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Solar electrical model PV modeling using Gaussian roulette wheel selection (GRWS) algorithm

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ABSTRACT

Full shading/Partial shading of PV arrays is one of the most discussed and worked upon problem in the field of solar photovoltaic as it reduces the output power and exhibits multiple peaks in the PV and I-V characteristics. As, a result the modules have to be reconfigured to get a maximum power output. This paper presents an optimization based approach for Independent Power Producers connected modules in a PV array. The physical locations of the modules remain unchanged while the electrical connections are altered. The proposed technique utilizes, Gaussian(standard deviation)Roulette wheel selection (GRWS) as an optimization method, which gives the final connection matrix for the new electrical interconnection which extracts the maximum power from the PV array. This is done to obtain uniform shade dispersion throughout the panel. The proposed method has been tested and simulated in Matlab-Simulink environment under partial shading conditions.

Keywords:Solar cell, PV system, Energy optimization etc.

I. Introduction

The energy needed for technology age is the most important topic. With the developing technology, the rapid increase of world population causes an increase of energy consumption. Because of having the negative effects of new kinds of energy to the human health, using the oldfashioned energy production methods and depleting of the energy sources, research of new and renewable energy sources has become more common. Obviously the Sun is the most natural energy source, having both, the least damage to the nature and being easily available for everyone. For the reason of our country's geographical location, we are luckier than most of other countries for having sun energy. Solar cells are the photovoltatic (PV) devices converting the Sun energy directly into the electrical energy. The current and voltage provided by the smallest structure unit of PV systems are very low. To get a usable energy, a PV panel must consist of a lot of solar cells connected in series or in parallel to each other. Panels can also be connected in series or in parallel with others. By connecting the panels serially, the voltage range can be increased; and by connecting the panels in parallel,the current capacity can be increased as well. PV panels constitute the PV array by serial or parallel connections; and PV array in question can be named "solar PV array" [3, 4]. The electrical energy produced by PV panels can be affected by the radiance, the temperature, the angle of the surface and by shading. Even if the PV panels are identical, each PV panel still can produce different current and voltage. The PV panel with lower power produces lower current at serial connections, and lower voltage at parallel connections. Thus, output of the PV system is affected negatively. Each PV panel's current and voltage difference have to be taken into account at suitable circuit design for solar arrays [5, 6]. A study [4], related to shading effect of PV panels, has determined the optimal connection model at different conditions of temperature and radiation. Another study has examined the power production for different PV panel connection types by using the Function of GA algorithm on MATLAB platform [7]. Study [8] investigates the effect of mismatch losses of PV panel array located on the large area by using the Sudoku method. In this study, different PV panel array connections, depending on the selected inverter types were investigated and visualized using MATLAB programming language. The PV panel replacement in the solar array and the optimization of circuit design is achieved using genetic algorithm. The parameters (radiance, temperature, angle of surface and partial shading) affecting the PV panel's output are included in the PV system to get more efficient results.

II. LITERATURE REVIEW

Ali Al-Karaghouli, L.L. Kazmerski [13] addresses the requirement for PV nearby planetary group to control a wellbeing facility in the rustic regions in southern Iraq. The creators utilized HOMER programming PC model to decide the most monetary framework. They proposed framework with an every day heap of 31.6 kWh which is made out of 6-kW PV

