# System Performance of a Grid Integrated Distributed Generator using ETAP

**Arpita De**

***Abstract*: *Uneconomical augmentation of the grid framework has prompted the usage of electric power toward the end users and has been demonstrated to be practical and to a degree effective. With expanded criticalness on eco-accommodating innovations the utilization of sustainable power sources, for example, small scale hydro, wind, solar, biomass and biogas is being investigated. This paper introduces the potential effects of matrix associated photovoltaic (PV) array on electrical systems demonstrated using the Electrical Transient and Analysis Program (ETAP) software by validating the system performance parameters of the Deetyakhedi Feeder in Jhalawar district, Rajasthan under different loading conditions on Grid failure and the Sub-feeder disconnection case. This paper elaborates by underlining the significance of generating power from PV panels which exhibits and explains the development in solar technology. Effects of framework associated with solar PV Electricity on Power Systems are additionally discussed in this paper pursued by the authors' synopsis from the various writing's and discoveries with respect to the greatest suitable Solar PV infiltration that can be securely incorporated into existing systems by analyzing the System performance of the Grid Integrated Distributed Generator using ETAP Software. The conclusion covers the various Loading conditions at the Grid failure case and the Sub-Feeder disconnection case evaluating various conditions under which the system again regains its stability after specific time intervals.***

***Keywords*: *Grid Integration, Distributed Generator, Renewable Energy, System Performance, Solar PV, Voltage Regulation*.**

## I. INTRODUCTION

Prerequisite of energy in its most reasonable structure is the need of a large number of individuals all over the globe. It tends to be fuel, utilized in transportation, electrical vitality for lighting loads, and so on. The worldwide environmental change has added to the issue of shortage of non-renewable energy sources. Presently the time has come to investigate the arrangement of energy catastrophe, made by the decrease of non-renewable energy sources without changing the environmental conduct. For standalone mode, transportation of traditional energy generating sources (like coal, oil, and flammable gas) is very troublesome and network expansion is additionally not financially savvy because of remoteness and troublesome geographical territory. Sustainable power source is the most fitting answer for energy supply in disconnected and remotely located territories [1]. Usage of locally accessible Distributed Generator (DG) is the most ideal choice to meet the energy requirement prerequisite.

Contingent upon the site conditions, single or integrated technological innovation would be chosen for the DG mode.

These goal-oriented targets focuses of lessening the reliance on petroleum products—and subsequently, diminishing the ozone harming substance discharges that can't be accomplished without dynamic investment by the worldwide global arena, which is answerable for around two third the world's ozone depleting substance [2]. In any case, this undertaking is made troublesome by the expansive interest for power. Electrical energy generation at present speaks to 12% of all out worldwide energy utilization; be that as it may, this rate is relied upon to increment later on to get 34% of the overall energy consumption by 2025. Along these lines, a mind boggling situation exists: on one hand, greenhouse gases being released by the energy generation that require a noteworthy decrease; then again, electrical power generation must increment to fulfil developing need for power.

Solar energy, if appropriately used to produce power utilizing photovoltaic (PV) technology, can satisfy all the power needs of humankind. A basic count uncovers that the measure of solar energy got in 1 hour by the earth is comparable to the world's yearly energy utilization.

Figure 1 shows the internal schematic of the ETAP software for the modelled system. The system under study generates various test conditions of various loading parameters for the performance analysis of the feeder under Grid failure condition and the disconnection of the Sub feeder at the Load Side.

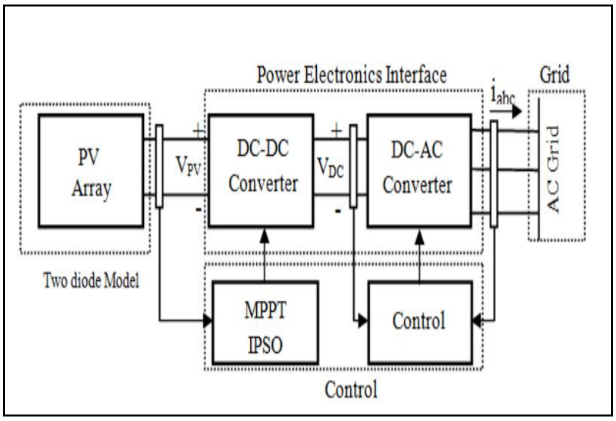


**Fig 1: Block Diagram of System in ETAP software**

It was thought of that incorporating Solar PV into power systems would not be a troublesome undertaking; nonetheless, when the infiltration level of Solar PV power began to build, utilities started to confront new non-conventional issues essentially because of the irregular irradiation of sun [3]; Solar PV module yield is profoundly subject to natural conditions, for example, PV module temperature and Solar irradiance. Diverse climate variations of an area brings changes in the yield intensity of PV modules, and along these lines, the power generation needs to manage not only the rising demand of the energy but also the varied generation from the PV Modules [4].

