * (260 - E_b)/40 + 0.65\} \times 2 \quad (5)$$

Having known P_d^{*}, I_{dd}^{*} i.e. reference direct component of DG current at voltage angle is computed as,

$$I_{dd}^{*} = (P_d^{*} \times 7500 \times \sqrt{2}) / 415 \quad (6)$$

C. MPPT algorithm:

MPPT algorithm extracts maximum power from the solar PV with the help of dc-dc converter and also maintain DC link voltage. The primary function it increases optimal point operation of DGs.

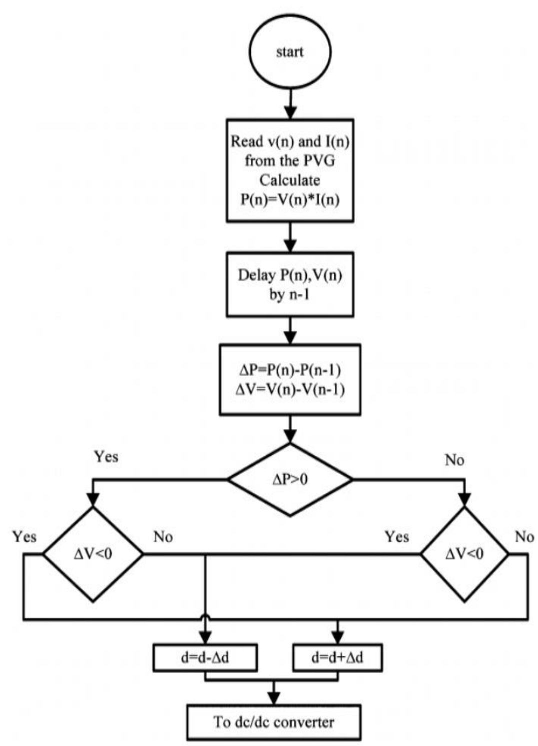

Fig.4. Control diagram of GSC system set

III. Proposed System

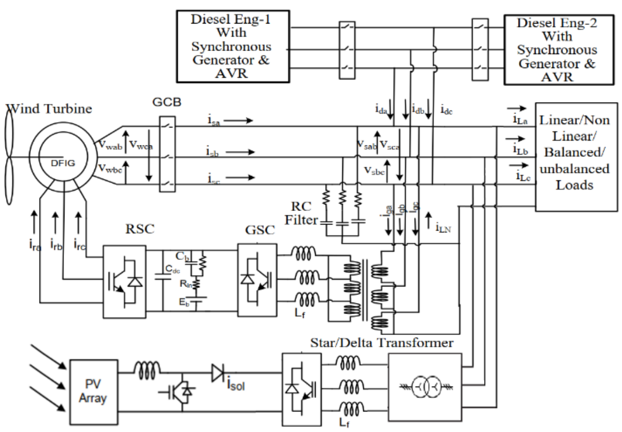

Fig. 5. Proposed System

Fig. 5.1 shows a schematic diagram of the Proposed System with a BESS. The Proposed System is designed for a locality having peak load demand of 15 kW. The capacity utilization factor of the generator in line with the commercially available machine, is taken as 20 % [13]. The rated capacity of each DG is taken 7.5 kVA and there are two DGs in proposed system. The total capacity of both the DGs, is 15 kVA. The rated capacity of the WEG, is taken as 15 kW. Proposed System consists of DFIG with two voltage source converters (VSCs) connected to rotor and stator [6].

In the presented scheme, the VSC connected to the rotor is termed as rotor side converter (RSC) and the VSC connected to stator as generator side converter (GSC). As shown in Fig. 5, the AC sides of RSC and GSC, are connected to rotor windings and the generator terminals, respectively. The rated line voltage of DG as well as DFIG, is 415 V.

The description of major components of Fuel Efficient Zone along with sizing criteria, is shown in the following sub-sections.

IV. Results And Discussion

Simulated results of proposed system at different practical conditions are shown in Figs. 6-7. Figs. 6-7 shown performance of proposed system at balanced inductive load and Efficient fuel zone operation of two DGs. Fig. 9 presents results of proposed system at unbalanced condition under nonlinear inductive loads. Fig. 10 presents performance during outage of WEG from DG grid. Figs. 11-12 present performance at reconnection of the wind turbine as well as the effect of varying wind speed. Fig. 13 shows performance of proposed system at low demand and high generation. Simulated results establish the compatibility of wind-diesel hybrid system for all type of loads as well as load regulation to Efficient fuel zone operation [5].

A. Performance of the proposed system Showing Efficient fuel zone Operation of two DGs

The performance of proposed system under synchronization and Efficient fuel zone operation at varying loads, is shown in Fig. 7 and Fig.8, respectively. Both DGs are started with balanced 12 kW connected load as shown in Fig.8. After attaining steady state synchronous speed, wind generator is taken in to service. The loads of 8 kW in a step of 4 kW are removed at t=9.5 s and at t=10.5 s. Based on the voltage level of DC bus, reference DG power, P_d^* of value 1.3 p.u. is generated. It is seen from Fig. 8 that the reduction of the load, P_L doesn't reduce DG loading and DG remains in Efficient fuel zone. The surplus power is diverted to the battery through GSC. The coordinated control of RSC and GSC, maintains the diesel generators power output at the reference level.

