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Power Management in Isolated AC Microgrids using WECS and BESS

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ABSTRACT:

In this project the possibility of controlling the power generated inside an isolated microgrid, assuring the control of the voltage at the energy storage systems terminals, without using dump loads to dissipate the surplus of energy or a physical communication between converters. a new methodology to control the generated power by the wind turbine, a new design and tuning of the terminal voltage controller of the battery bank and by the presentation of experimental results, including variable wind speed operation. With energy storage systems based on battery it is not necessary to measure or estimate the state of charge of the batteries, only measuring the terminal voltage of them is sufficient. The proposed method allows for a continuous and smooth reduction of the power generated by the existing sources in the microgrid and therefore a charging procedure where the batteries can be charged up to 100% of their capacity. In this project, the power system consists of a power electronic converter supplied by a battery bank, which is used to form the AC grid (grid former converter), an energy source based on a wind turbine with its respective power electronic converter (grid supplier converter), and the power consumers (loads).

I. INTRODUCTION:

Wind turbines can be classified into the vertical axis type and the horizontal axis type. Most modern wind turbines use a horizontal axis configuration with two or three blades, operating either down-wind or up-wind. A wind turbine can be designed for a constant speed or variable speed operation. Variable speed wind turbines can produce 8% to 15% more energy output as compared to their constant speed counterparts, however, they necessitate power electronic converters to provide a fixed frequency and fixed voltage power to their loads. Most turbine manufacturers have opted for reduction gears between the low speed turbine rotor and the high speed three-phase generators. Direct drive configuration, where a generator is coupled to the rotor of a wind turbine directly, offers high reliability, low maintenance, and possibly low cost for certain turbines. Several manufacturers have opted for the direct drive configuration in the recent turbine designs. At the present time and in the near future, generators for wind turbines will be synchronous generators, permanent magnet synchronous generators, and induction generators, including the squirrel cage type and wound rotor type. The main problem with wind energy in weak grids is the quasi-static voltage level. In a grid without wind turbines connected the main concern by the utility is the minimum voltage level at the far end of the feeder when the consumer load is at its maximums as shown in fig1.

So the normal voltage profile for a feeder without wind energy is that the highest voltage is at the bus bar at the substation and that it drops to reach the minimum at the far end. The settings of the transformers by the utility are usually so, that the voltage at the consumer closest to the transformer will experience a voltage, that is close to the maximum value especially when the load is low and that the voltage is close to the minimum value at the far end when the load is high. This operation ensures that the capacity of the feeder is utilized to its maximum.

When wind turbines are connected to the same feeder as consumers which often will be the case in sparsely populated areas the voltage profile of the feeder will be much different from the no wind case. Due to the power production at the wind turbine the voltage level can and in most cases will be higher than in the no wind case. As is seen on the figure2 the voltage level can exceed the maximum allowed when the consumer load is low and the power output from the wind turbines is high. This is what limits the capacity of the feeder. The voltage profile of the feeder depends on the line impedance, the point of common coupling of the wind turbines and on the wind power production and the consumer load.

In summary, this paper contributes with the possibility of controlling the power generated inside an isolated microgrid, assuring the control of the voltage at the energy storage systems terminals, without using dump loads to dissipate the surplus of energy or a physical communication between converters. With energy storage systems based on battery it is not necessary to measure or estimate the state of charge of the batteries, only measuring the terminal voltage of them is sufficient. The proposed method allows for a continuous and smooth reduction of the power generated by the existing sources in the microgrid and therefore a charging procedure where the batteries can be charged up to 100% of their capacity.

Furthermore, the proposed strategy can be applied to any type of primary source, since the reduction of power is adjusted for each particular type of power source. It means that it can be used with both non-dispatchable and intermittent energy sources as well as with dispatchable sources such as a diesel generator.

II. Grid connection of WECS:

The proposed hybrid system comprises of a WECS and lead acid battery bank. The system is designed for a stand-alone dc load. The layout of the entire system along with the control strategy is shown in Fig. 1. The specifications of the WT, PMSG, and battery bank are tabulated in the Appendix. The WECS consists of horizontal axis WT, gear box with a gear ratio of 1:8 and a PMSG as the WTG. Since the load is a stand-alone dc load the stator terminals of the SEIG are connected to a capacitor bank for self-excitation. The ac output is rectified by three-phase uncontrolled diode rectifier. However, there is a need for a battery backup to meet the load demand during the period of unavailability of sufficient wind power. This hybrid wind-battery system requires suitable control logic for interfacing with the load. The uncontrolled dc output of the rectifier is applied to the charge controller circuit of the battery. The charge controller is a dc–dc buck converter which determines the charging and discharging rate of the battery.

