# Impact of Photovoltaic Power Plant on the Transient Stability Compared With Synchronous Generator

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**Abstract:** In the recent years the power system is changing and distributed generation (DG) units are used in power systems at the distribution level regularly. The power demand is increasing and it can be fulfilled by use of renewable energy sources like solar energy. This paper discusses the using of Photovoltaic power plant as a DG in distrusted network and its effect on transient stability. In order to scrutinizing the effect of PV system as a DG in redial distribution system, 3 IEEE standard test systems are simulated with Dig SILENT software. In all 3 networks a short circuit fault is taken and the effect of that is analyzed in 2 modes; first with synchronous generators (SG) and second with Photovoltaic (PV) power plant and the results are compared. Comparing the results shows that in all 3 networks PV power plant work could save the stability in active power and voltage without using any extra devices.
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## 1. Introduction

The traditional way in electric power generation is centralized power plants and a broad distribution network. However, the power system is changing and distributed generation (DG) units are used in power systems at the distribution level.

DG has different types depending on the type of energy sources, such as renewable and non-renewable energy sources. In recent years, it can be witnessed a rapid development of renewable energy, e.g. wind power, photovoltaic (PV), etc. throughout the world. The main motivations behind this fast-growing development are the rising environmental concerns, i.e. greenhouse gas emission, and carbon footprint reduction, and the increase in the fuel cost used for the electricity production.[1].

Accelerated tendency to industrialization and raised interest in environmental issues recently led us to explore the use of renewable sources such as solar energy. Photovoltaic (PV) power plants are increased as a renewable source due to its advantages. Compared to other electricity generating technologies, however, PVs are still more expensive; improvements in technology will hopefully bring this cost [2].

In a traditional power system, synchronous generators (SG) have the most important task in the secure operation and the stability of power system. During a disturbance, the speed governor and AVR/exciter regulate the frequency (active power) and terminal voltage (reactive power) of the SG respectively back to steady state operating point. The stability of the SG and the power network is therefore maintained. However the controllability of the SG controllers is restricted by the operating limits of the SG [3].

Several high level studies analyzed the impacts of DG on the power system design and operation [4], [5]. However, only recently also transient phenomena are being studied in detail [6], [7]. One interesting phenomena is transient stability. In [8] impact of fixed and variable speed wind generators on the transient stability of a power system network are studied.

In This paper investigates transient stability of a power system, in which the SGs are replaced by PV power plant with the same generation capacity. In both cases, with SG and PV, speed governor and AVR/exciter regulate the frequency (active power) and terminal voltage are not used and being stable or not is just based on characteristics of the power plant. 3 IEEE standard test system with 12 bus, 33 bus and 69 bus are used in this study. Networks are simulated by DIgSILENT Ver. 14.

This paper is organized as follow. Section II describes the simulated test systems and the amount of DG in each network. Section III presents the results of taking a short circuit fault in each test system in modes; with SG and PV power plant. Output Active power and voltage of DG are shown before fault, during the fault and after clearing the fault. The conclusion of the paper is presented in section IV.

## I. Simulated test systems

The test systems and characteristics of synchronous generator and PV would be different in each case and are depend on the network. PV just products active power but synchronous generator power factor is 0.8.

### *A. 12 Bus Radial Test System*

This system is introduced in [9]. In this network power plant could generate 235.6 kW and is located in bus number 9. The conditions are same for synchronous generator and PV power plant.

### *B. 33 Bus Radial Test System*

The network is introduced in [10]. In this case the best place for installing the DG is bus number 6 with an amount of 2400 kW.[10]

### *C. 69 Bus Radial Test System*

In 69 bus radial distributed system the active generated power via Dg is 1883.8 kW. The DG is located in bus number 61. All characteristics of this network are introduced in [11].

## II. Simulated results

### *A. 12 Bus Radial Test System*

Network is simulated in DIgSILENT software. The short circuit fault is started 0.5 sec after starting the simulation and it is occurs on line number 7. It would be finished after 0.3 sec.

