# Study and analysis the impact of photovoltaic energy source on the electrical power grid stability

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**Abstract**

The increasing need for electrical energy, in addition to the ongoing integrating of renewable energy sources (RES) with electric power systems, has led to a number of new challenges regarding the efficiency, management and planning of the electrical network and its distribution systems, so it became necessary to study and analyze the impact of integrated renewable energy sources with the electric power network to determine these challenges and study the possibility of reducing their impact on the functioning and efficiency of the electric grid. Also, the increase in global demand for cheap and clean energy such as renewable energy sources has led to an increase in the number of these sources, which led to an increase in their impact on the performance, stability and effectiveness of electrical distribution systems. In this research, a number of technical factors related to the quality and effectiveness of the voltage output were studied and analyzed for evaluating the effect of PV source on the electric power grid by measuring and recording the losses of active or reactive energy in addition to the voltage changes in the electrical grid systems that occurred in case of integrating with renewable energy source. The simulation model in this research was implemented using MATLAB Simulation software .The results have been compared with standard. 9-IEEE bus grid.

**Keywords:** Electrical power, renewable energy, MATLAB Simulink , 9-IEEE standard.

## 1. Introduction

Increasing the $CO_2$ emissions and limiting fossil fuel reserves have pushed researches for exploiting abundant renewable energyy sources. The European Union has set a very ambitious target, by 2050, in terms of reducing $CO_2$ emissions below 80% of the level that was represented in 1990. [1]. Renewable energy sources are becoming more represented in electrical power grids and replace sources that are responsible for the emitter of $CO_2$ [2].Penetration of renewable energy, especially solar power source, is on the rise. Total production capacity from renewable energy sources was over 2240 GW in 2016. A steady decline in the price of technology for renewable sources can lead to their even greater presence [3]. In addition to the environmental pollution factor, which was the main driver of investment in renewable energy sources [4].

The integration of overall power sources results in many benefits far away, and among these benefits is that it can meet the needs of local consumption, thus achieving the absence of the need to transmit energy and electricity over large distances [5]. The result achieved from the decentralized production of renewable energy is to reduce the lines pressure in addition to some reduction in the active and reactive losses of active and reactive energy in that electrical power system. As a result, this reduces the possibility of overloading power transmission and distribution lines and leads to increased safety in the main network. In addition, the transmission system operator will be responsible for the case of power loss in his network, and as a result the reduction of losses will have some economic benefit [6]. The analysis of the effect obtained in the case of the integration of renewable energy sources with the electrical power distribution system has become the subject of research and study by a number of researchers [7]. The researchers dealt with the basic problem of finding the optimum location and capacity of the distributed energy sources [8]. The primary function can be different, and the primary purpose is to reduce losses, increase efficiency as well as improve voltage conditions [9].

Energy calculations are a very useful tool that provides information about the state of a power system. The results of calculation will provide us with variable values for the capacitance and phase angle of the voltage under certain load and output conditions. The input and output variables of the system are considered as random variables and in this way we can get different and possible states of the main network state. Then the optimum power amount will be calculated for each set of random inputs variable data. The results are recorded in each calculation of optimum power, and this process is repeated until the algorithm's interrupt state is satisfied [10].

The development of distributed generation systems based on renewable energy sources affects energy networks. Furthermore, due to the fact that it is not possible to generate electricity continuously from RES compared to conventional energy sources, it is difficult to maintain the balance and stability of the system. Therefore, many different studies are made in the literature to see the impact of renewable energies, such as:

- Lima and others have studied the impact of wind power generation on the Iberian electricity market. Some of the forecasting analyses present historical data for the period 2008-2016. As a result of these studies, particularly undesirable situations have been observed in the grid when wind energy production forecasts cannot be made correctly [11].

