CONTROL SCHEME FOR PERFORMANCE ANALYSIS OF GRID CONNECTED PV AND WIND TURBINE ISLANDING SYSTEM

[1]Akuthota Venkatraman, [2]T.Srinivasarao

[1]P.G Student {Power System Engineering}, [2]Associate Professor

Department of EEE, Sri Vahini Institute of Science and Tech

Tiruvuru, Krishna (Dist), A.P, (India)

ABSTRACT

Intentional islanding describes the condition in which a microgrid or a portion of the power grid, which consists of a load and a distributed generation (DG) system, is isolated from the remainder of the utility system. The proposed system presents power-control strategies of a grid-connected hybrid generation system with versatile power transfer. This hybrid system allows maximum utilization of freely available renewable energy sources like wind and photovoltaic energies. For this, an adaptive MPPT algorithm along with standard perturbs and observes method will be used for the system.

.Also, this configuration allows the two sources to supply the load separately or simultaneously depending on the availability of the energy sources. The turbine rotor speed is the main determinant of mechanical output from wind energy and Solar cell operating voltage in the case of output power from solar energy. Permanent Magnet Synchronous Generator is coupled with wind turbine for attaining wind energy conversion system. This paper describes a control strategy that is used to implement grid-connected and intentional-islanding operations of distributed power generation. This paper proposes an intelligent load-shedding algorithm for intentional islanding and an algorithm of synchronization for grid reconnection.

Index Terms: Distributed Generation (DG), Grid-Connected Operation, Intentional-Islanding Operation, Islanding Detection, Load Shedding, Synchronization.

I. INTRODUCTION

With increasing concern of global warming and the depletion of fossil fuel reserves, many are looking at sustainable energy solutions to preserve the earth for the future generations. Other than hydro power, wind and photovoltaic energy holds the most potential to meet our energy demands. Alone, wind energy is capable of supplying large amounts of power but its presence is highly unpredictable as it can be here one moment and gone in another. Similarly, solar energy is present throughout the day but the solar irradiation levels vary due to sun intensity and unpredictable shadows cast by clouds, birds, trees, etc. The common inherent drawback of wind and photovoltaic systems are their intermittent natures that make them unreliable. However, by combining these two intermittent sources and by incorporating maximum power point tracking (MPPT) algorithms, the system's power transfer efficiency and reliability can be improved significantly. The integration of renewable energy sources and energy-storage systems has been one of the new trends in power-electronic technology. The increasing number of renewable energy sources and distributed generators requires new strategies for their operations in order to maintain or improve the power-supply stability and quality. When the microgrid is cut off from the main grid (intentional-islanding operation), each DG system has to detect this islanding situation and has to be switched to a voltage control mode to provide constant voltage to the local sensitive loads [13]–[15].

This paper describes a control strategy that is used to implement grid-connected and intentional-islanding operations of microgrids. The described method proposes two control algorithms, namely, one for grid-connected operations and the other for intentional-islanding operations. Specifically, this paper proposes an intelligent load-shedding algorithm for intentional islanding and an algorithm for synchronization for grid reconnection.

II. PROPOSED HYBRID ENERGY DG SYSTEM

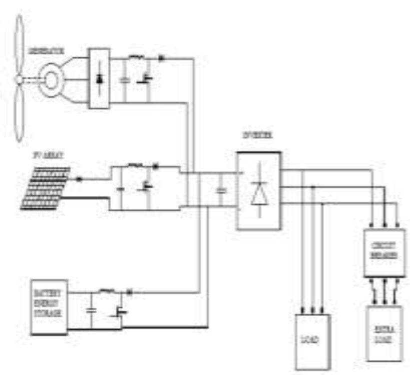

Fig 1: Configuration of Hybrid Energy DG System

The wind turbine captures the wind's kinetic energy in a rotor consisting of two or more blades mechanically coupled to an electrical generator. The equation describes the mechanical power captured from wind by a wind turbine [4] can be formulated as:

$$P_m = 0.5\rho A C_p v^3$$

The theoretical maximum value of the power coefficient is 0.59. It is dependent on two variables, the tip speed ratio (TSR) and the pitch angle. The pitch angle refers to the angle in which the turbine blades are aligned with respect to its longitudinal axis. *TSR* is defined as the linear speed of the rotor to the wind speed.

