

## Smart grid PV generation system challenges, issues and solutions

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### Abstract

Great efforts are being made all over the world towards the promotion of clean energy for environmental protection and scheduling energy consumption pattern to meet its increasing demand. The grid is to be modified or upgraded to promote clean energy, control the energy consumption pattern and bring security to grid. Solar PV systems have become common-place in many cities and regions, and is a core technology in purpose-built low-energy homes, but evidence is emerging that in many cases electricity output may be significantly lower than expected. There are many challenges and issues in the implementation of smart grid. This paper presents challenges and issues in smart grid concept with solutions.

**Keywords:** smart grid, clean energy, renewable energy generation, photovoltaic system

### 1. Introduction

The uptake of photovoltaic (PV) systems around the World for domestic application has been remarkably fast in the past decade, driven by a combination of policy action and the rapidly reducing cost of the technology. In Australia, the number of dwellings with PV has gone from a few hundred to over 1.84 million PV installations, with a combined capacity of over 7.8 GW, in just a single decade <sup>[1]</sup>. Putting this in perspective, more than 20% of all Australian households now have a rooftop PV system, and in some regions the uptake is nearly one in every three homes. This rapid transition to a paradigm of self-generation and local energy demand management is in complete contrast to the previous status quo of householder as an energy purchaser. In many cases, the end-user household has no experience of the new technologies, and little understanding of how sunlight is converted into usable power for their domestic needs. This should not be not surprising as households have traditionally been focused on enjoying energy services rather than supplying the electricity market. This paper explores the end-user experience of households, in the context of purpose-built low-energy homes, suddenly becoming the operator, and in some cases the owner, of a grid-connected power generation plant.

#### A. Growth in Domestic Scale PV Uptake

Since the introduction of the Australian Mandatory Renewable Energy Target (RET) in 2001 with an original target approximating 5% of total electricity generation, later expanded to 20% renewable energy by 2020, Australia has seen a significant uptake in domestic PV systems. Similarly, many other countries or regions have established renewable energy targets that have contributed to the uptake of domestic PV systems. In Australia, rapid growth in solar PV uptake took-off from about 2008 when a number of State Governments added new incentives in the form of feed-in tariffs to supplement incentives from the RET, and exploded in 2011 when the RET incentive was increased fivefold <sup>[2]</sup>. This acceleration in uptake has been supported by improving economics associated with ever-growing production volumes and improvements in unit efficiency <sup>[3]</sup>.

<sup>4]</sup>. As the economics of PV systems has improved the average size of domestic rooftop systems installed in Australia has increased from about 2 kWp in 2010 to about 6 kWp in 2018 <sup>[1]</sup>.

#### B. Performance of grid-connected PV Systems

While there is increasing evidence about the economic, energy system and environmental benefits of installing rooftop PV systems, there is also research which finds that some systems underperform. In the UK, it was found that 4.1% of systems suffered long-term underperformance relative to their nominal efficiencies <sup>[6]</sup>. Other studies <sup>[7-8]</sup> identified dozens of fault types a range of PV system components including modules, connection lines, converters, and inverters, each leading to serious underperformance in system efficiency and energy yield. The researchers in the Australian study <sup>[5]</sup> used two main methods to determine faults, the first was to examine high-resolution (minute) gross solar energy data, and gauge whether the peak output on a clear day at solar noon seemed about right, or too low. This method requires knowledge of the sun's path and zenith angle relative to the panel, and is far too complex for the average end-user. The second method compared the inverter output power for each minute of a 12- month monitoring period, of the suspected faulty system to that of a known working system. Comparing the frequency vs. output power on a semi-logarithmic scale clearly shows if a system's output is significantly lower than a comparable system. This method is also too complicated for the average end-user, and requires additional data. Once the suspected faults were investigated and rectified by the PV system installers, significant improvements in gross solar energy were seen for these houses, when comparing monthly gross solar energy generation for a 12-month period before and after the fault was investigated. This could be understood by the average end-user providing they had access to monthly monitored data, which the households in this case did. This highlights the need for consumers to have a better understanding of how their PV system works and what to do if there are issues. Otherwise we face a situation where millions of houses have this technology

installed, but are not getting full benefit from it.

