IMPROVEMENT AND POWER LOSS REDUCTION IN DISTRIBUTION SYSTEM SMART GRID COMMUNICATION NETWORKS

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Abstract:
The ever-increasing demand for electricity has posed reliability, security, economic and environmental challenges in front of the current electricity power system. A smart grid concept is a key solution to these issues because it uses digital technology to revolutionize the conventional electricity power system. This article presents a comprehensive analysis of power quality challenges with grid integration of renewable DG systems and current research status of associated mitigation techniques. Firstly, this paper puts emphasis on theoretically illustrating all the crucial power quality challenges associated with grid integration of renewable energy, and secondly, a thorough survey, of all PQI techniques introduced till date, is elaborated along with highlighting the opportunities for future research. Furthermore, all the crucial power quality issues, the impact of high penetration of renewable energy and mitigation techniques on power quality, are demonstrated also by simulating a grid integrated PV based DG system in MATLAB/Simulink. This article is believed to be very beneficial for academics as well as industry professionals to understand existing PQ challenges, PQI techniques, and future research directions for renewable energy technologies.

1.0 INTRODUCTION

Power quality is an aspect, which is critically responsible for reliability in smart distribution grids and hence paying attention to that is unavoidable. Utilizing the energy of RESs requires generating units to be integrated with the distribution network grids. The stable operation of grid integrated renewable DG systems is a challenging task due to associated PQ challenges arose by environmental intermittency and generation technological differences from fossil fuel- based DG systems those are constant source of energy.4-8 Only the smooth integration and stable operation of such integrated DG systems can turn the idea of future smart grids into a reality. [1] During last few years, the widespread integration of power electronic inverters, employed for integrating DG units with the grid, has created major trials and tribulations for distribution power networks, especially harmonics distortion and complications in attaining frequency stability because of the decrease in the overall inertia. to cover the following aspects of the reliability of the DS in smart grid communication networks:

Renewable DG: Renewable DG brings commercial, operational and ecological benefits. In this section, first, we provide a brief overview of RESs, the major RESs including their pros and cons, then, we discuss the role of DG on DS reliability.

ESS: Owing to the crucial role of ESSs in enhancing grid stability, reducing energy wastage and greenhouse gas emissions, we review the challenges and future prospects of ESSs in certain countries. [2] Moreover, we highlight how the integration of RESs with ESSs affects effectively and efficiently in the reliability improvement.

Reliability assessment: In this part, we cover a reliability analysis of the relevant studies and striven to highlight the various concepts of the reliability of distribution network (DNs) from different perspectives and the influence of some other factors on power system reliability.

2.0 LITERATURE REVIEW

As digital technology has changed the way we live, the demand for electricity is increasing and will increase significantly in the future. The electric power is provided through the electricity grid, where it is generated, transmitted, distributed to customers over long distances. The traditional or current electricity grid is an environmentally extravagant and a limited one-way interaction system, which makes it difficult to meet ever increasing energy demands in the 21st century. As a result, many challenges are faced in terms of reliability, power quality, security, environmental, and economic issues. The solution to all these problems is to make the system smarter, i.e. a smart grid. The smart grid [3] is a combination of the electricity grid with information and communication technologies (ICT). It is made by two-way communication technologies, where electricity and information can be exchanged between providers and customers. The advantages of smart grid technology [4], [5] are numerous. Distributed Generation (DG) meets the quality and reliability of energy as well as power supply. DG is also highly efficient with the performance varying between 65% and 95% [6]. Although the participation of renewable energy sources (RESs) in the DG has made it more complex, it created a path for the realization of the smart grid. This complexity includes the high variability of output and to solve this issue, Energy Storage Systems (ESSs) are integrated into the DG. ESSs, when coupled with RESs, can smooth output fluctuations and balance the power flow in the network to meet energy demand sustainably and reliably [7]. DG provides an excellent backup and even faster recovery to the existing power grids in case of system failures and adverse scenarios such as the destruction of power plants during wars and terrorist attacks [8]. Apart from these advantages, DG also helps in meeting the high loads at the remote locations and hence saves upon the cost of developing and maintaining additional infrastructure in adverse terrains

