# Solar Power Integration Impact on Power Grid Perfomance

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## Abstract.

A study has been conducted on the integration of solar power into power grids. The main aim of this study to analyse the impact of solar PV penetration on the power grid performance and its futuristic solution to overcome those issues. In the overall study found that the current variation at some place reach beyond the highest level of fault current, volage levels improved at busses and power losses decreases in the network about the 50% at 80% solar PV penetration level.

**Keywords**. Solar power, Penetration, Power factor, fault current, voltage and current variation, power losses.

## 1. Introduction

Renewable energy sources produce electricity using natural resources, which are less harmful to the environment than those that rely on conventional fuels. These sources can also help lower the overall power losses and pollution levels in the system. Although renewable energy sources can help lower the pollution levels and power losses in the system, they have various issues that need to be considered before they can be added to the system. Some of these include over-voltage, under-voltage, harmonics, and transient stability [1][2][3].

The increasing capacity of renewable energy sources such as solar power has increased the risk of short circuits in the grid. This is especially true when a microgrid is running in its own mode. One of the most common calculations that electrical designers have to make is the short circuit calculation. An electrical apparatus should be able to withstand the current and voltage of a fault for a certain period of time[4]. Protective equipment should also be designed to remove any potential faults that may be present in the system. Faults in these components should be fixed within the equipment's tolerance. Through extensive research, electrical engineers have been able to thoroughly examine the various facets of transient analysis. The goal of this process is to determine the minimum and maximum currents that a system's fault should have. All electrical equipment should have the necessary ability to withstand a fault at a given level.[5]. The maximum and minimum currents of the system are usually determined for the building of an earthing system and for the protection of an advanced protection system. Having the necessary knowledge about the type of defect that can be found in the system is very important to ensure that the equipment is protected. In order to protect the equipment, the pickup setting should be chosen using the lowest available fault current. The use of the electrical transient analysis programming, known as the ETAP, can greatly reduce the time it takes to perform a short circuit calculation[6][2][1]. In this study, the Electrical Transient and Analysis Program is used to investigate the best placement for PV plants and their maximum penetration level (ETAP 19.5). To confirm the choice, the IEEE 14 bus system is emulated. To select the best outcomes for a given objective function, ETAP has the capacity to simultaneously execute several scenarios[2].

## 2. LOAD FLOW CALCULATION

A load flow analysis is a process that involves analyzing the flow of electricity through a power system. It can determine the voltage magnitude and the amount of current that' is flowing down the lines. It can also calculate the real and reactive power losses. The results of this procedure are used to start studies on the electric power system's components. This process is very important in the planning of a system's new extension or installation. The study performed on this project took into account the 1.3kV lines that are running through the IEEE 14 bus feeder network. The total operational load of the system is 259 megawatts, while the reactive load is around 73.5 MVAR. The results of the analysis were analyzed using the Gauss-Sidel method. The four solar PV plants are connected to the distribution feeders of IEEE 14. The total load of the network is determined by taking into account the overall energy usage by the renewable energy sources. The analysis also took into account the different power injection levels[1] [6].

In this case, solar PV has no impact on the system's load. Case 2, 3, and 4 show that it has fulfilled the system's 20%, 40%, and 60% load requirements, Case 5: Solar PV has fulfilled the 80% of the system's active load. Case 6: It has also fulfilled the 100% of the system's active load, case 7: fulfil the 120% of the system active load.[2].

A single line diagram is used to describe systems since it is assumed that their distribution is uniform. The load flow solution calls for generating an admittance matrix of dimension where n is the system number (n x n). A bus's own admission is represented by the diagonal elements of the admittance matrix, whereas mutual bus admission is represented by the off-diagonal elements[6][7].

$$Y = \begin{bmatrix} Y_{11} \dots \dots \dots Y_{44} \\ \dots \dots \dots \dots \dots \\ \dots \dots \dots \dots \dots \\ Y_{55} \dots \dots \dots \ Y_{88} \end{bmatrix} \tag{1}$$

The initial Gauss Sidle method, calculated voltage magnitude and angle of the particular bus provide as the parameters that define actual and reactive power and non-linear equation is solving by iterative methods (Gauss Sidle and Newton Raphson)

