Performance evaluation of centralized inverter and distributed micro inverter systems based on solar radiation model

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Abstract- *The effects of solar radiation, temperature, partial shading and mismatching effects, vegetation, dust etc. generally affect the electrical power output produced in a solar photovoltaic system. This paper is aimed at maximizing the power output of each module by proposing the incorporation of micro inverters in the PV modules for the distributed applications. The maximum power is tracked using MPPT control technique for both the distributed and centralized inverter applications and simulated with MATLAB Simulink. A solar radiation computer model based on hourly solar radiation is designed in MSExcel using the Liu and Jordan solar radiation model for clear sky, and the values obtained are compared against the power output for both applications. At each changing value of solar radiation, the power output for the distributed application was higher than that obtained for the centralized application. In the PV array analyzed, the mean power output obtained for the centralized inverter system is 0.6kw and for the proposed distributed micro inverter system, the mean power output obtained was 1.5kw. These values were obtained at 1000W/m² and 25⁰C standard testing condition STC for the solar PV system.*

***Key words*: Maximum power point tracking, micro inverter, solar radiation, standard testing conditions**

1. INTRODUCTION

The distributed generation systems through the use of renewable energy sources such as the photovoltaic systems, wind energy systems , hydro energy systems, biomass generators, steam generating systems, nuclear systems etc have become widely recognized alternative energy sources of energy harnessed through these systems. These non-conventional sources of energy have in recent times gained acceptability as a result of their ability to provide clean and renewable production of energy through distributed energy systems. The solar photovoltaic systems are used to harness the energy from the irradiation of the sun in which the energy output is dependent on the intensity of the sun on the solar panels [1]. Most recent technologies have developed in the production and manufacture of photovoltaic systems, such as improvements on the crystalline panels, increased efficiency, power quality, cost effectiveness, conversion techniques, synchronization efficiency etc. These various improvements in the manufacture of solar photovoltaic system have led to the manufacture of distributed solar inverter systems giving rise to micro inverters. Photovoltaic systems are basically composed of PV modules and array, the charge controller, the battery storage, the converter devices DC to DC converters and DC to AC inverter. The solar distributed energy systems can function reliably as a standalone or grid connected system. In the design of the grid connected micro inverter system the basic function of the solar cell is considered. A micro inverter is a module incorporated inverter. A Photovoltaic micro inverter system refers to a solar PV system comprised of a single low power inverter system for each PV panel. Each solar panel incorporates its own inverter.

The photovoltaic cells are mainly semiconductor devices which exhibit electrical properties similar to a diode. When the energy from the sun is incident on the panels, the PV cells operate as a current source and as a source of electrical energy. The voltage output and hence the power output from the photovoltaic modules is inversely proportional to changes in temperature, therefore for a given temperature rise there is a voltage drop and hence reduced power output. The solar irradiance however is directly proportional to the current of the PV modules, the higher the intensity of the light energy, the higher the current from the panels. The solar irradiance has minimal impact on the voltage and hence the power output, and also temperature rise has a reduced effect on the current of the PV array. The three classic points on a module current voltage (IV) curve are the short circuit current, open circuit voltage and maximum power point as shown in figure 1. When the PV module is connected to no load, the current flow through the PV cell is equal to zero, as a result there is an open circuit and the maximum voltage at which the open circuit occurs is V_{OC} , the resistance offered as a result at that maximum voltage is infinity $R = \infty$. When a load is connected, the voltage gradually drops, and the point where the voltage reduces or is equal to zero, a maximum short circuit current I_{SC} flow through the PV cell that means a short circuit occurs. The resistance offered as a result at that maximum short circuit current is equal to 0, $R = 0$ [2].

The solar inverter system to be used and the optimal energy output are required to be harnessed from the sun's irradiation on the solar panels. The technique that is required for this purpose is the maximum power point tracking algorithm. The algorithm analysed in this work is an improved perturb and observe maximum power point algorithm. The aim of the design of photovoltaic (PV) systems is to extract the maximum power from the PV panels and inject it into the ac grid. The IV characteristics of a PV cell shows the plots of current against voltage IV curve and power against voltage PV curve as shown in figure 2. The maximum power point tracking (MPPT) of a uniformly irradiated PV array and the maximization of the conversion efficiency have been the main design issues. However, when the PV plant is connected to the grid, special attention has to be paid to the reliability of the system, the power quality, and the implementation of protection and grid synchronization functions [3].

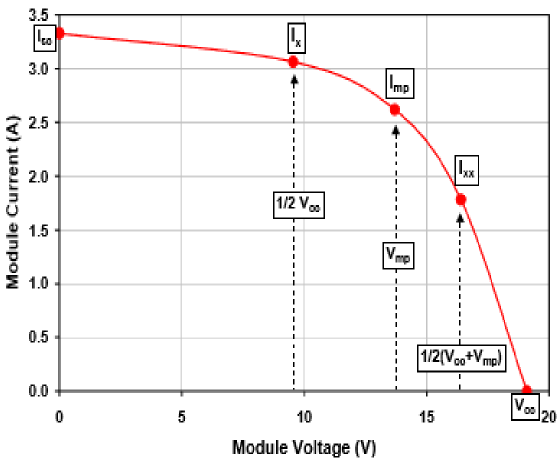

Fig -1: Classic points on the IV curve [4]