**Revised Manuscript Received on January 15, 2020**

***** Correspondence Author

**Arpita De***, Energy Centre, Maulana Azad National Institute of Technology (MANIT), Bhopal, India. Email: arpita.1802@gmail.com

## II. INCREASE IN THE PV ENERGY INSTALLATIONS

The worldwide Solar PV incorporation limit has expanded incredibly in the course of recent decades. During the previous 15 years, worldwide PV incorporated limit has encountered a yearly developmental pace of about 45% as appeared in Figure 2.

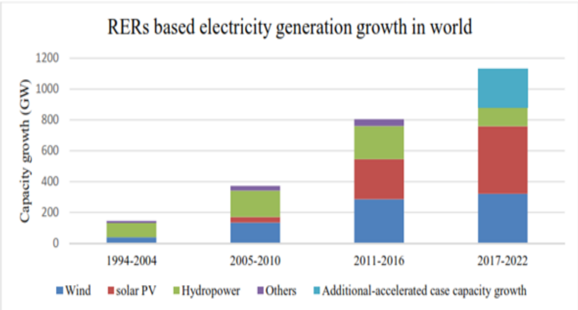


**Fig. 2: Rise in RES based electricity generation worldwide**

This is on the grounds that the worldwide energy generation segment understood that producing power from renewables will be the main accessible alternative to fulfil the developing interest for power generation when all accessible petroleum derivative assets are devoured. Another purpose behind that is the foreseen advantage of PV power generation on national economy [5]. A million dollar interest in Solar based PV will make just 30%–42% of the energy delivered by other power producing methods yet 2.4–6.4 times more occupations opportunities would likewise be generated.

## III. INFLUENCE OF GRID CONNECTED SOLAR PV ENERGY

When grid integrated PV set-up is introduced to upgrade the efficiency of the electric system; PV elaborates its characteristics (just as some other dispersed generator) that give vitality at the consumer side of the feeder, diminishing the feeder dynamic power stacking and consequently improving the voltage profile of the feeder. Therefore, PV arrays can defer the activity time of shunt capacitors and arrangement voltage controllers, in this manner expanding their lifetime. PV arrays can likewise lessen the misfortunes in circulation feeders if ideally placed and sized. The model given in [6] shows that for a distribution feeder providing 10 MW consistently reduces burden along its length, if 4–6 MW of PV generated energy is introduced in the feeder. PV DG can build the Load carrying capacity, which is the measure of burden on an energy system that can deal with, while fulfilling certain unwavering quality criteria, of existing systems. To fulfil the expanded need while fulfilling a similar dependability criterion, utilities need to enhance their energy generation limit.

PV modules integration can likewise force a few negative effects on control systems, particularly if their energy capacity generation level is high. These effects are subject to the location and the size of the PV arrays used [7]. As indicated by the IEEE standard 929–2000, PV modules are arranged dependent on the evaluations into three particular classes: (1) Small systems appraised at 10 kW or less, (2) intermediate of the frameworks appraised between 10 kW and 500 kW, and (3) large frameworks appraised over 500 kW. The initial two classes are typically introduced at the distribution level, rather than the last classification which is normally introduced at the transmission levels. In the case of this paper, the capacity of the Solar PV system is of 47 kW on which the system performance is analyzed.

### A. Effects of input parameters on SPV output

PV modules' yield cannot be predicted and is exceptionally reliant on natural environment conditions. For example, temperature and Solar Irradiation levels as delineated in Figures 3a and 3b, individually. Halfway shadowing because of passing mists, temperature, and Solar Irradiation arbitrarily varies which are dependent on the whole factors that will influence PV module assembly, bringing about fast variations in its output yield.

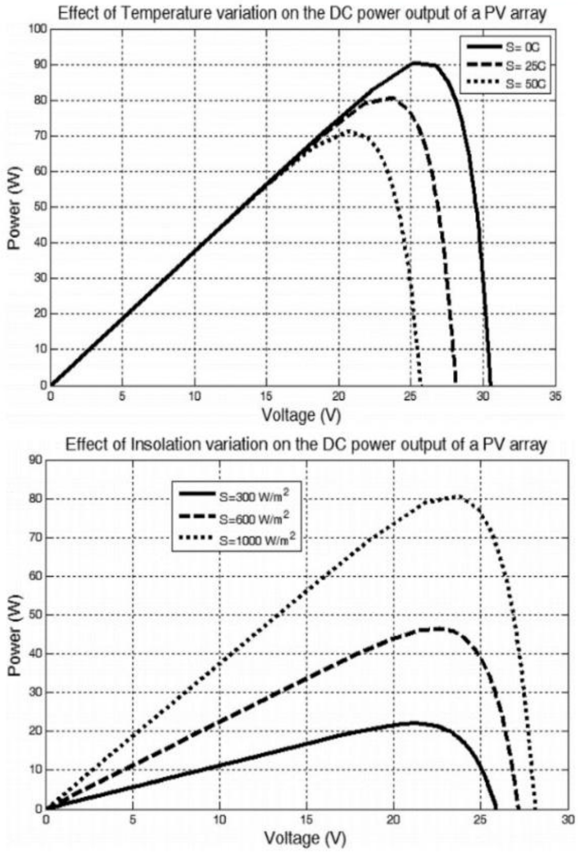


**Fig. 3a. Effect of module temperature**
**Fig. 3b.** Effect **of Solar irradiation**

In a practical study of 47 kW solar PV systems on a distribution feeder line, the energy output was taken. Real power fluctuations result in enormous frequency changes in the electrical distribution system, whereas reactive power variations result in voltage fluctuations [8].

