INTEGRATING HYBRID POWER SOURCE INTO AN ISLANDED MV MICRO GRID USING MULTILEVEL INVERTER

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Abstract: This paper presents a control strategy for an islanded medium voltage micro grid to coordinate hybrid power source (HPS) units and to control interfaced multilevel inverters under unbalanced and nonlinear load conditions. The proposed HPS systems are connected to the loads through a cascaded H-bridge (CHB) multilevel inverter. The CHB multilevel inverters increase the output voltage level and enhance power quality. The HPS employs fuel cell (FC) and photovoltaic sources as the main and super capacitors as the complementary power sources. Fast transient response, high performance, high power density, and low FC fuel consumption are the main advantages of the proposed HPS system. The proposed control strategy consists of a power management unit for the HPS system and a voltage controller for the CHB multilevel inverter. Each distributed generation unit employs a multiproportional resonant controller to regulate the buses voltages even when the loads are unbalanced and/or nonlinear. Digital time-domain simulation studies are carried out in the PSCAD/EMTDC environment to verify the performance of the overall proposed control system.

Keywords: Hybrid Power Source, a cascaded H-bridge, PSCAD/EMTDC, multilevel inverters.

1. INTRODUCTION

The development of renewable energy has been an increasingly critical topic in the 21st century with the growing problem of global warming and other environmental issues. With greater research, alternative renewable sources such as wind, water, geothermal and solar energy have become increasingly important for electric power generation. Although photovoltaic cells are certainly nothing new, their use has become more common, practical, and useful for people worldwide.

The most important aspect of a solar cell is that it generates solar energy directly to electrical energy through the solar photovoltaic module, made up of silicon cells. Although each cell outputs a relatively low voltage if many is connected in series, a solar photovoltaic module is formed. In a typical module, there can be up to 36 solar cells, producing an open circuit voltage. Although the price for such cells is decreasing, making use of a solar cell module still requires substantial financial investment. Thus, to make a PV module useful, it is necessary to extract as much energy as possible from such a system.

A Maximum Power Point Tracking is normally operated with the use of a dc-dc converter is step up or step down The DC/DC converter is responsible for transferring maximum power from the solar Photo voltaic module to the load. The simplest way of implementing a Maximum Power Point Tracking is to operate a Photovoltaic array under constant voltage and power reference to modify the duty cycle of the dc-dc converter. This will keep operation constant at or around the maximum peak power point. There have been many different solutions presented for methods of peak power tracking. Secondary goal is to develop such a system with the purpose of obtaining as much energy from a solar cell as possible. Secondary goal will be to create such a system that operates with optimum efficiency as well. Implementing such a design will be useful in the future because solar cell use is limited greatly by efficiency limitations and cost factors.

Numerous industrial applications have begun to require higher power apparatus in recent Years. Some medium voltage motor drives and utility applications require medium voltage and Megawatt power level. For a medium voltage grid, it is troublesome to connect only one power Semiconductor switches directly. As a result, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations. A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for a high power application. The main objectives of the project work are as follows,

- To design model of Photovoltaic system.
- To design the DC/DC converter with Maximum Power Point Tracking (perturb and observe) algorithm are used.
- To design the eleven levels cascade H-bridge multilevel inverter with reduce the voltage Total Harmonic Distortion

All the above mentioned designs have been developed with the help of MATLAB Simulation Software.

2. OPERATION PRINCIPLES OF THE PROPOSED CONTROL STRATEGY

The proposed control strategy comprises 1) a power management for the HPS system, and 2) a voltage control for the CHB multilevel inverter. To manage the power and regulate the dc-link voltage of the HPS unit, two independent controllers are designed. Furthermore, a voltage control loop is proposed to provide a set of balanced sinusoidal voltages at the terminals of CHB multilevel inverter in the presence of nonlinear and unbalanced loads.