**Real Power**

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} - \gamma_i + \gamma_j) \tag{2}$$

**Reactive power**

$$Q_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \gamma_i + \gamma_j) \tag{3}$$

The calculated values known as power residuals for the terms $\Delta P_i$ and $\Delta Q_i$ is represented as:

$$\Delta P_i = P_i^{sch} - P_i \tag{4}$$

$$\Delta Q_i = Q_i^{sch} - Q_i \tag{5}$$

One or more transmission lines, loads, and generators can be connected to one another at a point or node called a bus. Each bus in a power system study has four values associated with it: the voltage magnitude (|V|), the voltage phase angle ($\gamma$), the active power (P), and the reactive power (Q). Two of these bus quantities are known, and the other two need to be calculated by solving an equation. The two known quantities that have been mentioned are used to categories the buses. Three categories are used to group buses. The three bus types: Swing (P & $\gamma$), and Generator (P & V) Load Bus, (P&Q constants)[8][6].

This issue can be resolved in two different ways. First off, the measured real-and reactive-value requires internal iteration if the variables are picked up and determined at the beginning of the resolution approach (eq. 2 & 3). Second, to detect power inaccuracies and intolerance, improved accuracy iterations are necessary (eq. 4 and 5). The first iteration in this study is referred to as a calculation iteration, while the second iteration is referred to as a precision iteration.

TABLE NO. 1 - PENETRATION LEVEL OF SOLAR PV CONNECTED IN CASE WISE.

| Total connected active load ( kW) in network = 310 Kw | | | | | | | |
|---|---|---|---|---|---|---|---|
| **% Penetration** | **PV1 at Bus 2** | **PV2 at Bus 3** | **PV3 at Bus 4** | **PV4 at Bus 6** | **PV5 at Bus 13** | **PV6 at Bus 14** | **Total Solar PV (kW)** |
| **Case1(0%)** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Case2(20%)** | 51.8 | 0 | 0 | 0 | 0 | 0 | 51.8 |
| **Case3(40%)** | 51.8 | 51.8 | 0 | 0 | 0 | 0 | 103.6 |
| **Case4(60%)** | 51.8 | 51.8 | 51.8 | 0 | 0 | 0 | 155.4 |
| **Case5(80%)** | 51.8 | 51.8 | 51.8 | 51.8 | 0 | 0 | 207.2 |
| **Case6(10%)** | 51.8 | 51.8 | 51.8 | 51.8 | 51.8 | 0 | 259 |
| **Case7(120%)** | 51.8 | 51.8 | 51.8 | 51.8 | 51.8 | 51.8 | 310.8 |

TABLE NO. 2 – SOLAR PV PANEL RATING

| Parameter Rating of solar PV | |
|---|---|
| Short-Circuit Current (Isc) Module | 8.33 A |
| Open -Circuit Current (Voc) Module | 33.97 V |
| Voltage & Current at Maxpower (Vmp, Imp) Module | 27.19 V,7.89 A |
| Sun irradiance MAX. level | 1000W/m2 |

## 3. RAISING THE VOLTAGE AT THE 14 BUS FEEDER

As seen from the simulation results, the level of PV penetration rises as well as the voltage of the buses also rising. The voltage of each of the 14 buses is shown in Fig. 2 with solar PV penetration rising from 0% to 120%. The level of solar PV penetration rises together with the percentage of voltage. The rise in voltage at various nodes continues to be within the prescribed limit (0-1.5%).

