Study and Analysis the Impact of Solar Energy Source on Stability of Electrical Power Grid.

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الخلاصة

ان زيادة الطلب العالمي على توليد الطاقة الكهربائية الرخيصة والنظيفة من مصادر الطاقة المتجددة ادى الى زيادة عدد هذه المصادر مما ادى الى زيادة تاثيرها على اداء واستقرارية انظمة توزيع الطاقة الكهربائية عند ربطها بمنظومة التغذية الرئيسية. الهدف من هذا العمل هو دراسة وتحليل تاثير مصدر الطاقة الشمسية عند ربطها مع منظومة الشبكة الكهربائية على استقرارية جهد وطاقة المنظومة الرئيسية. تم اجراء الاختبارعن طريق دراسة مجموعة من العوامل الفنية التي يمكن من خلالها تحديد تأثير مصدر الطاقة الشمسية على شبكة الطاقة الكهربائية عن طريق حساب مقدار الفقد في الطاقة النشطة والمتفاعلة، وتغيرات الجهد في الشبكة الكهربائية عند ربط مصدر الطاقة الشمسية بالشبكة الرئيسية. يمكن استخدام النتائج الحاصلة كقاعدة بيانات لتقدير مدى التأثير الحاصل في هذه الحالة. تم تنفيذ نموذج المحاكاة باستخدام برنامج MATLAB وتم مقارنة النتائج مع بيانات الشبكة الكهربائية القياسية . (9-bus IEEE)

Abstract

The increase of global demand for cheap and clean power from renewable energy sources has increased the number of these sources, increasing their impact on the performance and stability of electrical distribution systems when integrated to the main line feeder. In this work, number of technical factors related to electrical production quality have been examined in order to evaluate the impact of solar energy source on electrical power grid. The tests were carried out by measuring the losses of active and reactive power and the voltage changes in the electrical grid due to connecting the solar source to the main grid. The results obtained can be used as a database to estimate the impact of solar power supply on the stability of the grid. The simulation model was conducted by using the MATLAB Simulink and the results were compared with the standard (9-IEEE) bus grid..

1. Introduction

Increasing the CO_2 emissions and limiting fossil fuel reserves have pushed renewable energy sources into the forefront. 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 and more represented in electricity generation and replace sources that are responsible for CO_2 emissions. In this way they contribute to the decarburization of future power systems [2].

Penetration of renewable energy, especially wind, 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 ecological factor that was the main motivation for investing in renewable energy sources. The integration of such sources has brought many benefits to the main grid. One of the advantages is that the consumption requirements can be provided at the local level, which reduces the need for transmission of electricity to large distance [4].

The direct consequence of decentralized production from the renewable energy is the reduction of strain on the lines and the losses of active and reactive energy in the system. This reduces the probability of overloading the lines and increases the safety of the main grid. At the same time, the transmission system operator is responsible for the losses of energy in his network, so that the reduction of losses has an economic benefit [5].

An analysis of the impact of the integration of renewable energy sources into the electric power system becomes the subject of research by a large number of researchers. The authors in deal with the problem of finding the optimal location and capacity of distributed energy sources. The objective function can be different; the most common is minimization of losses or better voltage conditions [6].

Power calculations represent a very useful tool that gives information about the state of the power system. The results of calculation give us variable values of amplitude and phase angle of the voltage on the bus under certain load and production. In the calculations of power, the input and output variables of the system are considered as random variables and in this way it is possible to obtain different possible states of the main grid [7].

However, with the development of efficient tools and modern computers, MCS method was often used in probabilistic power calculations. This method represents an iterative process where in each iteration random values for each of the stochastic variable systems (consumption and output from the renewable energy source) are selected based on the distribution density function [8].

Then, the optimum power is calculated for each set of input random variables. The result of each calculation of optimal power is recorded and the process is repeated until the state for interrupting the algorithm is met [9].

2. Mathematical calculations:

To determine the impact of solar energy source, some technical parameters have studied and analyzed in two stets, the initial state of the system without integrating the solar sources and the second state involving solar energy sources. In this paper, three technical aspects are considered: power losses, voltage deviation and load capacity. The emphasis on the influence of solar power plants connected to the network in load nodes, solar irradiation is intermittent and stochastic. In order to reliably assess the impact of solar power source on the main power system, it is necessary to establish an appropriate model for estimating production from photovoltaic panels.

2.1. Solar irradiation intensity parameter f(r): p

In a certain period, solar irradiation can be approximated by a Beta distribution whose probability intensity function has the following form [10]:

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

Where r & rm represent the instantaneous and maximum solar irradiation at some time interval,

α & β are the parameters of the Beta distribution, and Γ is the Gama function. Parameters of the Beta distribution of solar radiation can be obtained from the mean value of solar irradiation μ and variance σ for some time [10]:

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

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

The Beta distribution parameters are obtained by the measurement of irradiation at some intervals, the mean value of **(α = 3.034, β = 2.299)** and the maximum solar irradiation **(r_m = 1.029 kW / m2)**. When the known Beta function for solar irradiation, the output power of a solarpower plant can be obtained.