2.1 Control Strategy of the HPS

The proposed control strategy of the hybrid FC/PV/SC power source is shown in Fig. 3. The HPS uses the FC and PV units as the main power sources and the SC as the complementary power source. The PV unit enables the FC to obtain an appropriate operating point at which the hydrogen consumption is minimized. The SC modules support the FC and PV to achieve good transient response and meet the grid power demand. The utilization of three separate full-bridge converters in parallel facilitates the power management capability and increases the overall performance and flexibility of the HPS. The HPS controller is designed such that the SC converter regulates the dc-link voltage, and the FC and PV converters fulfill the dc-link power demand.

The unidirectional power flow of the FC and PV converters results in decoupled dynamics for FC, PV, and SC systems. Therefore, the control design for each converter is carried out individually. Parameters of the SC and FC controllers are determined by the appropriate selections of bandwidth and phase margin using MATLAB Control Toolbox. According to the proposed control strategy, the dc current of the SC module must accurately follow its reference to zero. A PI controller determines the duty cycle of the FC converter. The reference signal generated by the controller is limited not to exceed the FC capability in injecting the current. The corresponding limitation for the current demand is calculated according to the typical range of utilization factor, which ensures the desired operation of FC stack. Furthermore, the FC current slope is limited to avoid the fuel starvation phenomena and to guarantee the safe operation of the FC stack. For control design purposes, the dc/dc converters are modeled using the state-space averaging technique. Based on the average model of the full-bridge converter, the FC control-to- input current transfer function is obtained as the closed-loop systems show good robust stability margins. To attenuate the current ripple of the downstream inverter and to accommodate the slow dynamics of the FC stack, parameters of the controller are designed such that the current-loop bandwidth is more than 628.3 rad/s [21]. Therefore, as seen from the current-loop bandwidth of the FC converter is set to 4360 rad/s to obtain a phase margin of 88.4◦. The FC processor plays a vital role in regulating hydrogen flow according to the output power from the FC stack.

The detailed mathematical model of the FC processor is described The SC voltage control loop regulates the dc-link voltage using a PI controller. When the SC is charging (discharging), the duty cycle of the SC converter will decrease (increase) to maintain the dc-link voltage regulation. Based on the average model of the full- bridge converter, the SC control-to-output voltage phase-shifted PWM strategy balances the dc capacitors voltages and mitigates the input current harmonics of the CHB multilevel inverter.

According to the internal model principle, a reference (disturbance) can be asymptotically tracked (rejected) if the controller contains the Laplace transform of the reference signal in its transfer function. The output currents ($I_{o\alpha}$ and $I_{o\beta}$), which can be considered as disturbances in the control system, contain fundamental and higher order harmonics when the load is nonlinear. Notice that since the loads are connected to the micro grid buses via Y/Δ transformers, neither zero-sequence nor third-order harmonic currents exists in the inverter side of the DG units.

To achieve zero steady-state error in the presence of harmonic currents, a multi- PR controller is proposed According to the bandwidth of the voltage control system (400 Hz), only the fifth- and seventh-order harmonics can be compensated.. To obtain the coefficients k i s, the following performance characteristics are to be met.1) the closed-loop system achieves good stability margins.2) the bandwidth of the open-loop system should be less than 10% of the switching frequency. 3) The reference should be tracked within two cycles with zero steady-state error. 4) The disturbance (harmonic currents) should be rejected. Considering the aforementioned performance indices and using MATLAB SISO tools, the coefficients of the controller are designed and listed. The frequency response of the open-loop controlled system considering. It is clear that the desired phase margin gain margin, and bandwidth for the system are achieved. The phase margin is almost 30◦, gain margin is infinite, and the bandwidth of the system is close to 400 Hz. In addition, the gain of the system at 50 Hz and the other harmonic frequencies is high which results in significant disturbance rejection.

