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Original Article

Modeling of Hybrid Microgrid

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Abstract: *Renewable energy based distributed generators (DGs) play a dominant role in electricity production, with the increase in the global warming. Distributed generation based on wind, solar energy, biomass, mini-hydro along with use of fuel cells and microturbines will give significant momentum in near future. Advantages like environmental friendliness, expandability and flexibility have made distributed generation, powered by various renewable and nonconventional microsources, an attractive option for configuring modern electrical grids. A microgrid consists of cluster of loads and distributed generators that operate as a single controllable system. As an integrated energy delivery system microgrid can operate in parallel with or isolated from the main power grid. The microgrid concept introduces the reduction of multiple reverse conversions in an individual AC or DC grid and also facilitates connections to variable renewable AC and DC sources and loads to power systems. To the customer the microgrid can be designed to meet their special requirements; such as, enhancement of local reliability, reduction of feeder losses, local voltages support, increased efficiency through use of waste heat, correction of voltage sag or uninterruptible power supply. In the present work the performance of hybrid AC/DC microgrid system is analyzed in the grid tied mode. Here photovoltaic system, wind turbine generator and battery are used for the development of microgrid. Also control mechanisms are implemented for the converters to properly coordinate the AC sub-grid to DC sub-grid. The results are obtained fromthe MATLAB/ SIMULINK environment.*

Keywords: *Global Warming, Microgrid, Distributed Generators, Electricity Production.*

I. INTRODUCTION

General information regarding microgrid As electric distribution technologysteps into the next century, many trends are becoming noticeable that will change the requirements of energy delivery. These modifications are being driven from both the demand side where higher energy availability and efficiency are desired and from the supply side where the integration of distributed generationand peakshaving technologies must be accommodated [1].

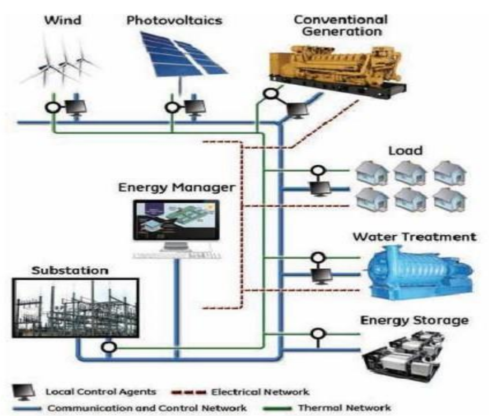

Fig 1.1. Microgrid power system

Power systems currently undergo considerable change in operating requirements mainly as a result of deregulation and due to an increasing amount of distributedenergy resources (DER). In many cases DERs include different technologies that allow generation in small scale (microsources) and some of them take advantage of renewable energy resources (RES) such as solar, wind or hydro energy. Having microsources close to the load has the advantage of reducing transmission losses as well as preventing network congestions. Moreover, the possibility of having a power supply interruption of end-customers connected to a low voltage (LV) distribution grid (in Europe 230 V and in the USA 110 V) is diminished since adjacent microsources, controllable loads and energy storage systems can operate in the islanded mode in case of severe system disturbances. This is identified nowadays as a microgrid. Figure 1.1 depicts a typical microgrid. The distinctive microgrid has the similar size as a low voltage distribution feeder and will rare exceed a capacity of 1 MVA and a geographic span of 1 km. Generally more than 90% of low voltage domestic customers are supplied by underground cable when the rest is supplied by overhead lines. The microgrid often psupplies both electricity and heat to the customers by means of combined heat and power plants (CHP), gas turbines, fuel cells, photovoltaic (PV) systems, wind turbines, etc. The energy storage systems usually include batteries and flywheels .The storing device in the microgrid is equivalent to the rotating reserve of large generators in the conventional grid which ensures the balance between energy generation and consumption especially during rapid changes in load or generation.

II. SYSTEM AND IMPLEMENTATION

2.1 EXISTING SYSTEM

- These models use mathematical equations to represent the behavior of individual components within the microgrid, such as generators, storage systems, and loads.
- Stochastic methods consider uncertainties in renewable energy resources, load demand, and component failures.
- Techniques like Monte Carlo simulation and stochastic optimization are employed to analyze the reliability, resilience, and economic viability of hybrid microgrids under uncertain conditions.