B. Performance of proposed system at Unbalanced Nonlinear Inductive Load

The unbalanced nonlinear load is commonly used at distribution level and performance of the system under such loads is shown Fig. 9. current, *icon* and under extreme unbalanced load too the system continues to maintain balanced currents of generators with acceptable level of harmonics as shown in Table-I. *THDV* (Total Harmonics Distortion) of voltage at the load terminal meets requirement of the IEEE-519-2014 standard [20].

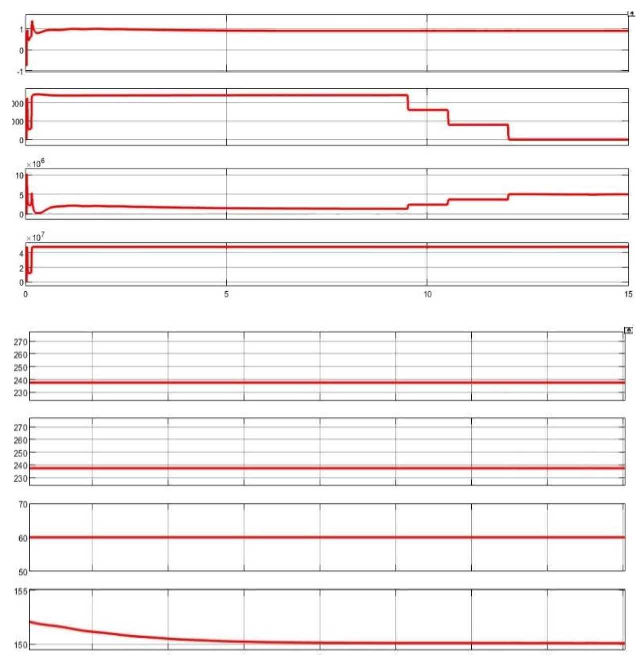

Fig. 6. Performance of proposed system showing Efficient fuel zone operation of DGs.

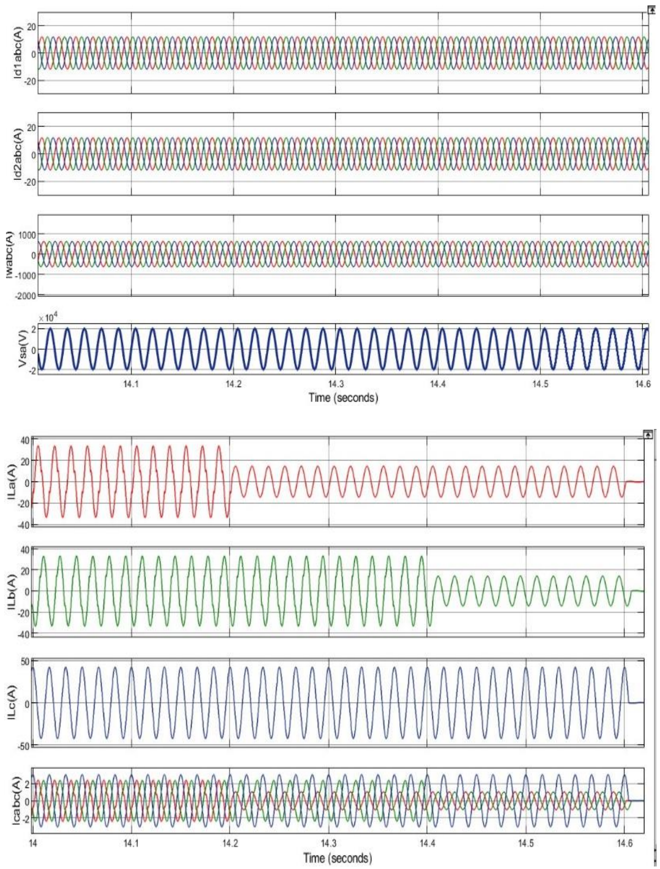

Fig. 7. Performance of proposed system under unbalanced and nonlinear load

The system is started at balanced load of 15 kW comprising of 7.8 kW nonlinear load and 7.2 kW linear load. At t=14.2 s, the load of phase 'a' is removed. At t=14.4 s, the phase 'b' load is also removed making the complete system at single phase load. It is observed from Fig. 9 that the harmonics requirement of load is met by converter

V. Conclusion

The proposed system has promising scope for islands, which are totally dependent on the diesel-based generation. The load regulation capability of the diesel generator to operate in Efficient fuel zone reduces specific fuel consumption. The MPPT feature of proposed system in control, helps in maximizing generation and further helps to reduce the cost of the energy. The system is also able to maintain phase currents balanced as well as and current harmonics within an acceptable limit for all types of loads. The effectiveness of the system is demonstrated using simulated and test results and it is found that the power quality is within acceptable limit under all practical scenarios.

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