modules, 80 batteries (225 Ah and 6 V), and a 3-kW inverter. The aggregate beginning cost, net present cost, and cost of power delivered from the framework are 50,700 US$, 60,375 US$, and 0.238 US$/kW h, separately. The investigation demonstrates that the cost of power created from the diesel generator is four times more noteworthy than that delivered from the PV framework, which highlights the advantage of utilizing this framework in remote regions. The examination likewise demonstrates that utilizing this little PV framework rather than a diesel generator can keep the arrival of 14,927 kg/year of CO2, 36.8 kg/year of CO, 329 kg/year of NOx, 4.08 kg/year of HC, 30 kg/year of SO2, and 278 kg/year of suspended particles. Souissi Ahmed, Hasnaoui Othman, Sallami Anis [14]; the creators proposed an improvement arrangement of a half and half arrangement of sustainable power source by utilizing the Homer programming for remote ranges in Tunisia. The Hybrid frameworks include blend of various vitality sources like wind/battery, PV/battery, wind/PV/battery, wind/PV/diesel/battery. The climatic information are particular for the region of Hawaria in Tunisia. The ideal setup of the half breed framework wind/PV/diesel/battery planned for dependable load supply and furthermore considered the meteorological information changes is reasoned from two ideal designs chose: (wind/PV/battery) and (diesel/battery). For the wind/PV/battery the ideal setup is made by 8 kW board PV, 2 wind turbine, 118 batteries and 12 kW control converters. The underlying expense and the operation cost 165.450 US$, 2.102 US$/yr separately. The aggregate net present cost 189.559 US$ and the cost vitality created 0.540 US$/kWh. For the diesel/battery the ideal design is formed by 5 kW diesel generator, 18 batteries and 2 kW control converters. The underlying expense and the operation cost 11.934 US$, 10.707 US$/yr, individually. The aggregate net present cost 134.747 US$, the cost vitality delivered 0.382 US$/KWh and the diesel 11.269 L. For the wind/PV/diesel generator/battery with heap of 85 kWh/d the ideal design is created by 8 kW board PV, 2 wind turbine, 118 batteries, 5 kW diesel generators and 12 kW control converters. The creators demonstrates that the mix of a diesel generator, as buck-up source, with the half and half wind/PV/battery framework is the best answer for assurance the solid supply without intrusion of the heap under the climatic information change. The ideal measuring of the half and half wind/PV/diesel/battery framework is found from the two ideal designs picked: (wind/PV/battery) and (diesel/battery). ZeinabAbdallah M. Elhassan, Muhammad FauziMohd Zain [15]; talked about the proficient arrangement of economical sustainable power source for local utilized and its aggregate cost in Khartoum in Sudan. The creator's technique was the accumulation of the essential information of sunlight based radiation, wind speed and other required info information, and after that the creators utilized HOMER programming to build up the cross breed streamlining reenactment. The proposed load is 54 kWh/d, and 5.3 kW as a pinnacle. The cost of the PV module including establishment has been thoughtful as 220 SP/W for Sudan. The cost of turbine with tower and establishment has been considered as 96000 SP/turbine. For load higher than 1 kW, turbine from southwest wind control (demonstrate: W175, limit, 3 kW) has been considered at the cost of 200000 SP/turbine with tower and establishment. The operation and upkeep cost has been taken as 500 SP/year. Moreover 800 kW converter and 3500 batteries were viewed as and the aggregate net present cost 19.1 US$. The creators found that it is ideal to utilize wind/PV mix framework for 50 homes rather than single home framework. Moreover if the turbine cost diminishes in Khartoum the general cost of vitality would be low. The reproduction comes about show that using inexhaustible generators, for example, wind generator and PV decreases the working costs utilizing a second rate class of lodging at Khartoum state. Deshmukh et al. [16] depicted strategies to model half and half sustainable power source framework (HRES) segments, HRES outlines and their assessment demonstrating that the cross breed PV/wind vitality frameworks are ending up noticeably progressively famous and highlighted the issues identified with entrance of these vitality frameworks in the present appropriation arrange as it gives prospects of fusing in power era ability to enhance control quality, because of the scattered era.

Wei et al. [17] showed productive white natural light-emanating gadget in view of exciplex with higher luminance and iridescent proficiency and this bi-utilitarian gadget with electroluminescence (EL) and PV exhibitions is promising to be utilized as white presentations or backdrop illumination source later on as it can be charged by sun based vitality through extra mechanical assembly free of work and can likewise be utilized as an optical sensor to UV light.