2.2 PROPOSED SYSTEM

- Hybrid optimization techniques combine different optimization algorithms, such as genetic algorithms, particle swarm optimization, and simulated annealing, to solve complex optimization problems in hybrid microgrid design, operation, and control.
- Various commercial and open-source software packages, such as HOMER, DigSilent, and MATLAB/Simulink, are commonly used for modeling hybrid microgrids.
- These tools offer graphical interfaces for designing and simulating microgrid configurations, assessing their performance, and optimizing system parameters.
- Integrated energy systems analysis assesses the synergies and trade-offs between different energy vectors to optimize overall system performance and resource utilization.

2.3 MODELING OF PV PANEL

The photovoltaic system can generate direct current electricity without environmental impact when is exposed to sunlight. The basic building block of PV arrays is the solar cell, which is basically a p-n junction that directly converts light energy into electricity. The output characteristic of PV module depends on the cell temperature, solar irradiation, and output voltage of the module. The figure shows the equivalent circuit of a PV array with a load.

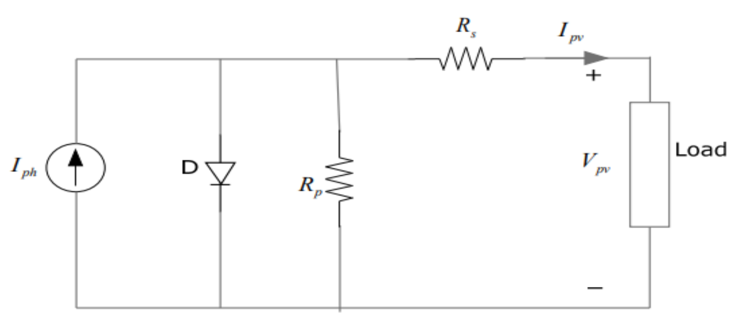

Figure 2.1 Equivalent circuit of a solar cell

The parameters used for the modeling of photovoltaic panel are shown in the table

Symbol	Value
V_{OC}	403 V
q	1.602×10^{-19}C
k	1.38×10^{-23} K
A	1.50
I_{SC}	3.27 A
K_I	1.7×10^{-3}
T_{Ref}	301.18 K
I_{RS}	2.0793×10^{-6} A
T_C	350 K
λ	0-1500 W/m^2
N_P	40
N_s	900
E_G	1.1 eV

Table 2.1 Parameters for photovoltaic panel

III. MAXIMUM POWER POINT TRACKING

As an electronic system maximum power point tracker (MPPT) functions the photovoltaic (PV) modules in a way that allows the PV modules to produce all the power they are capable of. It is not a mechanical tracking system which moves physically the modules to make them point more directly at the sun. Since MPPT is a fully electronic system, it varies the module's operating point so that the modules will be able to deliver maximum available power. As the outputs of PV system are dependent on the temperature, irradiation, and the load characteristic MPPT cannot deliver the output voltage perfectly. For this reason MPPT is required to be implementing in the PV system to maximize the PV array output voltage.

3.1 Necessity of maximum power point tracking

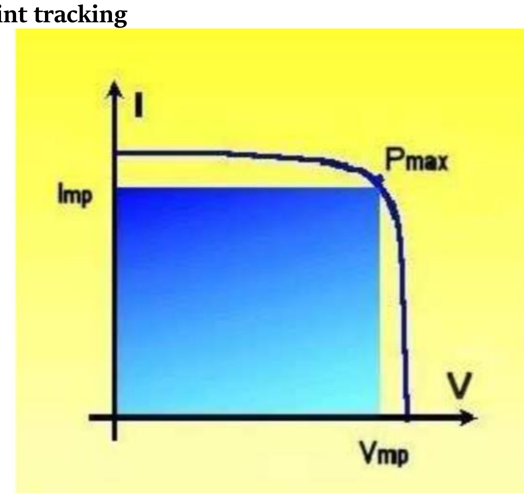

FIG 3.1 MPP characteristic

In the power versus voltage curve of a PV module there exists a single maxima of power, i.e. there exists a peak power corresponding to a particular voltage and current. The efficiency of the solar PV module is low about 13%. Since the module efficiency is low it is desirable to operate the module at the peak power point so that the maximum power can be delivered to the load under varying temperature and irradiation conditions. This maximized power helps to improve the use of the solar PV module. A maximum power point tracker (MPPT) extracts maximum power from the PV module and transfers that power to the load. As an interfacing device DC/DC converter transfers this maximum power from the solar PV module to the load. By changing the duty cycle, the load impedance is varied and matched at the point of the peak power with the source so as to transfer the maximum power.

