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Influence of Power Quality Issues on Renewable Energy Sources

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Abstract –*This paper discusses the power quality issues related to renewable energy sources, particularly, Photovoltaic (PV)-based systems. Focus is given to voltage dips and swells as they are the most severe power-quality issues to sensitive loads. As the dip magnitude increases, it becomes challenging for the PV-inverter to cope and maintain the PV in synchronism. The influence of voltage dips on PV-inverter is investigated via Matlab/Simulink simulation.*

***Key Words*:**Power Quality, voltage dips,voltageswells, PV-inverter,RE sources.

1.INTRODUCTION

Power Quality is gaining increasing attention in the electric power industry. The term 'good power quality' can be used to describe a power supply that is always available, always within voltage and frequency tolerances, and has a pure noise-free sinusoidal wave shape. A Power Quality (PQ) problem can be defined as deviation of magnitude and frequency from the ideal sinusoidal wave form [1]. The major power quality concerns are power flow variation which causes voltage and frequency deviations, unbalance voltage and current, poor power factor, harmonic distortions, voltage flicker, voltage sag / swell and others [2]. At recent days emphasis has increased on distributed generation (DG) networks with integration of renewable energy systems into the grid, which lead to energy efficiency and reduction in emissions. With the increase of the renewable energy penetration to the grid, power quality (PQ) of power transmission system is becoming a major area of interest. Most of the integration of renewable energy systems to the grid takes place with the aid of power electronics converters. The main purpose of the power electronic converters is to integrate the DG to the grid in compliance with power quality standards. However, high frequency switching of inverters can inject additional harmonics to the systems, creating major PQ problems if not implemented properly [3]. There are several important reasons to monitor power quality. The primary reason is economic; particularly if critical process loads are being adversely affected by electromagnetic phenomena [4]. When renewable sources communicate with the power grid, there are some mutual effects between them. Grid produces issues that can influence renewable sources, which can be summarized in the following points:

- Micro-grid is different from the main grid, in case of microgrid large and sudden changes in load may result in voltage transient with large magnitudes in the AC bus [5].
- Harmonic current injected into the DG system can also cause the rise of voltage harmonics due to the system impedance [6].
- If unbalance in voltage is alarming, the solid state circuit breaker (CB), connected between the microgrid and utility grid, will open to isolate the microgrid. When voltage unbalance is not so intense, CB remains closed, resulting in sustained unbalance voltage at the point of common coupling (PCC) [7].
- Connecting the DG to a lightly loaded feeder the power flow can reverse and the voltage at the DG connection point start to rise. This means that the supply voltage for customers connected nearby DG units starts to rise as well. This voltage rise is a steady state effect. A sudden change in the output power can also occur when the wind exceeds a certain upper limits (25 m/s).At that point, the wind turbines have to be protected against overload and strong mechanical forces and are disconnected and shut down [8].
- The unwanted harmonic currents in some Type of Wind turbine generators can cause unnecessary extra losses in the copper windings and torque pulsations, and they may even excite mechanical modes of the turbine components [9].
- On the other hand, renewable sources themselves produce power quality issues that may influence the grid, which can be summarized in the following points:

- The impact of renewable sources on voltage flicker which is considered recently as an urgent power quality problem that can affect motor starting, temperature rise, overloading of generators, motors and may cause health risk problems due to the annoying light flicker which is consequence of voltage fluctuation [10].

- Voltage fluctuation in Micro-grid lead to change the tide of power flow of system [11].

- Unbalance can create a situation in the network to draw excessive reactive power, mal-operation of protective system [6].

- When unbalanced current increases relative to the total current of the system, voltage imbalances emerge in some parts of the system. The zero and negative sequence currents associated with unbalanced loads can create several problems such increased losses in the system and High temperatures in induction motors and transformers, vibration in induction motors which causes mechanical stress and reduces their life span, reduction in power factor which increases KVA demand and line losses [12].

- The voltage sag can cause huge economic losses in power system[13].