3. SIMULATION RESULTS

The simulation model is shown in figure4.1, The eleven level cascade H-bridge multilevel inverter powered by PV system has been developed by using MAT LAB with the use of this proposed method sinusoidal steeped output waveform is obtained and the harmonics are reduced. Therefore the efficiency of the inverter is increased Fundamental harmonics are also significantly reduced. A key component in this paper is the DC to AC eleven level multilevel inverter. The inverter must perform reliably and efficiently to supply a wide range of ac loads with the voltage and required power quality necessary for reliable and efficient load and system performance. The multilevel inverter is designed to allow interconnection MPPT with PV system.

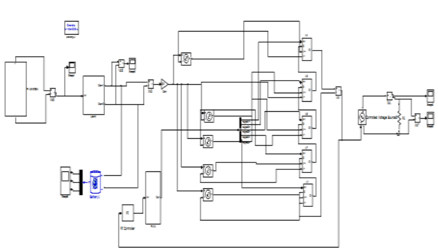

Figure 1: Overall Simulation Diagram

3.1 Simulation Model of PV System

The simplest model of a PV cell is shown in equivalent circuit Fig 2 below that consists of an ideal current source in parallel with an ideal diode. The current source represents the current generated by photons, and its output is constant under constant temperature and constant incident radiation of light. There are two key parameters frequently used to characterize a PV cell shorting together the terminals of the cell, the photon generated current will flow out of the cell as a short-circuit current(Isc) thus, Iph=ISC. When there is no connection to the PV cell (open circuit) the photon generated current is shunted internally by the intrinsic p-n junction diode. This gives the open circuit voltage (V) It is seen that the temperature changes affect mainly the PV output current. The PV cell output voltage is a function of the photocurrent that mainly determined by load current depending irradiation level during on the solar the operation.

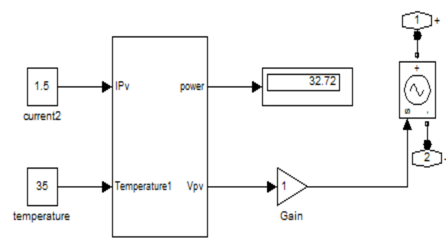

Figure 2: Simulation Model of PV System

The simulation diagram of the Simulation Model of MPPT DC/DC Converter is shown.In case of , MPPT algorithms are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array.

3.2 OUTPUT VOLTAGE WAVEFORM OF A PV PANEL

The output of the PV is shown in Fig 4. The PV output of 21.8 V is obtained by adjusting the values of temperature. The amount of power produced by the PV system depend on the amount of
PV radiation .The power output can therefore be optimized by choosing a correct system configuration corresponding to a given load.

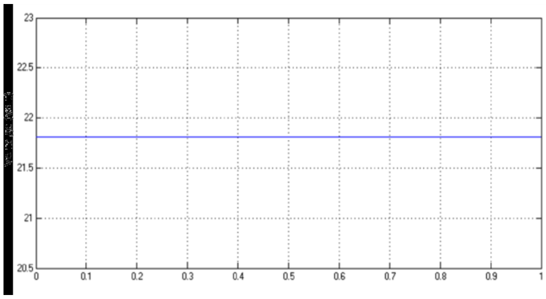

Figure 3: Output Voltage Waveform of A PV Panel

3.3 OUTPUT VOLTAGE WAVEFORM OF MPPT DC/DC CONVERTER

The output of the MPPT DC/DC converter is shown in Fig 4 MPPT is used for solar installation system. The output voltage varies with the input voltage. And this MPPT good output regulation. This MPPT is capable of improving the voltage level from 110 V to the required level.

