CONCEPT PAPER

ON

THE ASSESSMENT OF

SOLAR PV (SPV) SYSTEM

FOR

POWER QUALITY

AND

SAFETY ISSUES

CENTRAL ELECTRICITY AUTHORITY

2018

1. INTRODUCTION

Solar energy has become the most popular renewable energy source wherein energy is extracted directly from sun using photo-voltaic (PV) modules, but due to the intermittent nature of solar availability and other weather conditions, there is challenge to provide reliable power through Solar PV(SPV) system .

Though SPV are basically either Grid connected or Off grid, following four configurations are commonly used for solar PV system:-

- Grid connected SPV system without battery storage,
- Grid connected Net Metering system with Battery storage- system disconnected from Grid in the event of use of battery at the time grid failure
- Off-grid standalone SPV system (micro grid) with battery- system supplying power to a cluster of houses
- Off grid dedicated stand alone SPV system used for independent houses, street lights, pump sets etc.

In first three systems, there is a requirement of inverter while the fourth system may provide DC or AC based on the user requirement.

The output power of PV system can be harnessed to full extent under various atmospheric conditions of solar intensity and temperature by use of modified control strategy with the help of MPPT design. The inverter is nothing but power electronics converters which also works as voltage regulators for output power but may develop harmonics in output voltage during conversion from DC to AC which would be injected in to the grid leading to various power quality problems in the grid.

Many a times, depending on the type of applications and use, the solar PV(SPV) system is accompanied with either a battery system of adequate capacity for absorbing the intermittency in generation of SPV and delivering stable voltage to grid or to act as an energy storage system like Battery Energy Storage Systems (BESS),which stores the excess generation of SPV and deliver the same during peak hours to enhance power supply reliability in the grid for consumers.

In a grid connected SPV system there are two challenges related to power quality (PQ) - one is at source end like power factor, reactive power compensation, harmonics and voltage regulations and the other is handling the PQ issues arising out of the nonlinear loads on this PV system which can generate sag swells and switching transients in the network. In general, these power quality issues decrease the efficiency and longevity of the Distribution Transformers, Voltage regulators, capacitors and machines etc, hence becomes more pertinent to address. Any integration of renewable energy sources to the grid has to meet standard power quality requirements.

For handling the PQ particularly, the power factor, reactive power compensation, harmonics and voltage regulations at SPV end and the safety issues with SPV are discussed as below:

2. PQ ISSUES ON POWER FACTOR , REACTIVE POWER COMPENSATION, HARMONICS AND VOLTAGE REGULATIONS AT SPV END

The rush to harness solar energy from the sun to make electricity has displaced a good portion of conventional power generation, and at the same time, the loads with sizable reactive component can actually deteriorate power factor in the system.With increased penetration of Solar PV Plants(SPV), importance of power factor, power factor correction, reactive power requirementand harmonics will be relevant for consumers as well as utilities.

It is a known fact that capacitive loads in the grid cause leading power factor and over voltages, whereas inductive loads causes lagging power factor and under voltages. The low power factor of the system puts high transmission burden (and losses) on the power grid and because of this, most Regulators have provisions for allowing the utility to charge a penalty for low power factor mostly to bulk consumers.

Conventional SPV systems operate at unity power factor, regardless of reactive power needs of the utility network. Effectively, such PV system when connected to grid, reduces the power factor at the load end, as the part of the active power is met through SPV, (where SPVcapacity is less than theload at consumer end), and grid is then supplying balance active power, but maintains the same amount of reactive power to the connected load. This can be explained through simple example as below:

Example:-

The premises as in Figure-1 is consuming 1000kW of active power, and 450KVAr of reactive power, resulting in a power factor of 0.912 (lagging) and nominal lower system voltage.

In case, this premises installs a 500kW SPV system which exports power at a unity power factor, only the active power that is imported from the grid would be reduced(to the extent of generation of (SPV). The reactive power drawal from the grid will remain same. With 500 kW generation from the SPV plant, drawl from the grid will be 500kW and 450kVAR. Effectively, power factor of grid power will be 0.743 lagging. Thus, the voltage at load end would further dip.