3.0 RESEARCH METHODOLOGY

The grid integrated single DG unit gives rather more clear insights into the energy conversion process. Figure shows the complete schematic of the grid integrated wind- based DG system.50 It consists of a wind turbine fed permanent magnet synchronous generator (PMSG) interfaced to high voltage power grid through the power electronics- based conversion system that further comprises a diode bridge rectifier, DC to DC boost converter, a voltage source inverter (VSI), transformer, and transmission feeder. Though wind energy conversion systems can be broadly classified on a different basis such as power output, generator type, speed of operation, and turbine orientation also. Figure 3C gives a clear insight into the classification. Here, the most important base of classification is the type of generator employed for WECS, and the same has been emphasized for classification in the current study. Doubly fed induction generator (DFIG) is utmost frequently employed in the wind power generation industry. Topological configuration of DFIG- based grid integrated DG system is shown in Figure 3D, and it makes clear that stator terminals of DFIF are directly connected to high voltage DG bus through step- up transformer while the rotor is connected through a partial rated power electronics interface. In DFIG, a gearbox is mandatory due to dissimilarities between the speed characteristics of wind turbine and generator. Power electronics interface consists of two types of converters, one is a rotor side converter

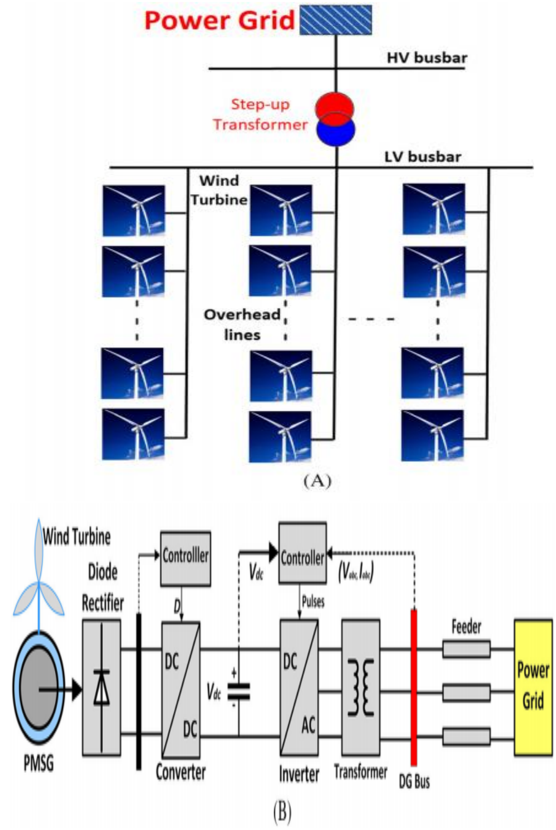

Figure 3.1 A, Topological configuration of WPP. B), The complete schematic of grid integrated wind-based DG system

Topological configurations of renewable dg systems:

During the past few years, several renewable energies have undergone humongous growths relatively. The photovoltaic, wind, and hydroelectric are among the extremely exploited RESs. the topological configuration of SCIG- based grid integrated DG system. Alterations in the speed of the rotor of the SCIG are negligible since the only speed alterations that can happen are variations in the rotor slip. For some specific applications, SCIGs are still employed in variable- speed WECSs by application of full- scale power electronic converters. The extraction of maximum power from the wind is challenging in the case of SCIGs since it can result in overloading of the generators. Consequently, for extracting the optimal power from wind, pitch angle regulation is preferred. Figure shows several advantages and disadvantages of SCIG- based WECS To connect the slowly rotating turbine rotor to the electrical generators such as DFIG and SCIG, multistage gearboxes (1:100) are mandatory for high wind speed operation; single- stage gearboxes (1:10) are required for medium wind speed operation. Generators such as PMSGs are directly driven from the turbine rotor without the need of speed conversion gearbox system. High wind speed conversion gearboxes are very less reliable and generally need replacement within a few years. Topological configuration of PMSG- based grid integrated DG system is already depicted in Figure