### B. Increased ancillary services requirements

Since the integrated grid goes about as a energy buffer to make up for any power variances and firm up the yield intensity of PV sources, in this way, energy producing stations' yields should be balanced much of the time to adapt to the PV control vacillations.

Retrieval Number: E5751018520/2020©BEIESP
DOI:10.35940/ijrte.E5751.018520



Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

For instance, if a cloud blanked out a PV framework providing 1 MW of power in 10 s, at that point the electric matrix ought to have the option to infuse additional power at a pace of 1 MW/10 s or else voltage and recurrence unsettling influences will happen in the power framework. Thus, utilities need to join quick energy generation to make up for these power losses from PV modules before voltage and frequency varieties surpass the defined range of permeability [9].

## IV. GRID – INTEGRATED ENERGY SYSTEM STABILITY ISSUES

As described before, PV clusters' yield is flighty and is profoundly reliant on natural conditions. This enormously impacts the power system framework activity as they can't give a dispatchable stockpile that is flexible to the fluctuating interest, and along these lines the power generating framework needs to manage enormous request of generation as well as distribution. PV modules don't have any rotating masses; subsequently, their dynamic conduct is totally constrained by the attributes of the interfacing inverter. This paper demonstrated that PV modules may have advantageous or negative effects on the power generating system security relying upon their areas of incorporation, etc. As the incorporation level of PV increases, progressively regular generators are being supplanted by PV modules [10]. Therefore, the fluctuation in the grid framework diminishes.

## V. POWER QUALITY PROBLEMS

At coupled AC topologies the AC system of the power grid is legitimately associated with the power system by a transformer and an AC-DC converter is utilized for the dc organize. On the other hand, decoupled AC system designs are created by an AC-DC and DC-AC platform; which implies there is no immediate association between the power generator and the AC grid integrated system [11]. The most significant setups distinguished for topologies of Power quality issues are one of the significant effects of high PV usage on distribution systems; power control inverters used to interface PV clusters to control lattices that deliver harmonics; in this way, they may expand the overall total harmonic distortion (THD) of both voltage and currents.

Another power quality problem is the inter-harmonics that keep appearing at less harmonic limits (below the thirteenth harmonic). These inter-harmonic values may come in contact with loads near the area of the inverter being used by the system [12]. Indeed, even harmonics can likewise add on to the undesirable negative grouping flows influencing three phased loads [13]. DC infusions also may gather and course through distribution end transformer, prompting a potential harm. IEEE Std. 1547 confines DC infusion from a PV module framework to 0.5%.

## VI. EXPANSIVE REACTIVE POWER NECESSITIES

PV inverters typically work at unit power factor for 2 reasons. The primary explanation is that present standard - (IEEE 929-2000) does not permit PV inverters to work in the voltage regulating mode. The subsequent explanation is that proprietors of small PV module assembly, the main income for their kilowatt-hour yield is only incentivized, and not for their kilovolt-ampere hour generation [14]. Consequently, they operate their inverters at unit power control factor to augment the dynamic power produced and appropriately. Be that as it may, responsive power prerequisites are as yet the equivalent and must be provided totally by the utility [15]. A high pace of reactive power supply isn't favored by the utilities in light of the fact that for this situation distribution transformers will work at exceptionally low power factor (at times it can arrive at a value of 0.6). Transformer’s proficiency diminishes as their power factor diminishes, accordingly, the general misfortunes in distribution transformers will build lessening the general Solar PV Module framework’s effectiveness [16].

## VII. PERFORMANCE INVESTIGATION OF THE SYSTEM

### A) System Description

The proposed system is a Sub Feeder named Deetyakhedi feeder in Jhalawar district, Rajasthan. Power to be received at the load by Solar Panel is the multiplier of the load required and the potential of the LT side. The total solar power radiation per day is calculated by the average window period of the solar insolation. Voltage regulation is calculated and the Energy balance equation is verified in the ETAP Software for the optimization of the System Performance Analysis.

Then, the units of power are calculated by the generation of the energy by the Solar PV panels of the 47 kW capacity and henceforth the system installation and tariff per year are calculated thereby helping in deciding the Payback and designing the Optimum system for the improved voltage profile at an optimum cost.

