ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Monthly Peer Reviewed Open Access International e-Journal

Design of Control Strategy for Integration of Grid with Hybrid Wind Energy Conversion System (HWECS) For Power Control in Distribution Power Generation System (DPGS)

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Abstract:

The paper proposes the control technique for integration of wind energy conversion system with distribution system. Grid connected wind system is having disadvantage of fluctuate wind conditions. Hybrid energy sources wind, hydrogen, and super capacitors are connected to Dc-link. System efficiency has an important role in order to harvest the maximum available renewable energy from DC or AC sources whilst providing power backup capability.

The control system having operation of better power management across DC-link connected between the hybrid wind energy conversion system and grid. In this paper there are two types of control strategies are proposed for effective power control of the distribution power system. The two control strategies are "source following" and "grid following". Comparisons between control strategies are done by verifying in the MATLAB/Simpower System tool and performance characteristics are given for validation in simulation results section.

Index terms :

Wind Energy Conversion System (HWECS), Distribution Power Generation System (DPGS), power management, Grid integration.

I.INTRODUCTION:

Electrical power demand within a micro-grid power system requires reliable functionality, storage of energy, diagnostics, remote device control and monitoring as important functions of modern Distributed Power Generation (DPG) modules. Renewable energy sources like solar, wind, and micro-hydropower can be interfaced through the DPG modules with the micro-grid system which can operate in islanded mode (off-grid) and grid-connected mode.

The micro-grid operation needs to respond to the load demand under any circumstances therefore back-up with energy storage elements is essential. The micro-grid presented in this paper is a low voltage application and it is comprised of DPG modules, distributed energy storage elements, electrical distribution gear and controllable loads. DPG modules are critical components within the micro-grid systems and need to have flexible features in order to respond for a wide range of applications. DPG are designed to operate in islanded mode, utility grid-connected or genset-connected (diesel, liquid propane generators).

DPG converter modules may have the following modes of operation: voltage-controlled source, current controlled source, active rectifier and active power filter mode. The converted energy produced can be delivered to the local loads within the micro-grid structure or exported to the utility grid.

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In active rectifier mode, with ac to dc energy conversion the DG has a multi loop embedded control with power factor correction and dc voltage and current are controlled typically for battery charging [1]. In active power filter mode selective ac current harmonics are generated to cancel out the load current harmonics from the fundamental line frequency [2]. PV inverters are typically DPG operating in current controlled mode, with dc to ac energy conversion where ac current is controlled in magnitude and phase [3]. Transformers less PV inverters represent an attractive solution due to higher efficiency, smaller size and weight, reduced cost [4].

Hybrid-converters interface dc energy sources (e.g. PV generators, wind turbines, fuel cells) and ac energy sources (e.g. utility grid, gensets) at both dc and ac ports. In voltage-controlled source mode, with dc to ac energy conversion, the ac voltage and frequency are controlled to meet the power quality requirements. In this mode of operation the hybrid converter can operate in islanded micro-grid where multiple modules can be paralleled in order to support the ac loads.

Methods of active current sharing with communication between paralleled modules are available in the technical publications. The advantage of this method is ease of synchronization of paralleled DPG with the grid prior to the transfer, peer-to-peer data interchange between DPGs for centralized micro-grid power management, single phase to three phase system conversion with multiple DPG modules [5]. The disadvantage is the need of hardware interconnection between DPGs and droop control methods is a more attractive solution in order to avoid the communication signals between multiple paralleled modules [6]. With voltage-controlled source DPG in islanded mode, the ac loads harmonics can be evenly shared among the DPG modules with implementation of enhanced droop harmonic compensation control methods [7].

For higher electrical power demand multiple DPG can be parallel connected; the ac transfer islanded/grid connected command among DG units is issued by the system master via CAN bus. For a no-wire communication between the voltage-controlled DPG modules special attention should be given during the transfer since the independent voltage-controlled sources do not transfer in the same time.