- the negative and zero sequence voltage or current Resulting from unbalance affects the performance of power metering devices, reduce life span of electrical appliances, increases the power loss, etc [6].

- The negative phase sequence, result of voltage unbalance that is the most relevant for causing damage to direct online motors by creating a reverse torque [14].

- Excessive harmonics in power network can cause the following issues; over loading of neutral in three phase power system, overheating of transformer and cables, voltage distortion in secondary side of distribution Transformer, increases the system power loss, affects the performance level of measuring instruments, mal operation of protective relays, increases di-electric losses and thermal stress in capacitor bank, increases copper loss and heat loss in electrical equipment's, etc. in power system network [6].

- Effects of power quality can be shown up in many aspects of industrial operations. The aspects include loss of production, manufacturing interruptions, loss of revenue, decreased competitiveness, lost opportunities, product damage, and wasted energy and decreased equipment life. [4]

- Integrating growing numbers of renewable power installations and microgrids onto the grid can result in larger-than-expected fluctuations in grid frequency .probability that the deviation is more than 2 per cent or so, which is a big deviation [15].

- There is an issue of ongoing availability of energy from renewable sources, and it can lead to a complete failure of the powerplant. Due to variability in production, there is also a flicker problem [16].

2. Power Quality Issues by Renewable Energy Sources

Renewable energy systems and distributed generation networks, offer a range of benefits that can provide local and national assistance in terms of environmental benefits, economic benefits and increased efficiency. However, Renewable energy output is largely governed by weather conditions -which are highly variable. This leads to frequent supply-demand mismatches, thereby causing a drift in frequency, voltage and current from the standard value. Can be summarized Reasons power quality issues by Renewable Energy Sources in the following points:

- Generation of PV grid is depends on atmospheric conditions. So, the generation is not constant all the time. For improving the efficiency of PV Grid, efficient control scheme are required to deliver the maximum power, which inevitably leads because the poor power quality.
- Power variation from intermittent nature of RE sources, lead to a voltage and frequency variation [6].
- The frequent start-up and shutdown operation of renewable power generators will lead to voltage fluctuations especially sag [13].
- Variation output power of distributed generation lead to voltage fluctuation and flicker [11].
- Total harmonic distortion (THD) voltage and current levels are high in some conditions such; penetration of PV at higher level, far end feeder, low load, Power Electronics converter and load operates at leading power factor [2].
- Unbalance in microgrid may occur due to the following reasons; uneven distribution of single phase loads, uneven power generation from single phase type power sources, unbalanced three phase loads, unequal impedance of three phase distribution network, etc[6].

3. Possible mitigation techniques

The grid connected renewable energy sources are sensitive to the power quality issues. Therefore, power quality monitoring is an essential concern to protect the electrical and electronics equipment [17]. mitigation of the power quality (PQ) issues can be achieved by monitoring and compensating via power electronic devices [18]. Several types of power enhancement devices have been developed over the years to protect equipment from power disturbances. Filters play an important role in harmonics mitigation, reactive Power compensation, load balancing, neutral current compensation, reducing flickers, compensations related to voltage sags and swells [19]. The filters are classified into three categories namely passive, active and hybrid filters.

a. Passive power filter.

The passive filtering is the simplest conventional solution to mitigate the harmonic distortion [20, 21]. Conventional passive filters consist of inductance, capacitance, and resistance elements configured and tuned to control harmonics. Figure 1 shows common types of passive filters and their configurations [22]. It is connected in parallel with nonlinear load. But the disadvantage of this method is they require large value high current inductors which are expensive and bulky.