At first synchronous generator is used as a DG source. The effect of fault on active power and voltage are shown in pictures bellow.

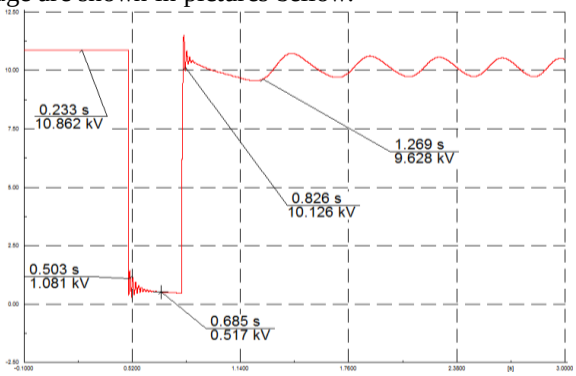


***Figure 1.*** Voltage stability in 12 bus system with SG

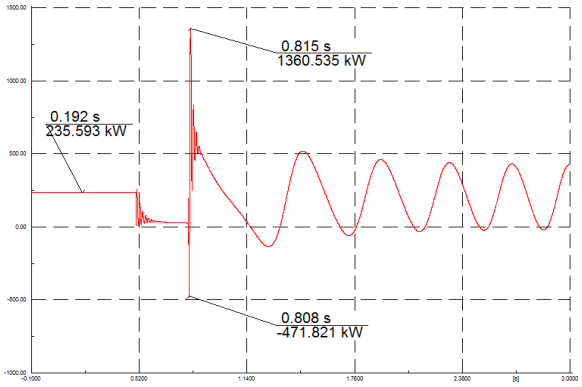


***Figure 2.*** Active power stability in 12 bus system with SG

Active power and voltage are not stable in this case.

In next step, synchronous generator would be replacing with PV power plant. The fault conditions are the same as pervious. The effect of fault on power plant is like Fig below.

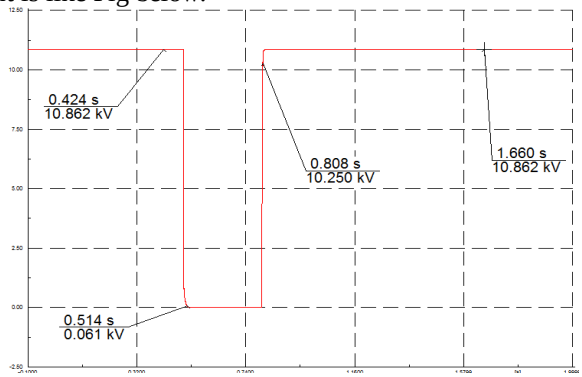


***Figure 3.*** Voltage stability in 12 bus system with PV

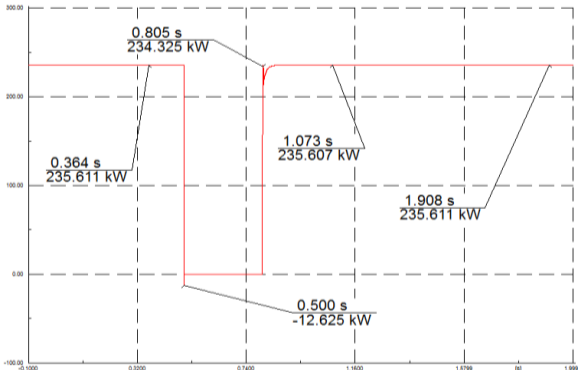


***Figure 4.*** Active power stability in 12 bus system with PV

As shown in above Fig. power and voltage are stable when PV is used as a DG source.

### *B. 33 Bus Radial Test System*

The short circuit fault place is on line number 3. Fault is started 0.5 sec after starting the simulation and it would be finished after 0.4 sec.

Firstly, DG is a synchronous generator that is located on bus number 6. The effect of fault on active power and voltage are shown in pictures bellow.