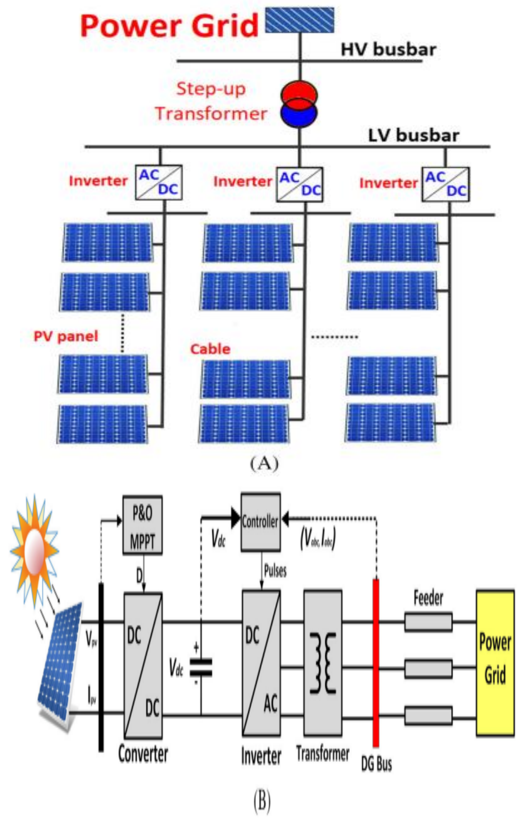

Figure: A, Topological configuration of PV power station. B, The complete schematic of grid integrated PV- based DG system

Moreover, because of the inconstant speed functioning, the gearless- driven PMSG system is capable of generating 10% to 15% surplus energy than the fixed single- speed operation. If the gearless- driven PMSG is compared with the three- stage gear- based DFIG and taking all the parts of WTs into consideration, the overall weight of the two WT systems may not have any huge dissimilarity; nevertheless, DFIG 3G is generally the lightest one and rather economic option with standard components.

4.0 Simulation- based demonstration of PQ challenges and mitigation techniques

For demonstrating the power quality challenges and mitigation techniques, a test distribution system is considered with integrated PV- based DG system and mixed types of loads. Figure shows the single line diagram (SLD) of the test distribution system. The minor modification with respect to commonly employed standard test distribution networks is the integration of PV- based DG system at PCC and connection of a nonlinear load along with a linear one at load bus. A unit of 100 KW, three- phase DG is integrated at PCC by transformer and feeder. For simulation purpose, a 200 HP- rated three- phase induction motor- based drive is made to act as a nonlinear load while a three- phase unbalanced RL load works as a linear load.

Impact of PQI techniques on power quality

Now to show the impact of PQI techniques on power quality, VQI as well as CQI techniques is applied. In present work, VQI has been performed by STATCOM while CQI has been done by LCL filter and SAPF for DG system and load system, respectively.