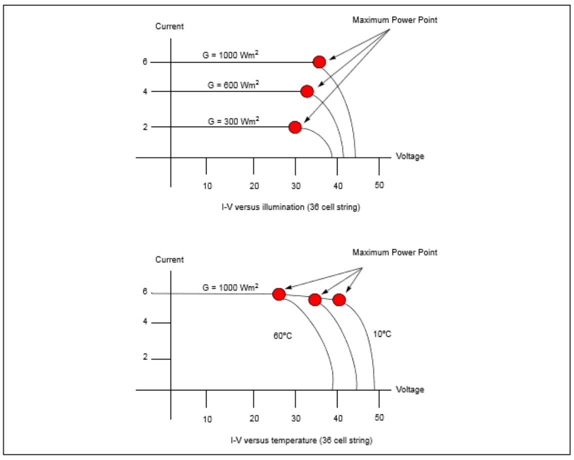

Fig -2 I-V characteristics of PV cell [5]

1.1 Solar Radiation Models

There are various factors to consider in siting a solar generating plant. These factors are dependent on the prevailing capacity of solar irradiation and temperature within the area. Nigeria lies within a high sunshine belt and, within the country; solar radiation is fairly well distributed. The annual average of total solar radiation varies from about 12.6 MJ/m2 -day (3.5 kWh/ m2 -day) in the coastal latitudes to about 25.2 MJ/ m2 -day (7.0 kWh/ m2 -day) in the far north." Assuming an arithmetic average of 18.9 MJ/ m2 -day (5.3 kWh/ m2 -day), Nigeria therefore has an estimated 17,459,215.2 million MJ/day (17.439 TJ/day) of solar energy falling on its 923,768 km2 land area. The above arithmetic average may be interpreted as the application of each of the above radiation values to approximately half the area of the country, thus giving a total of (12.6 + 25.2) x (923,768/2) which gives the same value as before. Annually, the above average solar intensity is 6898.5 MJ/m2 -year or 1934.5 kWh/m2 -year, a value that can be used to calculate the available solar energy.[6] The solar radiation measuring stations of the Nigerian Meteorological Agency are mostly airport and aerodrome weather stations which were originally set up to aid civil aircraft navigation. Thus, the stations themselves cover only about thirty localities. To obtain a good solar radiation database there is need to set a lot more radiation measurement stations all over the country, particularly in the northern areas where the radiation belt is very high. Radiation studies done have relied on the data from the meteorological stations to develop equations applicable to either zones of the country or to the whole country which are useful for solar equipment manufacturers and designers. Such studies need to be validated with much more data evenly spread all over the country. Most of the solar radiation data taken at the meteorological stations are for the total or global solar radiation. There are also solar radiation models developed in computing the amount of solar irradiation of any given area based on the longitudinal and latitudinal positions of the area, the solar declination angle, hour angle etc. These models include ASHRAE model, Atwater and Ball model, Bird model, Davies and Hell model etc. The amount of Solar radiation can also be computed using software models such as PVsyst, MatlabSimulink, RETScreen etc.[7].

2. REVIEW OF RELATED WORKS

A review of PV grid connection inverters was carried out in [8], and they were found to have high conversion efficiency, and power factor exceeding 90% for a wide operating range while maintaining current harmonics or total harmonic distortion at less than 5%. The control and tracking circuit such as MPPT, inverter current control and power factor control were implemented. This paper was mainly on review of the outlined functions of grid connected PV systems, while the analysis carried out in this work compared the performance between two applications of inverter systems, the centralized and distributed grid connected Photovoltaic systems, proposing the later as a better option as it offers higher conversion efficiency, and tracking efficiency using MPPT. In [9] a grid connected micro inverter system was analysed. They reviewed past and present conditions of inverters. The same topology used here, was used in this paper, a dc-dc boost half bridge converter connected to the PV system, the Pulse width modulation and MPPT tracking was also carried out at converter level except in this work, the MPPT control algorithm was incorporated at the inverter level for the distributed and centralized applications and the efficiency measured for both converter, inverter and MPPT control functions and compared. In [10] various inverter topologies and their connection to single phase grid were studied, these topologies were compared, and evaluated against demands, lifetime, component ratings and cost. The research carried out in my work compared two inverter topologies against similar parameters based on a solar radiation model. [11] analyzed shading effect on PV modules and how it can affect the peak power output by comparing two topologies, and a recommendation made out of the comparison, while the focus of this work was the effect solar radiation values had on the output of centralized and distributed inverter applications. In [12] a PV array performance model was developed in Sandia National laboratories, which can be used to design (or size) a photovoltaic array for a given application based on expected power and/or energy production on an hourly, monthly or annual basis while this paper used the Liu and Jordan model used in [13] to obtain the hourly, daily, monthly and annual solar radiation values based on longitudinal positions of a given area. In [14] the performance of solar PV modules is tested under different irradiance levels. The relationship between the model powers versus its current under different irradiance levels is plotted while this research compares the power output for both inverter applications based on varying solar radiation values.. In [15] the evaluation of the global solar energy potential at Uturu at latitude 05.33^0N and 06.03^0N was carried out based on temperature data while in my research the solar radiation model can be used based on the longitudinal position of a given area. [16] analysed the correlation between measured and predicted values of solar radiation in Mubi, Nigeria. The daily measurements were carried out using a constructed pyranometer this has a limitation to this research which can analyze the solar radiation potential of any location based on longitudinal position of a place. [17] Used same solar radiation models to estimate the radiation potential of FUTO, without any actual application to system simulation as opposed to the application carried out in the Matlab simulink simulations of the two photovoltaic systems under study in this research.

