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Optimal Control and Management of Distributed Generation Units in a Microgrid

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ABSTRACT

A single-phase grid-connected photovoltaic (PV) inverter topology consisting of a boost section, a low-voltage single-phase inverter with an inductive filter, and a step-up transformer interfacing the grid is considered. A micro grid consisting of different distributed generation (DG) units that are connected to the distribution grid. An energy-management algorithm is implemented to coordinate the operations of the different DG units in the micro grid for grid connected and islanded operations. The proposed micro grid consists of a photovoltaic (PV) array which functions as the primary generation unit of the micro grid and a proton-exchange membrane fuel cell to supplement the variability in the power generated by the PV array. A Maximum Power Point Tracking solar regulator will simulate the load required by the solar panel to achieve the maximum power from the cell. The regulator will work out at which point the cell will output the maximum power and derive from this the voltage and current outputs required for maximum power to be achieved.

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Overview of energy management:

Over the last decade, efficient and reliable communication control technologies, coupled with an increase is master electrical facilities, such as electric vehicles and smart meters, have resulted in an increasing number of consumers participating in demand response management (DRM) (Braithwait, 2010; Jekins, 2009; Zhai, 2011; Heffner, 2006; Lasseter, 2011). The current research is also focused on achieving a smarter grid through demand-side management (DSM), increasing energy reserves and improving the power quality of the distribution system, such as harmonic compensation for nonlinear loads (Lasseter, 2011; Molderink, 2010; Mohsenian-Rad, 2010; Chowdhury, 2009). These new trends enable higher levels of penetration of renewable generation, such as wind and solar power into grid. The integration of renewable sources can supplement the generation from the distribution grid. However, these renewable sources are intermittent in their generation and might compromise the reliability and stability of the distribution network. Energy-storage devices, such as batteries and ultra–capacitors are required to compensate for the variability in the renewable sources.

The incorporation of energy-storage devices is also critical for managing peak demands.A micro grid consisting of a photo voltaic(PV)array, a proton-exchange fuel cell (PEMFC), and a lithium-ion storage battery (SB) is proposed. PEMFC is used as a backup generator unit to compensate for the power generated by the intermittent nature of the PV array. The SB is implemented for peak shaving during grid-connected operation, and to supply power for any shortage in generated power during is landed operation and to maintain the stability of the distributed network. An energy- management algorithm is designed for the micro grid to coordinate the sharing of power among different DG units. The equivalent Single Phase Representation of DG inverters for Grid connected Operation is shown in figure 1.

The output of the DG inverter is interfaced with an LC filter represented by and to eliminate the high switching frequency harmonics generated by the DG inverter. The sum of the currents delivered to the load is given by,

$$i_L = \sum_{K=1,2,3} i = i_{L1} + i_{L2} + i_{L3}$$

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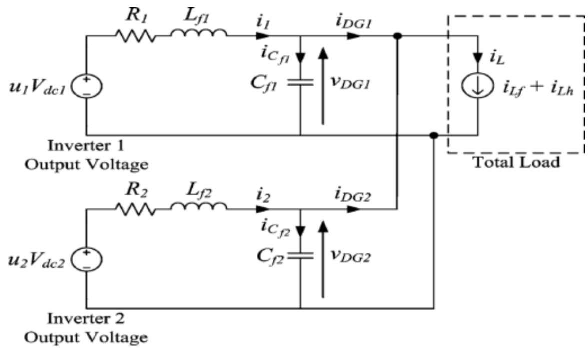

Fig. 1: Equivalent Single Phase Representation of DG inverters for Grid connected Operation.

To achieve unity power factor at the grid side, compensate for the harmonics in the load currents and concurrently achieve load sharing, the inverter of the DG unit supplies a current. In the grid- connected mode, the grid voltage is known and the microgrid shares the load demand with the grid. Control the power delivered to the loads, the output current of the DG inverter is controlled using the current control mode (CCM).

Architecture of proposed system:

The Overall configuration of proposed microgrid architecture is shown in figure 2**.**The main DG unit comprises a 40-kW PV array and a 15-kW PEMFC, which are connected in parallel to the dc side of the DG inverter 1 through dc/dc boost converters to regulate the dc-link voltage of the DG inverter at the desired level by delivering the necessary power. The PV array is implemented as the primary generation unit and the PEMFC is used to back up the intermittent generation of the PV array. When there is ample sunlight, the PV array operates in the MPPT mode to deliver maximum dc power , which is discussed in detail in (Yazdani, 2009) and (Tan, 2010) and the output voltage of the PV array is permitted to vary within an allowable range to ensure proper operation of the DG inverter.

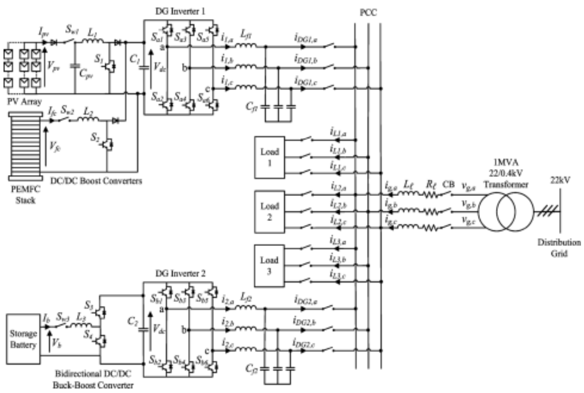

Fig. 2: Overall configuration of proposed microgrid architecture.