Fig.2 shows a typical "C Vs. λ" curve for a wind turbine. In practical designs, the maximum achievable ranges P from 0.4 to 0.5 for high speed turbines and 0.2 to 0.4 for slow speed turbines. Fig.2 shows that has its maximum value (C_{pmax}) at λopt. Which results in optimum efficiency and maximum power is captured from wind by the turbine.

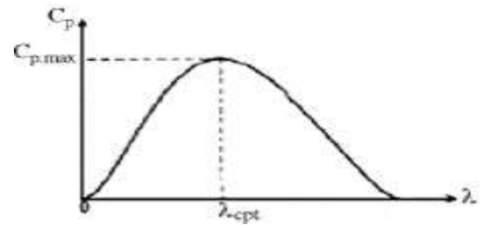

Fig 2: Power coefficient Vs Tip Speed Ratio

A solar cell is the most fundamental component of a photovoltaic (PV) system. The PV array is constructed by many series or parallel connected solar cells to obtain required current, voltage and high power [8]. Each Solar cell is similar to a diode with a p-n junction formed by semiconductor material. When the junction absorbs light, it can produce currents by the photovoltaic effect. The output power characteristic curves for the PV array at an insolation are shown in Fig. 3. It can be seen that a maximum power point exists on each output power characteristic curve. The Fig: 4 shows the (I-V) and (P-V) characteristics of the PV array at different solar intensities. The equivalent circuit of a solar cell is the current source in parallel with a diode of a forward bias. The output terminals of the circuit are connected to the load. The current equation of the solar cell is given by:

$$I = I_{ph} - I_D - I_{sh}$$

$$I = I_{ph} - I_0[\exp(\frac{qV_D}{nkT})] - \frac{V_D}{R_{SH}}$$

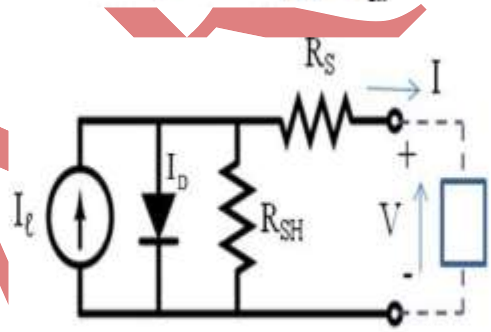

Fig 3: Equivalent circuit of PV Module

The power output of a solar cell is given by P = V * I

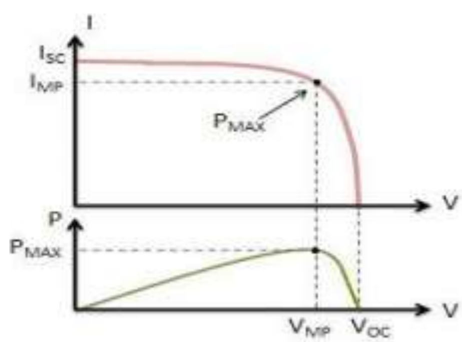

Fig 4: Output characteristics of PV Array

III GRID CONNECTED OPERATION MODE

For grid-connected operation, the controller shown in Fig. 1 is designed to supply a constant current output [8]. A phase locked loop (PLL) is used to determine the frequency and angle reference of the PCC [18], [19]. An important aspect to consider in grid-connected operation is synchronization with the grid voltage [20]–[22]. For unity power factor operation, it is essential that the grid current reference signal is in phase with the grid voltage. This grid synchronization can be carried out by using a PLL [19], [23], [24]. Fig. 2 shows the control topology used.

When using current control, the output current from the filter, which has been transformed into a synchronous frame by Park's transformation (1) and regulated in dc quantity, is fed back and compared with the reference currents I_{DQref}. This generates a current error that is passed to the current regulator (PI controller) to generate the voltage references for the inverter. In order to get a good dynamic response, VDQ is fed forward. This is done because the terminal voltage of the inverter is treated as a disturbance, and the feed forward is used to compensate for it [12].

The voltage references in dc quantities V_{DQref} are transformed into a stationary frame by the inverse of Park's transformation (2) and are utilized as command voltages in generating high-frequency pulse width-modulated voltages.