3. METHODOLOGY

The materials used in the analysis of this research are various PV components ranging from PV modules, boost converters and Inverters, and VSC Controller used for both centralized and distributed applications, simulated using the MATLAB Simulink. The PV array have rated values of 305W with 5 series and 66 parallel and 205W with 8 series and 61 parallel; the inverter has a rated capacity 1000kW for the centralized inverter system and 100kW micro inverter for each module of the micro inverter system based on the standard testing condition for operation of photovoltaic systems of $1000W/m^2$ and 25^0C. The photovoltaic systems under study were simulated based on changing values of solar radiation.

3.1 Centralized Inverter system

The Photovoltaic modules and inverter specification used for the centralized inverter system is shown in Table 3.1:

Table 3.1 Photovoltaic module and inverter specification for centralized inverter system

Grid Specifications	
Voltage rating	25kV
Frequency	50Hz
Number of phases	3
Solar Photovoltaic module/ Inverter specifications	
Module Type	Polycrystalline
Module capacity	305Wp, 205Wp
Module efficiency	80%
Inverter capacity	1000kW
Inverter Efficiency	97%
Temperature at STC	25^0C

3.2 Distributed Micro inverter system

The Photovoltaic modules and inverter specification used for the distributed micro inverter system is shown in Table 3.2:

Table 3.2 Photovoltaic module and inverter specification for microinverter system

Grid Specifications	
Voltage rating	25kV
Frequency	50Hz
Number of phases	3
Solar Photovoltaic module/ Inverter specifications	
Module Type	Polycrystalline
Module capacity	305Wp, 205Wp
Module efficiency	94%
Inverter capacity	100kW
Inverter Efficiency	99%
Temperature at STC	25^0C

The following tools were used in this paper

1. MS Excel office
2. Matlab Simulink
3. Liu and Jordan solar radiation model

The solar radiation and the temperature from the sun are the two main parameters that determine the expected power output reaching the solar panels. There are other factors which also limit the sun's intensity on the panels such as partial shadow effects, mismatching effects, presence of dusts and positioning of the panels based on the azimuthally angle of the sun. A measure of the solar resource of a particular area FUTO community based on the seasons of the year on clear sky basis is used to design a solar radiation computer model. There are various methods and models that have been adopted for either measuring or obtaining directly the solar irradiation data from a given location. These methods vary from information obtained from weather stations, global geographical information systems, use of solar radiation meters such as the pyranometers etc. These global information systems based on solar irradiation data does not cover some areas in the world, therefore models have been adopted based on the latitudinal position of the locations. The other parameters include: the hour angle, declination angle, latitude and longitude positions etc. Most models usually used are adopted for clear sky as against cloudy sky. The model adopted for this work is the Liu Jordan diffuse radiation model, other models include the ASHRAE model, Davies and hay model, Hoyt model etc.

The micro inverter systems are designed to operate at Standard testing conditions of 1000W/m^2 and 25^{0}c. The panels considered for this study are ten in number based on 220W rating for each, The system can be connected to any PV module with rating of 220W with input voltage range of 25VDC TO 45VDCand a maximum open circuit voltage of 55V (Dumais et al.,2010-2011). A Matlab simulink representation of the entire system is designed in this work incorporating both the dc-dc converters, micro inverters for distributed applications and also centralized inverter systems for the centralized application systems. The maximum power point tracking control algorithm is written based on varying the duty cycle of the pulse width modulation carried out in the buck and boost converters. The expected power output for both distributed application using micro inverters and centralized application using a central inverter are compared in terms of converter efficiency, power quality, cost effectiveness, etc and the results obtained show that the optimal power obtained through the use of micro inverters are higher compared to that of central inverter systems with high efficiencies.

The solar radiation potential of FUTO community was determined based on the Hottel and Liu Jordan clear sky radiation model. A calculator model was designed in this project using Microsoft Excel based on the several mathematical models incorporated in this model. The solar radiation model was designed to enable us determine , the expected maximum power for each value of solar radiation calculated from the model, this will enable us track the maximum power at changing values of irradiation. A similar work using same models was published in an American journal [17] using Matlab to generate an estimated annual solar radiation data with an expected power output. The model was used to design a calculator which will estimate the hourly solar radiation throughout the year from 0900 to 1800 in real time. At each given hour the total variation in solar irradiation are compared to the values at STC. The Hottel and Liu Jordan clear sky data was used because

- The mathematical models are easy and simple to estimate
- The parameters with estimated constants such as the zenith angle and latitude are already computed.
- There are different climate types it analyses such as tropical, mid latitude summer, subarctic summer and mid latitude winter.
- It does not involve ambiguous atmospheric data which are not readily available in the given location.
- It provides a high degree of accuracy.

There are some basic parameters used in the design of the computer model such as:

Beam Radiation (G_{cb}): This is called the direct radiation. It is the solar radiation received from the sun without scattering by the atmosphere.

Diffuse Radiation (G_{cd}): This refers to the radiation received from the sun which has been scattered by atmospheric particles, clouds or reflected off some surface.

Total Radiation (G_T): This gives a sum of the beam (direct) radiation and diffuse radiation. It is sometimes referred to as global radiation.

Irradiance: The rate at which solar radiation is incident on a particular surface per unit area. It is measured in W/m^2.

Latitude (Φ): This is the angular position north or south of the equator.

Zenith Angle (Θ_Z): This is the angle between the vertical and horizontal line to the sun that is, the angle of beam radiation on a horizontal surface.

Hour angle (H): This is the angular displacement of the sun east or west of the local meridian due to rotation of the earth on its axis through 15^0 per hour. It is positive in the afternoons and negative in the mornings.

Declination (δ): This is the angular position of the sun at solar noon. It varies seasonally due to tilt of the earth on its axis and its rotation around the sun.