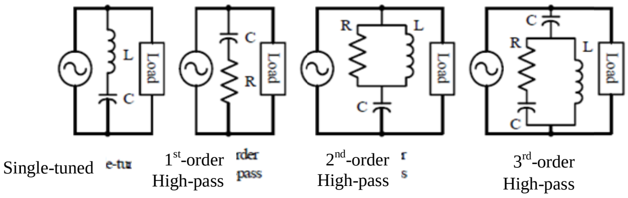


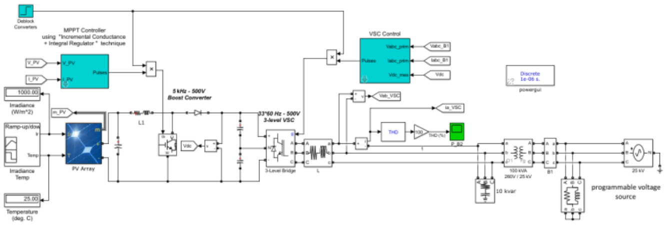
Fig – 1: Common types of passive filters.

b. Active power filter.

The technology of active power filter has been developed during the past two decades reaching maturity for harmonics compensation, reactive power, and voltage balance in ac power networks. The topology of active power filter is classified in to three types are Shunt active power filters, Series active power filters, Unified Power Quality Conditioner (UPQC). Since Shunt active power filters are widely used to compensate current harmonics, reactive power, and load current unbalanced. It can also be used as a static var generator in power system networks for stabilizing and improving voltage profile [23]. The series active filter senses the load side voltage and produces the harmonic of the load voltage in the negative direction and makes the voltage of the point of common coupling free of harmonics. This type of approach is specially recommended for compensation of voltage unbalances, voltage distortion, and voltage sags from the ac supply [24]. Unified power quality conditioner (UPQC) is aim at the integration of series active and shunt-active filters. The main purpose of a UPQC is to compensate for supply voltage imbalance, reactive power, negative-sequence current, and harmonics [25].

4. Case Study:

A 100-kW PV system-connected programmable voltage source is employed as the case study in the work. Fig. 2 shows the simulated model in MATLB/Simulink environment. The case study is developed by using the Matlab/Simulink SimPowerSystems toolbox [26]. The PV system consists of the PV array, boost converter and three phase voltage source inverter. The programmable voltage source is used to simulate the AC grid with the ability to generate voltage dips, voltage swells and inject the voltage harmonic distortion. The system was tested to study the effect of power quality problems generated in the grid such as voltage dips, voltage swell and the voltage harmonic on Inverters of PV Systems.



Fig– 2: Conventional simulink model for PV inverter.

A. Simulation of Voltage sag

Figer.3 shows waveforms of voltage sag generated by the voltage programmable voltage source, which applied for duration of 0.3s and shows waveforms of reproduced voltage sag on inverter at different voltage sag values. Where it was observed that whenever the greater the depth of voltage sags, the inverter will be faster out of control. As noted the inverter current didn't trip because of the voltage support provided by the control parameters during the disturbance. The inverter is only disturbed during the sagging period.

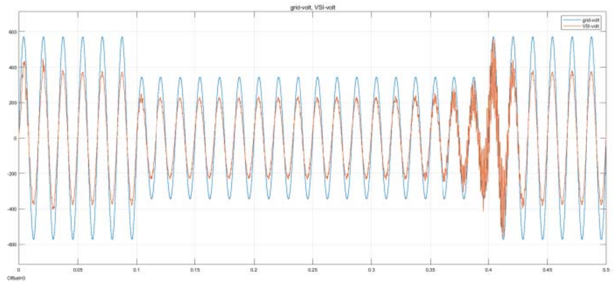


Fig – 3.a: voltage sag equal 0.6pu.

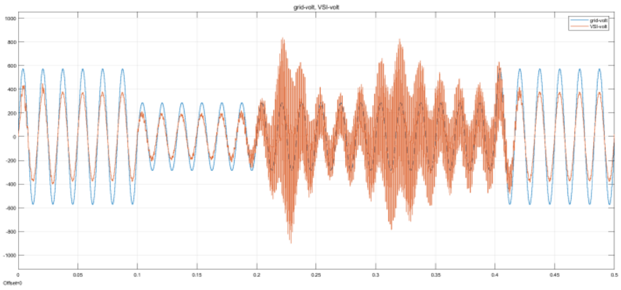


Fig – 3.b: voltage sag equal 0.5pu.