The goals of this paper are to introduce a new control method based on the micro-grid line frequency variation as agent of communication for energy control among the DPG modules while presenting the interfacing of wind energy conversion system using the wind inverter with hybrid converter system integration. Section II gives structure of hybrid power system; section III describes the control strategies for grid integration, simulation results for validation of proposed control strategies with grid integration in Section IV. And finally Section V concludes the paper.

II.STRUCTURE OF HYBRID POWER SYSTEM (HPS):

In this Section, a dc-coupled structure is mentioned in order to decouple the grid voltages and frequencies from other sources. All sources are connected to a main dc bus before being connected to the grid through a main inverter. Each source is electrically connected with a power-electronic converter in order to get possibilities for power control actions. Moreover, this HPS structure and its global control system can also be used for other combinations of sources. The block diagram representation of Hybrid Power System is shown in figure 1.

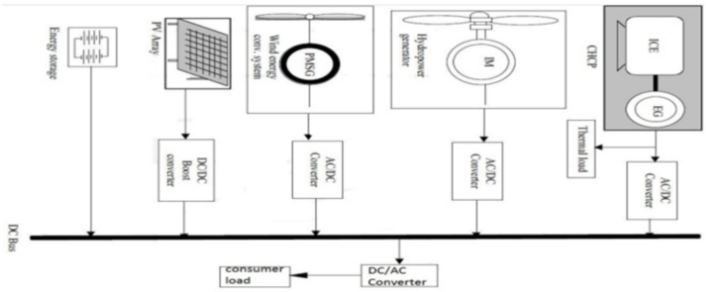

Figure 1: Block diagram representation of Hybrid Power System (HPS)

Stand alone mode:

When it is necessary to supply electrical loads in standalone configuration there is no particular standard that define the power quality requirements [8]. Anyway, the mains concepts of power quality regulation in grid connected systems can be used also for standalone systems and as general guidelines, a power quality level close to the one guaranteed for loads fed by the grid can be choosing.

In stand-alone systems, the main issue regarding electric Power Quality is to guarantee the supply continuity. The main causes of power supply interruption in stand-alone systems are due to fault in the renewable power plants. The electric grids that connect the renewable power plant to the loads are usually very short and simple so a fault event on the grid is very rare [9]. The structure of stand-alone grid connected RES is shown in figure 2.

In stand-alone systems, the supply interruptions caused by a lack of energy of the renewable power plants can be analyzed using the concept of Loss of Power Supply or Loss of Load (LPS or LOL) and Loss of Power Supply-Probability or Loss of Load Probability (LPSP or LOLP). The LPS and LPSP concepts are more or less equivalent to the LOL and the LOLP concepts, so only the LPS and LPSP indexes will be considered.

The LPSP index expresses the probability to have a supply interruption on the stand alone loads, due to a lack of power of the renewable power plant. In an existing system, the LPSP can be defined as the sum of the energy not supplied to the loads during the supply interruptions occurred in a year, divided by the total energy required by the loads during the year as indicated as:

$$LPSP = \sum_{i=1}^{N} {E_{1_{NS},i}} / {E_{1\_tot}} \quad - (1)$$

The LPSP can also be expressed in function of the power demand of the loads during the supply interruption and the duration of the supply interruptions as indicated as

$$LPSP = \left(\sum_{i=1}^{N} \int P_{1_{NS},i}(t).dt\right) / {E_{1\_tot}} \quad - (2)$$

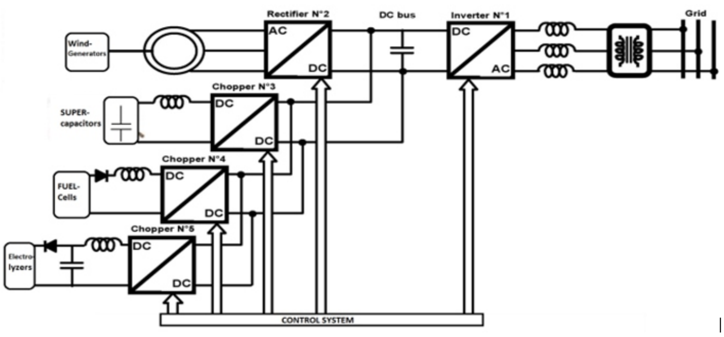

Figure 2: stand-alone RES connected HPS system

III.CONTROL STRATEGIES:

Energy management and power control of Hybrid Power System interconnected with Hybrid Active Wind Energy Conversion System is done by two control strategies. They are "Grid following" and "source following". Grid-Following Strategy: the dc-bus voltage is regulated by adjusting the exchanged power with the grid in grid following technique. The DC-bus

voltage control loop is $(p_{dc\_ref} - p_{g\_ref} - p_g - p_{dc})$. The required power for the dc-bus voltage regulation (p_{dc_ref}) is used to estimate the grid power reference (p_{g_ref}).

The source total power (p_{sour}) is a disturbance and should also be taken into account with the estimated wind power and the sensed total storage power.

The energy storage systems help the wind energy conversion system satisfy the power references, which are asked by the micro-grid operator. In steady state, the dc-bus voltage is regulated, and the averaged power exchange with the dc-bus capacitor can be considered as zero. Hence, in steady state, the grid power (p_g) is equal to the total power from the sources (p_{sour}). If the micro-grid system operator sets a power requirement (p_{gc_ref}), it must be equal to the sources' power reference (p_{sour_ref}). The block diagram of grid-following strategy is shown in figure 3.

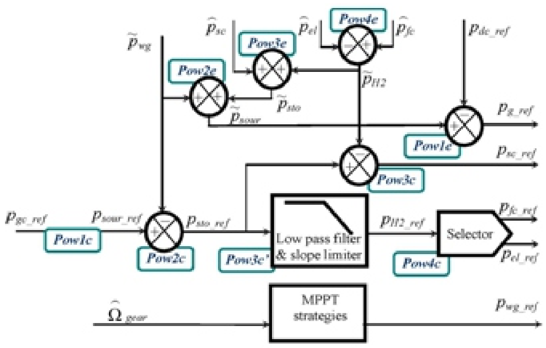

Figure 3: Block diagram of the grid-following strategy.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
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In order to help the wind energy conversion system respect the active-power requirement, the energy storage systems should be coordinated to supply or absorb the difference between this power requirement (p_{gc_ref}) and the fluctuant wind power (p_{wg}), as shown in Figure 3.

Among the energy storage systems, the FCs and the ELs are the main energy exchangers because a large quantity of hydrogen can be stored for enough energy availability. For efficiency reasons, the FC and the EL should not work at the same time. The activation of the FC or the activation of the EL depends on the sign of the reference (p_{h2_ref}). Thus, a selector assigns the power reference (p_{h2_ref}) to the FC (p_{fc_ref}) or to the EL (p_{el_ref}) according to the sign of (p_{h2_ref}). (Figure 3).

However, the power reference (p_{sto_ref}) is a fast-varying quantity due to the fluctuant wind power (p_{wg}) and the varying grid power (p_g). In order to avoid the fast-chattering problem when it is close to zero, it should be slowed down. Moreover, the FCs and the ELs have relatively slow power dynamics, and fast-varying power references are not welcome for their operating lifetime. Therefore, a low-pass filter (LPF) with a slope limiter should be added (Figure 3).

The SCs are not made for a long-term energy backup unit because they have limited energy storage capacities due to their low energy density. However, they have very fast power dynamics and can supply fast-varying powers and power peaks. They can be used as an auxiliary power system of the FCs and ELs to fill the power gaps during their transients.

Source-Following Strategy:

The total power (p_{sour}) from the energy storage and the WG can also be used to provide the necessary dc power (p_{dc}) for the dc-bus voltage regulation (Figure 4). In this case, the necessary total power reference (p_{sour_ref}) must be calculated by taking into account the required power for the dc-bus voltage regulation (p_{dc_ref}) and the measured grid power (p_g) as disturbance input by using the inverse equation of Pow1 (Figure 4).

