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Improvement of Power Quality of a Distributed Generation Power System

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ABSTRACT:

The aim of this work is to improve the power quality for Distributed Generation (DG) with power storage system. Power quality is the combination of voltage quality and current quality. Power quality is the set of limits of electrical properties that allows electrical systems to function in their intended manner without significant loss of performance or life. The electrical power quality is more concerned issue. The main problems are stationery and transient distortions in the line voltage such as harmonics, flicker, swells, sags and voltage asymmetries. Distributed Generation (DG) also called as site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy, generates electricity from the many small energy sources. In recent years, micro electric power systems such as photovoltaic generation systems, wind generators and micro gas turbines, etc., have increased with the deregulation and liberalization of the power market. Under such circumstances the environment surrounding the electric power industry has become ever more complicated and provides high-quality power in a stable manner which becomes an important topic. Here DG is assumed to include Wind power Generation (WG) and Fuel Cells (FC), etc. Advantages of this system are constant power supply, constant voltage magnitude, absence of harmonics in supply voltage, un-interrupted power supply. In this project the electric power qualities in two cases will be compared.

Case I: With the storage battery when it is introduced.

Case II: Without the storage battery. The storage battery executes the control that maintains the voltage in the power system. It will be found that the Electric power quality will be improved, when storage battery is introduced. The model system used in this Project work is composed of a Wind Turbine, an Induction Generator, Fuel Cells, An Inverter and a Storage Battery. A miniature Wind Power Generator is represented by WG. A fuel cell module is represented by FC. Transmission lines will be simulated by resistors and coils. The combined length of the lines from synchronous generator to the load terminal is 1.5 km. This model will be simulated using MATLAB/SIMULINK.

INTRODUCTION:

Renewable energy sources have attracted attention worldwide due to soaring prices of fossil fuels. Renewable energy sources are considered to be important in improving the security of energy supplies by decreasing the dependence on fossil fuels and in reducing the emissions of greenhouse gases. The viability of isolated systems using renewable energy sources depends largely on regulations and stimulation measures. Renewable energy sources are the natural energy resources that are inexhaustible, for example, wind, solar, geothermal, biomass, and small hydro generation. Among the renewable energy sources, small hydro and wind energy have the ability to complement each other.

For power generation by small or micro hydro as well as wind systems, the use of squirrel-cage induction generators (SCIGs) has been reported in literature. Although the potential for small hydroelectric systems depends on the availability of suitable water flow, where the resource exists, it can provide cheap clean reliable electricity. Hydroelectric plants convert the kinetic energy of a waterfall into electric energy. The power available in a flow of water depends on the vertical distance the water falls (i.e., head) and the volume of flow of water in unit time (i.e., discharge).

The water powers a turbine, and its rotational movement is transferred through a shaft to an electric generator. When SCIG is used for small or micro hydro applications, its reactive power requirement is met by a capacitor bank at its stator terminals. The SCIG has advantages like being simple, low cost, rugged, maintenance free, absence of dc, brushless, etc., as compared with the conventional synchronous generator for hydro applications. As regards wind-turbine generators, these can be built either as constant-speed machines, which rotate at a fixed speed regardless of wind speed, or as variable-speed machines in which rotational speed varies in accordance with wind speed.

For fixed-speed wind turbines, energy-conversion efficiency is very low for widely varying wind speeds. In recent years, wind turbine technology has switched from fixed speed to variable speed. The variable-speed machines have several advantages. They reduce mechanical stresses, dynamically compensate for torque and power pulsations, and improve power quality and system efficiency. The grid-connected variable-speed wind-energy-conversion system (WECS) based on SCIG use back-to-back connected power converters [. In such systems, the power converter decouples the SCIG from the grid, resulting in an improved reliability. In the case of grid-connected systems using renewable energy sources, the total active power can be fed to the grid.