### Related Work

Today, the stability of the electrical distribution grid and the generation of electricity is restricted only to large generators. However, the quickly development of networking technologies allows us to think about Smart grids. This new technology admits an intelligent and automatic way for distribution of electrical energy and in case of failure, it automatically optimizes an alternative way for its distribution and increases its reliability.



**Fig 1:** Typical distribution grid

Also, the smart grid is required to be self-healing and resilient to system anomalies <sup>[1]</sup>, according to this conception, it is possible to incorporate the domestic generation of electrical energy based on solar panels, to help to maintain the reliability and to decrease the losses due to transmission <sup>[2]</sup> of the main distribution system as shown in Fig. 1.

### Smart grids have many advantages

- They can integrate electric vehicles to the grid
- they do not need operators
- they have bidirectional power flow

Indeed, another common problem is the variation of the voltage produced by the consumption of reactive power that plays a main role in the power system control. This section gives review in the field of PV smart grid power system.

Libin *et al.* <sup>[9]</sup> studied the reactive voltage control strategy of grid connected photovoltaic system in order to increase the penetration rate and improve the stability of grid voltage. Grid connected PV system generally consists of a number of inverters, so it is necessary to analyze the control strategy of a single inverter and the reactive power output constraints.

Gautami *et al.* <sup>[10]</sup> investigated and emphasize the importance of the grid-connected PV system. The investigation was conducted to critically review the literature on expected potential problems associated with issues of PV based grid system. The main purpose of this paper is to discuss the basic understanding of photovoltaic (PV) based distributed generation power system and how these power flows will influence the performance and stability of a power system.

Yan *et al.* <sup>[11]</sup> proposed the active power-frequency droop control strategy and virtual inertia control strategy for single-stage grid-connected PV generation for electromechanical transient analysis in order to solve the problem of insufficient frequency regulation capacity caused by the large-scale grid-connected photovoltaic (PV) generation. By modifying the control structure of the inverter, PV generation actively got involved in frequency

regulation. The simulation results indicate that: the inverter can control the PV array to increase or decrease the active power generated according to the set droop control and virtual inertia control, so as to suppress the drop or rise of the grid frequency; in the dynamic process of frequency, the incremental power of PV generation induced by the dynamic action of the voltage vector of grid connection point is dependent on its virtual inertia control.

Omar *et al.* <sup>[12]</sup> improved the dynamic performances, guarantee a high quality of the THD despite irradiance variation and extract the maximum power while ensuring unity power factor. First, the whole system is presented in d-q-synchronous reference frame. After that, the Fuzzy-PI controller designed. PI controller parameters are adjusted online by Fuzzy rules. The proposed control is implemented in Matlab/Simulink environment and compared with the conventional proportional integral controller. The results show that the proposed control laws provide better performance in terms of references tracking and unity power factor. Furthermore, the harmonic analysis and total harmonic distortion revealed that the power quality injected into the electrical network is enhanced using the Fuzzy-PI control.

### Challenges

The developed countries have reliable electrical infrastructure and minimal growth rates. This allows them to concentrate on standardization of grid, smart meter implementation technology development and interoperability of grid tied distributed renewable energy generation. But for developing countries like India which have weak grid but growing energy needs will have to strengthen and extend the electric network along with implementation of information and communication technology, and automation system in order to make the grid smarter.

Also they have to give concentration on uninterrupted quality power supply to all households and reduction of transmission and distribution (T&D) losses <sup>[7]</sup>. Some of the challenges and issues which have to be addressed by both developed and developing countries in the implementation of smart grid are discussed here.

### A. Technology Development

There are tremendous developments in information and communication technology in the past decades. But for making the grid smarter as per our imagination, it is necessary to create a new communication infrastructure integrated or wholly separate from the existing World Wide Web which is resilient from attack and highly reliable.