Then, the total power reference of the storage systems is deduced by taking into account the fluctuant wind power with the inverse equation of Pow2. This power reference is shared among the FCs, the ELs, and the SCs in the same way as explained earlier.

In addition, now, the grid power reference (p_{g_ref}) is free to be used for the grid power control. The micro-grid system operator can directly set the power requirements (p_{gc_ref} and Q_{gc_ref}) for the grid connection system (p_{g_ref}=p_{gc_ref}). Therefore, the HPS can directly supply the required powers for providing the ancillary services to the micro-grid, like the regulations of the grid voltage and frequency. The block diagram of the grid-following strategy for the active WG is shown in Figure 4.

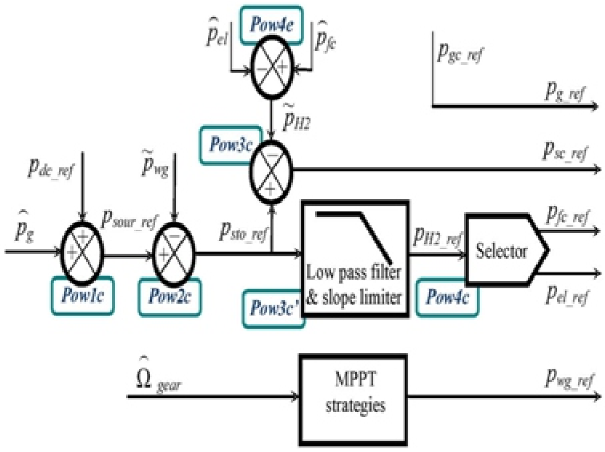

Figure 4: Block diagram of the source-following strategy.

IV.SIMULATION RESULTS:

In this section simulation results are given. The wind/hydrogen/SC HPS, five power-electronic converters are used to regulate the power transfer with each source. According to a chosen power flow, the following two power balancing strategies can be implemented.

1) The grid-following strategy uses the line-current loop to regulate the dc-bus voltage.

2) The source-following strategy uses the line-current loop to control the grid active power, and the dc-bus voltage is regulated with the WG and storage units.

Simulation circuit for Hybrid wind active power conversion system is shown in figure 5

By designing simulation circuit in matlab/simpower system active power generated by hybrid sources (wind, super capacitors, fuel cell, and electrolyzes) are observed.

Before comparing the two different control strategies (grid following and source following) performance, the active powers generated by input sources have to be observed.

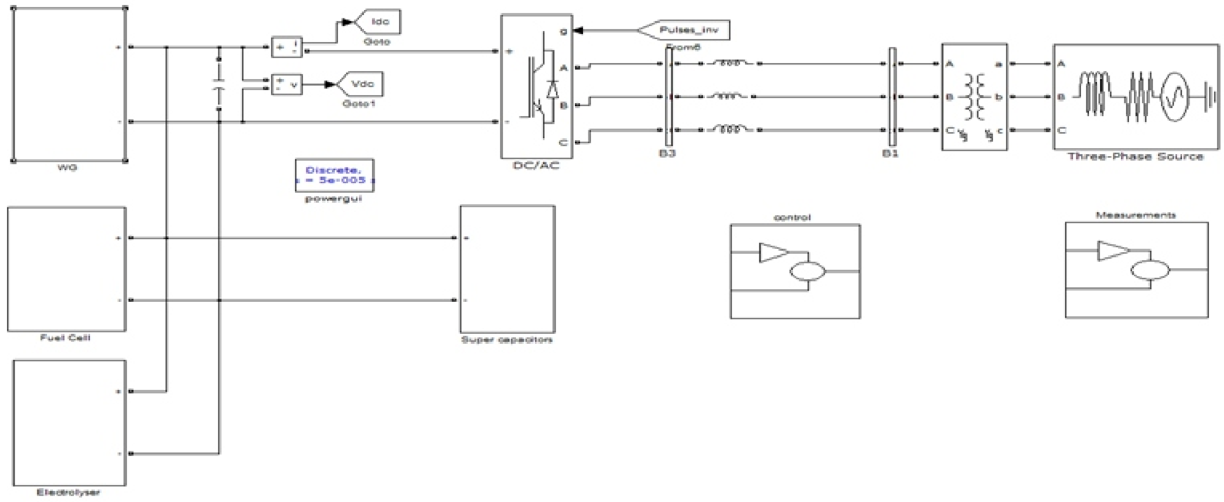

Figure 5: implementation of simulation test circuit for proposed HPS.

