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COORDINATION AND ENERGY MANAGEMENT OF DISTRIBUTED GENERATION INVERTERS IN A MICROGRID

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Abstract - This paper presents a microgrid 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 microgrid for grid-connected and islanded operations. The proposed microgrid consists of a photovoltaic (PV) array which functions as the primary generation unit of the microgrid and a proton-exchange membrane fuel cell to supplement the variability in the power generated by the PV array. A lithium-ion storage battery is incorporated into the microgrid to mitigate peak demands during grid-connected operation and to compensate for any shortage in the generated power during islanded operation. The control design for the DG inverters employs a new model predictive control algorithm which enables faster computational time for large power systems by optimizing the steady-state and the transient control problems separately. The design concept is verified through various test scenarios to demonstrate the operational capability of the proposed microgrid, and the obtained results are discussed.

I.INTRODUCTION

Microgrid is a new concept which plays a very important role in the future distribution network System. This project gives a centralized control nothing but coordinated control and energy management between the distributed generation inverters in a micro grid under various operating conditions like grid connected mode and islanded mode. Grid connected mode means the distribution grid is coupled with the considered micro grid and the islanded mode means the distribution grid is disconnected with the micro grid under such condition there is a mutual control between the distributed generation inverters in order to meet the particular demand.

Renewable energy generations such as wind, solar panels, PV systems, fuel cells and storage devices may act as distributed generations where the proposed system consisting of a PV array, proton exchange membrane fuel cell (PEMFC), and a lithium-ion storage battery (SB) these all connected to the distribution grid. These three renewable energy generations act as distribution generation units in the micro grid. The DG units interfaced with the power electronic inverters called as distributed generation inverters. To control this DG inverters we employed a new concept called model predictive control (MPC). This MPC control reduces the computational time very greatly by analyzing both the steady state as well as transient problems separately.

The PV array and the PEMFC both are acting as the main DG unit in which the PEMFC act as a backup generator unit if there is any problem in the PV array because of its intermittent nature. The lithium-ion storage battery in the microgrid is implemented for both peak shaving and islanded condition, in the grid connected operation it mitigates the peak demands and in the islanded operation it act to compensate for any shortage in the generated power. Energy storage elements such as storage batteries and some capacitors called ultra capacitors needed to compensate for the variations in the renewable generations where PV array and the proton exchange membrane fuel cell. In the microgrid generally there are problems divided into steady state as well as transient problems these are studied separately and optimally by the MPC controller to reduce the time required for its computation. If the controller other than MPC gives more computational time which is not desired in the microgrid conditions, like PI, PD, PID controllers they reduce the steady state error and improves the damping of the system they need more time for analyzing the problems. There is a concept of demand side management and demand response management is also involved in this project there is a energy management algorithm is designed for the microgrid to coordinate the dispatching of power between different distribution generation units.

II.DISTRIBUTED GENERATION AND MICROGRID

A part of power system which distributes the electrical power for local use is known as "Distribution system". It lies between the substation fed by the transmission system and the consumer meters.

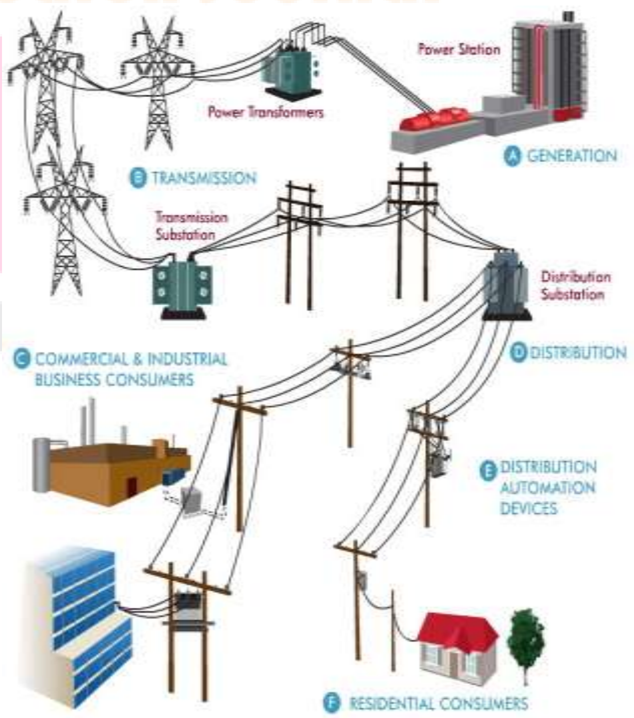

Fig.1 Simple model of Electrical Distribution system

Typical diagram of distribution system is shown in fig.1 the transmission system is distinctly different from the distribution system.

