Integration of DG Systems Composed of Photovoltaic and a Micro-turbine In Remote Areas

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Abstract—Utility side consumers are in the remote areas who are not linked by the central electrical grid network, hybrid systems such as Photovoltaic/Microturbine have been considered as the most reliable, desired and attractive unconventional source of power supply. This documents the analysis and simulation of a Photovoltaic/Microturbine hybrid system using MATLAB/SIMULINK, simpower system block sets as its simulation software. The system is designed entirely based on the concept of a parallel hybrid configuration. The software modeling of Photovoltaic/Microturbine system provides an in-depth understanding of the system operation before building the actual system and also the testing and experiments of system operation under disturbances is not possible on the actual system.

Keywords- Micro-grid, photovoltaic, micro-turbine, hybrid distributed generation, Simulation.

Most of the countries of the world are, looking towards natural resources, such as solar energy, wind energy, ocean energy, and geo-thermal energy etc. There is a considerable importance, research work and subsidy in this field. This worldwide interest is recognized to a various aspects such as search for new energy sources due to heavy pressure on conventional fuels, simplicity, cleanliness, and direct conversion in to electricity [1]

Electricity is one of the most significant energy sources for profitable activities. The fiscal growth of a country be influenced by on its efficient supply. The total installed power generation capacity in India is about 2,76,000 MW. However, there is a gap in the demand and supply position. With the industrialization growth, the requirement of electric power turns out to be growing, which is desired to consume extra fossil fuels and sources the flagging environment difficult. In the view of environment safe and save the inadequate fossil fuels, it is essential to cultivate and usage of smoke free energy. PV power generation is a noble approach to make use of renewable energy. Nevertheless, the action of PV array is unsteady as there is instability of radiation and temperature, and hence it is compulsory to combined work with governable power generation unit to enhance the stability of the entire system. A microgrid distributed generation system based on direct current bus has been considered comprising of PV power generation unit, micro turbine power generation unit, DC-DC converter and inverter unit [2].

I. PHOTOVOLTAIC SYSTEM MODELING

A. PV system description

Fig. 1 shows the general equation from the concept of semiconductors [8] [9] that mathematically define the I-V characteristic of the ideal photovoltaic cell is.

$$I = I_{pv, cell} - I_d \tag{1}$$

$$I_{a} = I_{o, cell} \left\{ \exp(qv/a * k * T) - 1 \right\}$$
(2)

Where

k

 $I_{pv,cell}$ - current produced by the incident light

- I_d Shockley diode equation
- $I_{0,cell}$ reverse saturation or leakage current of the diode [A]
- q Charge of an electron
 - Boltzmann constant
- T p-n junction temperature
- a Ideality constant of Diode.



Fig 1: Practical photovoltaic cell.

Equation (2) represents elementary photovoltaic cell which does not signify the I-V characteristic of a practical photovoltaic array. Practical Photovoltaic arrays are consists of additional parameters to the general equation such series resistance & parallel resistance:[14]

$$I = Ipv - Io \{exp[(V + I * Rs)/(Vt *a)] - 1\} - (V - I * Rs)/Rp \quad (3)$$

Where I_{pv} and I_o are the PV and saturation currents of the array and V_t = (NskT)/q is the thermal voltage of the array with N_s cells joined in series. Cells which are in parallel connection to rise the current and cells which are in series give addition of voltages. If the PV array is connected in parallel the photovoltaic and saturation currents may be expressed as: I_{pv} = $I_{pv,cellNp}$, $I_0=I_{0,cellNp}$. From (3) equivalent series resistance of the array (R_s) and equivalent parallel resistance(R_p). The above equation is the I-V curve seen in Fig.2., where three points are shown: short circuit(I_{sc}), maximum power point (V_{mp}, I_{mp}) and open-circuit (V_{oc}).



The hypothesis $I_{sc} \approx I_{pv}$ is commonly used in photovoltaic models because the photovoltaic cell current which is generated by incident light depends on the insolation and is also the ambient temperature as per equations given[7][9]:

$$I = [I_{pv,n} + K I \Delta T)]G/G_n$$
(4)

where $I_{pv,n}$ [A] is the photo current at the standard condition, $\Delta T = T - T_n$ (where T_n and T are the nominal and actual temperatures [K]), G [W/m²] is the insolation of the device surface, and G_n is the nominal insolation.