The hybrid active wind energy system is taken as primary input source, and super capacitors, fuel cells, electrolyzers are considered as supplementary sources for WECS. The active power generated by wind generator is shown in figure 6, fuel cell power generated is shown in figure 7, figure 8 shows the electrolyzer active power generated and finally super capacitors power injected is observed in figure 9.

The power control of distribution power generation system interconnected with renewable energy sources is very typical in operation. This needs very effective power control technique. In this paper the two new control strategies are proposed. And finally one control strategy is having the better power across grid interconnected. The control strategies are grid following and source following. The control circuit for Grid-following strategy is shown in figure 10.

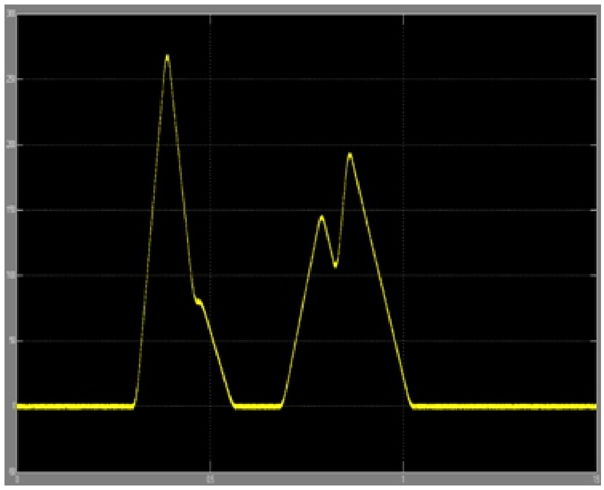

Figure 6: wind generator active power (p_wg)

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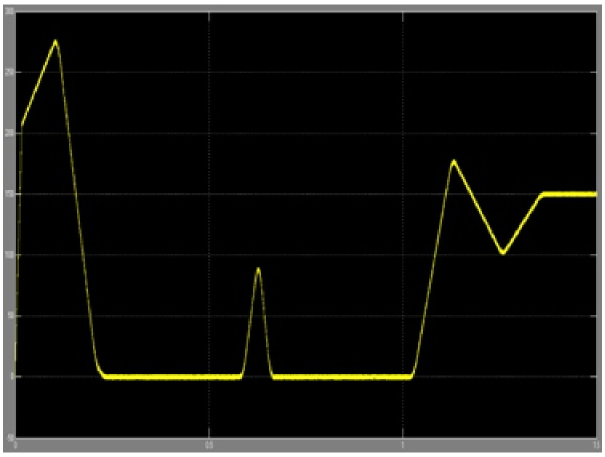

Figure 7: fuel cell active power (p_fc)

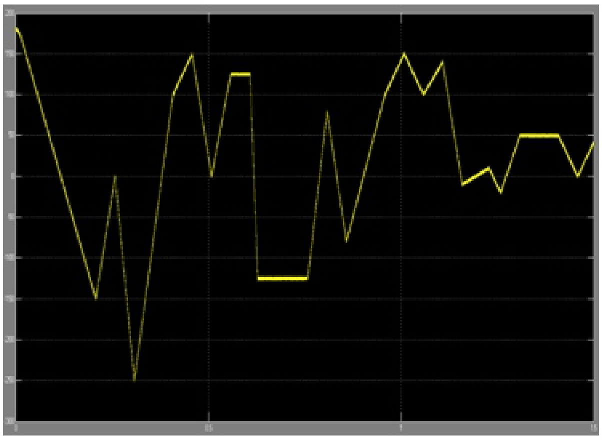

Figure 8: electrolyzer active power (p_el)