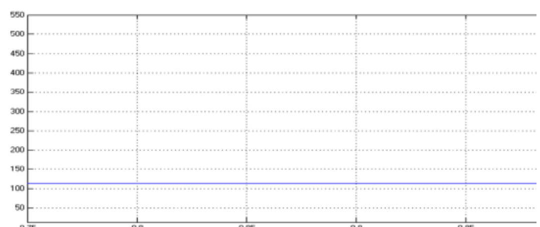

Figure 4: Output Voltage Waveform of MPPT DC/DC Converter

3.4 The output of cascade H-bridge eleven level inverter

The output of cascade H-bridge eleven level inverter is shown in Fig 6 and 7 the output voltage and output current has eleven levels. It can be achieved by using selection switching pattern method. In Figure shown below waveform is obtained is voltage and current Vs time. The output eleven level multilevel inverter fundamental frequency is 50 HZ.

The loads connected across the cascaded H-bridge multilevel inverter. Due to the parallel connection, voltage remains constant for all the resistive loads. But current varies as per the connected load.

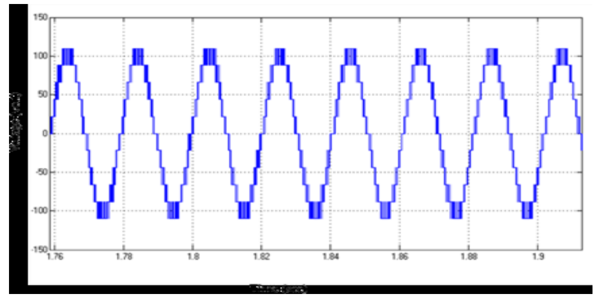

Figure 5: Output Voltage Waveform of Cascade Multilevel Inverter

3.5 SPECTRUM ANALYSIS OF TOTAL HARMONIC DISTORTION

The Total Harmonic Distortion (THD), of a signal is a measurement of the harmonic distortion present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency.

THD is used to characterize the linearity of audio systems and the power quality of electric power systems.

THD is the summation of all harmonic components of the voltage or current waveform compared against the fundamental component of the voltage or current wave. The eleven level output voltage 110 V and fundamental frequency is 50 HZ. The Total Harmonics Distortion is much reduced. The cascaded H-bridge multilevel inverter Total Harmonics Distortion is shown in Figure 4.10 The Total Harmonics Distortion of eleven level multilevel inverter is 4.63%.

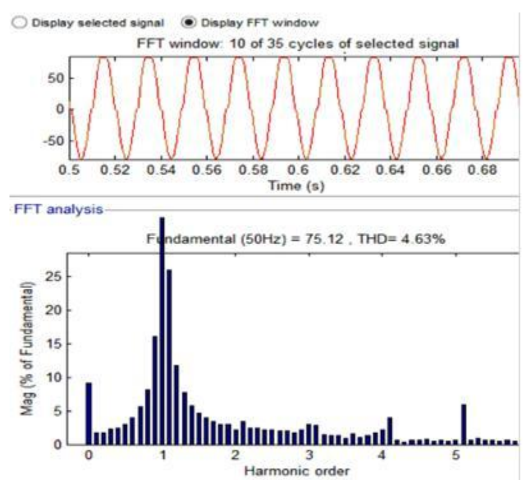

Figure 6: Spectrum Analysis of Total Harmonic Distortion

3. CONCLUSION

This paper presents an effective control strategy for an islanded micro grid including the HPS and CHB multilevel inverter under unbalanced and nonlinear load conditions. The proposed strategy includes power management of the hybrid FC/PV/SC power source and a voltage control strategy for the CHB multilevel inverter. The main features of the proposed HPS include high performance, high power density, and fast transient response. Furthermore, a multi-PR controller is presented to regulate the voltage of the CHB multilevel inverter in the presence of unbalanced and nonlinear loads. The performance of the proposed control strategy is investigated using PSCAD/EMTDC software. The results show that the proposed strategy**:**

- Regulates the voltage of the micro grid under unbalanced and nonlinear load conditions, 2) Reduces THD and improves power quality by using CHB multilevel inverters, 3) Enhances the dynamic response of the micro grid under fast transient conditions, 4) Accurately balances the dc-link voltage of multilevel inverter modules, and 5) Effectively manages the powers among the power sources in the HPS system.

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