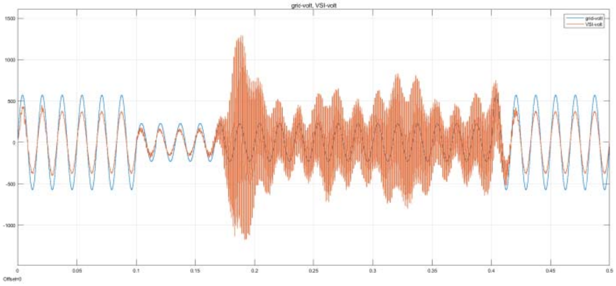


Fig – 3.c: voltage sag equal 0.4pu.

Fig – 3: Results under reproduced voltage sag

However, transformer-energizing voltage dips are associated with a large amount of even-harmonic distortion, which could lead to interference with the control of power electronic converters. In such a case, transformer saturation after a voltage dip may also cause interference [27]. When measuring the inverter current harmonics, it was found that it increases with increasing depth of voltage sag. Figer.4 shows harmonic of inverter current at different voltage sag values.

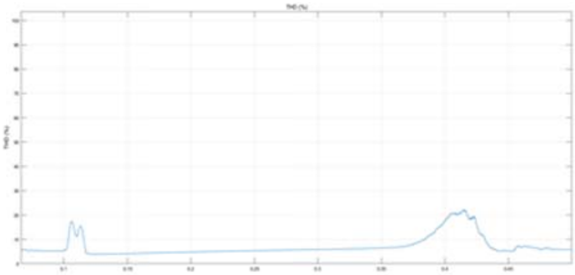


Fig – 4.a: harmonic at voltage sag equal 0.6pu.

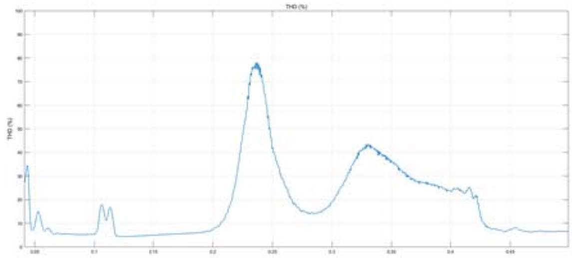


Fig – 4.b: harmonic at voltage sag equal 0.5pu.

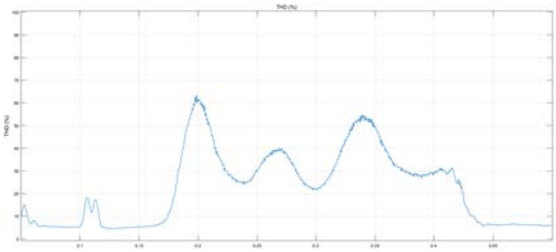


Fig – 4.c: harmonic at voltage sag equal 0.4pu.
Fig – 4: harmonic of inverter current.

Fig. 5 shows that the PV array keeps on generating active power of 100-kW. However, less active power is exported to the grid after the plant has tripped.