Ito et al. [18] introduced strategies of TiO2 film manufacture for color sharpened sun based cells that comprises of pre-treatment of the working photograph terminal by TiCl4, varieties in layer thickness of the straightforward nanocrystalline-TiO2 and use of a topcoat light-scatterin g layer and additionally the grip of a hostile to reflecting film to the anode's surface bringing about a change

effectiveness of worldwide air mass 1.5 (AM 1.5, 1000W/m2) sunlight based light to electric control more than 10% .

Jaber et al. [19] built up a PC reproduction model of the conduct of a photovoltaic (PV) gas-turbine half breed framework, with a compacted air store, to assess its execution and in addition to anticipate the aggregate vitality transformation productivity and found that cross breed plant delivers around 140% more power for every unit of fuel expended contrasted and comparing traditional gas turbine plants and lower rates of poison discharges to the air per kWh of power created.

K.R. Ajao, O.A.Oladosu and O.T. Popoola [20]; utilized HOMER programming for enhancement to locate the best money saving advantage of half breed - sun oriented influence era with respect to utilize taken a toll in Nigeria. The money saving advantage examination of a wind/sun powered cross breed framework was finished utilizing HOMER programming and correlation was additionally made with utility supply. Focal framework power is the slightest costly alternative yet may not be accessible to most country family units a long way from the matrix. Henceforth it is important to supply these regions from disengaged control sources. The proposed framework utilized (0.05 – 0.4 kW) PV board with (0.4 kW DC) FD arrangement wind turbine, (0.1 – 1.5 kW) converter, and (200 Ah/12 V, bank estimate: 1-8 batteries, vision 6 FM200D) battery. The creators result acquired from the advancement gave the underlying capital cost as 3,455 US$ while working expense is 69 US$/year. Add up to net present cost (NPC) is 4251 US$ and the cost of vitality (CoE) is 1.74 US$/kWh. The creators found that, the half and half framework have a compensation back time of around thirty-three years and at current expenses.

Bhuiyan et al. [21] concentrated the financial matters of remain solitary photovoltaic power framework to test its achievability in remote and provincial regions of Bangladesh and contrasted inexhaustible generators and nonrenewable generators by deciding their life cycle cost utilizing the technique for net present esteem examination and demonstrated that life cycle cost of PV vitality is lower than the cost of vitality from diesel or oil generators in Bangladesh and accordingly is monetarily plausible in remote and rustic zones of Bangladesh.

Alazraki and Haselip [22] surveyed the effect of little scale PV frameworks introduced in homes, schools and open structures in the course of the most recent six years under the PERMER (Renewable Energy Project for the Rural Electricity Market) co-subsidized by a scope of open and private sources and the structure of money related endowments has empowered these remote provincial groups to get a power supply supplanting customary vitality sources..

III. System description

Fig. 1 shows the equivalent circuit of a practical PV cell where the generated current Iph is proportional to the irradiation. The recombination losses are represented by the diode connected in parallel to the current source in reverse direction. This is because the recombination current flows in the opposite direction to the light generated current. The V-I equation of a simple solar model can be given by the following expression:

$$I_m = I_{ph} - I_d\left[\exp\left(\frac{q(V_{pv}+I_mR_s)}{nkT}\right)-1\right]-\left(\frac{V_{pv}+I_mR_s}{R_{sh}}\right) \quad (1)$$

Where, q is the charge on electron, n is the number of cells in series, k is the Boltzmann constant and T is the absolute temperature (Kelvin), I_{ph} is the photoelectric current, I_m is the current generated by the module.