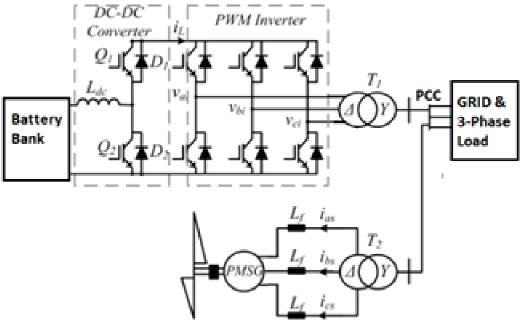

Fig 1: Grid Integrated WECS using BESS

The battery bank connected to the system can either act as asource or load depending on whether it is charging or discharging.

However, regardless of this the battery ensures that theload terminal voltage is regulated. Further, as shown in Fig. 1,the charging of the battery bank is achieved by MPPT logic,while the pitch controller limits the mechanical and electricalparameters within the rated value. The integrated action of thebattery charge and pitch controller ensures reliable operation ofthe stand-alone WECS.

III. Control Strategy for Wind-Battery System:

The wind flow is erratic in nature. Therefore, a WECS is integrated with the load by means of an DC–DC–AC converter to avoid voltage flicker and harmonic generation. The control scheme for a stand-alone hybrid wind-battery system includes the charge controller circuit for battery banks and pitch control logic to ensure WT operation within the rated value. The control logic ensures effective control of the WECS against all possible disturbances.

Control Strategy:

The implementation of the charge control logic as shown in Fig. 2 is carried out by three nested control loops. The outermost control loop operates the turbine following MPPT logic with battery SoC limit. To implement the MPPT logic, the actual tip speed ratio (TSR) of turbine is compared with the optimum value. The error is tuned by a PI controller to generate the battery current demand as long as the battery SoC is below the CC mode limit. Beyond this point, the SoC control logic tries to maintain constant battery charging voltage. This in turn reduces the battery current demand and thus prevents the battery bank from overcharging. The buck converter inductor current command is generated in the intermediate control loop. To design the controller, it is essential to model the response of the battery current with respect to the inductor current.

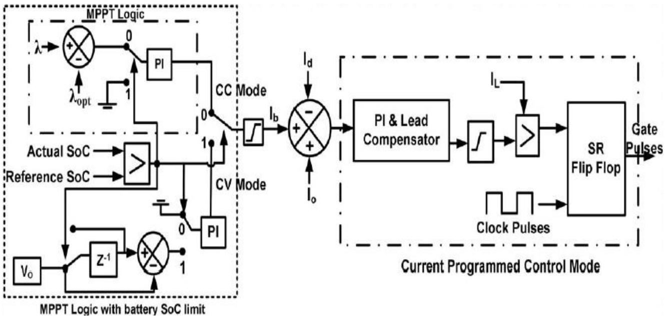

Fig 2: Control Strategy of dc-dc-ac converter

Pitch Control Scheme:

The pitch control scheme is shown in Fig. 7. As seen thep.u. value of each input is compared with 1 to calculate the error. The errors are tuned by PI controller. The “MAX” block chooses the maximum output from each PI controller which is then passed on to a limiter to generate the pitch command for the WT. The actual pitch command is compared with the limited value. The lower limit of the pitch command is set at zero. There arises an error when the actual pitch command goes above or below the specified limit. This is multiplied with the error obtained from each of the comparator. The product is compared with zero to determine the switching logic for integrator. This technique is carried out to avoid integrator saturation. The pitch controller changes the pitch command owing to variation in turbine rotation speed, power, and output voltage of rectifier, which ensures safe operation of the WECS.

Control of the bi-directional dc-dc converter:

The DC-DC converter (in GFC) is used to control the voltage in the capacitor Cdc. The action of the controller of the DC-DC converter can be considered equivalent to connecting a controlled voltage source, with mean value Vct, between the xy terminals of the converter circuit. If the losses in the converter are not considered, the voltage on Cdc depends only on the difference between the power at the battery bank terminals (Pb) and ($Pinv$) which is the power at the terminals of the delta side of the isolation transformer $T1$, being positive when the power flux is from the inverter to the grid and negative on the contrary.

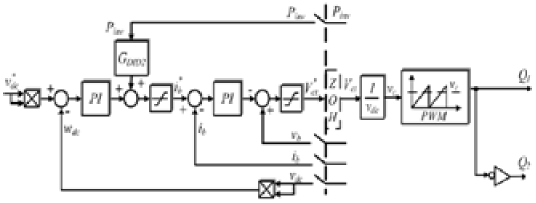

Fig 3: Block diagram of the commands for the switches of the DC-DC converter

In standalone and distributed renewable energy systems, there is no commercial or conventional grid to absorb any surplus power generated internally in the microgrid. Therefore, the generated power needs to be controlled when the load power is less than the amount of power that could be generated by the energy sources. This is necessary to keep the energy balance in the microgrid under control and to keep the battery bank voltage below or equal its maximum allowable value. This is necessary since voltages higher than the gasification voltage can decrease the lifespan of batteries or even damage them irreversibly.