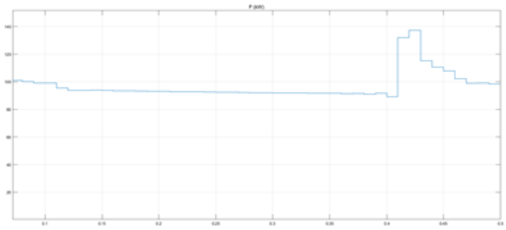


Fig – 5.a: Active Power at voltage sag equal 0.6pu

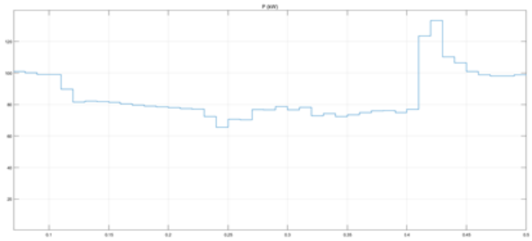


Fig – 5.b: Active Power at voltage sag equal 0.5pu

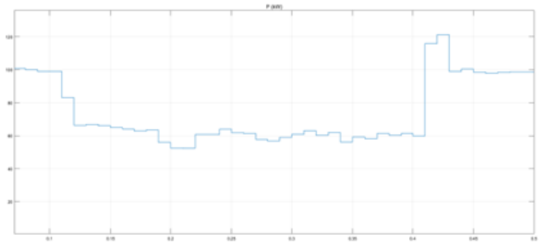


Fig – 5.c: Active Power at voltage sag equal 0.4pu
Fig – 5: Active Power Exported to the Grid

B. Simulation of Voltage swell

It was noted that when applying the voltage swell, there are no noticeable effects on the work of the inverter or the power transmitted from it, and it does not cause harmonic current, especially at the moment of the beginning and end of the trip. Figer.6 shows waveforms of voltage swell generated by the voltage programmable voltage source, which applied for duration of 0.3s and shows waveforms of reproduced voltage swell on inverter at 1.4pu values.

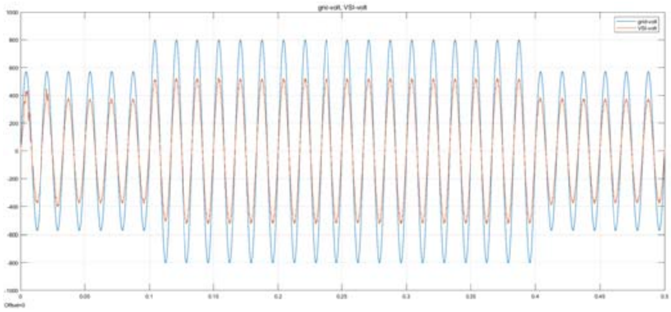


Fig – 6.a: Voltages swell equal 1.4pu.

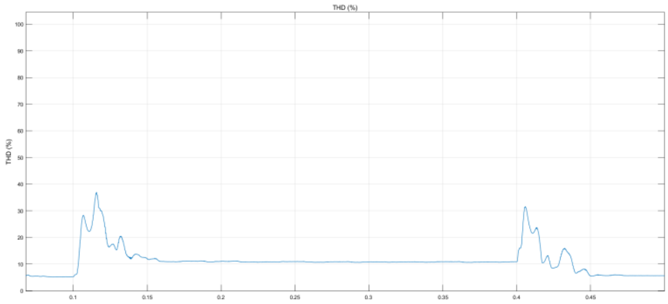


Fig – 6.b: harmonic at voltage swell equal 1.4pu.

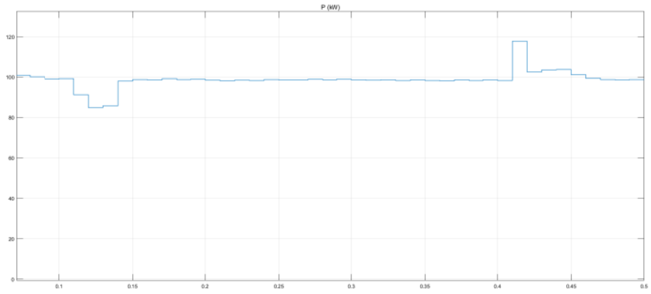


Fig – 6.c: Active Power at voltage swell equal 1.4pu.
Fig – 6: Results under reproduced voltage swell waveforms.

5. Conclusions

The paper has investigated the impact of voltage dips and voltage swell on the power quality of grid connected PV system. The simulation results show that the main impacts of voltage sag is dependent on depth of voltage sags. In few cases, a failure of the inverter to operate was noticed, that consequently reduces the electrical power given to the network. Voltage swell on the other hand can lead to nuisance tripping and equipment reduced life.

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