### B) Design Parameters:

The Figure 4 depicts the ETAP model of the feeder under analysis, in which the Solar DG is placed on T6 bus where the Solar DG is integrated for the Voltage regulation improvement and reduction in the system losses.

Optimal Position for the setting up of Solar Plant is at 415V side on T6 bus with a size of 47 kW. With the integration of DG at bus T6, the Voltage Regulation improves from 11% to 8.0%. The line losses at bus T6 are reduced to 5.90 kW in place of 11.31 kW after the incorporation of DG i.e. a saving of 47.81% in the line losses.

Load Flow Analysis yielded a resultant system loss of 143.21 kW which was less than the value of the Load Flow Analysis of the system with 151.74 kW system losses. Henceforth, the overall system losses are reduced by 5.62% after incorporation of Solar Distributed Generator.

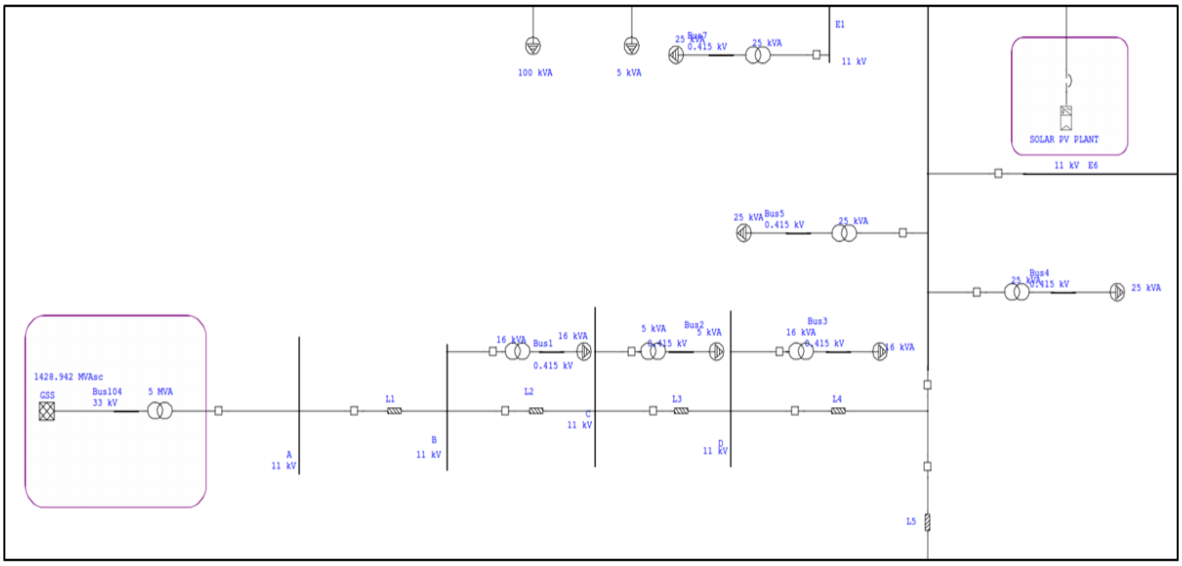


**Fig 4: ETAP model of feeder under analysis**

## VIII. ETAP SIMULATION RESULTS

Performance Analysis of the system is done on 2 cases i.e. when either the Grid feeder get disconnected and when one of the Load feeder gets disconnected; various impacts are observed in terms of Bus Voltages, Real Power Loading of the Bus and Bus Reactive Power Loading, thereby proving the system to be stable in the various testing states.

### Case 1: When Grid is disconnected

In the subsequent figures, performance analysis of the system under Grid failure condition is elaborated with the help of the Bus Real Power loading, Reactive-power loading of bus and the Nominal voltage regulation of the system at 60%, 80% and 100% loading.

**a) For 60% loading:**

From Figure 5 it can be depicted that the total load of 48kW is being shared by Solar PV and Grid till 0.3 seconds. At 0.3 second the Grid fails due to fault and it is observed that 41kW load at Bus 6 is now being fed by the Solar PV. The system becomes stable in 0.02 seconds.

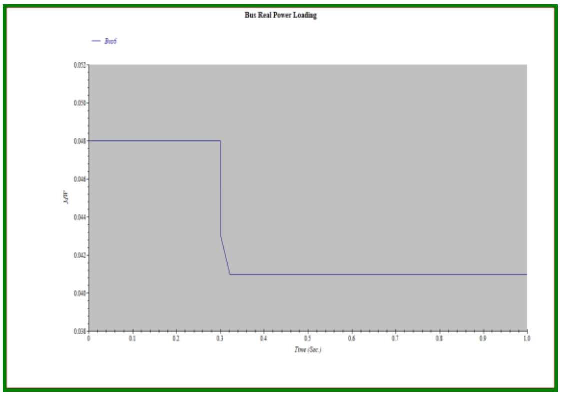


**Figure 5: Bus Real Power Loading**

The voltage-support requirements are a function of the locations and magnitudes of generator outputs and customer loads along with the configuration of the DG transmission system. Henceforth, Figure 6 depicts that when the Grid feeder fails, Bus Reactive Power falls from 29 kVAr to 25 kVAr and system becomes stable in 0.02 seconds.