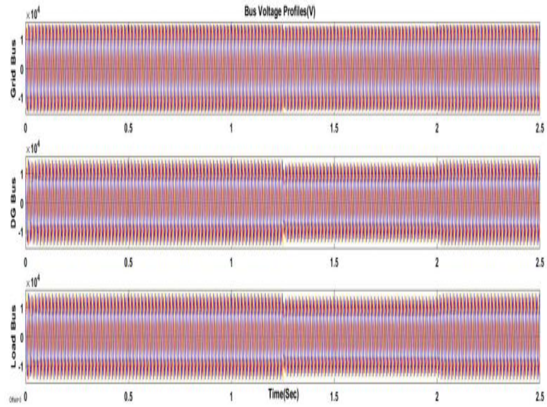

Figure: Bus voltage profiles

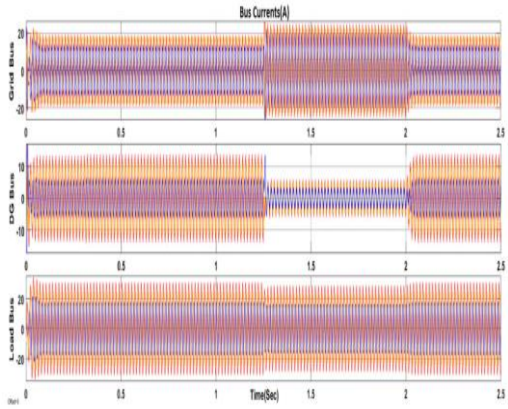

Figure: Bus currents waveforms

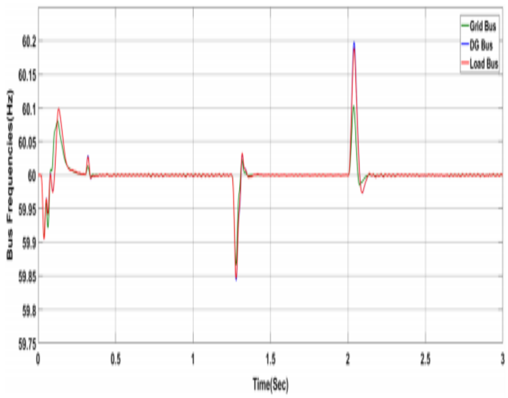

Figure: Bus frequency waveforms

Installed at PCC for mitigating voltage fluctuations caused by DG system, grid faults, and load bus power fluctuations. LCL filter has been employed at DG terminal for filtering harmonics. SAPF is installed at PCC for compensating load bus harmonics, reactive power, and voltage unbalance. The utilization of the renewable based DG has a great impact on improving the reliability of the smart grid system.

- The detailed analysis of different published approaches leads to the conclusion that while assessing power system reliability in the presence of renewable DGs, the solution to deal with the problem of location and sizing units of DG, power quality issues and DG models considering different uncertain factors needs to be further investigated.
- Renewable DG resources are not only the solution to enhance the grid reliability due to uncertainties of RESs, thus the combination of ESSs together with renewable DGs plays an important role in improving system reliability, stability, and power quality.
- However, most of the energy storage technologies are still very expensive, thereby the development of energy storage technology requires policy support from the government in order to expand in the energy market and develop the large-scale manufacturing facilities for storage devices.

Conclusion

In this paper, the reliability has been discussed in detail with its major concepts, methods, and indices. Power quality challenges with grid integration of renewable DG systems are thoroughly reviewed in this paper. Power quality issues are classified into two broad categories (voltage quality issues and current quality issues), and comprehensive review on associated improvement techniques is conducted. All the available PQI techniques for grids integrated renewable energy systems are meticulously and equally discussed including their functioning, pros and cons, and current area of emphasis. In addition, all the PQ issues have been explained by simulating a test distribution system, as well as the significance of applying PQI techniques has been evidenced. Many researchers can place great emphasis on developing the technology improved and cost- efficient online metering and monitoring technologies dedicated to grid- connected DG units. There is also the necessity of developing some advanced control techniques for grid interfacing inverter so as to enhance the capability of DGs to ride through the grid as well as load side disturbances thereby eliminating the need of auxiliary CPDs. Thus, if the aforementioned points are considered for future research, it will definitely promote the hassle- free operation of renewable DG systems and help the world economies in reaching their renewable energy targets a little sooner.

Smart grid applications:

To be equipped with new sophisticated automatic reclosing devices to isolate the faulty part from the rest of the system, thus, the implementation of auto reclosing in existing DN with high penetration of DGs will also need further investigation.

Future work:

To study not only the corrective maintenance strategies, but also the influence of preventive strategies on the reliability evaluation. Severe weather conditions should be also considered in the grid's current and planning performance and reliability since adverse weather events are happening more often than ever before, having serious impacts on the power system.

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