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A review on performance of artificial intelligence and conventional method in mitigating PV grid-tied related power quality events

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ABSTRACT

Integration of renewable energy resources into power networks is the trend in power distribution system. It is to reduce burden of centralized power plant and global emissions, increase usage of renewable energy, and diverse energy supply market. However, solar photovoltaic which is a type of renewable energy resource, is found to generate peak capacity for a short duration only. Next, its output is intermittent and randomness. In addition, it changes behavior of power distribution system from unidirectional to bidirectional. As a result, it causes different types of power quality events to the power networks. Therefore, these power quality events are urged to be mitigated to further explore the potential of solar photovoltaic system. This paper aims to investigate negative impacts of photovoltaic (PV) grid-tied system to the power networks, and study on performance of artificial intelligence (AI) and conventional methods in mitigating power quality event. According to the surveys, power system monitoring, inverter, dynamic voltage regulator, static synchronous compensator, unified power quality conditioner and energy storage system are able to compensate power quality events which are caused by PV grid-tied system. From the studies, AI methods usually outperform conventional methods in terms of response time and controllability. They also show talent in multi-mode operation, which is to switch to different operation modes according to the environment. However, they require memory to achieve above-mentioned tasks. It is believed that unsupervised learning AI is the future trend as it can adapt to the environment without the need of collecting large amount of data before the AI is implemented.

Contents

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1. Introduction

Renewable energy resources are believed to be able to meet the energy challenges that are unable to be solved by traditional centralized power plants. These sources increase the variety of energy supply market, decrease the global emissions and increase long-term sustainable energy supply. However, renewable energy resources are only able to generate its maximum power capacity for a short duration. Consequently, mass research and development in the renewable energy resources sector are happening worldwide in order to increase productivity and effectiveness in using these energies.

Among the renewable energy resources available today, the solar photovoltaic (PV) is the one in favor by most utility companies. Its inherent characteristics, free from pollution and availability in all sizes are further attracting interest from users. These advantages encourage the development of micro-grid PV systems. Micro-grid is an idea of supplying electrical power from a local renewable energy resource like a PV system. When the generated power exceeds consumption, extra power could be transmitted to other areas, and vice versa. Despite the benefits of the PV system, the downside of the PV system is that the output power highly relies on the solar irradiance and ambient temperature. As a result, the PV power production is stochastic and intermittent.

This phenomenon becomes more serious when penetration of the PV system is high (up to gigawatt). Moreover, electrical devices are needed to be incorporated with PV arrays to be connected to the grid for voltage conversion. Thus, this process may create various types of power quality issues to the grid, which would affect the quality of the electrical power undesirably. Therefore, an urgent need is required to investigate potential power quality disturbances caused by the PV system. This is important to enhance the reliability of PV grid-tied system.

Examples of poor power quality events are voltage swell, impulsive transient and harmonic interruption. Different levels of damage to equipment can be caused by these events [1]. Since a PV system is a combination of devices, it contributes different forms of power quality disturbances to the grid and affects quality of delivered power to consumer. Appropriate mitigations for this issue are urged to be found, as the impact of these disturbances is not only affecting an individual but a region.

Power distribution systems are available for more than a century. These systems have undergone a continuous evolution till today. Generation, transmission, distribution and protection have been integrated into power networks for a safe and reliable system. However, integration of PV system to power networks has changed the flow of power from unidirectional to bidirectional. This behavior affects current power networks adversely. Publications show that existing protection environment is insufficient to deal with this change [1] [38]. Hence, compensator equipment and new grid codes are required to integrate as advanced protection and mitigation measurements to the PV grid-tied system.

Artificial Intelligence (AI) is a type of human created intelligence based on machines or software. It is usually used to reduce human working load. Machine learning, which is one of the many areas in AI, is widely used in data analysis. It is able to assign commands from the results of data analysis by sets of algorithm. For example, vast amount of data is collected in power system monitoring for analytical purpose. However, it poses challenges to data analyser to identify potential power quality issues. This scenario can be solved by using AI techniques in a relatively shorter time.

AI has been deployed in many countries to carry operations such as planning, controlling and management in power system operation [2]. It is believed that AI is able to deal with real life uncertainties in a short time. Hence, it greatly reduces the burden of human. In addition, AI is well known in pattern analyzing and it could be used to control key protection components in a power network by learning from historical data. AI has also been implemented in controlling inverter to operate PV system autonomously [59,60].

This paper provides a comprehensive review on the topic of artificial intelligence's (AI) and conventional methods' performance in mitigating power quality events in PV grid-tied systems. Over 80 publications [1–87] are reviewed. The first sets of references [4–41] are on the causes and impact of power quality events due to PV grid-tied system. The second set [42–92] discusses methods that are being used in mitigating power quality events that are caused by PV grid-tied systems. From research findings, power system monitoring, inverter, dynamic voltage regulator (DVR), static synchronous compensator (STATCOM), unified power quality conditioner (UPQC), and energy storage system are approaches that are used in alleviating power quality issues. Performance of both conventional and artificial intelligence methods are reviewed and compared.

This paper is divided into four sections. An introduction is briefed in Section 1. Section 2 describes causes and effects of power quality events in a PV grid-tied system. The following section discusses performances of artificial intelligence and conventional methods in mitigating PV grid-tied system related power quality events. Lastly, the concluding remarks are given in Section 4.

2. Power quality

Power quality is a measure of the standard of delivered power. By delivering low quality electric power to the consumer, it could affect the accuracy of utility metering; cause malfunction to protective relays; cause destructive damage to equipment and others. Since a PV array is generating DC voltage and available in small sizes, unplanned installation of PV system to the grid could lead to power quality events. By increasing the number of PV systems in the grid, it contributes an observable amount of power to the grid. Therefore, any disturbances from PV systems could affect the region adversely. The examples of power quality events that occur due to PV system are power fluctuation, over voltage, etc.

Power fluctuation is a phenomenon where the generated power is unstable. It is generally deemed that power fluctuation is one of the main issues with the PV system. This is due to its inherent characteristic of the photovoltaic cell, where the output strongly relies on the surrounding environments, irradiance and temperature. As a result, the power production is not constant and unstable. In order to validate this event, simulations and experiments were carried out [3–5]. From experiments, these events are usually being triggered during noon time (from 1000 to 1300) [5,13], when the clouds are moving rapidly. Since the cloud behaves as an obstacle to block the irradiance from the sun, active power generated from the PV system will be reduced greatly. In addition, sizing and topology of PV system are believed to be another culprit to power fluctuation [4,5]. It is because a PV system with lower capacity is having a relatively smaller area causing the percentage of the whole PV panel being shaded is large. From research finding [93], power fluctuation of a PV system's standard is only available in technical requirement of Puerto Rico Electric Power Authority (PREPA) for interconnecting wind and solar generation. From PREPA, it only allows a fluctuation rate of 10% of rated capacity in 1-min.

Other than power fluctuation, high current harmonic content (THDI) is also found in PV grid-tied systems. Kow [94] proved that third order LCL filter is unable to filter current harmonic effectively. In general, a PV system outputs DC voltage intrinsically. Hence, an inverter has to be incorporated to connect the PV