A. Power Point Trackers:

Strings of series cells are usually handled independently and not connected in parallel, though (as of 2014) individual power boxes are often supplied for each module, and are connected in parallel. Although modules can beinterconnected to create an array with the desired peak DC voltage and loading current capacity, using independent MPPTs (Maximum Power Point Trackers) is preferable. A Simplest Solar MPPT Circuit is shown in figure 3. Otherwise, shunt diodes can reduce shadowing power loss in arrays with series/parallel connected cells. Grid parity (or socket parity) occurs when an alternative energy source can generate electricity at a levelizedcost (LCoE) that is less than or equal to the price of purchasing power from. The term is most commonly used when discussing renewable energy sources, notably solar power and wind power. Reaching grid parity is considered to be the point at which an energy source becomes a contender for widespread development without subsidies or government support. It is widely believed that a wholesale shift in generation to these forms.

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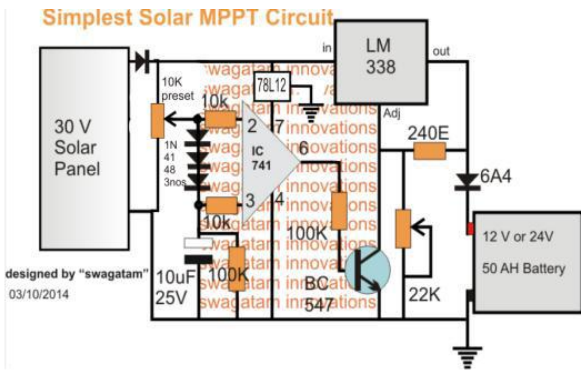

Fig. 3: Simplest Solar MPPT Circuit.

Model predictive control:

Model predictive control (MPC) refers to a class of computer control algorithms that utilize an explicit process model to predict the future response of a plant. At each control interval an MPC algorithm attempts to optimize future plant behavior by computing a sequence of future manipulated variable adjustments. The first input in the optimal sequence is then sent into the plant, and the entire calculation is repeated at sub sequent control intervals. Originally developed to meet the specialized control needs of power plants and petroleum refineries, MPC technology can now be found in a wide variety of application areas including chemicals, food processing, automotive, and aerospace applications. Several recent publications provide a good introduction to theoretical and practical issues associated withMPC technology.

Results:

MATLAB provides a number of features for documenting and sharing your work.

*A. **Output voltage on load 1:***

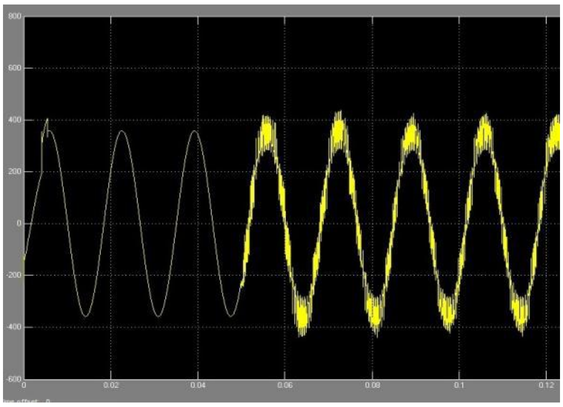

Fig. 4: Output voltage to load 1

B. Input load voltage 2:

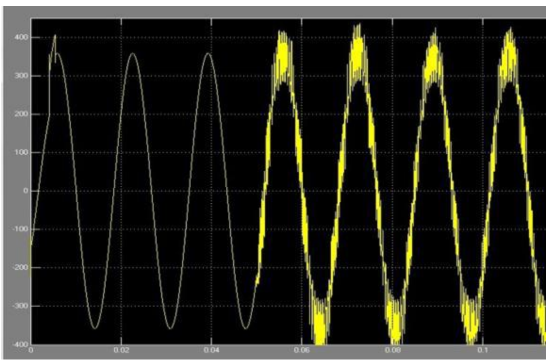

Fig. 5: Output on load voltage 2.

The waveforms of the total load current, the current supplied by the main DG uniti_{DG} and grid current i_G under this test case are shown in the above figure4.

During steady-state condition, the total harmonic distortion (THD) value of $i_L$is 42.1% as shown in the above figure5.

C. Input voltage scope 4:

It can be observed from figure 6 that the grid supplies 80% (46.4 kW) of the total real power delivered to the loads and dispatches an additional power of about 3 kW to charge the SB. It is also observed that the reactive power supplied by the grid is zero, resulting in unity power factor at the grid side.

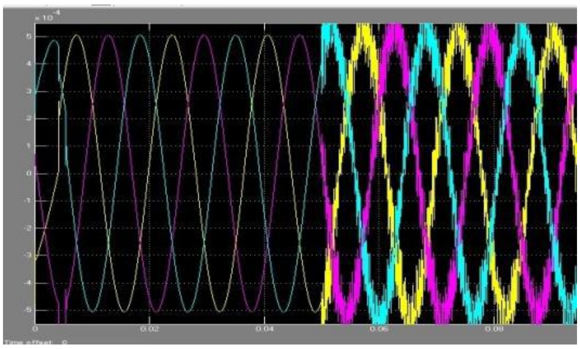

Fig. 6: Input voltage at scope 4

Conclusion:

In this paper, a control system that coordinates the operation of multiple DG inverters in a microgrid for grid-connected and islanded operations has been presented. The proposed controller for the DG inverters is based on a newly developed MPPT algorithm which decomposes the control problem into steady-stateand transient sub problems in order to reduce the overall computation time. The controller also integrates Kalman filters into the control design to extract the harmonic spectra of the load currents and to generate the necessary references for the controller. The DG inverters can compensate for load harmonic currents in a similar way as conventional compensators, such as active and passive filters, and, hence, no additional equipment is required for power-quality improvement. To realize the smart grid concept, various energy-management functions, such as peak shaving and load shedding, have also been demonstrated in the simulation studies. The results have validated that the microgrid is able to handle different operating conditions effectively during grid-connected and islanded operations, thus increasing the overall reliability and stability of the microgrid.

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