3.2 Algorithms for tracking of maximum power point

There are different algorithms which help to track the peak power point of the solar PV module automatically. The algorithms can be written as

a) Perturb and observe

b) Incremental conductance
c) Parasitic capacitance
d) Voltage based peak power tracking
e) Current Based peak power tracking

3.3 Perturb and observe

In this algorithm a slight perturbation is introduced in the system. The power of the module changes due to this perturbation. If the power increases due to the perturbation then the perturbation is continued in that direction. When power attains its peak point, the next instant power decreases and so also the perturbation reverses. During the steady state condition the algorithm oscillates around the peak point. The perturbation size is kept very small to keep the power variation small. It is examined that there is some power loss because of this perturbation and also it fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular and simple

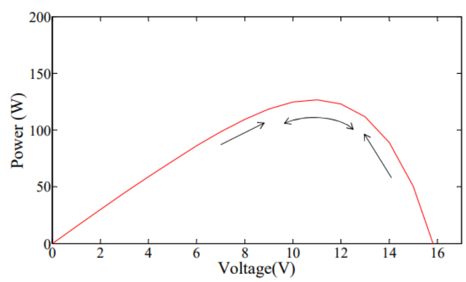

FIG 3.2 Perturb and observe algorithm

In the present work this algorithm is chosen. Figure 2.7 represents the flow chart of the algorithm. The algorithm observes output power of the array and perturbs the power based on increment of the array voltage. The algorithm continuously increments or decrements the reference voltage based on the value of the previous power sample.

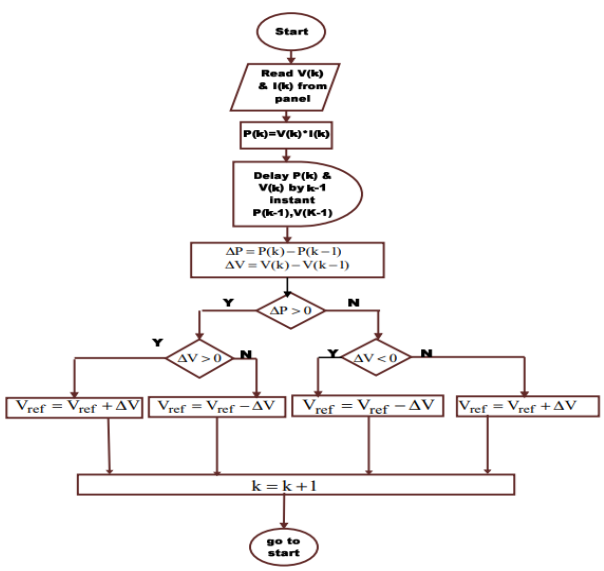

FIG 3.3 Flowchart Perturb and observe algorithm

Here a reference voltage V is set corresponding to the peak power point of the module. The value of current and voltage can be obtained from the solar PV module. From the measured voltage and current power is calculated. The value of voltage and power at k AB instant are stored. Then values at (k + 1) instant are measured again and power is calculated from the measured values. The power and voltage at (k + 1) instant are subtracted with the values from k instant. If we observe the power voltage curve of the solar PV module we see that in the right hand side curve where the voltage is almost constant the slope of power voltage is negative (dP/dV<0) where as in the left hand side the slope is positive (dP/dV<0). Depending on the sign of dP[P(k + 1) − P(k)] and dV[V(k + 1) − V(k)] after subtraction the algorithm decides whether to increase or to reduce the reference voltage.