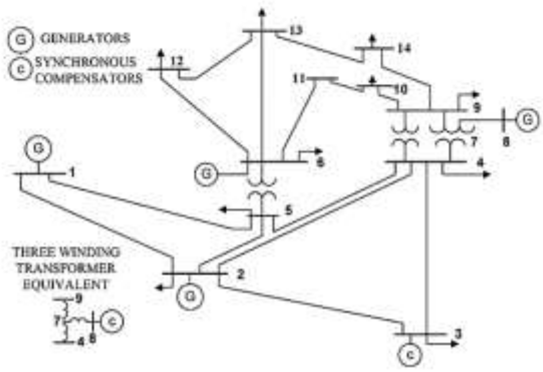


**Fig.1** – Integration of Solar PV at Bus 2,3,4,6,13,14 In IEEE 14 Bus System

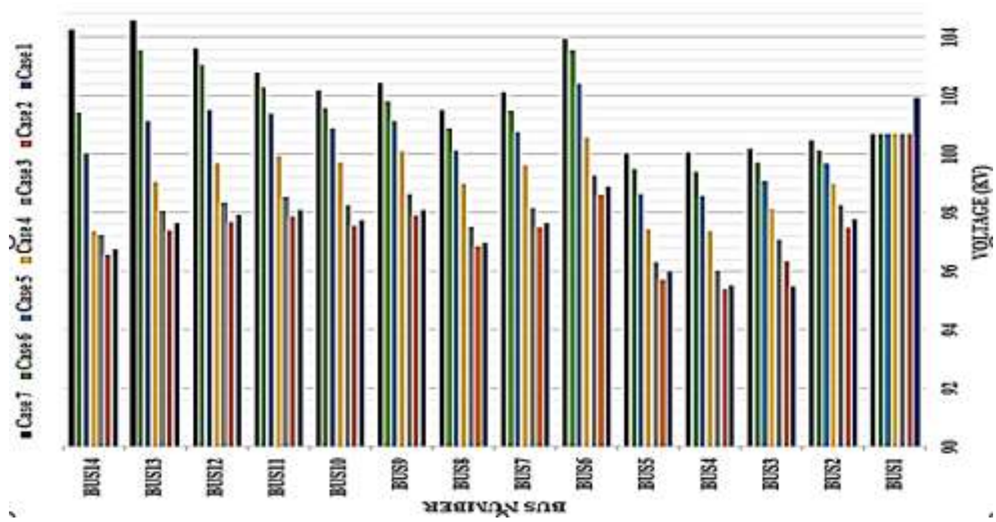

**Fig2.** – Voltage variation analysis with respect to Solar PV penetration

## 4. THE EFFECT OF SOLAR PV PLANTS ON POWER LOSSES IN THE DISTRIBUTION SYSTEM

The magnitude of power flow is inversely personal to the rate of power loss. PV technology has altered how the distribution network is used, resulting in atypical and bidirectional power flows. Therefore, the presence of PV systems and the consequent altered power flows may significantly affect power losses. Figure 3 illustrates this finding from an study of PV penetration that power loss lowers as PV penetration rises till 80% after 80% power loss increases gradually for case 6 & case 7.

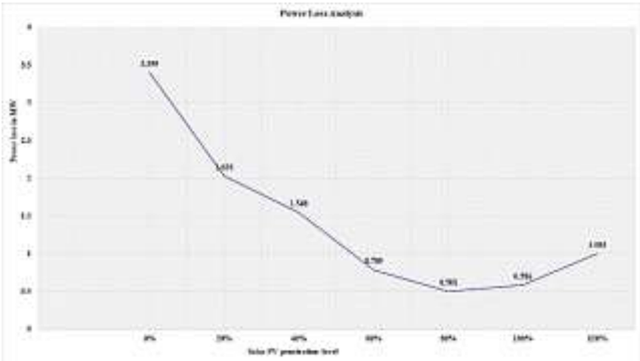

**Fig3**. – **Power Losses analysis for all penetration levels.**

# 5. THE EFFECT OF SOLAR PHOTOVOLTAICS ON POWER FACTOR.

The power factor is a significant aspect since it is essential for the efficient operation and reliable transmission of electric power. A decrease in power factor results from increased power output from the PV system. The increased active power from the PV system without any generation of reactive power may be used to interpret this. Because the grid supplies less active power while retaining the same level of reactive power, the power factor decreases as a result [9][6][10].

