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Controlling Of Solar Photovoltaic Generators Using MPPT and Battery Storage in Coordinated V-F and P-Q of Micro Grids

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Abstract

The micro grid concept allows small distributed energy resources (DERs) to act in a coordinated manner to provide a necessary amount of active power and ancillary service when required. This paper proposes an approach of coordinated and integrated control of solar PV generators with the maximum power point tracking (MPPT) control and battery storage control to provide voltage and frequency (V-f) support to an islanded micro grid. Also, active and nonnative/reactive power (P-Q) control with solar PV, MPPT and battery storage is proposed for the grid connected mode. The control strategies show effective coordination between inverter V-f (or P-Q) control, MPPT control, and energy storage charging and discharging control. The paper also shows an effective coordination among participating micro resources while considering the case of changing irradiance and battery state of charge (SOC) constraint. The simulation studies are carried out with the IEEE 13-bus feeder test system in grid connected and islanded micro grid modes. The results clearly verify the effectiveness of proposed control methods. The simulations are carried out in Mat lab and Simpower systems.

INTRODUCTION

The traditional power systems comprise of the generation system which consists of large central power stations, the transmission and sub-transmission systems to deliver power from remote generating plants to the site near load centers, and the distribution system to serve all end users such as residential, commercial and industrial loads. The power flow is hence, unidirectional, that is, from generation to the load centers. With the ever increasing demand of electricity that has been raising important power system operational issues like voltage and frequency instability, the integration of distributed energy resources into the modern power systems have become very popular since last few decades. The fast depletion of fossil fuel reserves and environmental concerns have provided greater incentive to integrate renewable energy based DERs like solar, wind and biomass in modern power systems.

DERs are usually connected to the power distribution system. DER includes distributed generation (DG), energy storage systems and demand response. DGs are defined as small generators located in close proximity of load with the size ranging from 10kW- 10MW. Though the standard definition of DG has not been agreed upon far, there are several other definitions proposed by several power system working groups and institutions like CIGRE1, IEEE2, IEA3, etc. DERs, in general, provide several technical, operational, environmental and market benefits when integrated to the modern deregulated power systems and hence, these act as important driving factors for their integration into the grid and in formation of micro grid. DERs can act as an emergency back-up power supply for the customers where the power outages cannot be accepted such as hospitals and manufacturing industries.

Due to the flexibility of DERs in terms of size, expandability, they have wider range of operation either as a base load generator or a peak shaving generators. This helps to cope with the rapid electricity price fluctuations when they participate in the deregulated market environment. Power system reliability and power quality are of major concerns when it comes to the liberalized power market. DERs can help in maintaining the power quality problems like voltage sags and harmonics and also in maintaining reliability of the system by preventing voltage collapse events and system outages by injecting needed amount of real and reactive power whenever the system has a deficit. While DERs can greatly assist in maintaining the power system reliability by providing backup power promptly whenever and wherever needed, some of the DER technologies like Combined Heat and Power (CHP) employed most commonly in simple cycle gas turbine can utilize the excess heat which would have been wasted otherwise and can increase the efficiency of the system by up to 70-80%. Due to the fact that DERs, especially, renewable energy based ones use cleaner energy sources like wind and solar power, they are capable of producing emission-free power and hence, have greater incentive to be considered due to the low carbon footprint.

Similarly, as all the DERs are modular and have capability of providing local power to the consumers, these small generators help in cutting off the transmission losses which indirectly reduces the cost and emission associated with generating equal amount of power from the central generation. And, with efficient technologies like CHP, the amount of energy consumed from the grid is greatly reduced and hence, the resulting emissions. Despite all the mentioned benefits from the DERs, several technical and economic challenges imposed with the increased integration of the DERs to the grid and even when used in the micro-grid mode cannot be denied.

Literature survey

This section summarizes various types of DER technologies which are commonly used in the grid connected and islanded micro-grids. DERs can be broadly categorized as: Non-Renewable energy-based and Renewable energy based. Combustion engine generator sets, Gas turbines and micro-turbines are few examples of non-renewable based DERs and wind power, solar generation, fuel cells, etc. are few examples of renewable Energy based DERs.

Non-Renewable energy-BasedDERs

Combustion Engine GeneratorSets:

Combustion Engine Generator Sets are the units consisting of an internal combustion piston-driven engine, an electrical generator along with necessary controls to make it operate in a stand-alone or grid connected modes. This kind of sets can be of variable sizes and can be used with variety of fuel types like biogas, methane, natural gas, propane, gasoline, and diesel and landfill gas. The needed mechanical power for the electrical generator is provided by the engine which also helps in maintaining the desired operating frequency in proportion to the rate of engine rotation. A truck type diesel engine running at 1800 rpm can help to generate a 60 Hz output voltage waveform from a four pole synchronous generator in the United States [10]. The electrical generator can be either induction or synchronous generator. However, since induction generator is not capable of controlling voltage or reactive power independently, it cannot be used in a stand-alone application. For this reason, synchronous generator is more popular.