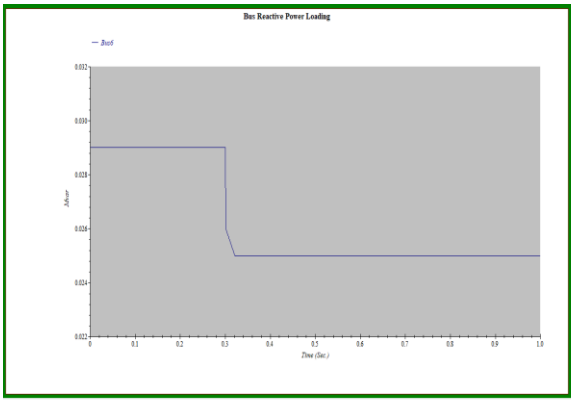


**Figure 6: Bus Reactive Power Loading**

Figure 7 depicts that at the time of Grid failure, Nominal load of the load feeder fails and only the essential load (load similar to the solar DG) of the T6 bus is fed by the DG. Its voltage regulation varies from 96.5% of nominal bus voltage to 88% of nominal bus voltage.

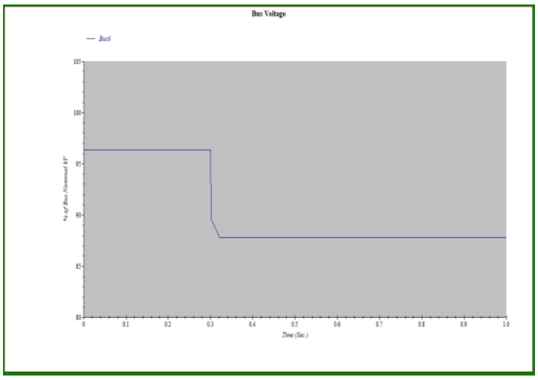


**Figure 7: Nominal Bus voltage for Case 1(At 60% loading)**

**b) For 80% loading**

From Figure 8, it can be depicted that the total load of 65kW is being shared by Solar PV and Grid till 0.3 seconds. At 0.3 second the Grid fails due to fault and it is observed that 41 kW load at Bus 6 is now being fed by the Solar PV. The system becomes stable in 0.02 seconds.

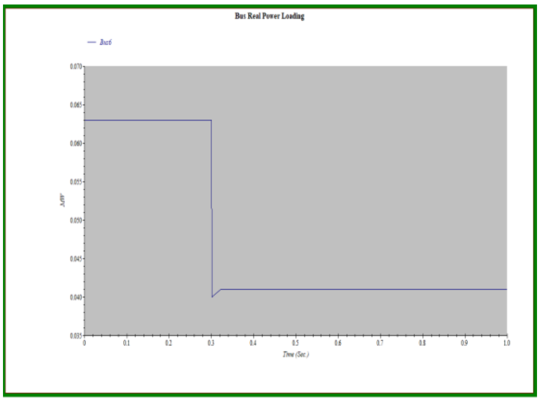

**Figure 8: Bus Real Power Loading**

Figure 9 depicts that when the Grid feeder fails, the critical clearing time of a system is 0.02 seconds, i.e. system regain its operating position in 0.02 seconds and the Bus Reactive Power falls from 39 kVAr to 24 kVAr.

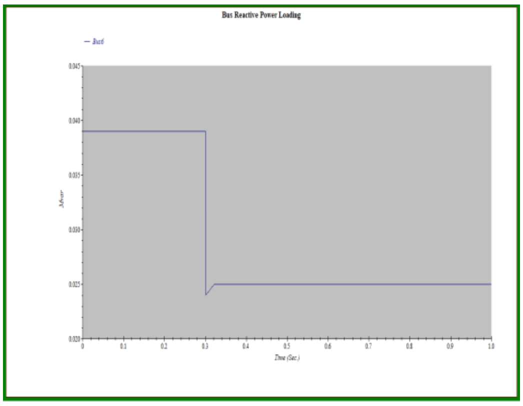

**Figure 9: Bus Reactive Power Loading**

Figure 10 depicts that at the time of Grid failure, Nominal load of the load feeder fails and only the essential load (load similar to the solar DG) of the T6 bus is fed by the DG. Once the grid failure occurs then the system takes 0.02 seconds to become stable. Its voltage regulation decreases from 95.9% of nominal bus voltage to 78% of nominal bus voltage.