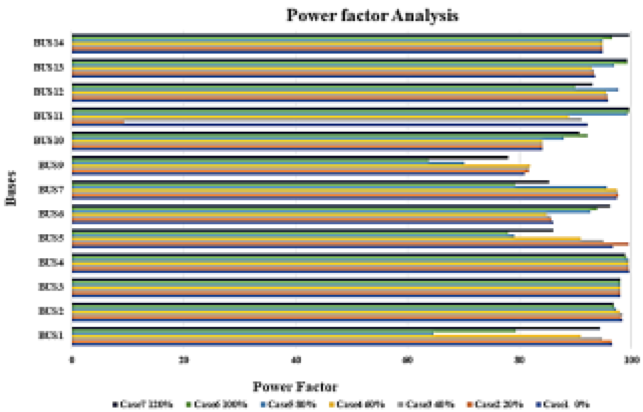


Fig4. – power factor of each case of solar PV penetration

# 6. SHORT CIRCUIT CURRENT WITH SOLAR PV

The goal of short circuit analysis is to determine the asymmetrical and symmetrical fault currents and their contribution to the overall electrical system. This process influences the short circuit ratings of equipment used in the distribution grid. The three types of fault that can be divided are the line to line, line to ground, and double line to ground. In this paper, the corresponding graphs are shown for the simulations of the L-G and L-L faults [1]. The results of this exercise show the magnitude of the buses that were involved in the line-to-line fault that was performed by an ETAP. Figs 4 and 5 illustrate the varying current values as the grid's penetration level changes. The results of the exercise show the significant faults in the micro-grid. The current values exhibited in these scenarios are shown in varying phases, with the former remaining above marginal in some areas and decreasing in others.[1][11].

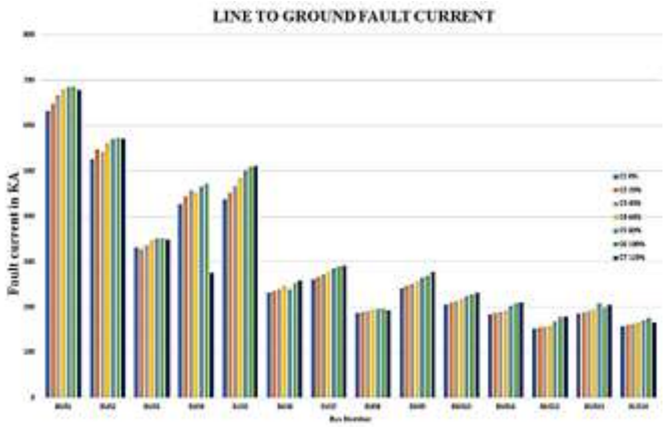


**Fig 5. – Analysis Of L-G Fault Current for IEEE 14 Bus Distribution Feeder**

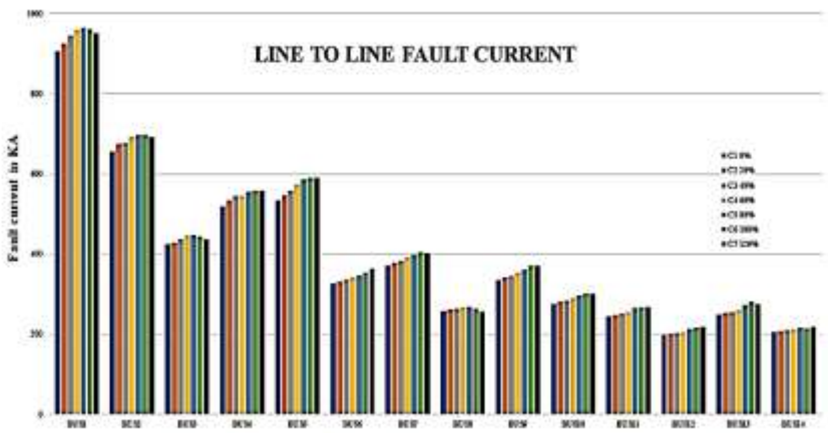


**Fig 6. – Analysis Of L-L Fault Current for IEEE 14 Bus Distribution Feeder**

The main bus that connects the various sub-buses and loads is shown in Figure 6. The distribution of the current during the line-to-ground fault is shown in Figure 5. The result shows that the defective phase of each bus leads to a large gain in the rated current, while the other phases experience an unequal displacement.

## 7. CONCLUSION

In the study found that the current variation in the penetration level of the connected devices can affect their system efficiency and life span. It is also found that the power factor of the system can vary at different penetration levels, which can cause it to be unbalanced. The study revealed that as the penetration level of the connected devices increases, the power losses decrease. However, after reaching a certain level of penetration, the power losses increase slightly. This research can should be used to develop an energy policy for renewable energy and its will be useful for the independent system operator for defining the integration capacity of RE.

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