The P&O method is claimed to have slow dynamic response and high steady state error. In fact, the dynamic response is low when a small increment value and a low sampling rate are employed. To decrease the steady state error low increments are essential because the P&O always makes the operating point oscillate near the MPP, but never at the MPP exactly. When the increment is lower, the system will be closer to the array MPP. In case of greater increment, the algorithm will work faster, but the steady state error will be increased. The small increments tend to make the algorithm more stable and accurate when the operating conditions of the PV array change. In case of large increments the algorithm becomes confused since the response of the converter to large voltage or current variations will cause oscillations, overshoot and the settling time of the converter itself confuse the algorithm.

Incremental conductance

The incremental conductance method can overwhelm the problems of tracking peak power under fast varying atmospheric condition.

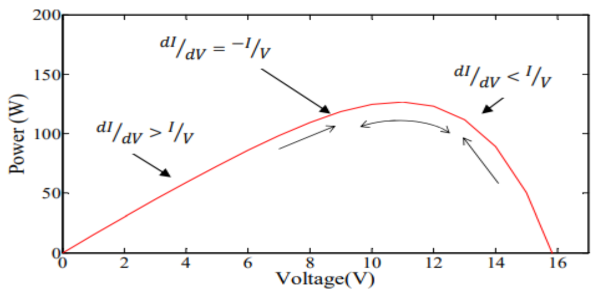

FIG 3.4 Incremental conductance algorithm

Parasitic capacitances

The improvement of the incremental conductance leads to the method of parasitic capacitance which considers the parasitic capacitances of the solar cells. This method makes use of the switching ripple of the MPPT which helps to perturb the array. The average ripple in the PV array voltage and power, generated by the switching frequency are measured 22 using a series of filters and multipliers and then used to calculate the array conductance. Then the algorithm decides the direction of movement of MPPT operating point. There is one disadvantage in this algorithm that the parasitic capacitance in each module is very small, and can perform well in large PV arrays where several PV modules are connected in parallel. There is sizable input capacitor in the DC-DC converter which filters out small ripple in the array power. This capacitor may cover the overall effects of the parasitic capacitance of the PV array [23].

3.4 Voltage control maximum power point tracker

The maximum power point (MPP) of a PV module is assumed to lie about 0.75 times the open circuit voltage of the module. Hence a reference voltage can be generated by calculating the open circuit voltage and then the feed forward voltage control scheme can be implemented to bring the solar PV module voltage to the point of maximum power. The difficulty associated with this technique is that there is variation of open circuit voltage with the temperature. As there is increase in temperature because of the change in open circuit voltage of the module, module's open circuit is needed to be calculated frequently. In this process the load must be disconnected from the module to measure open circuit voltage. So the power during that instant cannot be utilized [25].

3.4.1 Current control maximum power point tracker

The module's peak power lies at the point which is about 0.9 times the short circuit current of the module. The module has to be short-circuited to measure this point. After that module current is adjusted to the value by using the current mode control which is approximately 0.9 times the short circuit current. In this case a high power resistor is required which can sustain the short-circuit current. This is the problem with this algorithm. The module has to be short circuited to measure the short circuit current as it goes on varying with the changes in irradiation level [25].

3.5 Grid tied mode

In this mode the main converter is to provide stable DC bus voltage, and required reactive power to exchange power between AC and DC buses. Maximum power can be obtained by controlling the boost converter and wind turbine generators.

When output power of DC sources is greater than DC loads the converter acts as inverter and in this situation power flows from DC to AC side. When generation of total power is less than the total load at DC side, the converter injects power from AC to DC side. The converter helps to inject power to the utility grid in case the total power generation is greater than the total load in the hybrid grid,. Otherwise hybrid receives power from the utility grid. The role of battery converter is not important in system operation as power is balanced by utility grid.

3.5.1 Autonomous mode

The battery plays very important role for both power balance and voltage stability. DC bus voltage is maintained stable by battery converter or boost converter. The main converter is controlled to provide stable and high quality AC bus voltage.

3.5.2 Modeling and control of converters

In the present work five types of converters are used for the proper coordination with utility grid which will be helpful for uninterrupted and high quality power to AC and DC loads under variable solar radiation and wind speed when grid operates in grid tied mode. The control algorithms are described in the following section.