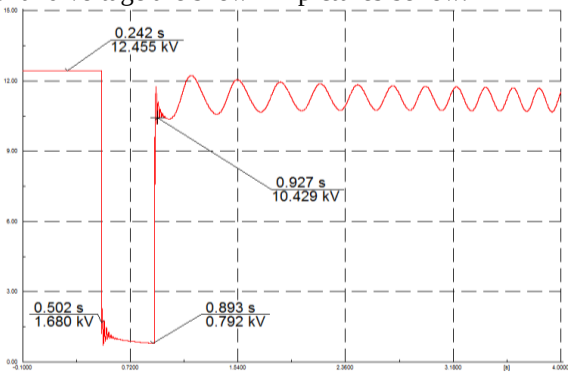


***Figure 5.*** Voltage stability in 12 bus system with SG

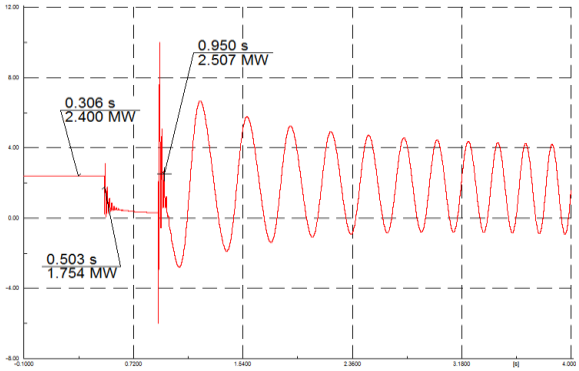


***Figure 6.*** Active power stability in 12 bus system with SG

Like pervious network, in this network power and voltage are not stable after fault.

Pictures below show the results for the same network but with PV power plant instead of synchronous generator.

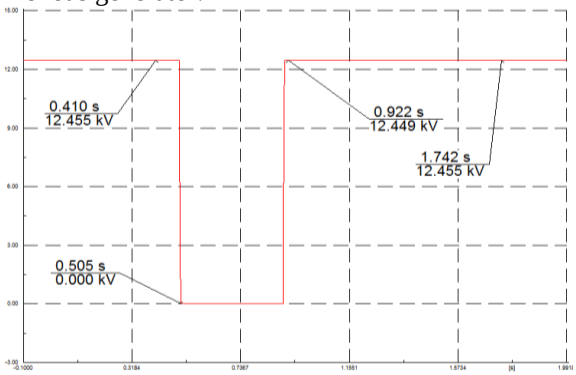


***Figure 7.*** Voltage stability in 12 bus system with PV

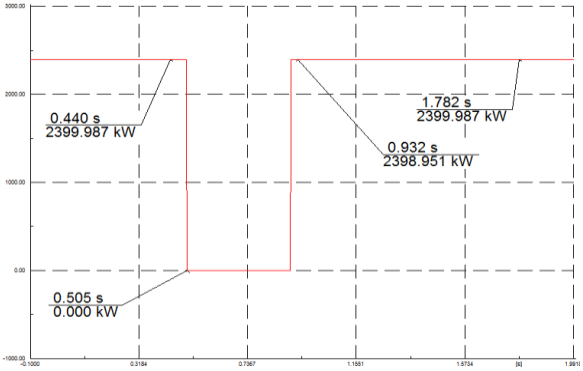


***Figure 8.*** Active power stability in 12 bus system with PV

In this case, both voltage and active power are stable because of using PV as a DG power source.

### *C. 69 Bus Radial Test System*

Like others, this network is simulated in DIgSILENT software too. The short circuit fault is started 0.5 sec after starting the simulation and it is occurs on line number 59. It would be finished after 0.4 sec.

In first mode, synchronous generator is used as a DG source. The effect of fault on active power and voltage are shown in pictures bellow.