Figure-1

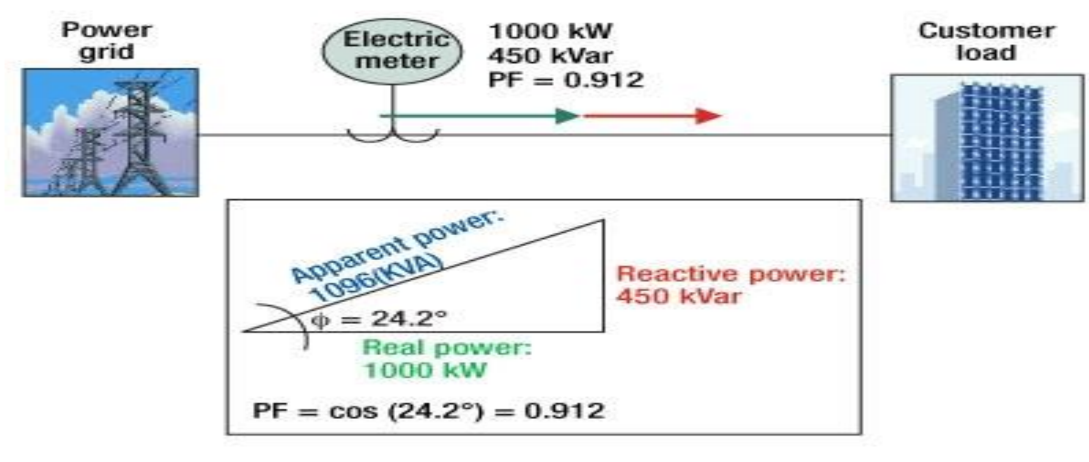
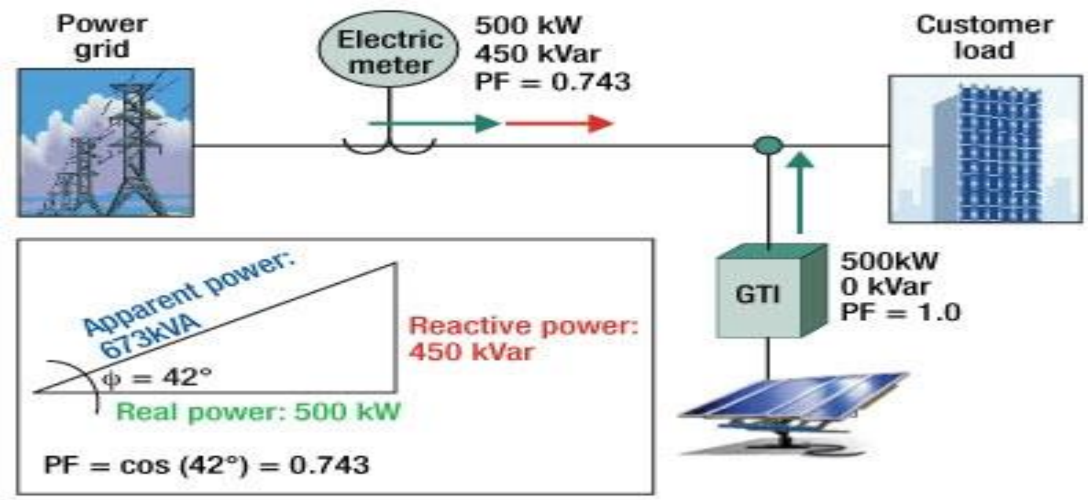


Figure-2



There may be similar situation of deterioration of power factor in case of leading power factor of load.Generally, voltage regulators and capacitors work well for controlling voltages on radial circuits. But with distributed power generation with more than one sources including SPVs, voltage control will be more challenging.

In the example 2 above, SPV power helps in displacing 50% of utility real power. In this case, the grid and SPV power each feed 500kW to the load. The consumer draws only 500kW of real power and the full 450kVARs of reactive power from Grid and the result is that the power factor has dipped to 0.743 lagging.

3. ANALYSIS OF THE PROBLEM:

As mentioned above, if reactive power is either under or over supplied, the voltage on the SPV end of network may fall or rise. Such rise and fall of voltage in system may be required to be the compensated with suitable switching on /off of Capacitor Banks or Reactors, depending on requirement at the load end of grid substation. In some cases, the voltage drop/rise may reach to a point where SPV Plants may have to switch off to protect themselves, thereby decreasing the generation and causing further problems.

This problem of poor power factor however can be addressed through the selection of appropriate inverter product for SPV. Multistage Inverters having reactive power and harmonics control can be configured to produce both active and reactive power, i.e. an output that is at a non-unity power factor and control the harmonics as well as the voltage. SPV inverter technology has the potential to overcome these barriers and provide significant added values beyond the simple kilowatt-hour production of energy.

4. QUALITY OF INVERTER:

The Grid-Tie Inverters (GTI), which is an electronic system that works on principle as that of a conventional stand-alone DC-AC inverter/converter but have soem smart features. The main difference lies in their control algorithm and safety features. GTI is capable of functioning as a converter with step up transformer, automatic synchronization and desynchronization (Isolator) with grid under various conditions such as failure of grid mains supply, or exceeding/decreased grid voltage level or frequency than limits and Tracking of power generation of SPV. GTI basically takes a variable DC voltage from the source i.e solar panels array and inverts it to AC and also boost the same to enable synchronization/interconnection with the grid power (inverter function).

This inverted power of SPV Array can be consumed by owner of SPV or can be exported to utility grid while in parallel with the grid depending on SPV generation and the load connected with owner's premises. The GTI also take helps in getting the maximum electricity output from SPV by use of Maximum Power Point tracker (MMPT) technology.