Distributed generation takes place on two-levels: the local level and the end-point level. Local level power generation plants often include renewable energy technologies that are site specific, such as solar systems (photovoltaic and combustion), fuel cells and wind turbines.

III.PHOTOVOLTAIC & FUEL CELL SYSTEM

Grid connected photovoltaic (PV) energy conversion systems are getting more and more observation in the last decade, mainly due to cost reduction of PV modules and government incentive, which has made this power source and technology ambitious among other power sources. Photovoltaic's is the field of technology and research related to the devices which directly convert daylight into electricity utilize semiconductors that display the PV effect. Photovoltaic effect involves the creation of voltage in a material upon exposure to electromagnetic radiation.

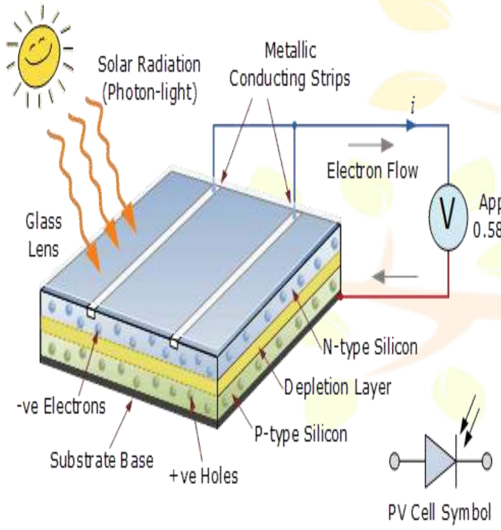

Fig.2 Block diagram of photovoltaic system

A fuel cell by definition is an electrical cell, which not like storage cells can be always fed with a fuel so that the electrical power production is continued for ever. They change hydrogen, or hydrogen-containing fuels, straightforwardly into electrical energy plus heat through the electrochemical reaction of hydrogen and oxygen into water. The process is that of electrolysis in reverse.

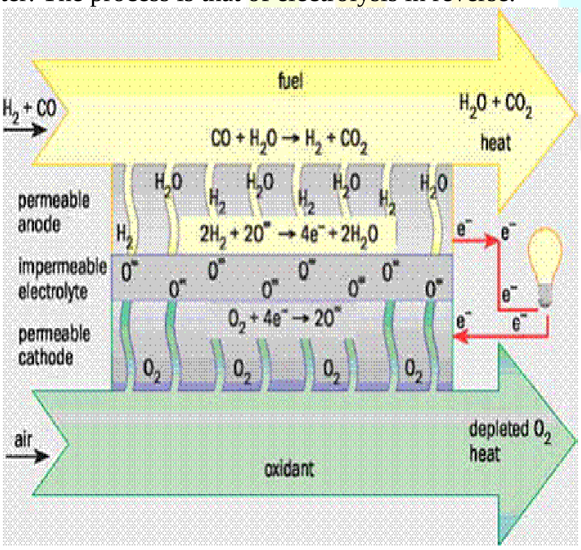

Fig.3 solid oxide fuel cell

IV.SYSTEM MODELLING AND CONTROL

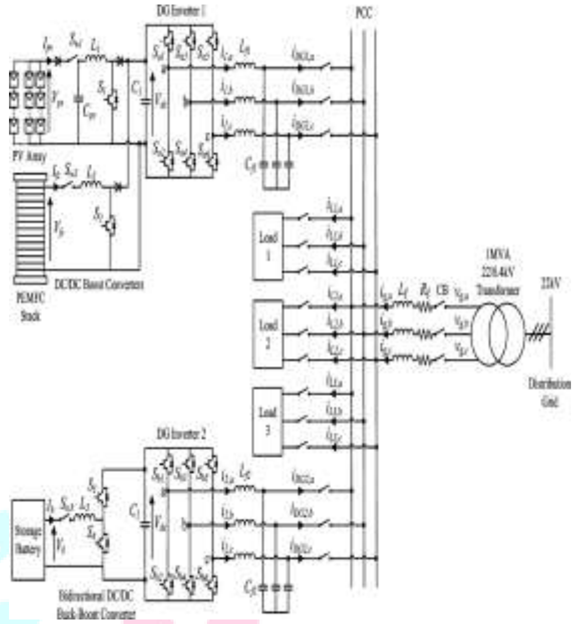
Fig.4 Overall configuration of the proposed microgrid architecture

A 40-kw photovoltaic array and a 15-kw proton exchange membrane fuel cell constitutes the the main DG unit in which the PV array act as the primary generation source and the PEMFC act as a secondary generation or backup generation but in the case of disconnection of PV array the PEMFC alone act as the main generation in order to given the required load.