Combustion/Gas Turbines:

Gas turbines comprises of a compressor, combustor and the turbine generator set which converts the rotational energy to electrical power. The energy is extracted from the flow of combustion gas. A simple cycle gas turbine is a mature technology which works on the Brayton or Joule thermodynamic cycle. The atmospheric air is compressed, and this compressed air is heated through fuel combustion.

The heated air-fuel mixture is allowed to expand through a turbine which will drive the generator. The gas turbines have relatively higher efficiency and slight increase in efficiency of one of the system components impacts the overall efficiency by a very high percentage. It has been observed that only small change in system components have increased the efficiency of gas turbines from 25% in the 1950s to 35-38% in the present models.

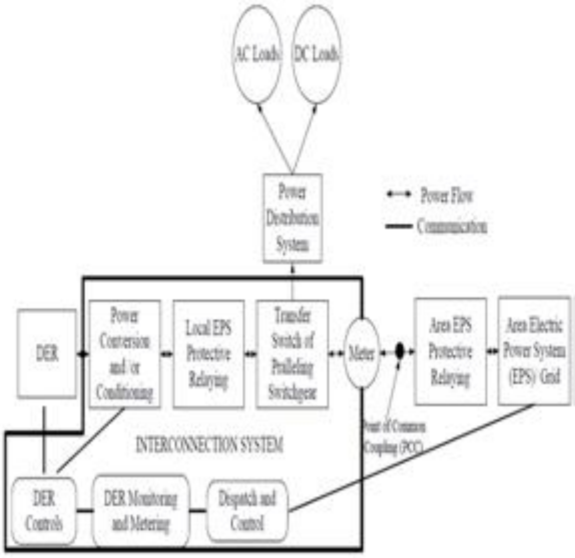


Figure1.Interconnection System Schematic

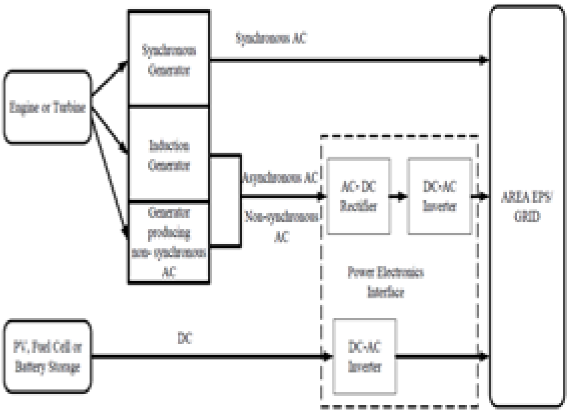


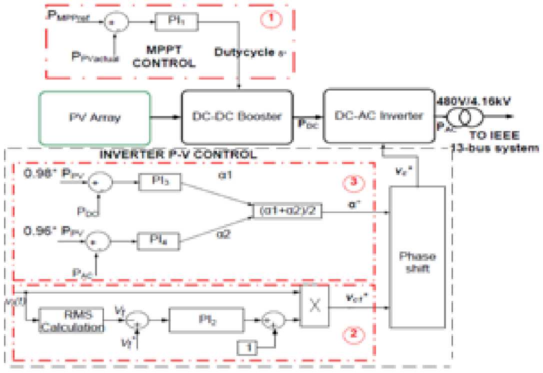
Figure2.Interconnectioninterfaces of DERs to the grid.