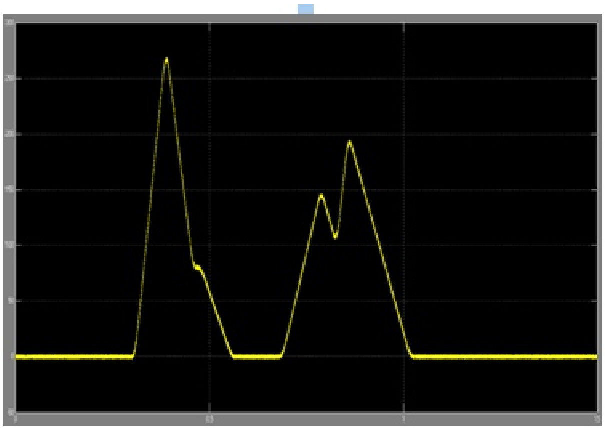

Figure 9: super capacitors active power (p_sc)

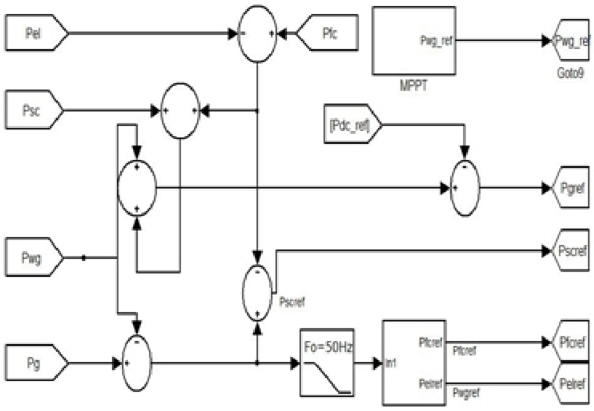

Figure 10: simulation power circuit in grid following strategy

For comparison of two different strategies proposed in this paper, there is need to verify the performance characteristics of Hybrid Power System operated with two control strategies. The DC-link voltage of bus when operated with grid following strategy is shown in figure 11. And reference grid power generated is shown in figure 12

Figure 11: DC-link voltage (v_dc) of HPS under grid following strategy.

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Figure 12: grid active power (p_g) of HPS under grid following strategy.

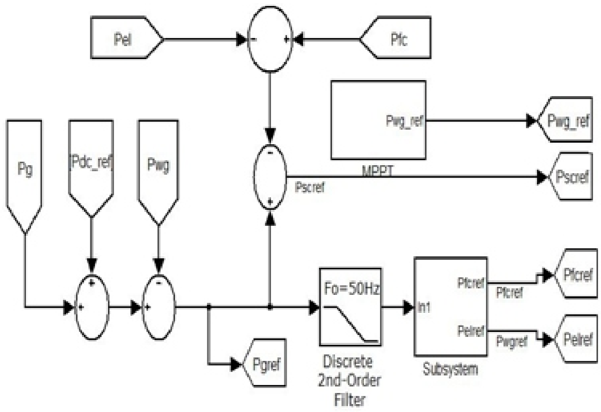

Figure 13: simulation Power circuit for source following strategy.

Figure 14: DC-link voltage (v_dc) under source following strategy.

Figure 15: grid active power of HPS under source following strategy

V.CONCLUSION:

In this paper hybrid active wind energy conversion system interconnected with distribution Power generation system is proposed. WG as a renewable energy generation system, SCs as a fast-dynamic energy storage system; and FCs with ELs and hydrogen tank as a long-term energy storage systems are connected with HPS through DC-coupled link. Energy management and power control between the RES and grid achieved by the two different control strategies.

They are grid following and source following strategies. Performance characteristics of power system are validated with both control techniques by MATLAB/SPS Tool. By simulation results it is concluding that Hybrid Power System is having better power control with source-following control technique when compared with grid-following strategy.

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