Generally both the PV array and the PEMFC are connected in parallel to the dc side of the DG inverter1 as shown in fig the proposed microgrid system design is such that it can be operated in both the modes that means either in grid connected or in islanded mode. The DC/DC boost converters regulate the output voltage of PV array and fuel cell stack and give the proper dc link voltage to the DG inverter1. When there is enough sunlight then the PV array operated in the MPPT mode to deliver the maximum dc power denoted by P_{pv} and the fuel cell generated power is denoted by $P_{fc.}$ The storage battery where considered is a lithium ion storage battery which is connected to the dc side of the 2^{nd} DG inverter as shown in fig.4 the storage battery performs the charging and discharging operations according to the requirements. In the grid connected mode the SB aims for peak shaving and in the islanded mode it supplies some amount of power because of the absence of the distribution grid. During islanded operation the power delivered by SB and the main DG unit balances the total load given by the equation

P_{DG} + Pb = PL……………………..……………….(1)

Under the constraint that

$P_b \leq$ Pb, max…………………………...……………..(2)

By using the state of charge (SOC) the energy constraints are given by

$SOC_{min} <$ SOC ≤ SOCmax………..……………...(3)

Generally the SOC cannot be obtained directly but by using several estimation methods can easily determined. When the microgrid is islanded from the main grid the SB may be in the charging mode or discharging mode or idle mode that is purely depends on the state of charge and the power delivered by the storage battery. The state of charge must be in the limits of minimum to maximum SOC that means the value of the SOC should be less than or equal the maximum SOC and must be greater than the minimum SOC.

The power delivered by the SB must be satisfy the constraint that it should be less than or equal to the power delivered by the battery. The battery gets charging in the grid connected mode normally and discharging in the islanded mode it is also in the idle mode when there is power balance by the main DG unit and the distribution grid. The loads that are connected to the proposed system are of linear type and the nonlinear type also in the linear loads the load current does not contain any harmonics but in nonlinear loads the currents get harmonics.

Model Predictive Control Design

The proposed microgrid system is a complicated system to provide the necessary control in this the new novel model predictive control MPC is used. Model predictive control (MPC) is an superior method of process control that has been in use in the process industries in chemical plants and oil refineries since the 1980s. In recent years it has also been used in power system balancing models. Model predictive controllers rely on dynamic models of the process, most often linear empirical models obtained by system identification. The main advantage of MPC is the fact that it allows the current timeslot to be optimized, while keeping future timeslots in account. This is achieved by optimizing a finite time-horizon, but only implementing the current timeslot. MPC has the ability to anticipate future events and can take control actions accordingly. PID and LQR controllers do not have this predictive ability. MPC is a digital control.

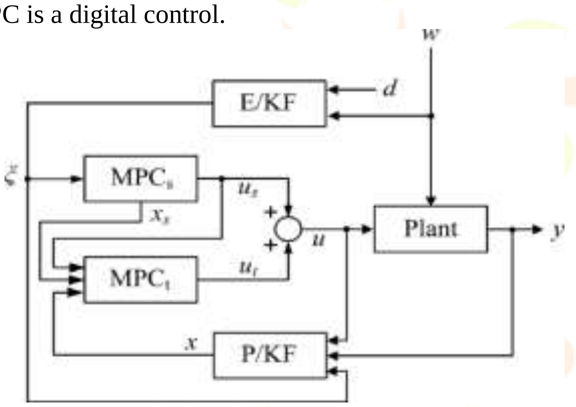

Fig.5 Overall MPC controller for the DG inverter with exogenous and plant kalman filter