The diode saturation current Io and its reliance on the temperature may be stated by (5):

$$I_{o} = I_{o,n} [T_{n}/T]^{3} exp\{(q^{*}E_{g}/a^{*} k) [(1/T_{n}) - (1/T)]\}$$
(5)

where E_g is the semiconductor's bandgap, and $I_{o,n}$ is the nominal saturation current:

$$I_{o,n} = I_{SC,n} / exp (V_{oc,n} / aV_{t,n}) - 1$$
(6)

 $V_{t,n}$ is the thermal voltage of N_s series-connected cells at the nominal temperature T_n . The PV model described in the former section can be enhanced if equation (5) is substituted by:

$$I_{o} = I_{SC,n} + K I\Delta T / exp(V_{oc,n} + Kv\Delta T / aV_{t}) - 1$$
(7)

This alteration targets to meet the Voc of the model with the hardware setup data for a wide range of temperatures. Eq. (6) is obtained from (5) by including the current and voltage coefficients KV and KI in the equation.



B. Description of the Micro-turbine generator

The high speed PMSG generator, turbine, compressor, recuperator, and power electronics unit are the components of MTG system shown in Fig. 4



Fig 4: Single-shaft micro turbine based generation system.

The MTG systems, works on the principle of the thermodynamic cycle generally called as the Brayton cycle. System presented here, in a radial compressor the inlet air is compressed and fed to the combustor. There the air which is compressed and mixed with oil and burned to produce high pressure combustion gas. This high pressure gas is then expanded on the turbine which is coupled to the electric generator (single shaft design). In order to increase the overall efficiency generally a microturbine will have an air to gas heat exchanger. The heat exchanger utilizes the expanded gas to heat the compressed air prior it goes to combustion chamber so this will ultimately decreases the fuel consumption during the combustion process [4].

A PMSG (Permanent Magnet Synchronous generator) is a high speed generator. This is usually used in the single shaft design. The output of PMSG is high frequency voltage (in kHz) and needed to convert this high frequency output voltage to 50Hz for normal application. Thus rectifier unit is used to convert high frequency output to DC and then converting to AC 50Hz [5]. The presented model focuses on the slow changing aspects of the microturbine generation system, this best suits for energy management of the MTG system collectively joined with other kindss of renewable energy systems. Thus, while exhibiting the MTG for the assumed purpose, the model is functioning under regular functioning conditions by ignoring fast changing aspects of the MTG like start-up, stoppage, inner faults and loss etc. The heat exchanger is only serves to improve the thermal efficiency of a MTG system which is not included in the model presented [10] [11].

C. Mathematical model for microturbine

The fig.5 shows the MTG method presented in this is built on the generic gas turbine model [3][4]. The basic elements of the single-shaft gas turbine modeled consist of speed, temperature control and the fuel system [5].



Fig.5

II. HYBRID PV-MICROTURBINE SYSTEM

A 12kW PV and a 32kW MTG microgrid generation system comprising of interfacing units such as AC-DC-AC for MTG and DC-AC for PV system is shown in this paper. Though this system can be other groupings of DG, here the combination of PV generation and MTG systems are used. PV plant is more on initial investment and low on running cost, once installed there will be very low maintenance cost involved. On the other side, MTG is low on initial investment and high on running cost. Also high maintenance cost compared to PV. The presented system produces CO_2 emission from the MTG is least compared to the fossil fuel generation method.



Fig.6 Block diagram of the suggested system.

III.SIMULATION RESULTS



Fig.7 Part of DC output voltage



Fig. 8 Part of Inverter output voltage



Fig. 9 Part of voltage at the load terminals





Fig. 10 Part of RMS voltage across load terminals

Fig. 11 Part of instantaneous load current

IV. CONCLUSIONS

The photovoltaic energy is vastly dependent on environmental condition such as ambient temperature and insolation. The limitation of above said system is overcome by integrating MTG system. Thus load voltage variation is found to be in the acceptable range. This microgrid system can withstand the disturbance in the load as well as the climatic conditions, and nullifies the problems of these variations at the supply voltage. This microgrid topology gives good performance under change in insolation, ambient temperature and load variation. This proposed microgrid topology can be used for isolated power generation in standalone areas or remote isolated groups.

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