Brief Summary of System Stability in Large Scale PV Generation

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The limitations of reserves and environmental concerns associated with the fossil-fuels have intimidated the development of new power plants that deploy the renewable energy as a source of producing electricity. The global PV market has experienced significant progress in the recent years, with 50 % growth in the year 2016 alone. The worldwide cumulative PV installed capacity is estimated to be more than 300 GW.

Increasing penetration of wind and solar energy in the electric energy generation mix are raising concerns among electric system operators because of the variability and uncertainty associated with the power sources. High penetrations of renewable generation might result in a need for more flexible generators, with fast ramping capabilities.

Basic of Solar Cell

A single layer solar cell can be modeled as Figure 1

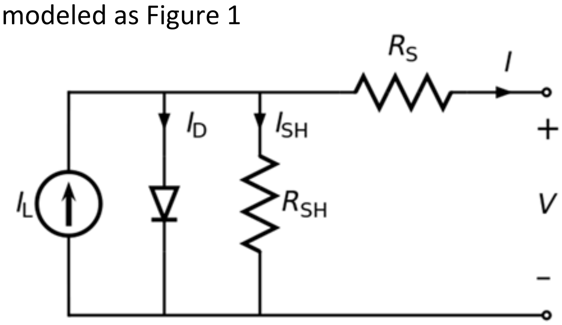

Figure 1

Where IL is photogenerated current

The photogenerated current is varying by solar irradiation. Solar irradiance is changing during the day as well as changing by season and weather. Figure 2 shows the solar irradiation during a day.

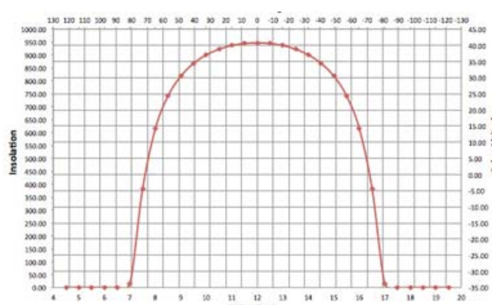

Figure 2

IV curve determines any operating point of a PV cell. IV curve is showing maximum short circuit Current I_{SC} and Open Voltage V_{OC} for particular solar irradiation. To enhance the PV cell’s life, the PV modules have to operate in MPP (Maximum Power Point) or close to it. Figure 3 shows the concept.

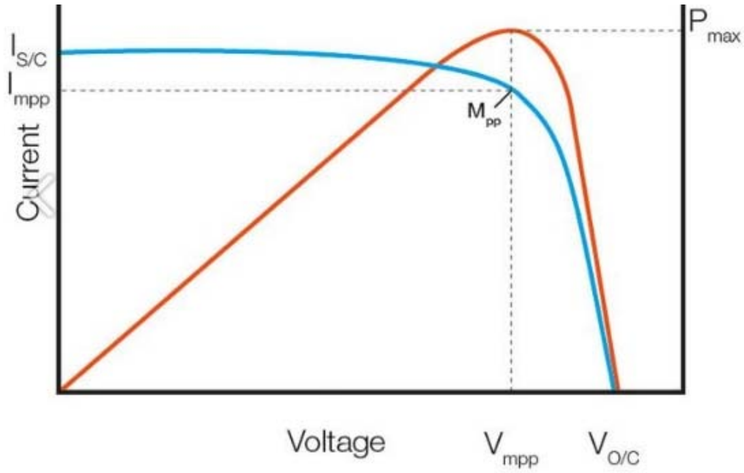

Figure 3

Power Stability

PV's MPP is changing with photogenerated current, MPP is dependent on to solar irradiation which is almost out of control. Such source looks unreliable as it is not responding to load demand. Combining the PV system with a storage system can address this problem. Figure 4 is an example of PV System with battery storage