V.SIMULATION RESULTS

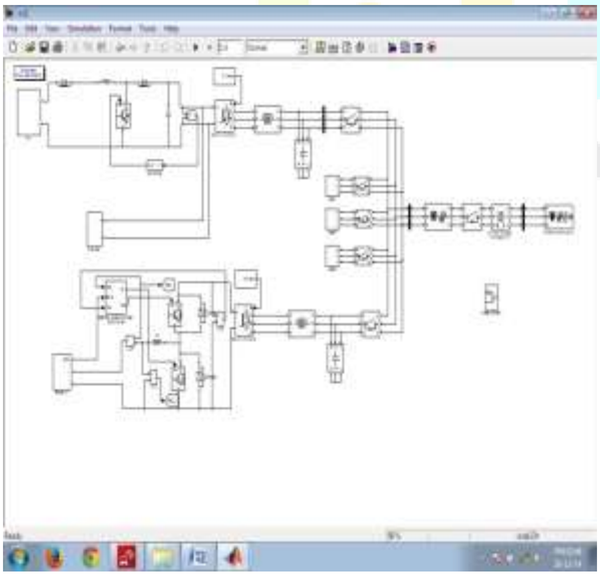

Fig.6 Simulink model for the proposed microgrid system

Fig.7 Per phase currents drawn by loads 1, 2,and 3

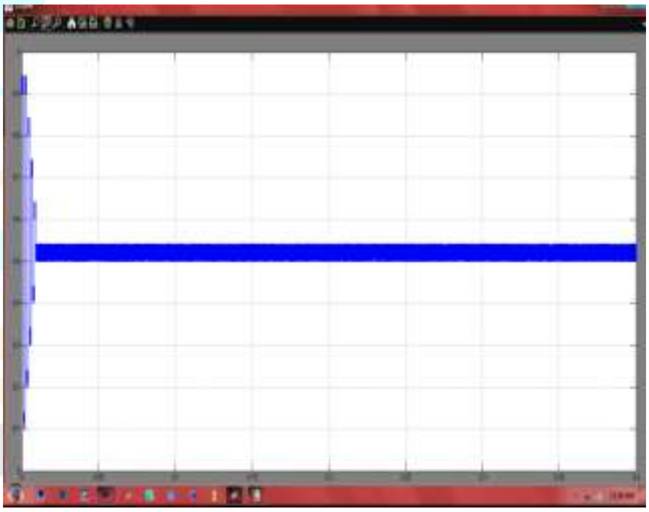

Fig.8 Waveform of the SB current during charging

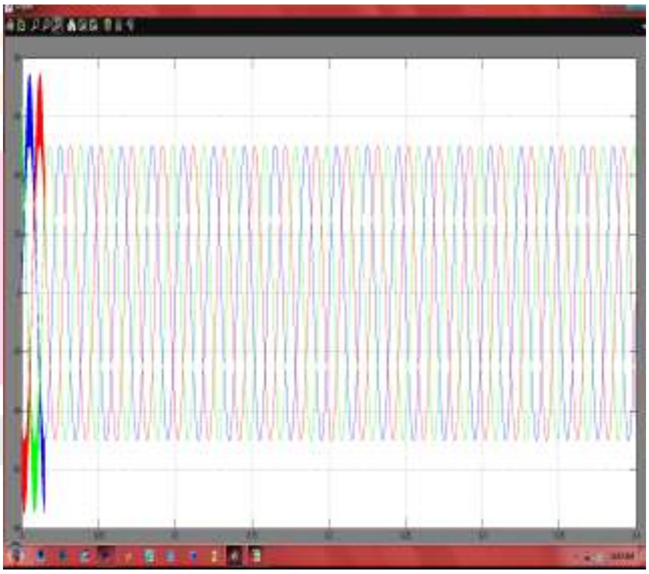

Fig.9 Waveform of three phase grid current

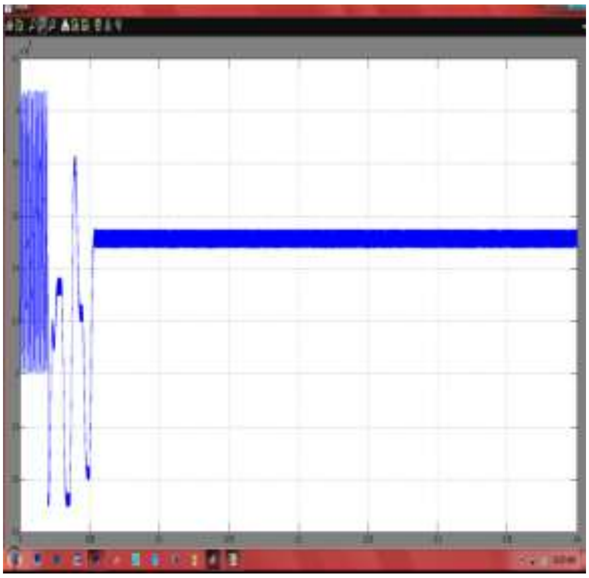

Fig.10 Real power delivered by the grid

Fig.11 Real power consumed by the loads

VI.CONCLUSION

This project proposed a control and management strategy for optimal and reliable operation of a microgrid for grid connected and islanded operations. The strategy uses Photovoltaic array (PV) as main power supply and DGs, storage battery as slave power supply. Coordination between multiple DGs in a microgrid system can be realized by using control system. MPC algorithm is implemented in the proposed controller which decomposes the control problem into steady-state and transient sub problems in order to reduce the overall computation time. 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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