For standalone systems supplying local loads, if the extracted power is more than the local loads (and losses), the excess power from the wind turbine is required to be diverted to a dump load or stored in the battery bank. Moreover, when the extracted power is less than the consumer load, the deficit power needs to be supplied from a storage element, e.g., a battery bank. In the case of stand-alone or autonomous systems, the issues of voltage and frequency control (VFC) are very important. In, the authors have addressed the issues of VFC for stand-alone systems using SCIGs. Some work has also been reported for stand-alone WECSs using doubly fed induction generator.

In a battery-based controller is proposed for control of voltage and frequency in the isolated WECS. However, maximum power tracking (MPT) could not be realized in this battery-based isolated system employing SCIG operated at fixed speed. In Singh et al. have proposed an electronic load controller for VFC at the stator terminals, and the controller transfers excess power from the hydropower generator to a dump load, whenever the load is less than the generated power. In this paper, a new three-phase four-wire autonomous (or isolated) wind–small hydro hybrid system is proposed for isolated locations, which cannot be connected to the grid and where the wind potential and hydro potential exist simultaneously.

One such location in India is the Andaman and Nicobar group of islands. The proposed system utilizes variable speed wind-turbine-driven SCIG w (subscript w for wind), and a constant-speed/constant-power small hydro-turbine-driven SCIG h (subscript h for hydro). For the rest of this paper, the subscript w is used to denote the parameters and variables of the wind-turbine generator, and the subscript h is used to denote the parameters and variables of the hydro-turbine generator. A schematic diagram of a three-phase four-wire autonomous system is shown in Fig. 1. Two back-to-back-connected pulse width modulation (PWM)-controlled insulated-gate-bipolar transistor (IGBTs)-based voltage-source converters (VSCs) are connected between the stator windings of SCIG w and the stator windings of the SCIG h to facilitate bidirectional power flow.

The stator windings of the SCIG h are connected to the load terminals. The two VSCs can be called as the machine (SCIG w) side converter and the load-side converter.The system employs a battery energy storage system (BESS), which performs the function of load leveling in the wake of uncertainty in the wind speed and variable loads. The BESS is connected at the dc bus of the PWM converters. The advantage of using BESS on the dc bus of the PWM converters is that no additional converter is required for transfer of power to or from the battery.

Further, the battery keeps the dc-bus voltage constant during load disturbances or load fluctuations.An inductor is connected in series with the BESS to remove ripples from the battery current. A zigzag transformer is connected in parallel to the load for filtering zero-sequence components of the load currents. Further, the zigzag windings trap triple n harmonic (third, ninth, fifteenth, etc.) currents. As shown in Fig. 1, the zigzag transformer consists of three single-phase transformers with a turn Ratio of 1: 1. The zigzag transformer is to be located as near to the load as possible. The neutral terminal of the consumer loads is connected to the neutral terminal of the zigzag transformer. For the hybrid system, a new control algorithm is proposed that has the capability of MPT, harmonic elimination, load leveling, load balancing, and neutral current compensation along with VFC.

DESIGN OF SCIG-BASED WIND-HYDRO HYBRID SYSTEM:

The system is designed for an isolated location with the load varying from 30 to 90 kW at a lagging power factor (PF) of 0.8. The average load of the system is considered to be 60 kW. The following subsections describe the procedure for selection of ratings for SCIGs, battery voltage, battery capacity, machine-side converter, load-side converter, specifications of wind turbine, and gear ratio.

Selection of Voltage of DC Link and Battery Design:

The dc-bus voltage (Vdc) must be more than the peak of the line voltage for satisfactory PWM control as [26]

$$V_{dc} > \left\{2\sqrt{(2/3)}V_{ac}\right\} m_a \qquad (24)$$

Where ma is the modulation index normally with a maximum value of one and Vac is the rms value of the line voltage on the ac side of the PWM converter. In this case, there are two PWM converters connected to the dc bus; therefore, the constraint on the dc-bus voltage is from the ac voltages of both the converters. The maximum rms value of the line voltage at SCIGw terminals as well as the rms value of the line voltage at the load terminals is 415 V. Substituting this value in (24), Vdc should be more than 677.7 V. The voltage of the dc link and the battery bank is selected as 700 V. Considering the ability of the proposed system to supply electricity to a load of 60 kW for 10 h, the design storage capacity of the battery bank is taken as 600 kW · h. The commercially available battery bank consists of cells of 12 V.