A number of PV cells connected in series constitute a PV module. Typically a module contains 36 PV cells connected in series. The resistance offered by the solar cells in the path of the current flow is denoted by Rs. Resistance offered to the leakage current is represented by Rsh. The photoelectric current is a function of the short circuit current and can be expressed asfollows:

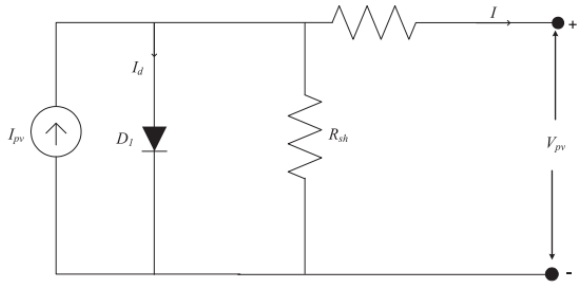

Figure 1: Equivalent circuit: practical PV cell

$$I_{ph} = I_{sco}\left(\frac{G}{G_0}\right)(1+\alpha(T-T_o))\left(\frac{R_s+R_{sh}}{R_{sh}}\right) \quad (2)$$

Where,Isco is the short circuit current of the module at standard insolation Go (1000 W/m²) and standard temperature To (25 1C) and α is the module's

temperature coefficient for the current. The PV modules are modeled using the equations mentioned above.

IV. Proposed method

Genetic algorithms (GAs) are a subclass of what are known as evolutionary algorithms [13]. These are computational models that mimic natural evolution in their design and implementation; i.e. they are based on survival of the fittest. GAs differ from conventional search techniques in that they operate on a coded parameter set of the solution, are global in their search, make use of a cost function that does not involve derivatives and finally employ pseudo-probabilistic rules and not deterministic ones. Genetic algorithms have been used in recent years in solving optimization problems in science and engineering applications [14, 15]. Implementation of GAs involves making the following preliminary decisions.

(1) Solution encoding. This involves coding a possible solution (individual) as a string of variables using some alphabet, e.g. binary {0, 1}. Individuals are likened to chromosomes and variables to genes. A chromosome (solution) is composed of several genes (variables).

(2) Evaluation function. This determines the fitness score attached to each chromosome (solution). The higher this score, the greater is the chance of an individual (solution) being selected for reproduction.

(3) Initial population generation. Generation of the initial population (set of possible solutions) can be random or from known approximate solution(s).

(4) Selection criterion. Methods of selecting individuals for reproduction are numerous and include roulette wheel sampling, stochastic universal sampling, tournament selection, elitism, sigma scaling, rank selection etc.

(5) Recombination/reproduction. This is achieved through two genetic operators, namely crossover and mutation. A number of variations of crossover are in use such as single-point, multi-point or uniform crossover. Insingle-point crossover where binary encoding is used, a locus (bit location) is randomly chosen. Bits after that locus are exchanged between two chromosomes to create two offspring (new solutions).

Mutation on the other hand involves randomly flipping some of the bits in a string (chromosome). A very small probability is usually attached to occurrence of mutation at each bit location (e.g. 0.001). This operation is performed to ensure that new areas of the solution are explored.

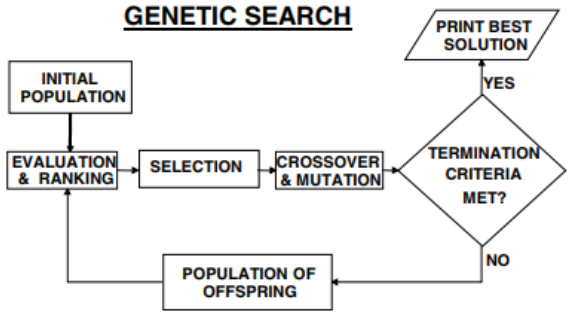

Figure 2: GA flowchart

(6) Termination criteria. The algorithm can be terminated if the maximum number of generations (iterations) is achieved, or convergence of the solution is attained (i.e. all solutions yield the same fitness value or differ by less than a specified tolerance). Based on the decisions made above, the search algorithm can be invoked. Figure 2 illustrates a typical GA flowchart.

4.1. Proposed implementation for solar cell parameter extraction

A MATLAB implementation of a GA [16] is used to extract the parameters of a solar cell under illumination.

Implementation of the GA for solar cell parameter extraction was based on the following.