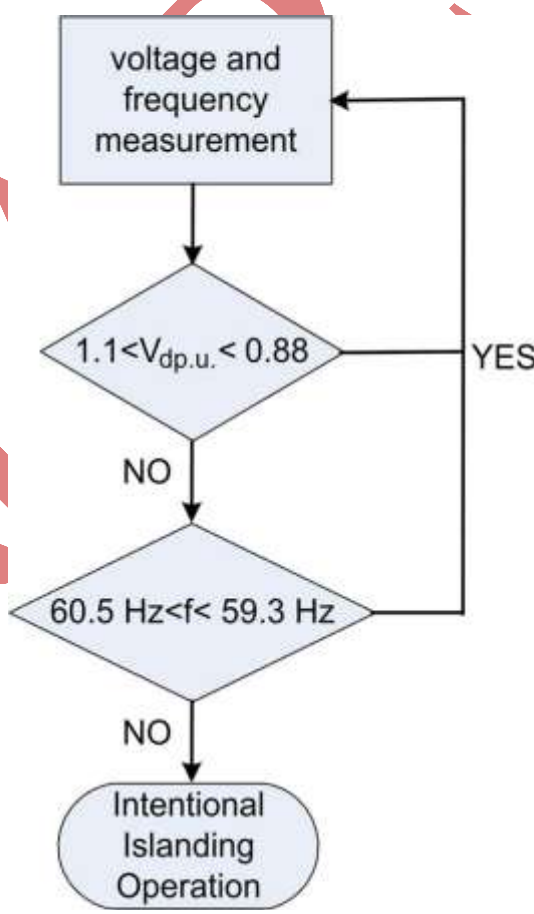

Fig. 5. Intentional-Islanding-Detection Algorithm

IV INTELLIGENT LOAD SHEDDING

Load shedding is defined as the process in which a part of the system load is disconnected according to a certain priority in order to steer the power system from potential dangers [31], [32]. During the grid-connected operation, the DG is operated to provide the optimum power to the grid according to many factors such as the availability of energy, energy cost, and so on [33]. The main grid is supplying or absorbing the power difference between the DG and the local load demand. When the main power grid is out (power outage), the DG that continues to inject predetermined optimum power can cause voltage and frequency transients, depending on the degree of power difference. The power difference makes the voltage and frequency drift away from the nominal values [34]. When the voltage and frequency drifts have reached certain levels, it is deemed that an islanding is occurring. This is the method that has been used to detect islanding. This methodology is enough for islanding detection. However, it is not enough for intentional-islanding operation, because often the local DG is either less or greater than the local load demand, and intelligent load shedding is needed. Therefore, it is essential to have an analytical solution of the voltage and frequency transients locally for the DG to have information and to make decisions and for intelligent load shedding to secure energy delivery to sensitive loads.

When the voltage at the PCC has reached either less than 0.88 p.u. or beyond 1.1 p.u., the main power grid is deemed as an outage of service according to the IEEE Std. 1547 [6]. The challenge is how to switch the DG inverter system to the voltage control mode and how to bring the voltage back to the normal range (0.88–1.1 p.u.) for intentional-islanding operation. The analytical solution of the simple-case scenario shown in Fig. 5 provides a possible solution to this challenge. Fig. 5 shows that the voltage change rate is closely related to the power differences between the DG and the load demand. The approach that is proposed in this paper is used to detect the voltage change rate and profile after the power outage and to determine how much load shedding is needed before going to the intentional-islanding operation and switching to the voltage control mode.

V SIMULATION RESULTS

Simulation study was carried out to analyze the dynamic performance of the proposed hybrid energy system design with the complete system is simulated using SIMULINK software. A 10-kW wind/PV/BESS hybrid system was considered. The system parameters used in the simulation study are presented below. All the three energy sources are accurately modeled in SIMULINK so as to predict their actual characteristics.

SIMULATED GRAPHS:

- The load demand to fulfill is 10 KW throughout the time scale except at 4 to 5 sec when it increases to 14 KW.
- Solar energy drops its irradiance to 15 % from 2 sec.
- Wind turbine initially rotating at 5m/s excels to base speed 12m/s after 0.5 sec. It's rotating speed is decreased to 25 % of its base speed.
- All these conditions are clearly observed in the below graph.