The nominal capacity of each cell is taken as 150 A · h. To achieve a dc-bus voltage of 700 V through series connected cells of 12 V, the battery bank should have (700/12) = 59 number of cells in series. Since the storage capacity of this combination is 150 A · h, and the total ampere hour required is (600 kW · h/700 V) = 857 A · h, the number of such sets required to be connected in parallel would be (857 A · h/150 A · h) = 5.71 or 6 (selected). Thus, the battery bank consists of six parallel-connected sets of 59 series connected battery cells.

The venin's model is used to describe the energy storage of the battery in which the parallel combination of capacitance (Cb) and resistance (Rb) in series with internal resistance (Rin) and an ideal voltage source of voltage 700 V are used for modeling the battery in which the equivalent capacitance Cb is given as [27]

$$C_b = \frac{(\mathrm{kW}\cdot \mathrm{h}^*3600^*1000)}{0.5\left(V^2_{\mathrm{oc\,max}} - V^2_{\mathrm{oc\,min}}\right)}. \qquad (25)$$

Taking the values of Vocmax = 750 V, Vocmin = 680 V, and kW · h = 600, the value of Cb obtained is 43 156 F.

Selection of Rating of Machine (SCIGw) Side Converter:

The maximum active-power flow through the machine side converter Psw = 55 kW, and the maximum reactive power flow provided from the machine-side converter (Qsw) is calculated as

$$Q_{sw} = \{V_{\text{msc}}^2/(2\pi f L_m)\} = 18.4 \text{ kvar}$$

Where Vmsc is the maximum line voltage generated at the SCIGw terminals, which is 415 V, at a frequency (f) of 50 Hz generated at a wind speed of 11.2 m/s. The V A rating (V Amsc) of the machine-side converter is calculated as V Amsc =P2sw + Q2sw =√552 + 18.42 =58kVA, and the Maximum rms machine-side converter current as Isw = V Amsc/(√3Vmsc) = 80.7 A.

The voltage and current ratings of the switching devices (IGBTs) are decided by the maximum voltage across the device and the maximum current through it. In view of (24), the voltage rating of the switching devices is decided by the dc-link voltage, whose maximum value is 750 V. Taking a 25% margin, the voltage rating of the switching devices of the machine-side converter should be more than 1.25 *750 V, i.e., 937.5 V.

The maximum current through the switching device is 1.25{Ir(p−p)msc + I(peak)msc }[26], where I(peak)msc is the peak line current through the machine-side converter, and Ir(p−p)msc is the peak-to-peak ripple current in the machineside converter, and 1.25 is the safety margin taken for design. For design purpose, the ripple in the machine-side converter current is assumed to be 5% of I(peak)msc.

SIMULINK:

Simulink (Simulation and Link) is an extension of MATLAB by Math works Inc. It works with MATLAB to offer modeling, simulating, and analyzing of dynamical systems under a graphical user interface (GUI) environment. The construction of a model is simplified with click-and-drag mouse operations. Simulink includes a comprehensive block library of toolboxes for both linear and nonlinear analyses. Models are hierarchical, which allow using both top-down and bottom-up approaches. As Simulink is an integral part of MATLAB, it is easy to switch back and forth during the analysis process and thus, the user may take full advantage of features offered in both environments. This tutorial presents the basic features of Simulink and is focused on control systems as it has been written for students in my control system

Sim Power Systems:

Sim Power Systems is a modern design tool that allows scientists and engineers to rapidly and easily build models that simulate power systems. Sim Power Systems uses the Simulink environment, allowing you to build a model using simple click and drag procedures. Not only can you draw the circuit topology rapidly, but your analysis of the circuit can include its interactions with mechanical, thermal, control, and other disciplines. This is possible because all the electrical parts of the simulation interact with the extensive Simulink modeling library. Since Simulink uses MATLAB® as its computational engine, designers can also use MATLAB toolboxes and Simulink block sets. Sim Power Systems and Sim Mechanics share a special Physical Modeling block and connection line interface.