The solar constant (Gsc): This is the energy from the sun per unit time received on a surface perpendicular to the direction of propagation of radiation at mean earth-sun distance outside the atmosphere. The world radiation centre adopted a value of 1367W/m^2, as the solar constant.

3.3 Liu and Hottel Mathematical Models for Estimating Clear Sky Solar Radiation

The atmospheric transmittance T_b for beam radiation is expressed as:

$$T_b = \alpha_0 + \alpha_1 \exp\left(\frac{-k}{Cos\theta_z}\right) \quad (1)$$

In the above equations 'A' is the altitude in kilometres (km). The constants α_0, α_1 and k can be found by multiplying their conjugates $\alpha_0^*, \alpha_1^*, and\ k^*$, which are represented for altitudes less than 2.5km by equations 3.1 to 3.4 given the correction factors for the various climate types.

3.4 Correction Factors for Various Climate Types

The correction factors for the various climate types ranging from tropical, midlatitude summer, subarctic summer and midlatitude winter used to compute the transmission coefficient for beam radiation T_b is shown in Table 3.1:

Table 3.1 Correction factors for various climate types

Climate Type	R_0	R_1	R_k
Tropical	0.95	0.98	1.02
Midlatitude Summer	0.97	0.99	1.02
Subarctic summer	0.99	0.99	1.01
Midlatitude winter	1.03	1.01	1.00

Using tropical climate type,

$$\alpha_0 = \alpha_0^* \times R_0 \quad (2)$$

$$\alpha_1 = \alpha_1^* \times R_1 \quad (3)$$

$$k = K^* \times R_k \quad (4)$$

Where

$$\alpha_0^* = 0.4327 - 0.00821(6 - A^2) \quad (5)$$

$$\alpha_1^* = 0.5055 + 0.00595(6.5 - A^2) \quad (6)$$

$$k^* = 0.2711 + 0.01858(2.5 - A^2) \quad (7)$$

The zenith angle θ_Z is given by:

$$\cos\theta_z = \sin\varphi \sin\delta + \cos\varphi \cos\delta \cos H \quad (8)$$

where:

φ is the latitude of the area, δ is the declination angle and H is the hour angle. Then δ and H are given by:

Declination angle, $\delta = 23.45 \sin[\frac{360}{365}(n - 81)]$ (9)

Hour angle, $H = 15° \times (time - 12)$ (10)

The clear sky beam normal radiation denoted by G_{cnb} is then given as:

$$G_{cnb} = G_{on} \times T_b \quad (11)$$

G_{on} is the extraterrestrial radiation which is incident on a plane normal to the radiation on the nth day of the year and is given by:

$$G_{on} = G_{sc}(1.000110 + 0.034221 \cos B + 0.001280 \sin B + 0.000719 \cos 2B + 0.000077 \sin 2B$$

where n is the day of the year, G_{sc} is the solar constant 1367W/m^2 and B is given by

$$B = (n - 1)\frac{360}{365} \quad (13)$$

From this the clear skybeam horizontal radiation G_{cb} (W/m^2) is given by:

$$G_{cb} = G_{on} \times T_b \times \cos\theta_z \quad (14)$$

The relationship between transmission coefficients for beam and diffuse radiation as given by Liu and Jordan is given by:

$$T_d = 0.271 - 0.294T_b \quad (15)$$

where T_d is the transmission coefficient for diffuse radiation. From this, the clear sky diffuse radiation, G_{cd} (W/m^2) can be calculated by the equation:

$$G_{cd} = G_{on} \times T_d \times \cos\theta_z \quad (16)$$

Finally the clear sky total radiation on a horizontal plane G_T (W/m^2) is obtained by the sum of the clear sky horizontal beam radiation and the clear sky diffuse radiation. This is given by:

$$G_T = G_{cb} + G_{cd} \quad (17)$$

The above mathematical models were used to develop a computer model using Microsoft excel to give values of hourly total solar radiation. The PV data obtained for the micro inverter system are spread over some of the selected data for daily, weekly and monthly computation to evaluate how the expected power output increases with increasing solar irradiation and then decreases after reaching maximum point.

The generated computer model showing all the interrelated mathematical models which calculate the amount of solar irradiation in a particular location is as shown in figure 3:

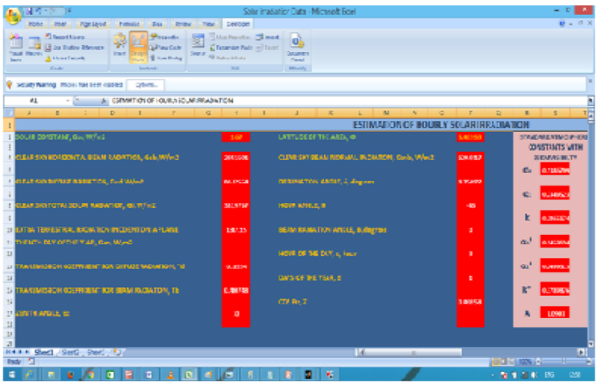

Fig -3: Hourly solar radiation computational model using MS Excel

The computer model for the correction factors for the different climate types considered in the model is shown in figure 4:

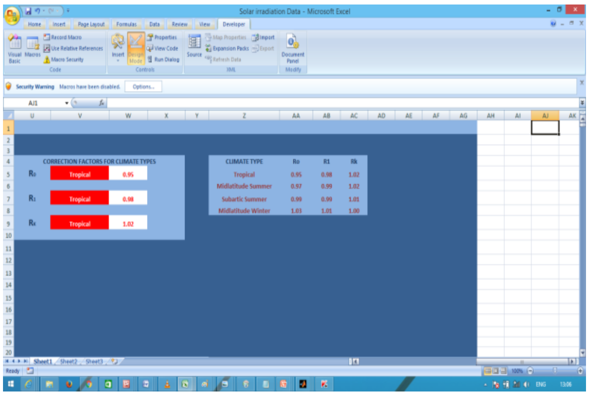

Fig -4: Correction factors for the solar radiation model based on different climatic weather conditions