- The researcher( Ozdemir et al.) has studied the effect of the integration of the renewable energy source with the main electrical grid on the energy efficiency of the grid in the European Union electric power transmission lines up to 2050, using the improvement of economic conditions in different integration cases [12].
- The (Researcher Flori and his group.) have explained the Brazilian experience when integrating renewable energies with the main network, while explaining the lessons learned and new challenges that must be studied and faced [13].
- Shafiullah et al. And colleagues conducted a simulation of an Australian grid electrical power distribution system model for the purpose of analyzing the impact of renewable energy on a large scale when integrated with a high voltage power transmission system [14].
- (Molina et al.) examines renewable energy costs and technological diversification as well as CO2 emissions and energy injection into the Chilean energy distribution system [15].
- Duane and colleagues introduced a method for studying and analyzing the effect of wind energy on the transmission and distribution system of electric power using the Weibull distribution function. The results obtained from this method were used to estimate the transmission capacities on electrical grid lines [16].
- (Syafawati et al.) has studied, analyzed and evaluated the potential of solar energy in Malaysia. This study also provided information on the intensity of solar radiation and the engineering dependence of natural resources in order to determine the potential [17].
- Lenci et al. He conducted a study and analysis of the importance of accurate forecasting of RES for power systems and identified the need for a control reserve in the increasing integration of the renewable energy source RES [18].He demonstrated the effect of the increase in distributed generation on the behavior of the electrical network in the event of failure. After a certain error occurred, he explained that the system after this should regain its balance. Therefore, all these possibilities must be examined and analyzed for distributed generation sources.
- Alsokhirs and his colleagues studied failure and transmission through distributed generation and determined the difference between the base case and without or with the presence of DGs in the event of any temporary failure in the electrical distribution system [19].

## 2. Methodology

In order to determine the effect of the PV energy source connected to the electric grid, we will study and analyze some important technical parameters in two cases, in the first case, we will study when the system is alone without integration with the solar source, while in the second case it will include the presence of a renewable solar energy source. As for the technical aspects: it will be in three sections, firstly: studying power loss, voltage deviation and load capacity.

Also, for assessing the impact of PV source, some technical factors have been studied and analyzed in two cases, the first one is when the system has not integrated with the photovoltaic source , while the second the power system integrated with photovoltaic energy source. In this paper, the power losses, load capacity and voltage deviation are studied and analyzed. Also a some attention has been considered on the effect of the connected PV power source on the load of the nodes. And finally determining the intensity of the random solar radiation. For better study and evaluate the effect of the integration of the solar source source on the efficiency and operation of the main power transmission system, for the purpose of creating a suitable model to determine the amount and production efficiency of photovoltaic panels.

### 2.1.The intensity coefficient of solar radiation

In a certain period of time, the solar radiation can be approximated and known by means of the beta distribution, whose probability intensity function is according to the following form [20]:

$$f(r) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} \left(\frac{r}{r_m}\right)^{\alpha-1} \left(1-\frac{r}{r_m}\right)^{\beta-1} \quad \cdots\cdots\cdots\cdots \quad (1)$$

Where $\boldsymbol{r}$ & $\boldsymbol{r_m}$ represent the instantaneous and maximum solar irradiation at some time interval,

$\boldsymbol{\alpha}$ & $\boldsymbol{\beta}$ are the parameters of the Beta distribution, and $\boldsymbol{\Gamma}$ is the Gama function. Parameters of the Beta distribution of solar radiation can be obtained from the mean value of solar irradiation $\boldsymbol{\mu}$ and variance $\boldsymbol{\sigma}$ for some time [20]:

$$\alpha = \mu \left[\frac{\mu(1-\mu)}{\sigma^2} - 1\right] \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (2)$$

$$\beta = (1-\mu) \left[\frac{\mu(1-\mu)}{\sigma^2} - 1\right] \quad \cdots\cdots\cdots\cdots \quad (3)$$

The Beta distribution parameters are obtained by the measurement of irradiation at some intervals, the mean value of $\boldsymbol{\alpha = 3.034}$, $\boldsymbol{\beta = 2.299}$ and max. solar irradiation $r_m$ = **1.029 (kW/m$^2$)**.

### 2.1.2. Loss parameters of active and reactive power:

Technical specifications of active ***lPa*** reactive power losses ***lPr*** compute the overall losses of the active and the reactive power in RES scenarios and base scenarios without RES. Their mathematical formulation is given by the formulas (4) and (5) [20]:

$$LPa = 1 - \frac{Re[Sy]}{Re[Soy]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \ (4)$$

$$LPr = -\frac{Ie[Sy]}{Ie[Soy]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \ (5)$$

Where ;

Sγ ; Totaln loss of active power in case of solar energy presence.

$S^0\gamma$ : Total loss of active power without solar energy sourse.

When the values of this parameters are ( $0 < LPa, LPr < 1$) ,there are a positive effects, with a higher , ther a loss reduction when there is loss in solar panel penetration, while negative values indicate an increase in power losses.