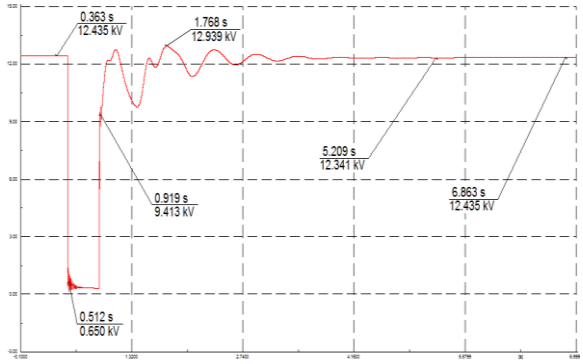


***Figure 9.*** Voltage stability in 12 bus system with SG

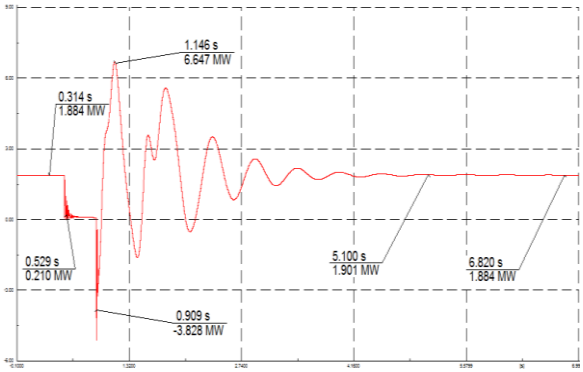

***Figure 10.*** Active power stability in 12 bus system with SG

The diagrams show that in 69 bus radial test system, after a longer period of time, the system could be stable as it was before.

In second mode, PV generator is used as a DG source. The effect of fault on active power and voltage are shown in pictures bellow.

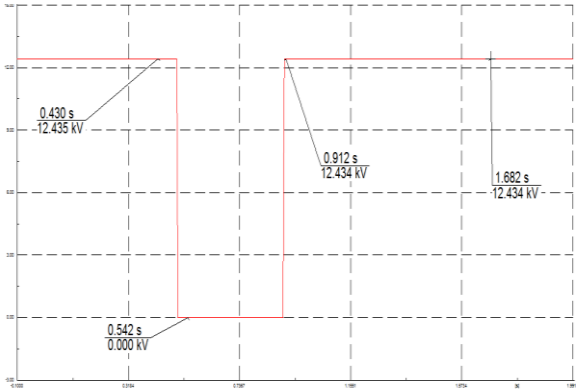


***Figure 11.*** Voltage stability in 12 bus system with PV

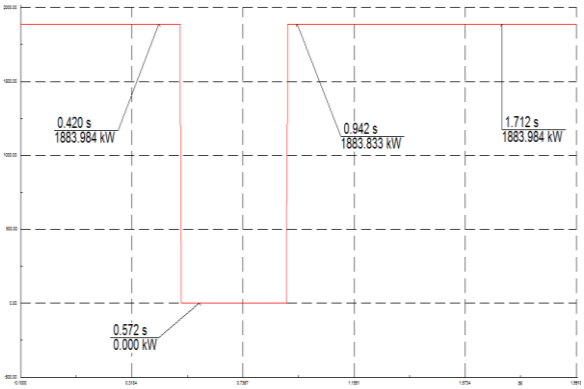


***Figure 12.*** Active power stability in 12 bus system with PV

Like two pervious test system, in 69 bus radial distribution system, the network with PV get stable in a short time after clearing the fault.

## III. CONCLUSION

Transient stability in 3 IEEE standard test system is compared between to case in each network. In first case DG is a SG and in second case DG is PV power plant. Fault conditions are same in both cases. According to results that are shown in pictures 1 to 12, in the case that PV is used as a DG, active power and voltage have same condition before and after fault. It means power and voltage are stable in this case and PV leads to a stable condition. On the other hand, in case that SG is used as a DG, in the same condition with PV case, active power and voltage are not stable after accruing the short circuit fault. In one word, using PV cause transient stability in distributions network because unlike the SG it does not have moving parts.

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