The Maximum Voltage is of PV Array is observed at around 640 V. the curve below explains that the varying irradiance is the deciding factor of the maximum voltage derived.

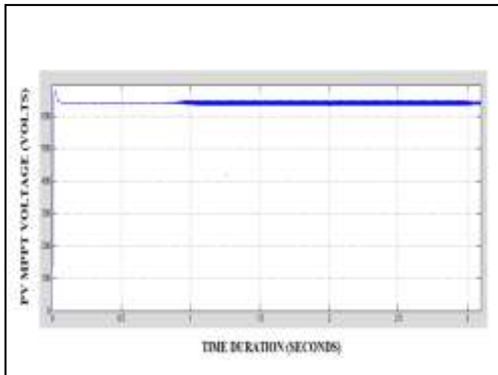

Fig 5 Phase Voltage observed at the PV array

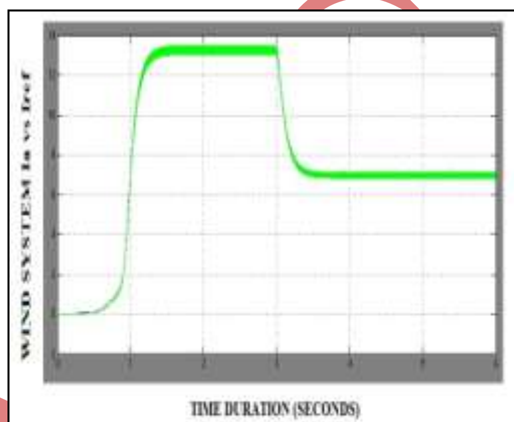

Fig 6 The relative variation curve of Actual Current (Ia) and Reference Current (Iref)

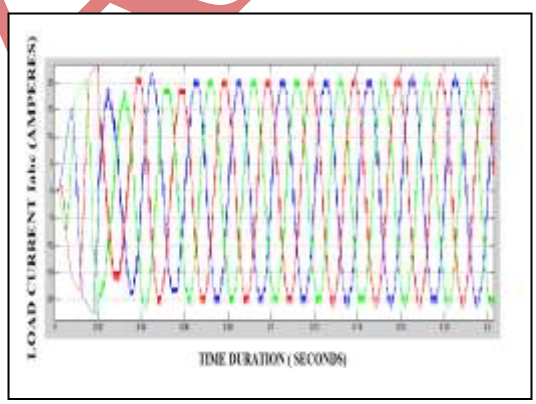

Fig 7 The load current supplied to the load is sinusoidal in nature as depicted in the simulation

VI CONCLUSION

Through this paper, the control, islanding detection, load shedding, and re-closure algorithms have been proposed for the operation of grid-connected and intentional-islanding DGs. A controller was designed with two interface controls: one for grid-connected operation and the other for intentional islanding operation. An islanding-detection algorithm, which was responsible for the switch between the two controllers, was presented. The simulation results showed that the detection algorithm can distinguish between islanding events and changes in the loads and can apply the load-shedding algorithms when needed. The re-closure algorithm causes the DG to resynchronize itself with the grid. In addition, it is shown that the response of the proposed control schemes is capable of maintaining the voltages and currents within permissible levels during grid connected and islanding operation modes. The experimental results showed that the proposed control schemes are capable of maintaining the voltages within the standard permissible levels during grid-connected and islanding operation modes. In addition, it was shown that the re-closure algorithm causes the DG to resynchronize itself with the grid.

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A.VENKATRAMAN was awarded B-Tech in Electrical and Electronics Engineering from Sri Sarathi Institute of Science And Technology Nuzvid A.P INDIA In the year 2011. He was pursuing M -Tech in Power System Engineering from Sri Vahini Institute Of Science And Technology, Tiruvuru, A.P, INDIA .His fields of interest was in electrical machines, power systems and control systems.

T.SRINIVASARAO working in Sri Vahini Institute of Science and Technology, Tiruvuru as an Associate prof in EEE dept. He was awarded B.E from Andhra university campus Visakhapatnam and He was awarded M.Tech from V.R Siddhartha engineering college, Vijayawada. His area of interest electrical machines and design, electrical circuits, power systems and power electronics