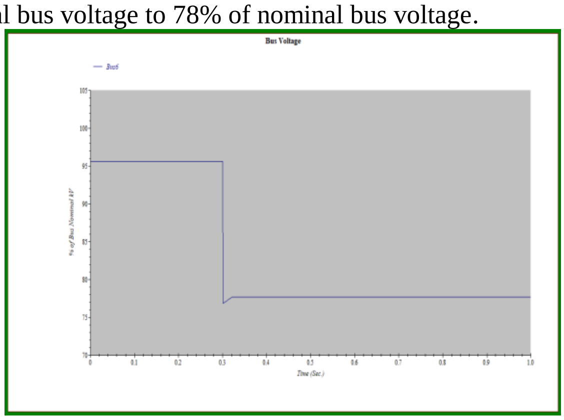

**Figure 10: Nominal Bus voltage for Case 1(At 80% loading)**

**c) For 100% loading**

From Figure 11 it can be noted that the total load of 79kW is being shared by Solar PV and Grid till 0.3 seconds. At 0.3 second the Grid fails due to fault and it is observed that 48 kW load at Bus 6 is now being fed by the Solar PV. The system becomes stable in 0.02 seconds.

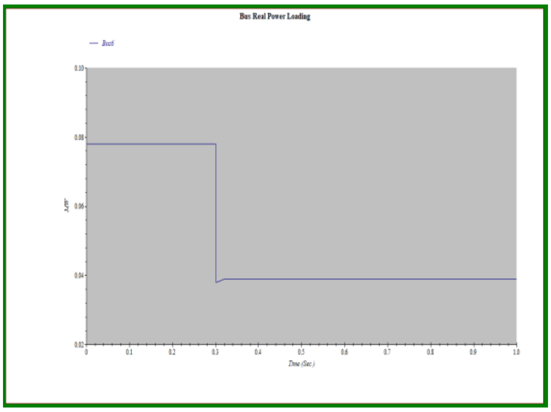

**Figure 11: Bus Real Power Loading**

Figure 12 depicts that when the Grid feeder fails, the critical clearing time of a system is 0.02 seconds, i.e. systems regain its operating position in 0.02 seconds after load failure and the Bus Reactive Power falls from 48 kVAr to 24 kVAr and system becomes stable again.

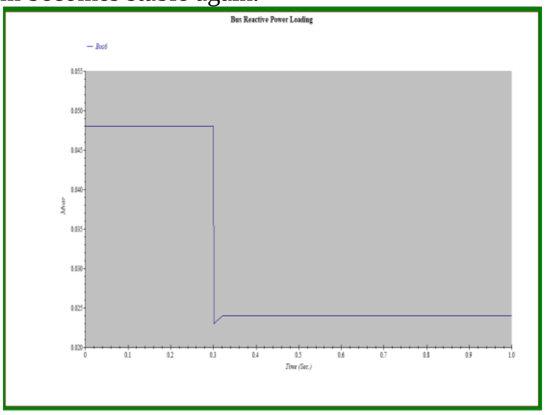

**Figure 12: Bus Reactive Power Loading**

Figure 13 depicts that at the time of Grid failure, Nominal load of the load feeder fails and only the essential load (load similar to the solar DG) of the T6 bus is fed by the DG. Once the grid failure occurs then the system takes 0.02 seconds to become stable its voltage regulation varies from 95% of nominal bus voltage to 69% of nominal bus voltage.

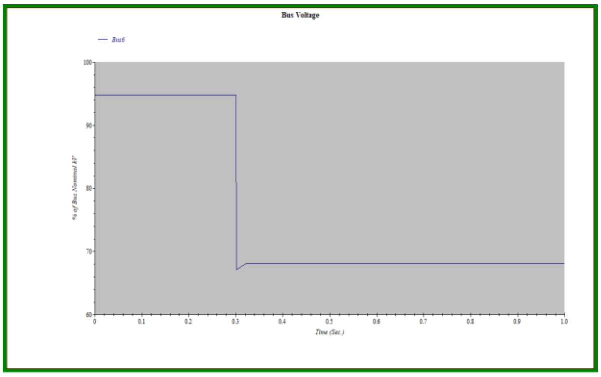


**Figure 13: Nominal Bus voltage for Case 1(At 100% loading)**

**Case 2: When one sub feeder at Load side is disconnected**

The load feeder at bus 6 has two sub feeders and in this case 2, it is assumed that fault occurs at one sub feeder at 0.3 second. From Figure 14 it can be depicted that at 0.3 seconds, one of the two load feeder fails due to fault. Critical clearing time is very less and rapidly the Real bus power loading falls from 78 kW to 40 kW, thereby stabilizing the system rapidly.