Sim Power Systems Libraries:

You can rapidly put Sim Power Systems to work. The libraries contain models of typical power equipment such as transformers, lines, machines, and power electronics. These models are proven ones coming from textbooks, and their validity is based on the experience of the Power Systems Testing and Simulation Laboratory of Hydro-Québec, a large North American utility located in Canada, and also on the experience of Ecolab de Technologies Superiors and University Laval. The capabilities of Sim Power Systems for modeling a typical electrical system are illustrated in demonstration files. And for users who want to refresh their knowledge of power system theory, there are also self-learning case studies.

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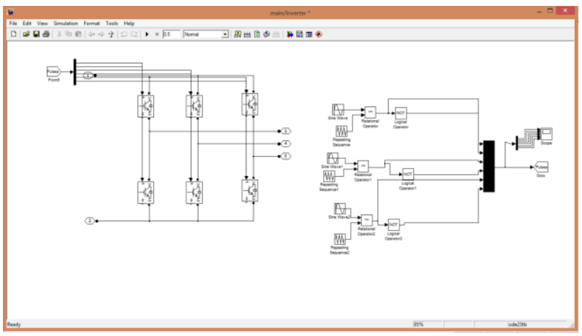
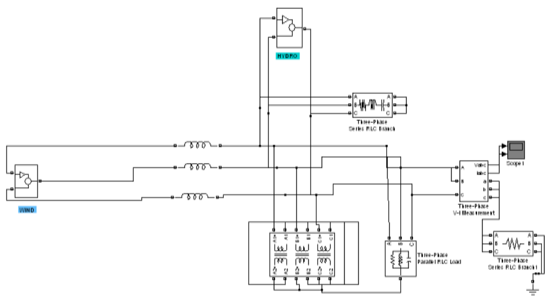
The Sim Power Systems main library, power lib, organizes its blocks into libraries according to their behavior. The power lib library window displays the block library icons and names. Double-click a library icon to open the library and access the blocks. The main Sim Power Systems power lib library window also contains the Powerful block that opens a graphical user interface for the steady-state analysis of electrical circuits.

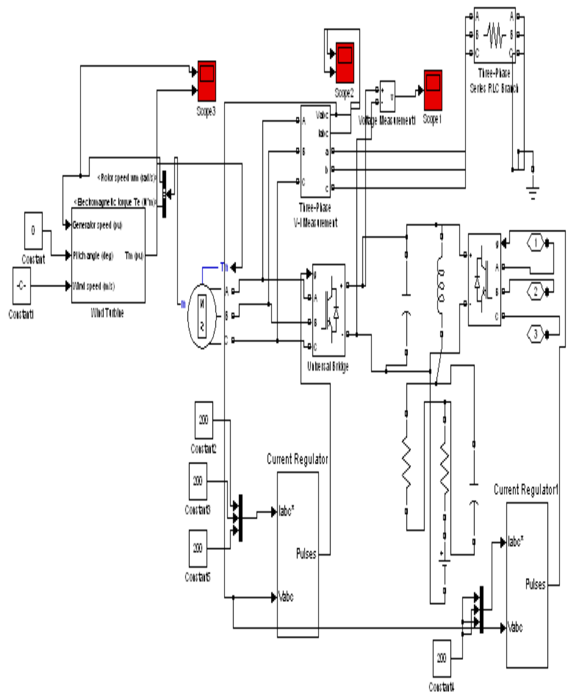
Nonlinear Simulink Blocks for Sim Power Systems Models

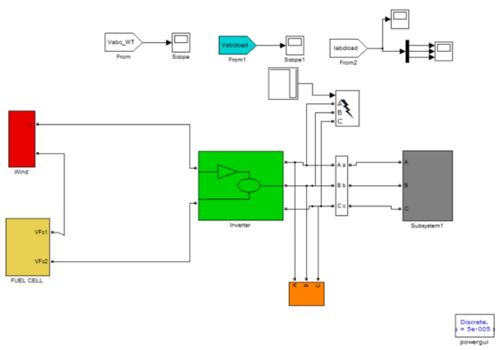
The nonlinear Simulink blocks of the power lib library are stored in a special\block library named powerlib_models. These masked Simulink models are used by Sim Power Systems to build the equivalent Simulink model of your circuit. See Chapter 3, “Improving Simulation Performance” for a description of the powerlib_models library.