Modeling and control of boost converter The main objective of the boost converter is to track the maximum power point of the PV array by regulating the solar panel terminal voltage using the power voltage characteristic curve.

For the boost converter the input output equations can be written as

$$V_{pv} - V_T = L_1 \frac{di_1}{dt} + R_1 i_1$$

$$I_{pv} - i_1 = C_{pv} \frac{dV_{pv}}{dt}$$

$$V_T = V_d(1 - d_1)$$

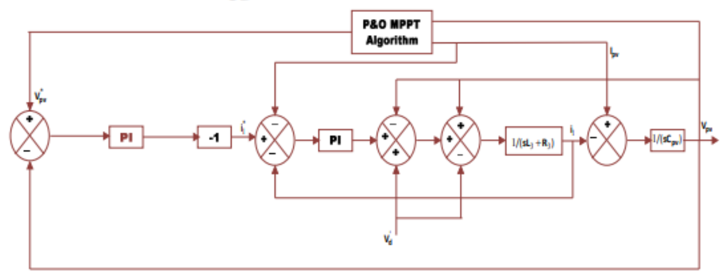

Fig 3.5. Control block diagram of boost converter

With the implementation of P&O algorithm a reference value i.e. V is calculated which mainly depends upon solar irradiation and temperature of PV array. Here for the boost converter dual loop control is proposed. Here the control objective is to provide a high quality DC voltage with good dynamic response. The outer voltage loop helps in tracking of reference voltage with zero steady state error and inner current loop help in improvisation of dynamic response.

IV. CONCLUSION

The modeling of hybrid microgrid for power system configuration is done in MATLAB/SIMULINK environment. The present work mainly includes the grid tied mode of operation of hybrid grid. The models are developed for all the converters to maintain stable system under various loads and resource conditions and also the control mechanism are studied. MPPT algorithm is used to harness maximum power from DC sources and to coordinate the power exchange between DC and AC grid. Although the hybrid grid can diminish the processes of DC/AC and AC/DC conversions in an individual AC or DC grid, there are many practical problems for the implementation of the hybrid grid based on the current AC dominated infrastructure. The efficiency of the total system depends on the diminution of conversion losses and the increase for an extra DC link. The hybrid grid can provide a reliable, high quality and more efficient power to consumer. The hybrid grid may be feasible for small isolated industrial plants with both PV systems and wind turbine generator as the major power supply.

4.1 SCOPE OF FUTURE WORK

a) The modeling and control can be done for the islanded mode of operation.
b) The control mechanism can be developed for a microgrid containing unbalanced and nonlinear loads.

V. REFERENCES

[1] S. Bose, Y. Liu, K. Bahei-Eldin, J.de Bedout, and M. Adamiak, "Tie line Controls in Microgrid Applications," in iREP Symposium Bulk Power System Dynamics and Control VII, Revitalizing Operational Reliability, pp. 1-9, Aug. 2007.

[2] R. H. Lasseter, "MicroGrids," in Proc. IEEE-PES'02, pp. 305-308, 2002.

[3] Michael Angelo Pedrasa and Ted Spooner, "A Survey of Techniques Used to Control Microgrid Generation and Storage during Island Operation," inAUPEC, 2006.

[4] F. D. Kanellos, A. I. Tsouchnikas, and N. D. Hatziargyriou, "Microgrid Simulation during Grid-Connected and Islanded Mode of Operation," in Int. Conf. Power Systems Transients (IPST'05), June. 2005.

[5] Y. W. Li, D. M. Vilathgamuwa, and P. C. Loh, Design, analysis, and real-time testing of a controller for multi bus microgrid system, IEEE Trans. Power Electron., vol. 19, pp. 1195-1204, Sep. 2004.

[6] R. H. Lasseter and P. Paigi, "Microgrid: A conceptual solution," in Proc. IEEEPESC'04, pp. 4285-4290, 2004.

[7] F. Katiraei and M. R. Iravani, "Power Management Strategies for a Microgrid with Multiple Distributed Generation Units," IEEE trans. Power System, vol.21, no. 4, Nov. 2006.

[8] P. Piagi and R. H. Lasseter, "Autonomous control of microgrids," in Proc. IEEE-PES'06, 2006, IEEE, 2006.