2.2.Loss parameters of active and reactive power (lPa & lP):

Technical parameters of active and reactive power losses lPa & lPr compute the total losses of active and reactive power in RES (renewable energy sources) scenarios and base scenarios without RES. Their mathematical formulation is given by the formulas (4) and (5) [10]:

$$LPa=1-\frac{\mathrm{Re}[Sy]}{\mathrm{Re}[Soy]} \qquad \text{(4)}$$

$$LPr=-\frac{\mathrm{Ie}[Sy]}{\mathrm{Ie}[Soy]} \qquad \text{(5)}$$

Where:

Sγ: refers to the total loss of active power in case of solar energy presence.

S 0γ: refers to the total loss of active power without solar energy soursee.

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

2.3. Voltage deviation index in the grid (Vd):

Maintaining the voltage in an acceptable range ensures the reliable 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, such as in case of asynchronous motors in which the starting torque is proportional to the voltage square, 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 electronic devices

The technical voltage parameter (Vd) refers to the maximum deviation of the voltage between the busbars. A uniform profile voltage is usually desirable in the operation of the system. Therefore, positive values of voltage parameter indicate a uniform voltage profile, while negative values mean a wider voltage deviation. In mathematical terms, the index is expressed by the following equations [10]:

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

Where:

Vmax and Vmin: Maximum and minimum voltage value in the system with solar source,

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

V0max & and V0min: Maximum and minimum voltage in the system without solar source.

2.4.Load level index (LL):

This Parameter refers to the load level of the transmission lines in the systems. It can affect the reduction of investment costs 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 [10]:

where:

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

SR_m: is the limit load of feeder. While NL is the number of feeders in the system.

This index serves as a means of determining 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.

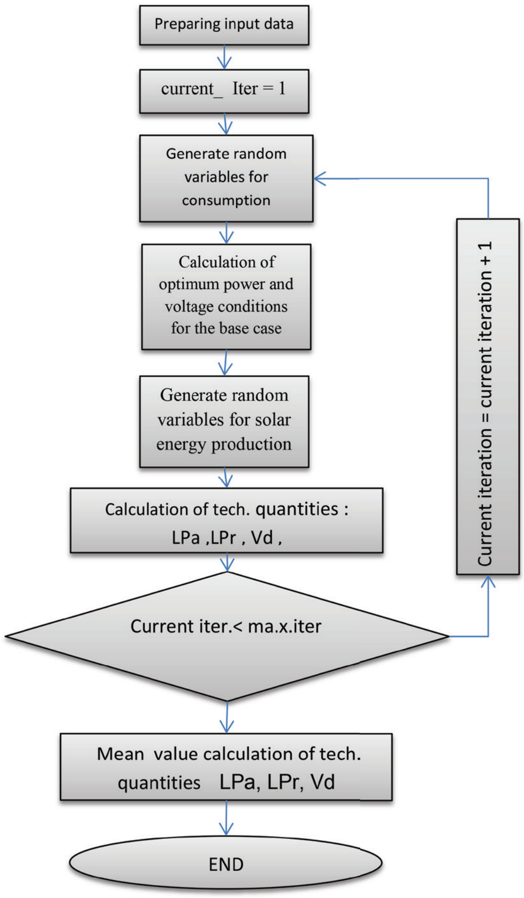

Fig.(1): The proposed algorithm.

3.Implementation of testing algorithm.

The proposed algorithm for calculating the technical parameters based on power and voltage calculations with and without integrating the solar source has been conducted in some steps in MATLAB Simulink as shown in the flowchart in Fig. (1).

Table (1) indicate the objective of each step.

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) MW, while the average load is (315) MW. In addition, it is assumed that there is a solar power 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 parameters.

Step No.	Task	Objective
1.	Preparation input data	Upper and lower limits of active and reactive 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 which the minimum objective function is achieved, while meeting the physical and 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 state of generating random variables is obtained to produce high precision in the system. Production was determined by taking values α = 3.034 and β = 2.299.
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.	Calculation of technical quantities: LPa, LPr, Vd	Calculation of technical quantities, taking into account 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 maximum limit, steps 3 through 8 will be repeated with one 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	Calculation of the mean value of the technical quantifiers based on the results of individual iterations.
10.	End	Display results and end of the algorithm.

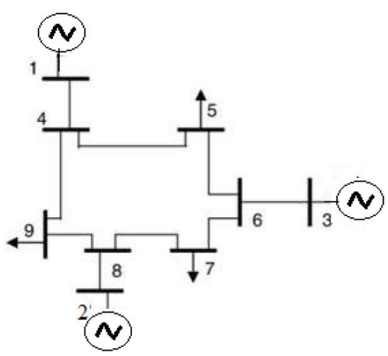

Fig.(2) : IEEE 9-Bus testing system[11].

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4.Results and discussion

1-Technical lPa and lPr (active and reactive power losses) 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.