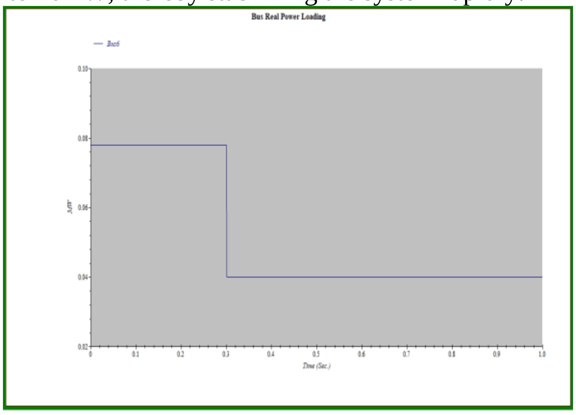


**Figure 14: Bus Real Power Loading**

Figure 15 elaborates that when one of the load sub feeder fails, the critical clearing time of a system is instantaneous, the Bus Reactive Power falls from 48 kVAr to 25 kVAr and system becomes stable

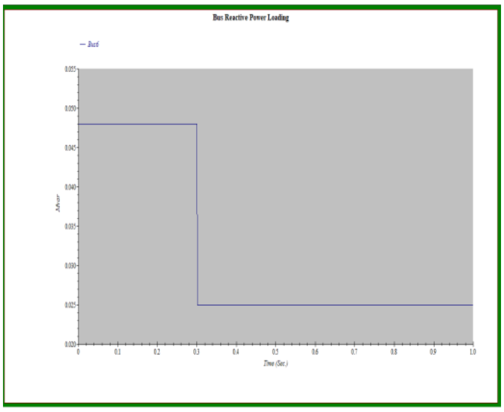


**Figure 15: Bus Reactive Power Loading**

Figure 16 depicts that the critical clearing time of a system is very less and almost instantly the voltage profile of the other sub feeder is increased from 94.8% of nominal bus voltage to 96.8% of nominal bus voltage, indicating that the voltage regulation is improved.

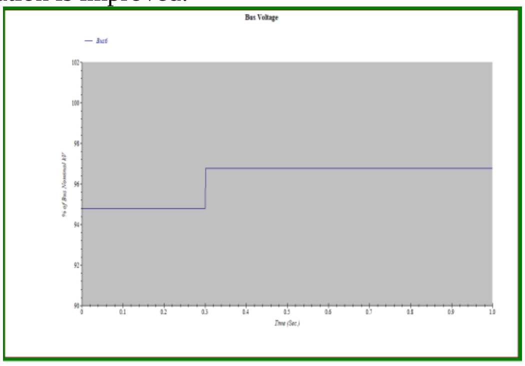


**Figure 16: Nominal Bus voltage for Case 2**

## IX. RESULTS

**Table 1 – Grid failure case**

| | **Loading factors** | **Bus Real Power Loading** | **Critical clearing time of the system** | **Bus Reactive Power Loading** | **Critical clearing time of the system** | **Nominal Bus voltage** | **Critical clearing time of the system** |
|---|---|---|---|---|---|---|---|
| **When Grid is disconnected** | **At 60%** | Before Grid failure – 48 kW After failure - 41 kW is fed by Solar PV | 0.02 Sec | Falls from 29 kVAr to 25 kVAr | 0.02 Sec | Voltage regulation varies from 96.5% of nominal bus voltage to 88% of nominal bus voltage | 0.02 Sec |

Retrieval Number: E5751018520/2020©BEIESP
DOI:10.35940/ijrte.E5751.018520



Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **At 80%** | Before Grid failure – 65 kW After failure - 41 kW is fed by Solar PV | 0.02 Sec | Bus Reactive Power falls from 39 kVAr to 24 kVAr | 0.02 Sec | Voltage regulation decreases from 95.9% of nominal bus voltage to 78% of nominal bus voltage | 0.02 Sec |
| | **At 100%** | Before Grid failure – 79 kW After failure - 41 kW is fed by Solar PV | 0.02 Sec | Bus Reactive Power falls from 48 kVAr to 24 kVAr | 0.02 Sec | Voltage regulation varies from 95% of nominal bus voltage to 69% of nominal bus voltage | 0.02 Sec |

**Table 2 – Feeder disconnection case**

| | **Bus Real Power Loading** | **Critical clearing time of the system** | **Bus Reactive Power Loading** | **Critical clearing time of the system** | **Nominal Bus voltage** | **Critical clearing time of the system** |
|---|---|---|---|---|---|---|
| **When one sub feeder at Load side is disconnected** | Real bus power loading falls from 78 kW to 40 kW | Instantaneous | Bus Reactive Power falls from 48 kVAr to 25 kVAr | Instantaneous | Voltage profile of the other sub feeder is increased from 94.8% of nominal bus voltage to 96.8% of nominal bus voltage | Instantaneous |

The system under consideration is the Deetyakhedi feeder, Jhalawar District in Rajasthan. It has generated various conditions of the Active, Reactive and Nominal Bus Voltages at various loading factors indicating how system responds when either the Grid fails or when one of the Sub-feeder gets disconnected. The system regains its stability after some fractions of seconds. Both of these cases are illustrated in Table 1 and Table 2.

## X. CONCLUSION

PV Solar integration in any system is relied upon to be one of the most developing sources of power in the following decades. In any case, they immensely affect the electrical power systems. Be that as it may, geographical constraints and the required increment in frequency regulation mandates, prove to be the typical bottlenecks against the appropriate integration of PV power in the electrical system network.