### 2.1.3. Index of voltage deviations in the grid ( $V_d$ ) :

Keeping the voltage in a required range ensures the good power transfer. The maximum permitted voltage deviations are precisely defined by the Grid Code. The most common is that the deviation is ± 5% or ± 10% of the nominal voltage acceptable. Some loads are particularly sensitive to voltage values beyond the limits set. This parameter is important for some cases especially in motors which their starting torque is proportional to ($V^2$), so that low voltages make it difficult to start this type of engine and high voltages accelerate the aging of the insulation and can damage devices.

The ( $V_d$ ) refers to the maximum deviation between busbars. A uniform profile voltage is usually desirable in the operation of this system. Therefore, positive values of voltage parameter indicate a uniform voltage profile, while negative values mean a more voltage deviation. In mathematical terms, the index is expressed by the following equations [21]:

$$Vd = (Vomax - Vomin) - (Vmax - Vmin) \quad \ldots\ldots\ldots\ldots\ldots. \ (6)$$

Where :

$V_{max}$ : Maximum and voltage value in system integrating with solar source.

$V_{min}$: Minimum voltage value in system integrating with solar source.

$V^0max$ : Maximum voltage in the system without solar source.

$V^0min$: Minimum voltage in the system without solar source.

### 2.1.3. Load level index (*LL)*

This Parameter refers to the load level of the transmission lines in the systems. It can affect the cost reduction related to the installation of new transmission lines that are necessary due to the increase in system load. In mathematical terms, the index can be expressed as [21] :

$$LL = \max\left(\frac{SL_m^0}{SR_m}\right)_{m=1}^{NL} - \max\left(\frac{SL_m}{SR_m}\right)_{m=1}^{NL} \quad \ldots\ldots \quad (7)$$

where :

$SL^0_m$ & $Sl_m$ : the load of feeder for the system with solar system.

$SR_m$ : is the limit load of feeder . while NL represent the number of feeders in the system.

This index serves as a means of assessing whether solar source integration raises or reduces the load level of the most overloaded transmission lines. So, reducing or increasing the load of lines directly affects the ability of the system to accept an increase in consumption in the future. This index indirectly points to the necessary investments in a new transmission capacitance.

### 2.2. Implementation of the testing algorithm

The proposed algorithm for calculating the technical parameters based on power and voltage calculations with and without integrating the photovoltaic source has been conducted in some steps in MATLAB Simulink as shown in the flowchart in figure (1) . Table (1) indicate the objective of each step .