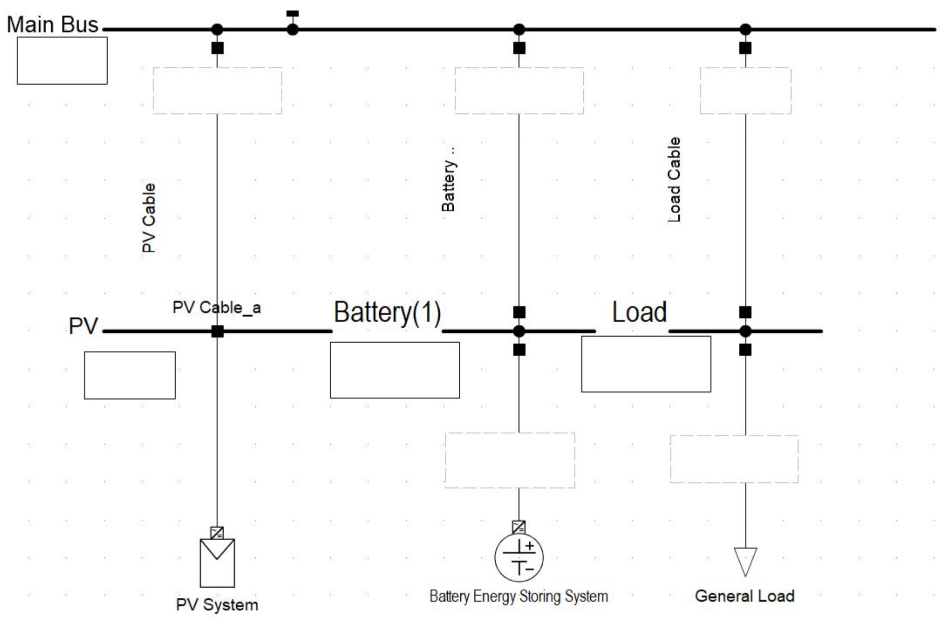

Figure 4

In this example PV is generating fix power of 2 MW, the load demand is changing from 2.6 MW to 3 MW and then drop to 1.7 MW. As mentioned PV generation is almost not controllable. The battery storage in this example cover the load fluctuation as shown in Figure 5.

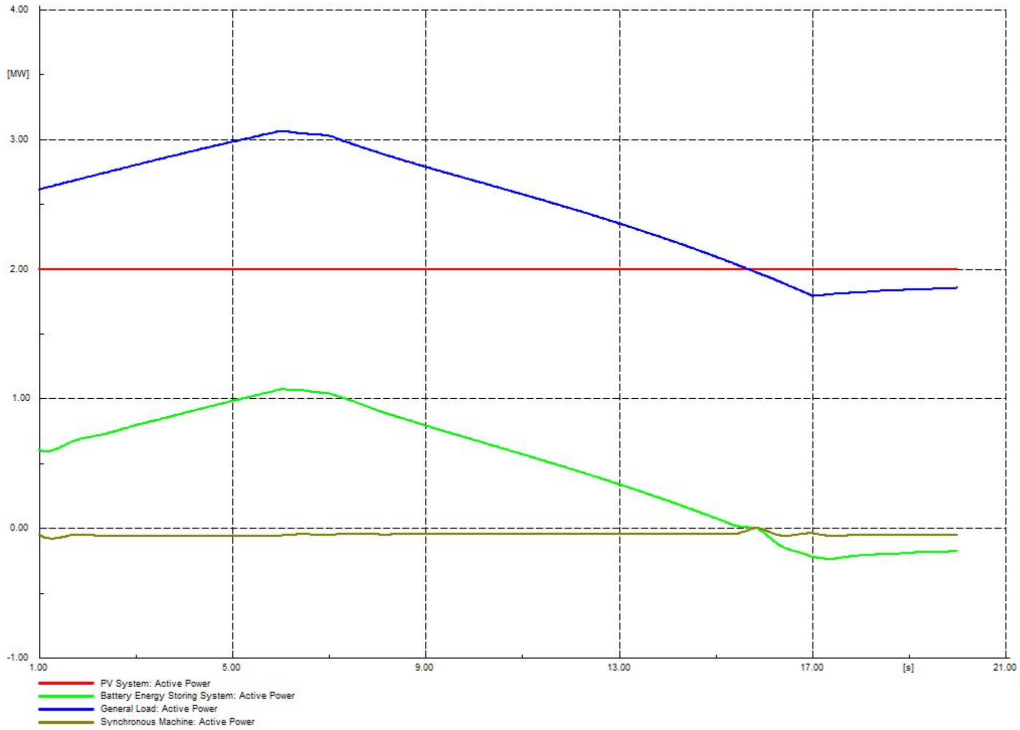

Figure 5

Batteries are charging when the PV generation is lower than load demand. Proper Sizing of battery storage, inverter and charger with regards PV generation models and Load profile need to be considered for network stability.