The clear sky total radiation G_T was computed for different hours of the day from 0600 t0 1800hours in the model, but the values of radiation was calculated from 0900 to 1800hours and an average daily solar irradiation can be plotted from the model. The computer model showing hourly, daily solar radiation is shown in figure 5:

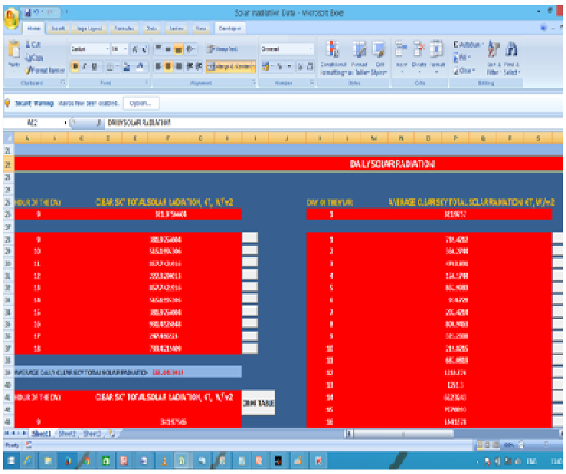

Fig -5: Hourly and daily solar radiations

The average values obtained for the daily solar radiation are computed to produce the monthly solar radiation for each of the given hours of the day for the 365days in a year. The model was designed in a way that each day of the year is a varying input to the model which automatically produces a value for total radiation, such that 1st of February is the 32nd day of the year, 1st of March is the 60th day of the year, 1st of April is the 91st day of the year and so on. The computer model showing the average hourly solar radiation for the month of January is shown in figure 6:

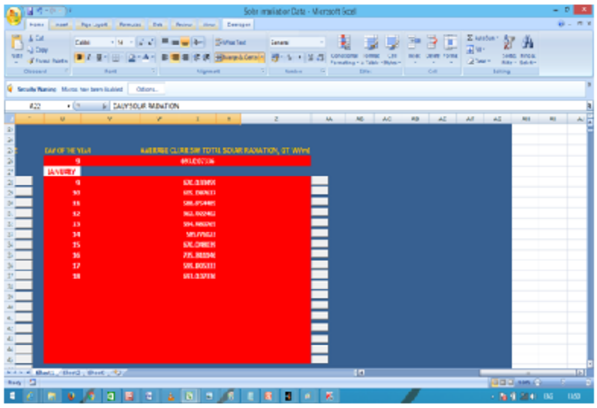

Fig -6: Average Hourly solar radiations for the month of January

3.5 Drop Table and Plots

The drop table in MS Excel used to design the computer model for solar irradiation is used to select from a range of variable inputs that has been assigned to a particular cell. They are obtained by assigning macro values to several cells which are eventually recorded to reproduce a value already being calculated for from the model. The plot cells are also assigned macro values and recorded to give plots for either, hourly, daily or monthly solar irradiation as indicated by the operator. An example of the model indicating drop table and plots for hourly and monthly readings is as shown in figure 7:

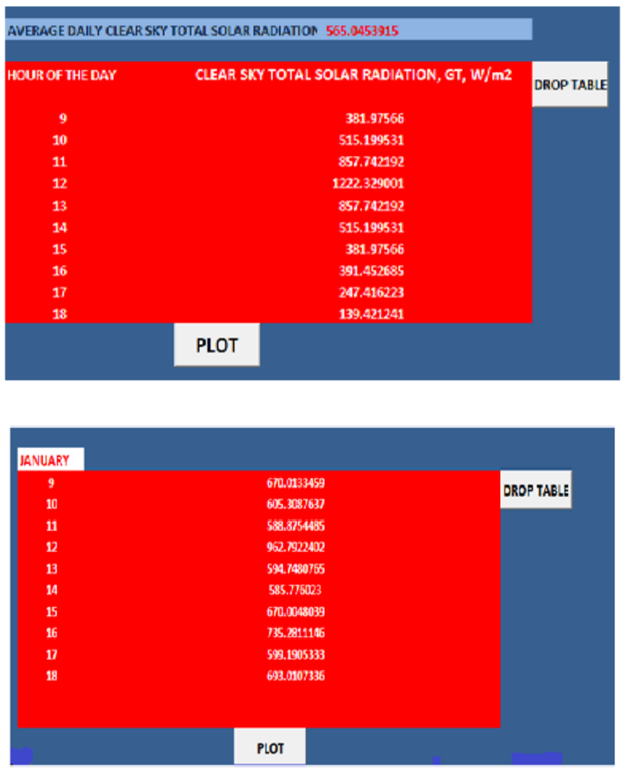

Fig -7: Drop tables and plots for the hourly solar radiation data

3.6 Solar PV Simulink Models

The several components of the PV system for both centralized inverter systems and photovoltaic micro inverter system where designed using MATLAB simulink. These components include the PV modules, the boost converters, the VSC controllers and grid integration components. The simulink models are shown in figure 8, 9 and 10:

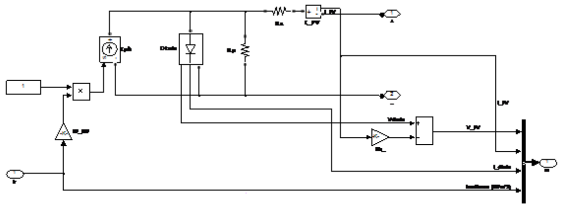

Fig -8: PV module simulink model

The Matlabsimulink model for PV as shown in figure 8 is designed taking into account photovoltaic cell properties for calculating the diode current from the given cell parameters. In literature this values can be assumed based on the experimental data, or computed directly from the PV and IV plots. These cell characteristics define the larger module properties in harnessing the expected maximum power.