2-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). For this reason, the values of the current overload technical indicators are not as smooth as the ILp and ILq indicators due to the specific topology ofp the test system. Namely, the facts that there are three sources that can provide reactive support in the system directly affect the integration of solar power sources on voltage level. In addition, the line breakdown also decreased because solar power plants located on consumer busses partially locally supply consumption. In Figs. (3), (4) and (5) are given the graphics of these measurement, while in Table (2) are given the basic characteristics.

It should be seen that the Beta distribution is modeled by the production of solar power plant only when there is solar irradiation. For this reason, this analysis covers only the

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 valu	0.13	0.135	0.065

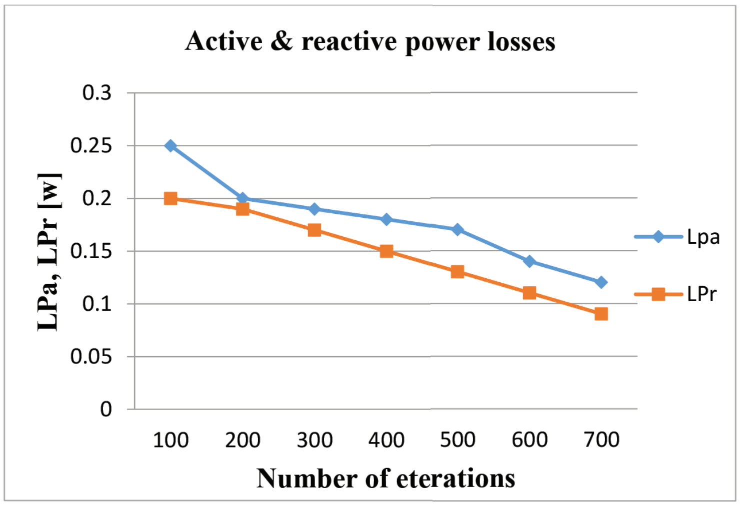

Fig (3). Active and reactive power loss indication.

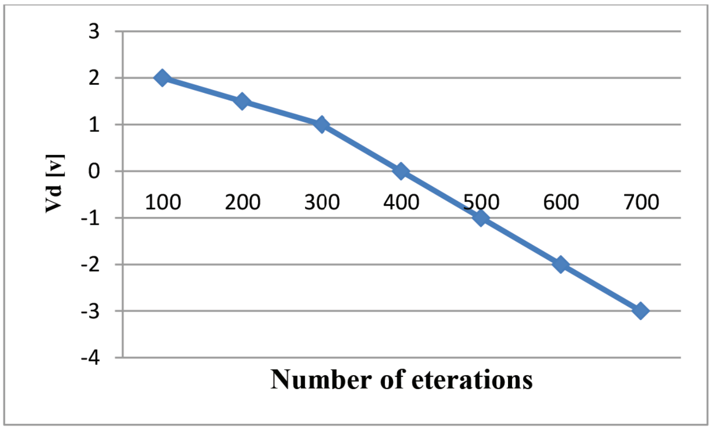

Fig.(4) Voltage profile indicator.

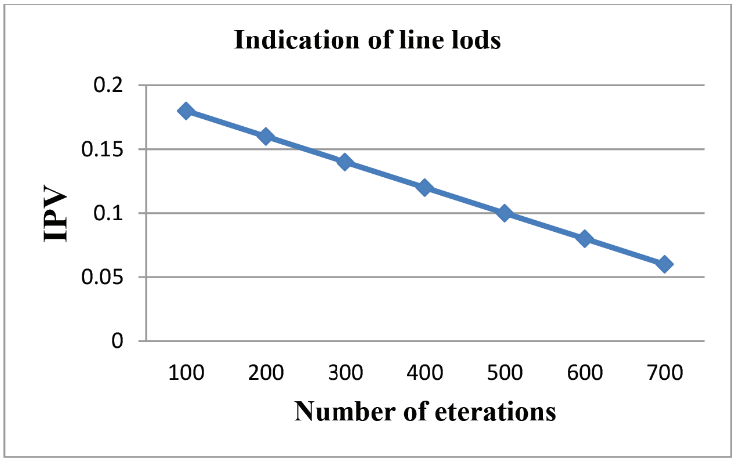

Fig.(5). Indicator of the line loads.

period of the day when there is a sun. 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 the solar energy source.

5.Conclusion

Increasing the 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 systems is a very complex task mostly due to their stochastic and intermittent nature. The aim of this analysis is to investigate the impact of renewable energy source on the transmission network system in order to avoid unwanted situations that could potentially harm the system. The conclusions of this paper rely heavily on the concept of probabilistic flows of forces. This method involves the stochastic behavior of consumption and production from the renewable energy source in the system. The influence of solar power plants on power losses, deviation of voltage and load of lines was observed. The conclusion of the paper is that the integration of renewable energy source generates reductions in active and reactive power losses, as well as reduces the load on the lines. This conclusion is justified because the integration of solar power plants that locally power consumption leads to the unloading of the lines and thus to the reduction of losses in the network. Another conclusion of this study is that the renewable energy source can have a different impact on the voltage conditions in the network. This is a direct consequence that network grids are dominantly dependent on reactive support near load centers

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