Advanced sensor systems are to be developed to implement in the smart premises and grid for phase measurement, to get consumer consumption information and to control automatic circuit breakers for minimum interruption and electrical appliances for peak shaving. Advanced components like smart appliances, smart meters, efficient energy storage devices, high voltage DC transmission devices, flexible AC transmission system (FACTS) devices etc are to be developed and implemented. Advanced software development to control and protect the grid and appliances of consumers is also the key factor to be included in technological development <sup>[1]</sup>. The smart grid will have the capacity of taking action on its own by advanced control methods and decision supports.

## B. Quality power to all households

In developing countries like India the per-capita consumption of electricity is only about one-fourth of world average. So a vast growth of power system network is needed for the next several years for supply energy to all households in a reliable manner. The quality of supply is also to be ensured to fulfil smart grid vision. The existing grid is to be renovated and expanded to ensure quality supply to all households. Also distributed renewable energy generation and option to save money by shifting loads from peak load to off peak period are to be promoted to reduce supply gap at peak hours and peak energy cost <sup>[7]</sup>.

## C. Reduction of transmission and distribution loss

The T&D loss are to be reduced to world standards. The main factors which affect the T&D loss are technical losses due to weak grid and financial losses like theft and collection efficiency reduction. The utilities should have to address these issues seriously.

## D. Renewable energy integration

The fluctuating and unpredictable nature of renewable energy sources like solar photovoltaic and wind mill require complex technologies to integrate with existing grid. The harmonics developed from the complex power electronics circuits used for integration also make many troubles in the power system. Other draw-back of renewable energy generation is requirement of large land area. The reliability of protection circuits to isolate it from the existing grid whenever required is a great challenge in the integration of renewable energy sources. Lack of technically skilled man power and wrong selection of optimal place for implementation will also affect the renewable energy integration.

## E. Consumer support

One of the main challenges in the smart grid implementation is lack of consumer awareness about the issues in the power sector. Consumer support is a must for implementation of smart grid to reduce peak load consumption and promote distributed renewable energy generation. The smart grid implementation will improve quality and reliability of power supply. It assures user friendly and transparent interface for consumers with utilities, increased choice for consumers including green power and option to save money by shifting loads from peak periods to off-peak periods. But the consumers should be aware of new technologies and support the utilities to get the benefits of smart grid both for individual and nation.

## Solutions

The implementation of smart grid is a long process since it requires mass technological and financial investment. Then it should be implemented in a phased manner. Each country should have to propose a policy for implementing smart grid considering existing infrastructure and growth rate. There are many utilities with diverse needs, regulatory environments, energy resources and legacy systems in a country. It is thus unlikely that a single solution will emerge as appropriate, cost effective and useful for all electric utilities and consumers <sup>[5]</sup>.

The evolution in the power electronics to handle high power by fast semiconductor switching using IGBTs plays a major role in integration of renewable energy sources. This power

electronics circuits may cause harmonics in the power system. The FACTS devices like static synchronous compensator (STATCOM), static series synchronous compensator (SSSC) and unified power flow controller (UPFC) will help to improve the stability and reliability of the grid which has large amount of renewable energy penetration. The filter circuits provided with these systems will mitigate the harmonics injected into the grid due to power electronics circuits. Realtime computer controllers which can implement advanced and complex algorithms also help to extract maximum power from renewable energy sources and reduce fluctuation in the renewable energy generation. It also protects the storage devices like battery from over charging.

This will enhance the life of battery. It is more economical and grid friendly if the fluctuated power generated by the renewable energy sources is utilised for irrigation purposes. The fluctuation in renewable energy generation can also be reduced by distributed renewable energy generation from a larger geographical area in small power plant instead of large power plant concentrating in one area. The output of solar photovoltaic may change 70% within five to ten minutes due to local phenomenon like cloud passing. The vast land area requirement and the fluctuation of renewable energy can be minimized by distributed renewable energy generation.

## Conclusion

Smart grid development is vital for meeting increasing demand of electricity and it can be implemented through a continuous process. Many issues and challenges will have to be faced by implementing agencies in the journey of making the grid a smarter one. In this paper some issues and challenges of smart grid implementation are discussed with solution.

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