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Renewable Solar Insolation as a Function of Distributed Energy Generation in Microgrids at Indian Sub-continent : An Economic Overview

Sandip Das

Assistant Professor, Department of Electrical Engineering, Hooghly Engineering and Technology College Hooghly-712103, India.

Abstract - *The goal of green engineering is to design products that will minimize pollution and improve the environment. Using solar energy is one way to provide clean energy using photovoltaic generators converting sunlight to electricity directly. However, the output of photovoltaic generators is variable and depends on the available solar insolation, temperature, attached loads, etc. In a microgrid with renewable energy sources, unit commitment is one of the challenging issues, due to the uncertainties in forecasting, the realization of renewable energy generation may significantly deviate from the forecasted value.*

For predictive generation planning and installation capacity of photovoltaic generators, a study based on its generation characteristic and trajectory, to determine the influence of the insolation parameters variation on the transient stability of the output of photovoltaic generators in distributed generation as a component of microgrid is indispensable. Computation and characteristics of the monthly variation of averaged solar insolation of India (20.5937° N, 78.9629° E) with respect to annual averaged insolation and Minimum and Maximum Difference from Monthly Averaged Insolation (%) incident on a horizontal surface (kWh/m²/day) is used to assess their impact on the energy demand factor of distributed energy resource, with its market economics.

Key Words: **Solar insolation, SPV energy generation, Transient stability, Indian Sub-continent, Demand Factor, Energy market.**

1. INTRODUCTION

Renewable energy technologies are having increasing presence in electric power systems around the world. According to the International Energy Agency forecast, electric power generation from renewable energy sources will nearly triple from 2010 to 2035, reaching 31% of the world's total power generation, with hydro, wind and solar renewable power providing 50%, 25% and 7.5%, respectively, of the total renewable energy generation by 2035. [1]

The impact of renewable energy generation sources planning is two-fold, as installed sources constraint and renewable energies nature. The intermittent nature of renewable energy generation can lead to insufficient generation and, hence, reliability issues, especially during the islanded operation.

Furthermore, microgrid planning is subject to other external uncertainties, such as long-term fluctuations in renewable energy reaching. The reduction in load predictability introduces higher uncertainties in the power generation scheduling. Similarly, the predictability of renewable energy sources is lower due to their smaller capacity in comparison with utility-scale of solar farms.

In this context, solar photovoltaic energy generation is experienced the fastest growing among all types of renewable technologies currently being investigated. Such that, the integration of large solar energy parks in power systems will affect considerably the dynamic behavior of the system, since solar photovoltaic energy based generation systems and conventional systems with synchronous generators present inherently different dynamic characteristics.

This is important to outline that in all these research works, the transient stability was assessed by observing the demand response to a contingency of the system, i.e., there was not used any advanced tool to obtain extra information beyond a visual observing criterion of the transient behaviour of the state variables. [2]

The study of transient stability in power systems is a significant part of assessing transmission system consistency. The traditional methodology to assess the transient stability of a system after the occurrence of a disturbance consists of simulating the nonlinear dynamic behavior and analyzing the transient behavior of the system state variables (angles and speed of generators, controllers, etc.). Thus, the transient stability analysis consists of observing if the state variables of the disturbed system will remain stable following a particular contingency [3]. Although this approach determines if the system is stable or not following a contingency, it does not have the capability of identifying or sensing the effect of the parameters into the transient stability of the system [4].

In order to get more information about the system and its transient behavior following a solar insolation variation, including how the system parameters influence in the solar photovoltaic generator's transient response, we propose to apply an effective methodology based on the sensitivity theory of dynamic systems [3]. The goal of proposing the application of the sensitivity theory to assess the solar photovoltaic generator's dynamic behavior is to find out how sensitive is the twelve month averaged solar insolation variation state variables to annual averaged insolation and Minimum & Maximum Difference from Monthly Averaged Insolation (%) incident on a horizontal surface (kWh/m²/day). Although, this is out of the scope of this paper, such invaluable information (trajectory sensitivities) could be used to improve the transient stability of solar photovoltaic energy generator's, by modulating the most sensitive system parameters, that could extract maximum power from PV arrays with the help of maximum power point tracking (MPPT). [5]

2. TRAJECTORY SENSITIVITY THEORY FOR DIFFENTIAL EQUATIONS SYSTEMS

Dynamic systems are usually described by a set of Differential Equations. Here, the variable pattern of insolation is considered as V, a vector of dynamic state variables g, h, t; where g is the time varying matrix of twelve month averaged solar insolation variation, h is time varying matrix minimum & maximum difference from monthly averaged insolation (%) and t is time variation in twelve months.

So, the insolation vector is explicitly modeled by the set of differential equations through the function, as

$$\frac{dV}{dt} = f(g, h. t);$$

With initial conditions and is a set of time invariant parameters of the system as,

$$\dot{V} = f(X); f(0) = 0;$$

2.1 Analytical formulation of trajectory sensitivities

The sensitivities of dynamic state vector with respect to a chosen system's parameter i.e. averaged solar insolation variation at a time along the trajectory are obtained from the partial derivative as,

$$\dot{V}(X) = \frac{\partial V}{\partial x_1}\dot{x_1} + \frac{\partial V}{\partial x_2}\dot{x_2} + \ldots\ldots + \frac{\partial V}{\partial x_n}\dot{x_n}$$

Where, n is 12, for different twelve month averaged values.