• Solution encoding: floating point representation.

• Parameter precision: 10^{-6}.

• Evaluation function: based on equation (3), expressed as

$$f(I_{ph}, I_{SD1}, I_{SD2}, Rs, R_{sh}, n_1, n_2) = -I_L - I_{ph} + I_{D1} + I_{D2} + I_{sh} \quad (3)$$

Where, all the variables are as defined before. (The GA program used [16] was developed for maximization of a multivariable function. Thus, $-f^2(\ldots)$ was used as the cost function and the optimal solution is attained when $f^2(\ldots) = 0$.)

• Initial population generation: randomly generated and of size ten.

• Selection criterion: roulette wheel.

• Crossover: simple crossover with two calls per generation.

• Mutation: boundary mutation with four calls per generation.

• Maximum number of generations: 25.

A set of values for the V-I characteristics serves as the input data for the GA. The parameters that are extracted by optimization are I_{ph}, I_{SD1}, I_{SD2}, Rs, R_{sh}, n_1 and n_2. Theoretically, the cost function should be zero for any I–Vpair when the exact value has been determined for each and every parameter. Before invoking the genetic algorithms, a search range has to be set for the solar cell parameters. Each range was centred on the specified value of the parameter and varied by ±5 to ±100%. The deviation between the extracted and the specified values of the parameters is then computed for each range. This is done because existing extraction techniques have different degrees of accuracies in determining solar cell parameters.

The following steps are the pseudo-code for the Gaussian algorithm

- Step 1: Start with N Gaussians.
- Step 2: Set a mean and standard deviation for each Gaussian.
- Step 3: Calculate the likelihood of all Gaussians. Likelihood is a statistical index which measures the distance of actual points from the formal Gaussians based on the selected mean and standard deviation.
- Step 4: If the likelihood has not improved since the last iteration, stop the algorithm. Otherwise try different values for mean and standard deviations for each of the Gaussians.

Gaussian can be defined as a random process, where any finite subset of this process has a joint Gaussian distribution [14]. Gaussian applies a distribution over functions that are specified by a mean function and a covariance function as shown in Equation (4).

$$(\boldsymbol{x}) = \boldsymbol{GP}(\boldsymbol{\mu}(\boldsymbol{x}), \boldsymbol{k}(\boldsymbol{x}, \boldsymbol{x}')) \quad (4)$$

The mean function, (x), is usually defined to be zero and the covariance $k(x, x')$ defines the prior properties of the functions considered for inference [15]. The k in the covariance represents the kernel function which projects the data into a higher-dimensional feature space to increase the computational power of the algorithm [16].

V. RESULT

A typical solar module consists of series connection of solar cells to get practically utilizable voltage. A number of such modules are connected together in series and parallel to get the requisite power. From the results and inferences from this project, it is concluded that there is a substantial power loss due to non-uniform illumination of a series string. The power generated by highly illuminated cells is wasted as a heat in the poorly illuminated cells. So, care should be taken to see that all the cells connected in series receive the same illumination under different patterns of shading. Such a care will give a better protection to the array and at the same time the total energy output will also be higher.