It isn't exaggeratory to state that electrical energy networks under the flow conditions are prepared to suit the foreseen increment in PV integration in the system. This research paper is unmistakably showing methods to address the effects and consequently, passable allowance of the PV incorporation for the electricity generation for the future.

*Retrieval Number: E5751018520/2020©BEIESP*
*DOI:10.35940/ijrte.E5751.018520*



*Published By:*
*Blue Eyes Intelligence Engineering*
*& Sciences Publication*

## REFERENCES


1. RRobert Passey, Ted Spooner, Iain MacGill, Muriel Watt, Katerina Syngellakis "The potential impacts of grid-connected distributed generation and how to address them: A review of technical and non-technical factors"; *Energy Policy* 39 (2016) 6280–6290.
2. H. R. Enslin, "Network impacts of high penetration of photovoltaic solar power systems," in 2010 *IEEE Power and Energy Society General Meeting* (2015), pp. 1–5.
3. KKanase Patil AB, Saini RP, Sharma MP, "Integrated renewable energy systemsfor off grid rural electrification of remote area", *Renewable Energy* 2017;5:1342–9.
4. N.K. Roy , H.R. Pota , M.A. Mahmud, M.J. Hossain; "Key factors affecting voltage oscillations of distribution networks with distributed generation and induction motor loads; *Electrical Power and Energy Systems* 53 (2013) 515–528; SciVerse ScienceDirect.
5. Hossam A. Gabbar , Abdelazeem A. Abdelsalam; "Microgrid energy management in grid-connected and islanding modes based on SVC; *Energy Conversion and Management*, 86 (2014) 964–972; ScienceDirect.
6. Schainker RB. Executive "Overview: energy storage options for a sustainable energy future", Proceedings of the *Power Engineering Society general meeting*, Vol. 2: 2014. p. 2309–14.
7. Chauhan A, Saini RP. "Statistical analysis of wind speed data using Weibull distribution parameters", Proceedings of the *1st International Conferenceon Non Conventional Energy* (ICONCE), vol. 1: 2014. p. 160–3.
8. N.K. Roy, H.R. Pota , M.J. Hossain; "Reactive power management of distribution networks with wind generation for improving voltage stability; *Renewable Energy*, 58 (2013) 85-94; SciVerse ScienceDirect.
9. Rene Prenc , Davor Škrlec , Vitomir Komen; "Distributed generation allocation based on average daily load and power production curves; *Electrical Power and Energy Systems* 53 (2013) 612–622; ScienceDirect
10. S.P. Chowdhurya, S. Chowdhurya, P.A. Crossley; "Islanding protection of active distribution networks with renewable distributed generators: A comprehensive survey; *Electric Power Systems Research* 79 (2009) 984–992; ScienceDirect
11. Anastasia S. Safigianni, George N. Koutroumpezis, Vassilis C. Poulios; "Mixed distributed generation technologies in a medium voltage network; *Electric Power Systems Research* 96 (2013) 75– 80; SciVerse ScienceDirect
12. Mohammad S. Widyan , Rolf E. Hanitsch; "Operating point stability analysis of SMIB power system equipped with high PV penetration; *Electrical Power and Energy Systems* 55 (2014) 522–530; ScienceDirect
13. Srinivasa Rao Potnuru, Dinesh Pattabiraman , Saravana Ilango Ganesan, Nagamani Chilakapati ; "Positioning of PV panels for reduction in line losses and mismatch losses in PV array; *Renewable Energy* 78 (2015) 264-275; ScienceDirect
14. Rakibuzzaman Shah , N.Mithulananthan , R.C.Bansal V.K.Ramachandaramurthy; "A review of key power system stability challenges for large-scale PV integration; *Renewable and Sustainable Energy Reviews*, 41 (2015)1423 –1436.
15. Mohammad Mahdi Rezaei , Jafar Soltani; "A robust control strategy for a grid-connected multi-bus microgrid under unbalanced load conditions; *Electrical Power and Energy Systems* 71 (2015) 68–76; ScienceDirect
16. Robert Passey, Ted Spooner, Iain MacGill, Muriel Watt, Katerina Syngellakis; "The potential impacts of grid-connected distributed generation and how to address them: A review of technical and non-technical factors; *Energy Policy* 39 (2011) 6280–6290; ScienceDirect


## AUTHORS PROFILE

**Arpita De** She is currently pursuing her PhD in Renewable Energy from MANIT, Bhopal. She holds a Master's Degree - M.Tech in Energy Systems Engineering and a Professional MBA degree in Power Management from University of Petroleum & Energy Studies, Dehradun. She has done her Bachelor of Engineering (Hons.) in Electronics and Communication from Rajiv Gandhi Technical University. She also has a certification in Advanced Certificate in Power Distribution Management from Indira Gandhi National Open University and International General Certificate in Occupational Health and Safety from NEBOSH.