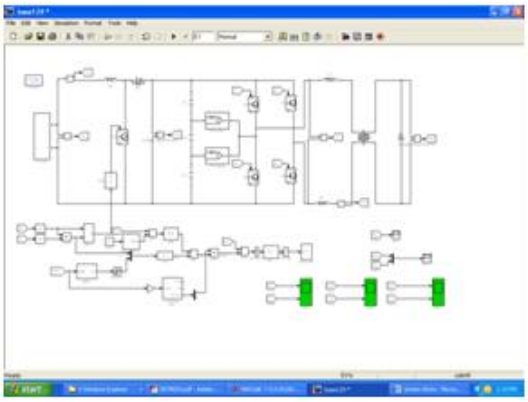
POWER SYSTEM FREQUENCY MEASUREMENT METHODS AND PROGRESSES

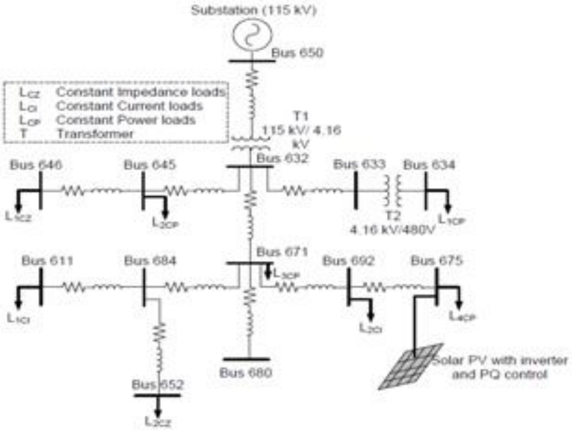
Unlike the measurement of bus voltage magnitude in power grids, the system frequency measurement is a critical issue. In North American interconnections, the power system frequency should be maintained in a very narrow band around 60 Hz during normal operation. Hence, the measurement of the grid frequency should be very accurate and fast. Various methods have been adopted to measure the power system frequency with various levels of accuracy, speed and simplicity.

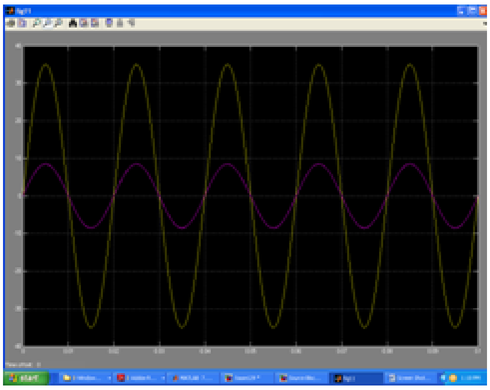
A very simple method adopted by the solid state relays in measuring the grid frequency is to detect zero crossing of the voltage waveform. But, however this method has a serious drawback of giving inaccurate results while measuring frequency of the voltage signal with distortion and noise as in this case, there will be multiple zero crossings. Several other methods have been proposed in the past to overcome a drawback of the zero crossing detection technique. These include: Discrete Fourier transform and recursive phasor computation, Kalman filtering technique and least error squares method of estimating frequency. A very fast and accurate method of frequency measurement is presented using a Digital Signal Processing (DSP) based technique. Here, the digitized values of the voltage samples taken at a specified sampling rate are considered for measurement. This method is claimed to provide a correct and noise-free estimate of near nominal, nominal and off-nominal frequencies within the time span of 25 milliseconds (ms). An iterative technique is proposed for estimating power system frequency in the resolution of 0.01-0.02 Hz in the time span of only 20 ms.

This method uses proper design and adjustment of orthogonal filters used to block harmonic components of the measured voltage. In current context, Wide area measurement systems (WAMS) implements Phasor measurement units (PMUs) and Frequency monitoring network (FNET) which is capable of measuring the power system states e.g. voltage, current, phasor angle, and frequency across a very large area. The synchronization of phase and frequency with respect to the controllable oscillator, and hence, the measurement of these parameters for the actual signal can be taken with the help of Phase Locked Loop (PLL). The basic PLL comprises of a phase detector, a loop filter and a voltage controlled oscillator (VCO). The phase detector compares the input signal with the output of voltage controlled oscillator; a loop filter helps in filtering out the output from phase detector and VCO is essentially, an oscillator in which the output frequency deviation is proportional to the input signal.









Grid Voltage & current

FUTURE WORKS

The future works of the dissertation could be performed in one of the following directions:

Adaptive control for microgrid:

The controllers used for the V-f/P-Q control are the PI controller loops, for the voltage /reactive power control, frequency/active power control and to maintain the power balance between AC and DC sides. The tuning of each of the controller gains to obtain the desired voltage and frequency response or active and reactive power is a big challenge at present. Inappropriate choice of the controller settings may lead to under achievement or over achievement of the referenced signals or even lead to instability.Hence, the future direction of the current research could be to control these PI gains adaptively based on the system conditions. A sensitivity approach of adaptive control based on Taylor series expansion could be formulated and tested in the proposed coordinated V-f / P-Q control scheme.

Application of control algorithms to multiple PhV generators:

In the present work, the proposed control algorithms are applied to a case with a single PhV generator to demonstrate the effectiveness of the proposed methods. With the increasing penetration of Solar PhV generators in the future distribution systems, the control problem could be more complex which should address the share of various PhV generators to provide for example, voltage and frequency control. The proposed methods can be extended with some other additions to handle multiple solar PhV generators.

Consideration of variability of irradiance into the control methods:

In the present work, the control methods are separately tested for various level of irradiance, however, the dynamic variability of solar irradiance is not considered. In the case of high-penetration solar PhV generators in a microgrid, the consideration of stochastic nature of PhV generation could be essential. Hence, the future direction of this work could be to consider the variability of irradiance and hence, the active power outputs of the PhV generators and to observe the ability of the proposed control algorithms to handle this situation.

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