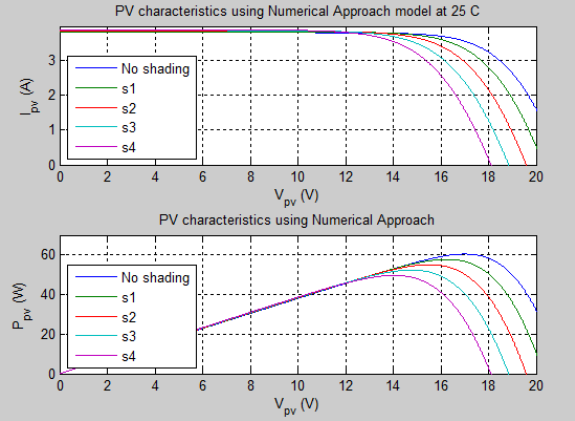

Figure 3: PV characteristics using Numerical approach model at 25° and GRWS

Above figure presents the optimization of PV module electrical characteristics using Gaussian roulette wheel selection (GRWS). A mathematical modelling is used to characterize the electrical characteristics of PV module. A 60 W, 20 V, PV module is used in this work. Under constant temperature and different solar irradiance were tested to the PV module using GA, its electrical characteristics shown in curves and compared to the data sheet and a reference and also 3-dimensional diagram as function of both solar irradiance and temperature shown and discussed. The result shows that the comparison of simulation results using GA with current-voltage and power-voltage curve illustrates a good correlation, if the temperature constant and solar irradiance increase will cause the short circuit current, open circuit voltage, maximum power and efficiency increase.

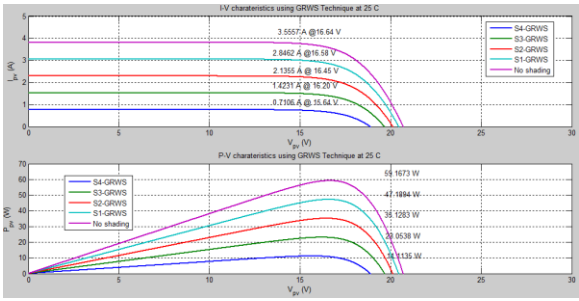

Figure 4: I-V characteristics using GRWS technique at 25° C

The I-V curve of a PV characteristic is a scale-up of the I-V curve on multiple cells, as illustrated in Figure 4.

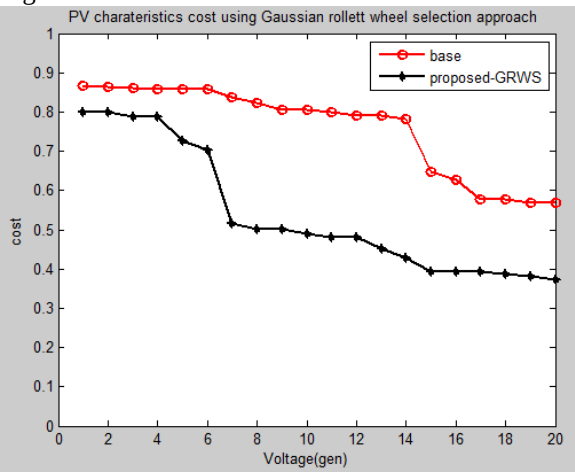

Figure 5: comparison between Base and proposed-GRWS over Cost and Voltage

As we can see that the proposed method (voltage) gets less cost as compare to Numerical system.

Photovoltaic (PV) power systems have been widely applied in commercial and domestic facilities. Electrical Energy Storage (EES) systems are mandatory in standalone PV systems for continuous power supply. In this work the efficiency and robustness enhancement methods for PV systems under partial shading have been investigated. Partial shading due to moving clouds and shadows of nearby obstacles on the PV module array causes significant efficiency degradation, since shaded and non-shaded PV modules have large discrepancy in their maximum power points. Use of by-pass diodes for each PV module may mitigate the negative effect from partial shading. However, this method alone may still face severe energy efficiency degradation caused by the energy loss due to parasitic effects in the EES elements under variable incoming power from the PV modules. Hence, this work investigates the effect of shading on photovoltaic cells.

VI. Conclusion

This paper presents a new Gaussian Roulette wheel selection based electrical array reconfiguration method inorder to increase power generation of a solar PV under partial shading conditions. In this method, the electrical interconnections of the modules are altered whereas the physical location of the modules remains unchanged. The proposed approach aims at equalizing the individual row currents by minimizing the standard deviation. This makes it feasible to reducethe mismatch losses and extract maximum power from array under any environmental conditions. For the given shading pattern, it is found there increase in the maximum power using the proposed technique. The system performance is analyzed, and it is proved that the proposed technique yields better results as compared to the existing interconnection scheme.

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