Stability During Fault

Up to recently, the grid was exclusively built with rotating machines that have quite a different behaviour under fault than inverter-based sources. The other problem with PV system is available short circuit current, both Storage and PV have high impedances, so they are not a good source of short circuit current. With current protection systems, It makes the fault detection difficult if it is not impossible. Having a source of current during the fault can address this issue, A synchronous condenser which is operated in a borderline condition between a motor and a generator with no mechanical load can be a good source of MVAR during short-circuit and reactive load adjustment.

Semiconductor devices are very sensitive to overcurrent but fortunately, they can be turned off very quickly to re-route excess current before the junction temperature becomes critical. Usually, inverters are turning off if their terminal voltage drops to under 50 ~ 70 % of nominal voltage. During short circuit inverters close to fault experience the under-voltage condition and turn off due to under voltage. For recovery need the voltage at inverters terminal recover. Figure 6 shows the concept

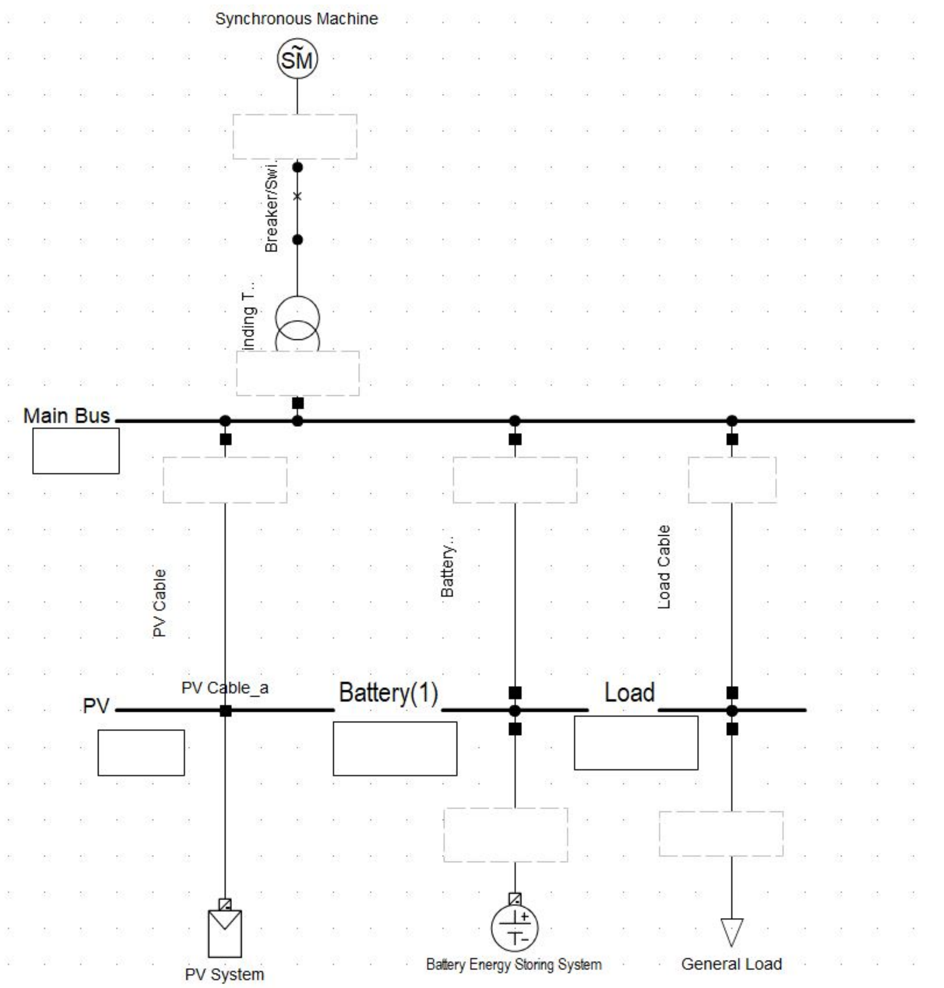

Figure 6

A synchronous machine on PV bus help this voltage recovery. After fault clearing, synchronous machine keep voltage high enough for the Inverters to startup. Fault clearance time is playing a great role in the possibility of recovery. As we see in Figure 7 after fault clearing (200 msec) synchronous machine keep the voltage high enough for the Inverters startup and system recover from this fault.