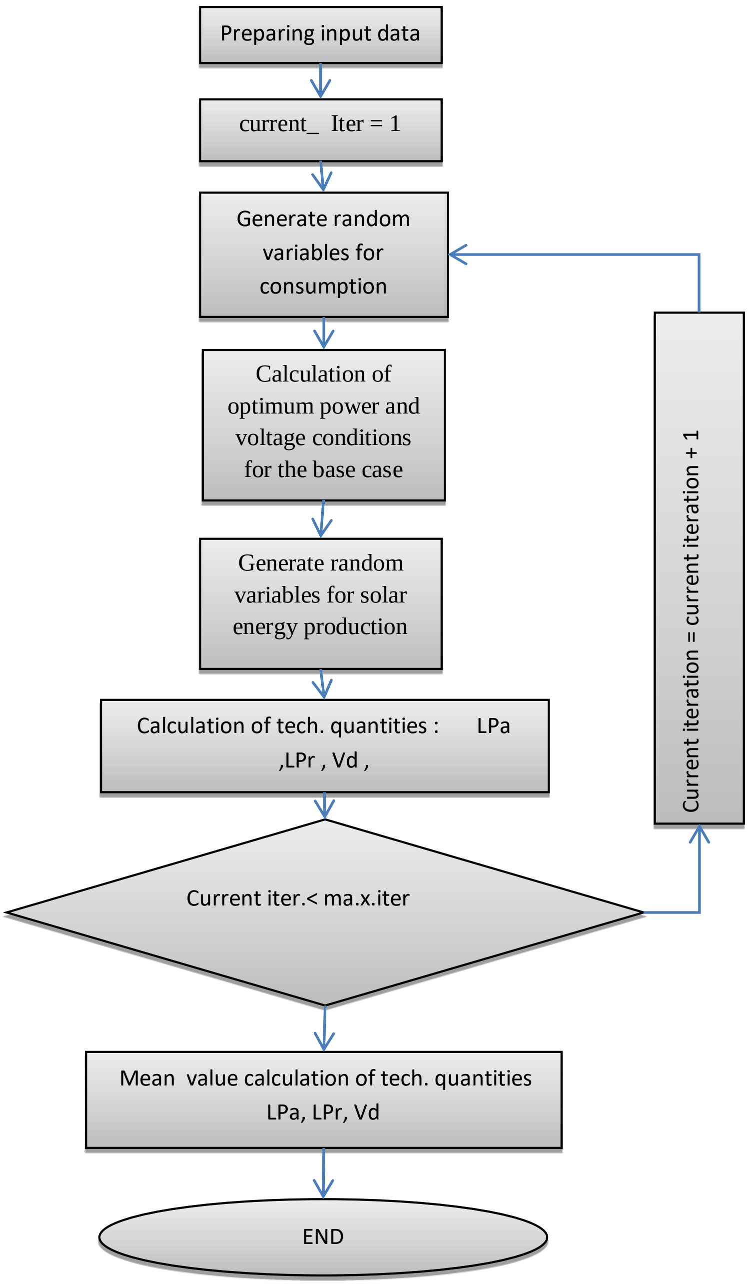


Fig.(1): The proposed algorithm.

The proposed algorithm was tested on a standard IEEE 9-system for calculating the power as shown in (Fig. 2). In particular, the system consists of three conventional generators that supply three consumer areas. Installed capacity is (820.00) MW, while the average load is 315 MW. In addition, it is assumed that there is a solar source in the load nodes whose total power in MATLAB Simulink installed capacity is 100 MW. The optimal distribution of power was performed according to the criterion of the minimum total production costs of the generator, whereby the curve of production cost of a generating unit representing a square function.

Table (1) : Steps of proposed algorithm for calculating the technical aspects.

| Step No. | Task | Objective |
|---|---|---|
| 1. | Preparation input data | Upper and lower limits of power levels, production cost coefficients, amplitudes of voltage nodes and apparent power transmitted through feeders & finally the consumption of active and reactive power in knots. |
| 2. | Set the current iteration counter =1 | Start the iteration counting. |
| 3. | Generate random variables for consumption | The loads are modeled over the normal distribution of N (μ, σ2) with parameters μ = 1 and σ = 0.07 in relative units. |

| | | |
|---|---|---|
| 4. | calculation of optimum power and voltage for base case | To find the distribution of active generating powers on generating nodes at minimum objective function is achieved, while meeting the technical limitations of the network. |
| 5. | Generate random variables for solar energy production | The objective function that needs to be minimized is the sum of the cost of production of all manageable sources in the electricity system. The generating random variables state is obtained to produce high precision in the system. Production is determined by taking values $\alpha = 3.034$ and $\beta = 2.3$. |
| 6. | Calculation of optimal energy and voltage levels. | Budget for optimal flows of energy and voltage levels if the energy is produced from a solar source. |
| 7. | Technical quantities:<br>LPa, LPr, Vd | Calculation of technical quantities by considering the basic situation and the case of solar source integrating. |
| 8. | Check the criteria for the exiting algorithm | If the current repeat number is smaller than the max.limit, steps 3 through 8 will be repeated with single addition. When the current frequency exceeds or equals the maximum, it will continue to step 9. |
| 9. | Mean value calculation of tech. quantities : LPa, LPr, Vd | Average value of technical quantifiers calculation. |
| 10. | End | Displaying of the results. |

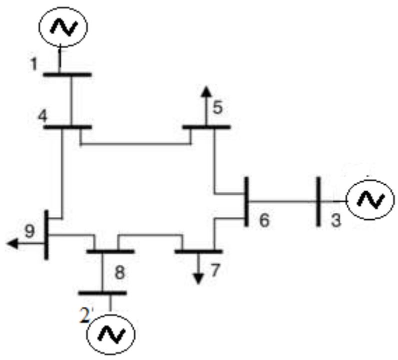


Fig.(2) **:** IEEE 9-Bus block diagram [11].

**3. Results and discussion**

Technical Indicators **LPa** and .**LPr** measurements show that by introducing dispersed solar power source near the load center results in some decrease in the loss of active and reactive power due to reduced transmission of power lines capacity.

Decentralized production can results in reducing the energy losses. The effect of the integration of solar source into the main grid depends on existence the source of the load (shunt capacitors, reactors). So, the values of the current overload technical indicators are not as smooth as the ILp and ILq indicators due to the specific topology of the test system. Namely, the facts that there are three sources that can provide reactive support in the system directly affect the integration of photovoltaic power sources on voltage level. In addition, the line breakdown also decreased because solar power plants located on consumer busses locally supply consumption. In figures (3),(4) and (5) are given the graphics of these measurement, while in table (2) are given the basic characteristics.