SIMULATION:

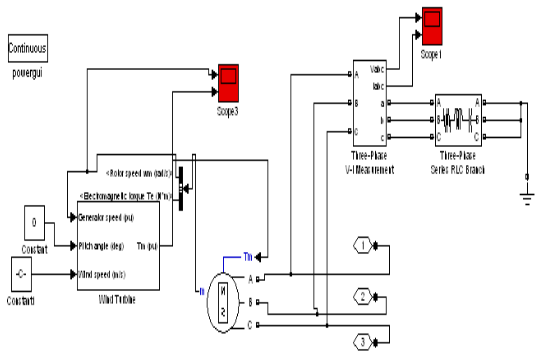








With storage battery



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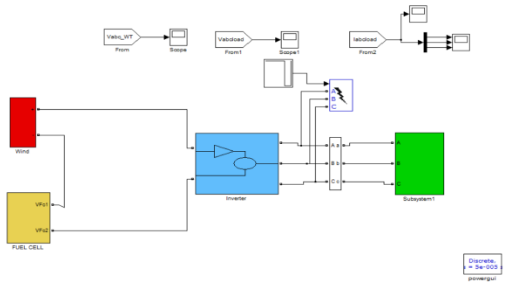
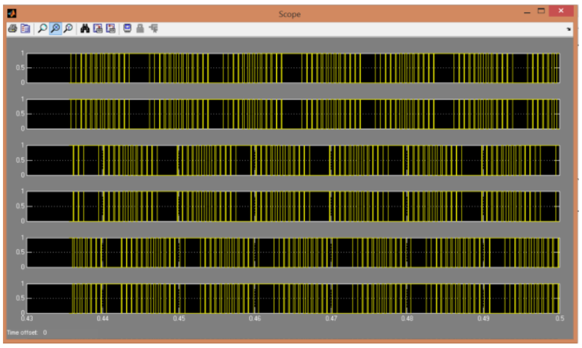
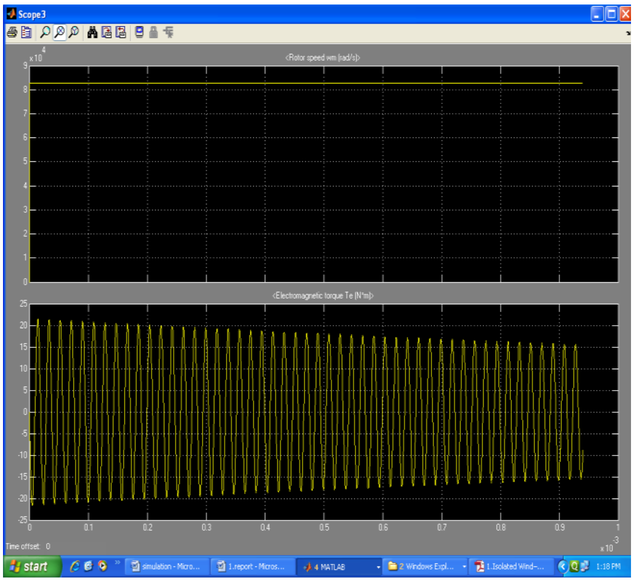