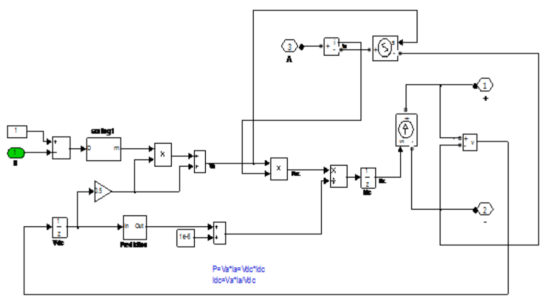

Fig -9: The boost Converter simulink model

The MATLAB Simulink converter for the boost converter as shown figure 9 is designed to boost or increase voltage value for grid integration. By varying the duty cycle of the pulse width modulation the boost converters, increase the incremental voltage values for harnessing the maximum expected value.

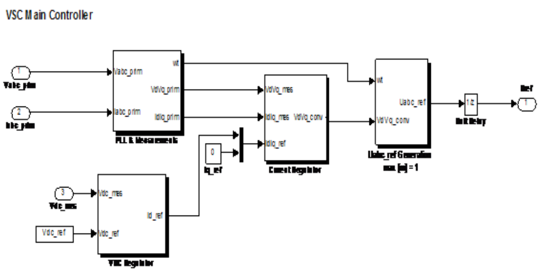

Fig -10: The VSC main controller Simulink model

The VSC main controller as shown in figure 10 is a control center for varying voltage and current inputs to the grid to ensure the maximum expected power is reached, in other words it serves to control changes in power output in grid interfacing or connection.

The simulation in figures 12 and 13 shows the Simulink models for all incorporated PV components for both centralized inverter systems and photovoltaic micro-inverter systems.

3.7 Implementation of the Perturb and Observe Maximum Power Point Tracking Algorithm

The Perturb and observe maximum power point tracking control algorithm is implemented in this research to sense changing values in voltages and current input from the PV module to the boost converter and inverter, in other to track the maximum power from the photovoltaic modules. This is achieved by varying the duty cycle of the pulse width modulation at the converter level, taking into account incremental and decrement values of voltages and current. The Perturb and observe algorithm is implemented at the converter level of the simulation to track the maximum power from both systems. The tracking algorithm developed is as follows:

Step one: Sensing the input values; the PV voltage and current values V_{old} and I_{old}

Step two: The duty cycle D of the boost converter, which is the output value is between 0 and 1

Step three: The increment value $deltaD$ used to increase and decrease the duty cycle is known

Step four: The value of the initial voltage, power and duty cycle V_{old} P_{old} and D_{old} are noted

Step five: The new power, new voltage and new duty cycle is calculated P_{new}, V_{new} and D_{new} and the change in voltage and power is noted.

Step six: If the change in power and voltage is less than zero, the duty cycle is increased by the incremental value, otherwise it is decreased. The flowchart for the algorithm is shown in Figure 11:

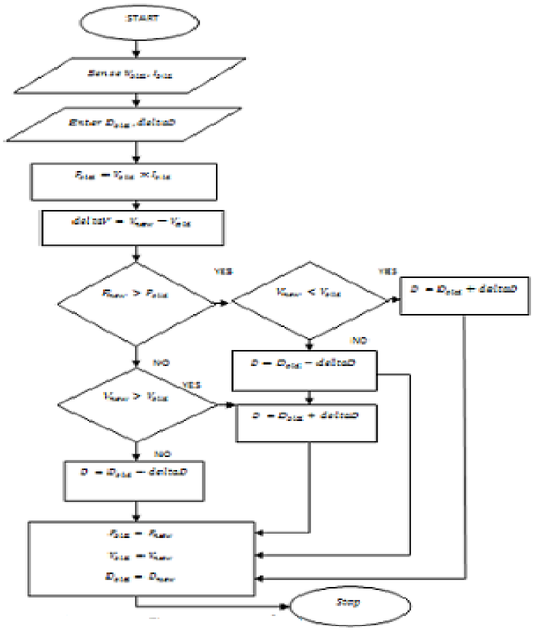

Fig -11: The Perturb and Observe MPPT flow chart

3.7.1 Designed PV simulink model for centralized inverter system

In centralized systems, when the voltage and current inputs to the boost converter is sent, it increases the duty cycle of the pulse width modulation (PWM) in the converter thereby reducing the current and voltage output to the converter leading to a reduction in expected power output. There are more losses due to power transmission in centralized inverter systems as compared to distributed micro-inverter systems. The simulink model is shown in figure 12