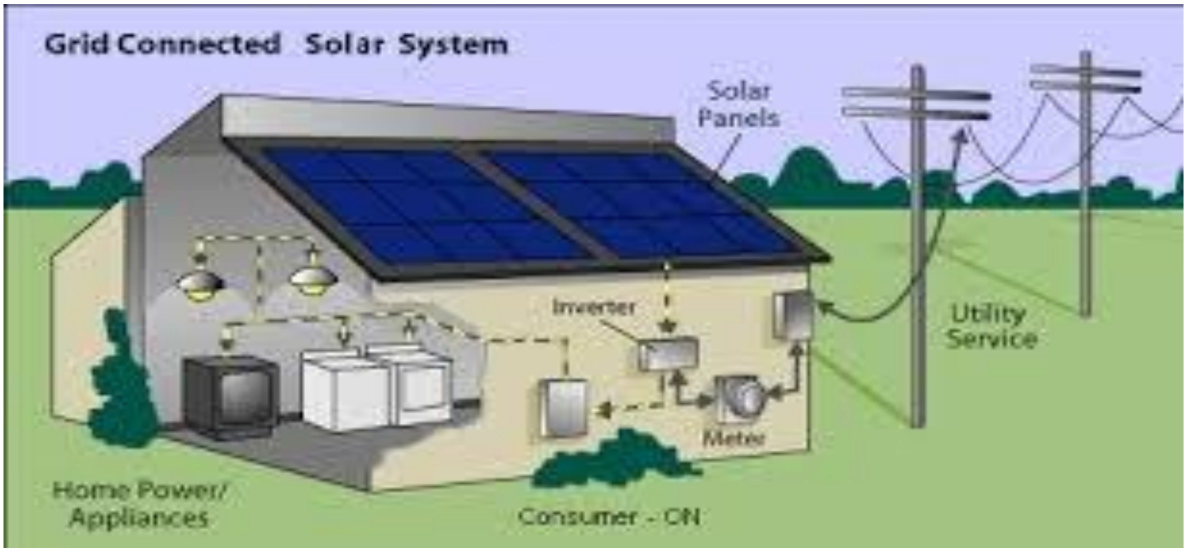
Multistage Inverters are useful for maintaining the power factor, reactive power as well as limiting the harmonics injection to grid when designed, set and tuned properly. These Multistage Inverters are designed with Inductance(L) /Capacitance (C) circuitry and with the harmonic filter circuitry with combination of Resistance (R) , Inductance(L) and Capacitance (C) for maintaining the reactive power and harmonics control at the SPV end respectively.

5. SAFETY CONCERN BY ROOF TOP SOLAR/WIND

There is some resistance by distribution utilities to the concepts of feeding generated power at consumers level to the grid from various renewable energy sources and micro scale generator units due the major issue of safety. Several utility sectors have warned that power injection in distribution grid by mass-scale distributed generators as well as consumers may cause possibility of electrocution because consumers can produce electricity using Grid connected systems primarily made up of SPV/Wind Power technology without proper safety features.

The intelligent Inverter (GTI) installed with SPV, helps in providing power to consumers and also feed an excess electricity generated in SPV than the required at consumers premises into the grid, would also automatically stops supply of electricity to the grid when the grid is down. Therefore, GTI automatically stops back feeding of electricity of SPV and prevent accident in the grid. Also , in this condition, power would also not be available to the consumer premises. Also, every roof top installation of RE have to follow the Grid Connected Regulations notified by CEA for 33 kV & below level and as per these Regulations, as isolator at the appropriate site have to be installed which can be accessed by the utility personal to physically isolate the SPV system at the time of maintenance of the Grid lines.

As per CEA (Installation and Operation of Meters) Amendment Regulations 2014, In case consumer want to use SPV power for its use at the time of grid failure, he has to install an automatic switching system to isolate its supply with SPV system from Grid to get the supply from SPV with Battery system safely.



To ensure the quality of the power through SPV system following are requisite :

1. Grid-interactive or grid tie inverter should have surge protection device at DC inputs and AC outputs. The design of inverter should be as per the Indian / International Standard and efficiency of the inverter should be more than 97%.
2. The smart inverters should provide an alert on any internal damage leading to change in output power quality.
3. The Inverter should shut down automatically if there is a power blackout or a fault with SPV for safety of the personal and other equipment.
4. The Inverter, for meeting the requirement of compensation of harmonics and reactive power, should have an in built / separate unit along with Inverter.
5. The inverter should have inbuilt harmonics recording for monitoring of the harmonics.
6. For Harmonics, the inverter output should comply with the provisions of CEA Regulations as notified by CEA (Standard for connectivity of Distributed Generation Resources) regulation 2013 and CEA(Technical standard for connectivity of the Grid) regulation 2007, as amended from time to time.
7. The effect of the change in loading pattern to be monitored by the owner/ agency installing the PV system and any additional harmonic filter requirements need to be studied and incorporated based on the load of network in case of large PV generating stations.
8. As the power supply would be disconnected at the time of grid failure and consumers are in requirement of power during unavailability of Grid supply, it is mandatory as per CEA Regulations to use AC Isolation arrangement at grid connected point to isolate Grid supply by a mechanical Switch .
9. An Isolator should also be installed at the grid connected point of Solar roof top SPV system which should be accessible to the utility staff to isolate the system at the time of maintenance of the distribution system.
10. Utility should also have a monitoring system in centralized control room for monitoring the status of SPV system installed at consumer premises for proper management & monitoring.