Table (2): Statistical analysis of the technical indicators.

| Parameter | LPa [w] | LPr [w] | Vd [v] |
|---|---|---|---|
| Max.value | 0.376 | 0.270 | 0.17 |
| Min.value | 0.001 | 0.003 | 0.01 |
| Average value | 0.13 | 0.135 | 0.065 |

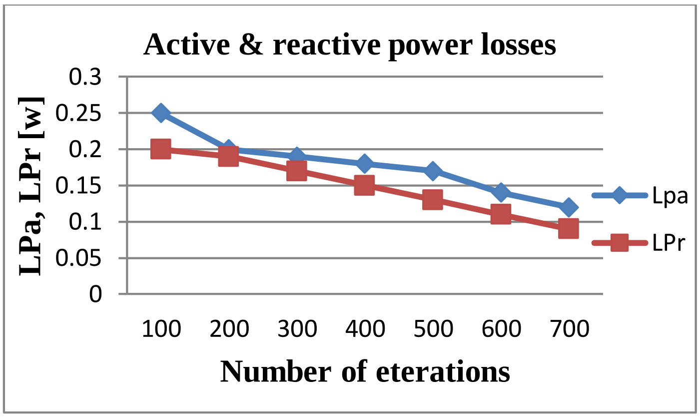


Fig (3). Active and reactive power loss indication.

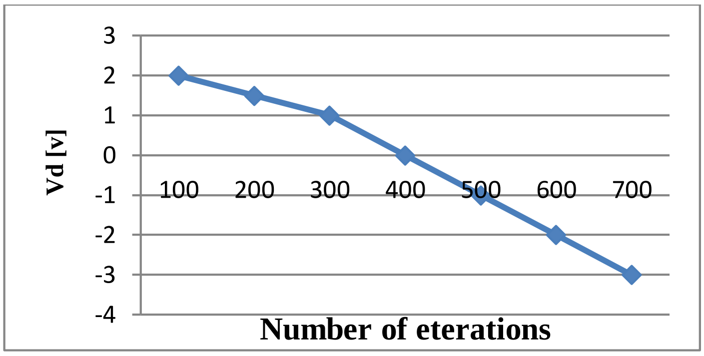


Fig.(4) Voltage profile indicator.

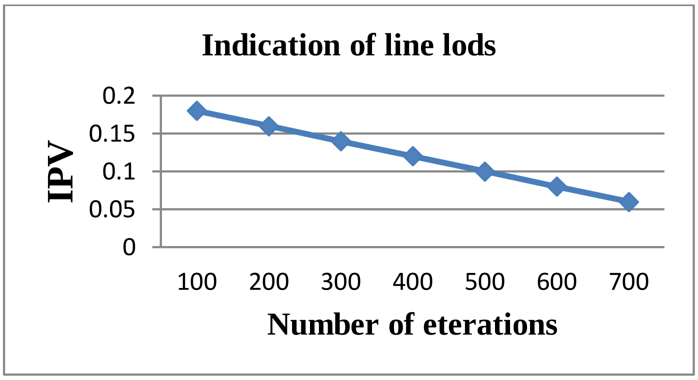


Fig.(5). Indicator of the line loads.

It should be noted that the Beta distribution is modeled by the production of photovoltaic power plant only when there is solar irradiation. So, this analysis can covers only the day interval when the sun is shine. During the night, when there is no production from solar power plants, the state of the power grid is identical to a condition without integration of solar source.

**4. Conclusion:**

Increasing of different gases emissions and climate change gave the renewable energy sources some advantage over conventional electrical sources. However, renewable energy sources integration into existing power system may be consider a complex problem due to their stochastic and intermittent nature. In this paper, the renewable energy source impact on the electrical network distribution system have been investigated to avoid unwanted situations that may harm the system. The investigation method involves the stochastic behavior of consumption as well as veneration from renewable energy source in the electrical power grid. The influence of photovoltaic power source on power losses, deviation of voltage and load of lines have been analyzed. The results obtained show that the integration of renewable energy source cause some reductions in active the power losses, as well as reduces the load on the electrical power lines. This conclusion is justified because the integration of photovoltaic power plants that locally power consumption leads to the unloading of the lines and thus to the reduction of losses in the network. Another results of this research is that the renewable energy source can have a different impact on the voltage level in the network. This is a direct consequence that network grids are dominantly dependent on reactive support near load centers.

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