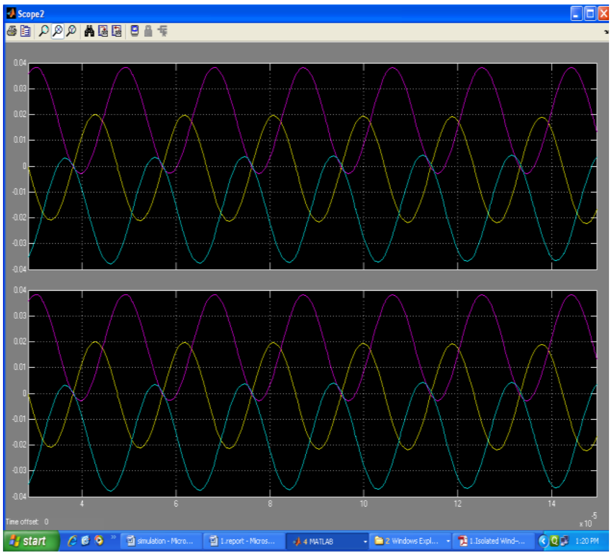
without storage battery

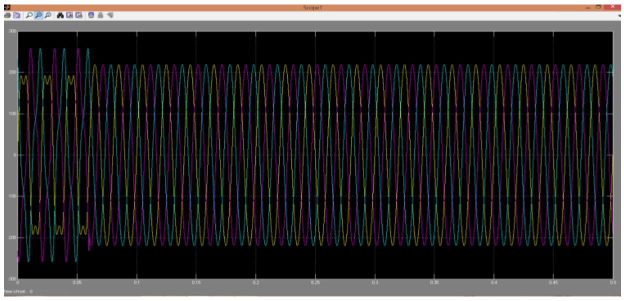
SIMULATION RESULT:



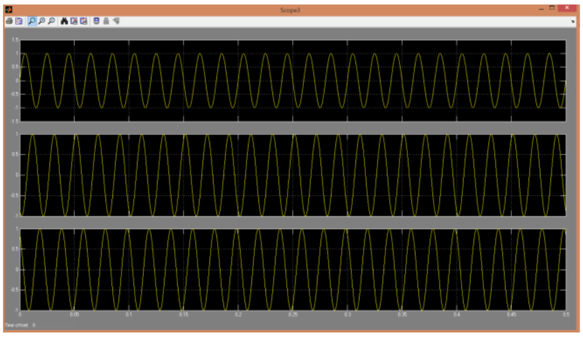
OUT PUT OF INVERTER



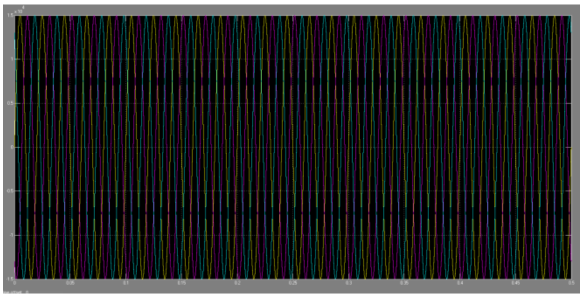




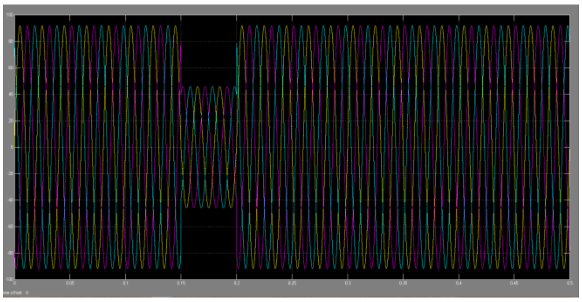
WITHOUT BATEERY LOAD VOLTAGE



WITH BATTERY LOAD CURRENT



output with battery



Output without battery

CONCLUSION:

In this paper a new multi-input Cuk-SEPIC rectifier stage for hybrid wind/solar energy systems has been presented. The features of this circuit are: 1) additional input filters are not necessary to filter out high frequency harmonics; 2) both renewable sources can be stepped up/down (supports wide ranges of PV and wind input); 3) MPPT can be realized for each source; 4) individual and simultaneous operation is supported. Simulation results have been presented to verify the features of the proposed topology.

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