The smooth evolution of the sensitivities along the trajectory is obtained by differentiating the values, where time varying matrices computed along the system trajectories. [4]

2.2 Numerical calculation of trajectory sensitivities

The numerical computation of Trajectory Sensitivities (TS) requires only a nominal and a perturbed simulation in the time domain. This formulation is easier to implement than that of an analytical formulation. If it is considered a very small perturbation over the nominal parameter such that the sensitivities can also be calculated in a simpler way by assuming that the slope of the tangent line to the nominal trajectory solution at is well approximated by the slope of the secant line through and the perturbed trajectory solution.

3. INDIAN SUB-CONTINENTAL SCENARIO

The solar insolation data available from NASA surface meteorology and solar energy for Indian Sub-continental Latitude 20.594 & Longitude 78.963 taken from the NASA GEOS-4 model elevation is in table 1 and table 2.

Table -1: Solar insolation data of 1st Half-yearly

Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m²/day)						
Lat 20.594 Lon 78.963	Jan	Feb	Mar	Apr	May	Jun
22-year Average	4.78	5.63	6.30	6.80	6.66	5.03

Table -2: Solar insolation data of 2nd Half-yearly

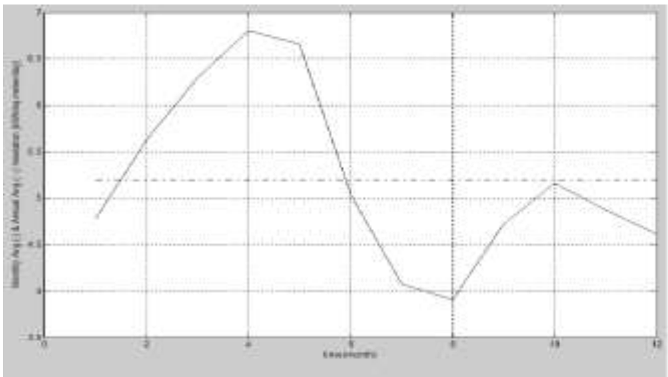
Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m²/day)						
Lat 20.594 Lon 78.963	Jul	Aug	Sep	Oct	Nov	Dec
22-year Average	4.07	3.91	4.72	5.16	4.87	4.61

Where the annual averaged value is 5.20 kWh/m²/day. [5]

3.1 Nature of solar insolation throughout the year

The graphical representation of these insolation trajectories throughout the year with its average values shows a varying nature of characteristics. This would be helpful to predict its energy generation, as a futuristic view.

Chart -1: Monthly average and annual average in respect of time.



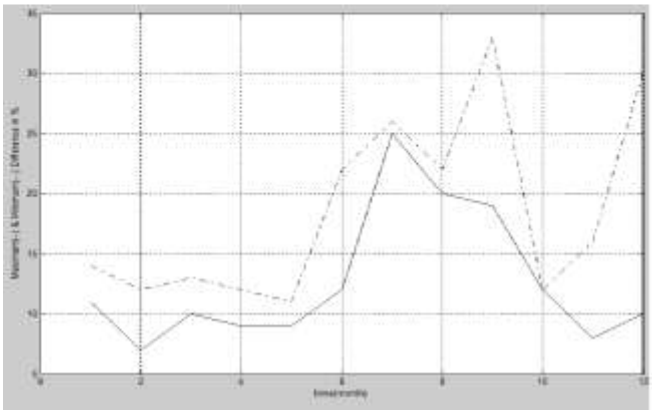
The characteristics insolation trajectories show, its have much higher value in one half of the year and in other half it's a little bit lower from the average. Depending upon this the demand factor can be managed by using distributed energy sources and supplying from microgrid or making it islanding.

3.2 Compensating the demand at peak time minimizing energy cost

Demand Factor is always change with the time to time or hours to hours of use and it will not constant. The connected load is always known so it will be easy to calculate the maximum demand if the demand factor for a certain supply is known at different time intervals and seasons.

The demand of energy at peak load can be compensated with the surplus of SPV distributed generation, as per the predicted nature of generation characteristic, of a particular area and forecasted load. Thus scheduling of connecting of distributed resources forming the microgrid and islanding of the same may be designed. The trajectory of maximum & minimum generation based on insolation and their deviation from yearly average generation in Chart – 2 shows it properly.

Chart -2: Maximum and minimum insolation difference from average in %, with respect of time.



These predictive mode of energy conversions with microgrid made effects on energy market economics & its tariff structures, as Genco (Generating Company), Transco (Transmission Company), Discom (Distribution Company), Resco (Retail Energy Service Company), Market Operators (MO), System Operators (SO), Transmission System Operator (TSO), Independent System Operator (ISO) and customers works as different entity.

4. CONCLUSION

These distributed energy conversions made effects on energy market structures, as Genco (Generating Company), Transco (Transmission Company), Discom (Distribution Company), Resco (Retail Energy Service Company), Market Operators (MO), System Operators (SO), Transmission System Operator (TSO), Independent System Operator (ISO) and customers work as different entity. Proper pre-scheduled operation of microgrid at peak load of the conventional grid system, would drop down the energy cost, and would work for betterment of the society.

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BIOGRAPHIES

Sandip Das has done his M.E. from Electrical Engineering Department of Jadavpur University, Kolkata (W.B.), and India. Now he is working as Assistant Professor in the Department of Electrical Engineering, H.E.T.C., affiliated to Maulana Abul Kalam Azad University of Technology. His core area of interest is Renewable & Non-conventional Energy, Energy Management and Electrical Energy Generation, Control & Distribution.