IV. SIMULATION RESULTS:

A WECS needs to be efficient to ensure continuous power flow to the load. The effectiveness can be achieved by integrating the hybrid wind-battery system with suitable control logic. This includes the charge control logic and the pitch control logic. The charge controller regulates the charging and discharging rate of the battery bank while the pitch controller controls the WT action during high wind speed conditions or in case of a power mismatch. Both the control strategy are integrated with The hybrid system and simulated with various wind profiles to validate the efficacy of the system. The system is connected to a load profile varying in steps from 0 to 4 kW. The WT parameters like shaft speed, TSR, blade pitch and output power are analyzed with variation in wind speed conditions. The current profile of the converter, load, and the battery are also monitored with the wind profile. To ensure uninterrupted power flow, load demand is given more priority over battery charging.

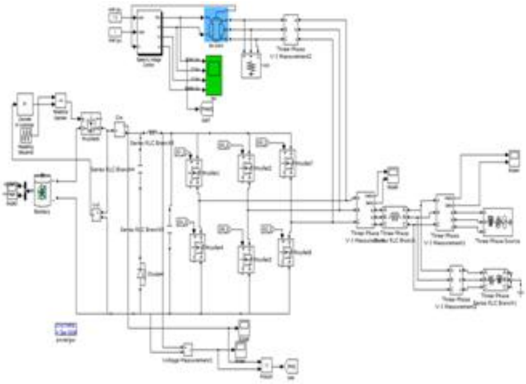

Fig 4: simulation circuit proposed system

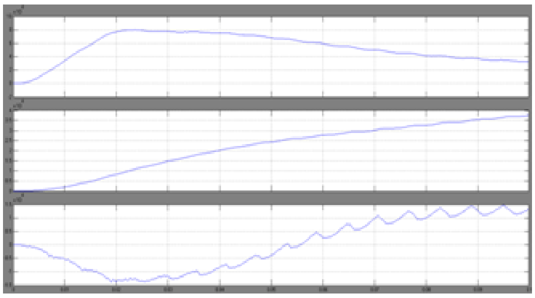

Fig 5: Wind Active Power, DC power, Wind Reactive power

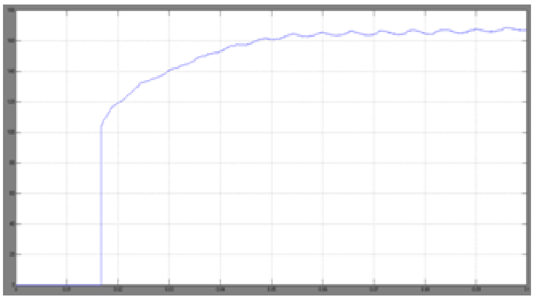

Fig 6: DC Voltage

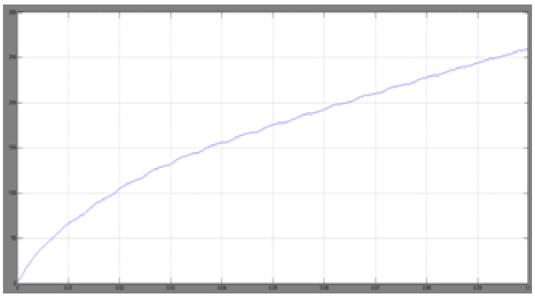

Fig 7: DC current

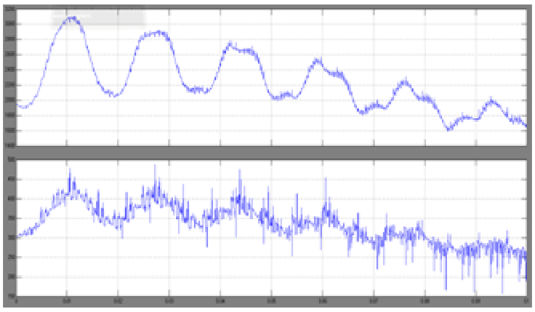

Fig 8: Load Active and Reactive power

V. CONCLUSION:

The project presents the power quality improvement in grid connected wind generating system and non li-near unbalanced load from wind-based control scheme. The power quality issues and its consequences on the consumer and electric utility are presented. The operation of the control system developed for the wind-BESS in MAT-LAB/ SIMULINK for maintaining the power quality is simulated. It has a capability to cancel out the harmonic parts of the source current. It maintains the source voltage and current in-phase and support the reactive power demand for the wind generator and load at PCC in the grid system, thus it gives an opportunity WECS with BESS have shown the outstanding performance. The above tests with proposed scheme has not only power quality improvement feature but it also has sustain real power capability to support the load with the energy storage through the batteries.

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