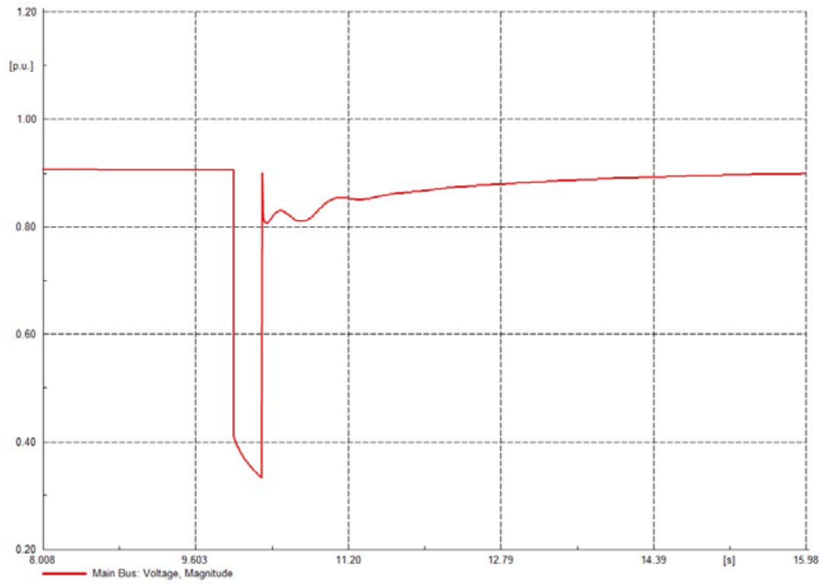

Figure 7

Figure 8 shows the same system with fault clearance time of 600 msec. System total collapse is what expected in this circumstances.

Figure 8

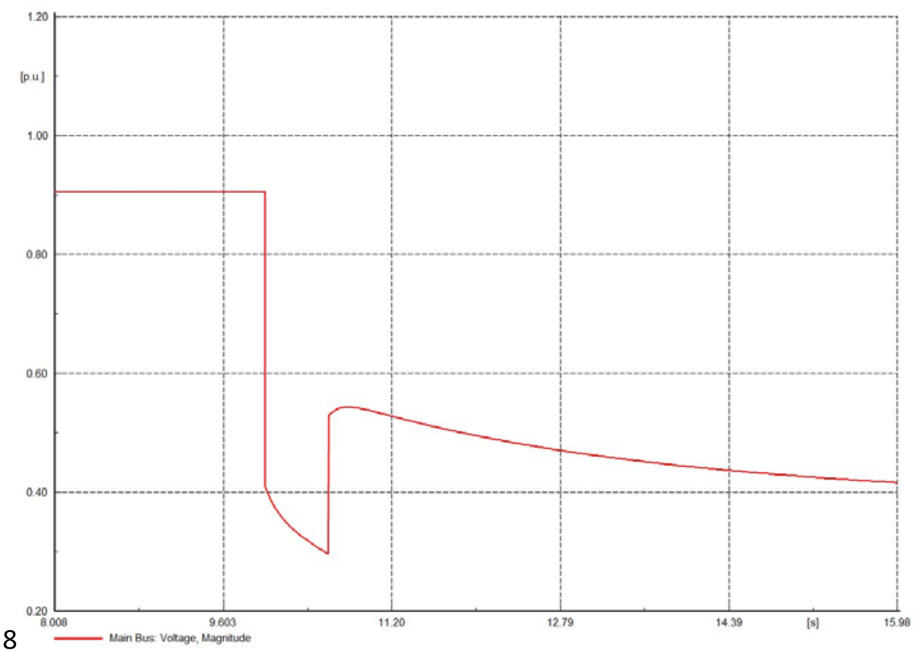

Figure 8