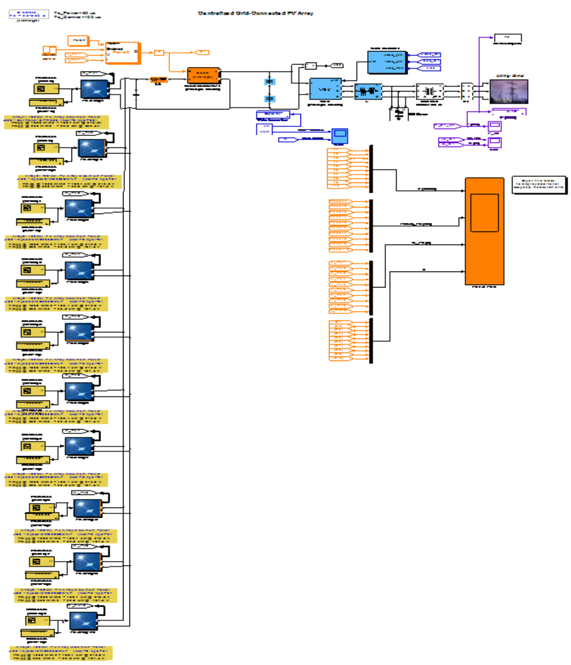

Fig -12: Matlab Simulink model for centralized inverter system

3.7.2 Designed PV simulink model for distributed microinverter system

In micro-inverter systems, there are individual boost converters leading to a reduced duty cycle of the PWM for each boost converter leading to increased voltage and current values thereby giving an increased expected power output. The powers losses are minimal due to transmission distances are shorter as compared to the centralized inverter systems. The value of solar irradiance used at standard testing conditions (STC) for photovoltaic micro-inverter systems is 1000w/m^2. The power outputs from both applications were changing simultaneously with changing values of the solar radiation. The simulink model is shown in figure 13

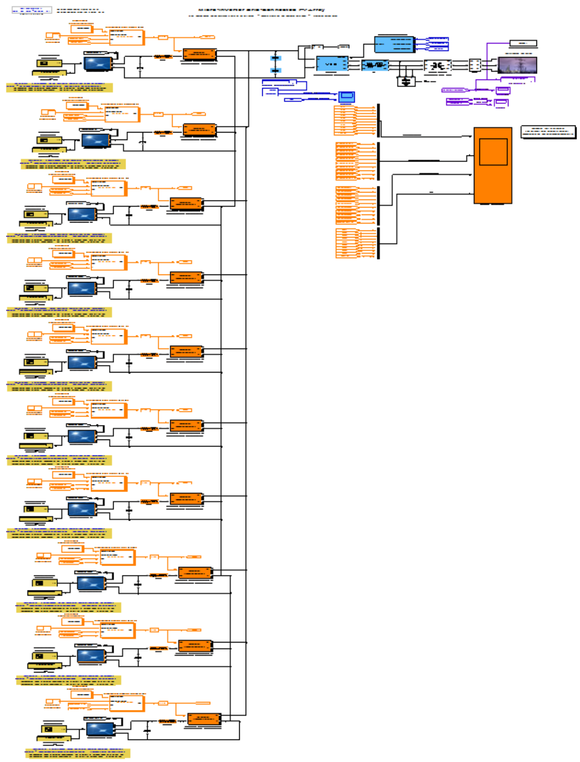

Fig-13: Matlab Simulink model of Distributed Micro-inverter System

4. RESULTS AND DISSCUSIONS

This paper analyses the results for both centralized and distributed inverter applications based on the expected power output. The configurations used for both applications are designed using MATLAB simulink and the simulations are run to produce the expected output from each application. The perturb and observe maximum power point tracking technique is used to track the maximum power from each string of modules. There is only one MPPT control algorithm in the boost converter for the centralized inverter application and an MPPT control algorithm for each PV module in the proposed photovoltaic micro inverter system for the distributed application. The results are obtained and compared from both applications in tracking the expected power with higher efficiency proposed for the distributed application.

The expected power output and voltage reduces with respect to reduction in solar irradiation. The value of current is unaffected by changes in solar radiation but is affected by changes in temperature. The power output of both applications is minimally reduced as a result of the solar radiation parameter considered. This proportionality between power, voltage, current and irradiation was implemented in the MATLAB Simulink design for both the centralized and distributed micro-inverter systems and the results obtained.The values of expected power output are seen to be significantly higher in distributed micro-inverter systems than in centralized inverter systems. The mean power output gave 0.6kW for the PV array for the centralized inverter systems and 1.5kW for the PV array for the distributed micro-inverter system when the simulations were run. This indicates that the proposed distributed photovoltaic micro-inverter system produces a higher expected power output than the centralized inverter system through maximum power point tracking. The output plots for the centralized and distributed applications is shown in figure 14 and 15

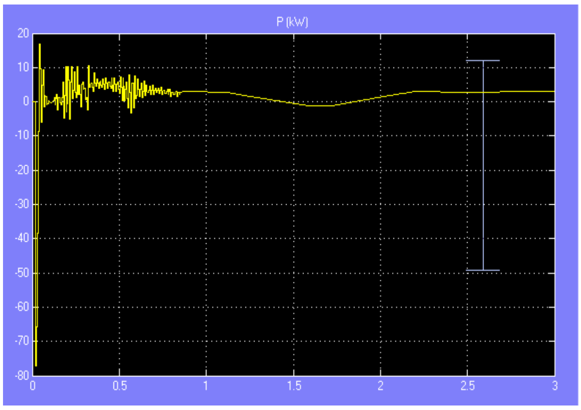

Fig -14: Power output for Centralized inverter system

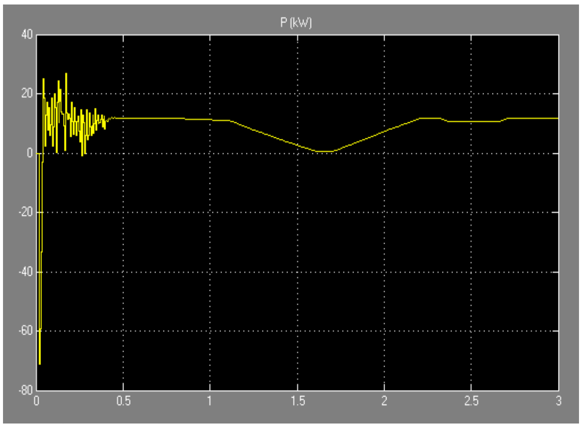

Fig -15: Power output for Distributed micro inverter system

4.1 Comparison plots between centralized inverter systems and photovoltaic microinverter system

In the comparison plot between the two power outputs from both applications; the green plot represents the expected power output from the photovoltaic micro-inverter system and the blue plot represents the expected power output from the centralized inverter system. This is seen to be significantly higher for the micro-inverter system than for the centralized inverter system as shown in figure 16

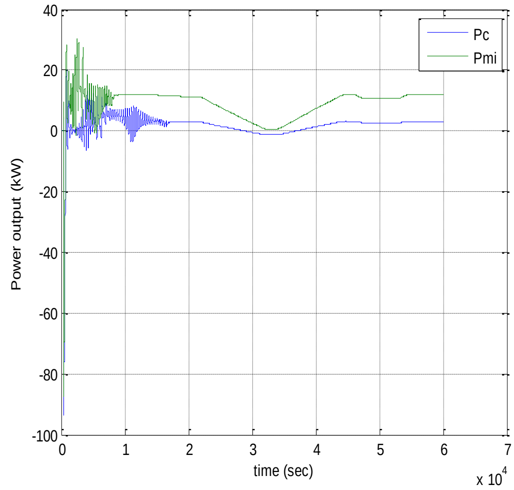

Fig -16: Comparison of power output for centralized and Micro-inverter

The solar radiation, mean power output and voltage plots for both systems are shown in figure 17 and 18. The mean power output gave 0.6kW for the centralized inverter systems and 1.5kW for the distributed micro-inverter system when the simulations were run. This indicates that the proposed distributed photovoltaic micro-inverter system produces a higher expected power output than the centralized inverter system through maximum power point tracking.

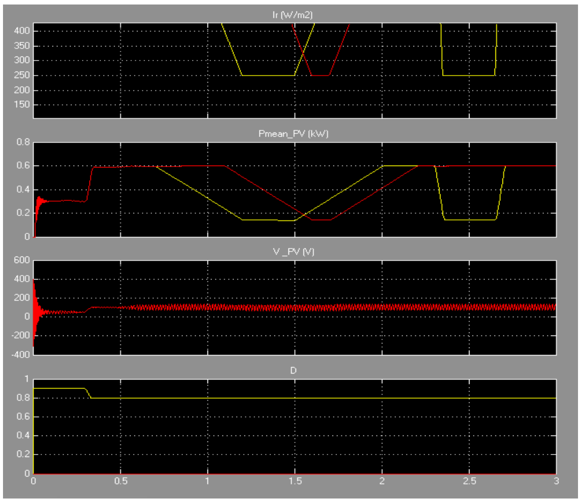

Fig -17: Power output per module for Centralized inverter system

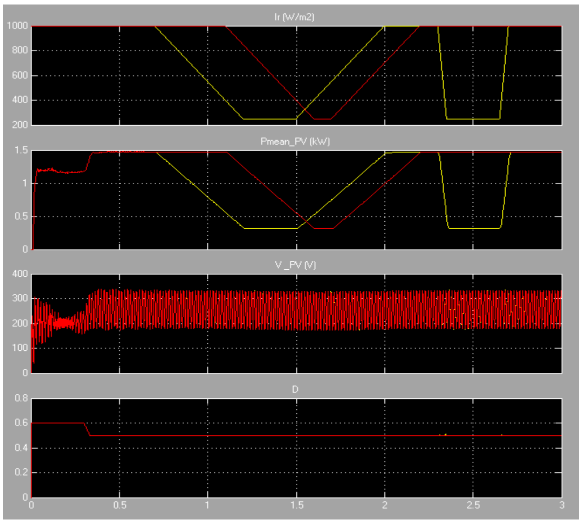

Fig-18: Power output for photovoltaic micro inverter system

5. CONCLUSION AND RECOMMENDATION

In this work the performance evaluation of the centralized inverter system was compared to that of the distributed micro inverter systems. The performance parameter used is the solar radiation. The hourly and daily solar radiation values of the given location (FUTO) were obtained from the solar radiation model and used in the simulation of both systems.

The Perturb and Observe maximum power point algorithm was developed and implemented at the converter level in the simulation. The two systems were simulated based on changing values of solar radiation obtained from the computer model and the MPPT algorithm. This indicated that the expected power output from the distributed micro inverter system was higher. The power output values from the plots were varying sinusoidally for both systems, giving a mean power output value of 0.6kW for the centralized inverter systems and 1.5kW for the distributed micro-inverter system when the simulations were run. The irradiation, power and voltage plots and also the comparison plots for both applications, from the simulations all indicate that the power output from the distributed microinverter system was higher than that obtained from the centralized application.

Recommendation

In the course of the work it was observed that the PID controller used in monitoring the expected power output from the simulations from both applications resulted in continuous variables. The simulation can further be improved with the use of discrete variables. It is recommended for further research that a fuzzy logic controller for measurement of discrete variables be provided and results compared with that the results the PID controller gives. The research currently carried out in the area of micro inverters and grid connection are usually for home and office use, further research is recommended for micro inverters to be used in larger power plant with high installed capacity.

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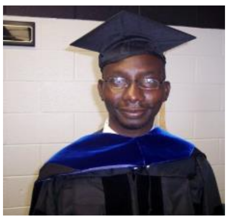

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