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Power Quality Concerns due to Power System Improvements with Renewable Energy Sources and its Remedies

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Abstract

Power quality issues are becoming increasingly important due to the rapid changes in energy network infrastructure caused by technological advancements in distributed generation. Distributed generation involves the use of small-scale, decentralized power sources that can be located close to the end-users, and can include solar panels, wind turbines, and fuel cells. While distributed generation can help to reduce greenhouse gas emissions and increase energy efficiency, it can also create new challenges for the power grid, particularly in terms of power quality. To address these power quality issues, numerous solutions are available at present. One approach is to use advanced control systems that can monitor and manage the voltage and frequency of the power grid in real-time. This can involve using smart inverters that can adjust the power output of distributed generation sources to maintain a stable voltage supply. Other solutions involve the use of energy storage systems, such as batteries or flywheels, which can help to smooth out fluctuations in power output from distributed generation sources. Another approach is to improve the design and operation of the power grid itself. This can involve the use of new transmission and distribution techniques, such as the deployment of microgrids or the integration of energy storage systems into the power grid. Additionally, advances in power

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electronics and communication technologies can be used to improve the reliability and the efficiency of the power grid.

Keywords: Power quality problems, Power quality solution, renewable energy sources, power grid

1. Introduction

A power system's primary goal is to generate high-quality energy, transport it efficiently, and provide an electric energy to the customer at a reasonable price. The conventional power system has no issues with the environment or the availability of energy. Synchronous generators operating in parallel produced pure sinusoidal voltage that complied with quality standards and was delivered to the consumers at that time. Electricity was produced solely from fossil fuel energy sources. Most drives used motors that were powered directly from the power source, without the use of power electronics, flexible controls, or energy-saving measures. Due to a lack of energy-saving techniques, the majorities of lighting loads were also linear, entirely resistive, and did not include power electronics circuitry. Because of this, older power systems' majority of loads was linear and received their power from fully basic supply voltage. Energy must be delivered to all clients at the voltage output magnitude and frequency by the utility grid. Additionally, all consumers are required to use sinusoidal waveform current with a power factor of 1.

Issues with voltage sag, fluctuations, flickering, voltage spikes, and voltage swell are a few of the power quality problems that can occur. Power quality issues [1] are currently of the utmost importance. A complete transformation in the nature of electric loads resulted from the prevalent use of electronic equipment, including knowledge technology equipment, power electronics, such as programmable logic controllers, adjustable speed drives, and energy-efficient lighting. The global economy has become more interconnected as a result of technological advancements, and many events already have profitability that are typically greater compared to those in the previous era. As majority of works carried out relies on the quality of the electric power, it has become a very essential necessity.

Modern power system infrastructure upgrades have transformed how energy would be used, which has also resulted in challenges in power quality [2,3]. Due to the widespread use of power electronics, harmonics and reactive current have been brought into power systems. Harmonics and reactive current are produced in power systems as a result of the switching to drives that are fully converter-controlled from motors that are traditional. In addition, modifications in consumption patterns in the architecture of today's power systems have resulted in novel challenges in power quality. Depth analysis and discussion have also been conducted on the potential state-of-the-art approaches to these issues year after year.

In addition to committing to a 40% non-fossil fuel electricity production by 2030, India has set a Nationally Determined Contribution of a 33-35 percent reduction in the economy's carbon emissions intensity compared to 2005 levels. The nation has set a goal of generating 175 GW of installed of green energy by the end of 2022, comprising 60 GW of onshore wind. India’s Renewable Energy (RE) transition practice against targets is shown in Fig.1.

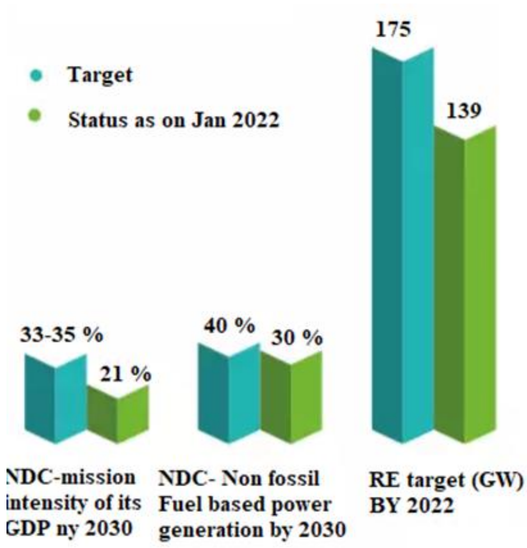

Figure 1. India’s RE transition practice against targets

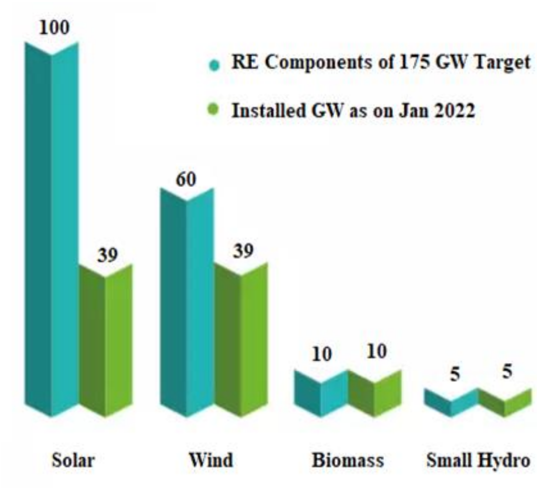

Figure 2. India’s RE components installed as on Jan 2022

This research's main objective is to investigate new issue in the quality of power delivered and to provide an optimum, most effective solution. This study offers an in-depth review of literature on the problems of power quality that usually arise because of the latest changes brought into the power system infrastructure.

This work is structured as follows: Section II categorizes power quality issues and IEEE standards related to it, as well as explores the origins of these problems. New problems with power quality have developed as a result of modifications in generating techniques. Section III addresses further power quality solutions that have emerged as an outcome of modifications carried out in transmitting and consuming devices. The scope of the additional research is recommended.

2. Power Quality Problems

Power quality problems refer to any deviation or distortion from the ideal characteristics of the electricity supply, which can affect the performance and efficiency of electrical equipment and devices. Power quality, as previously stated, is the retention of a power system's rated voltage and current at levels that are close to sinusoidal in frequency and magnitude. The system's efficiency would suffer from any power quality interruptions. Most of the time, regulation of the power quality primarily refers to voltage management. This is such that voltage can generally be regulated more readily than current.

More specifically, several parameters can be used to describe the quality of power, including service continuity, magnitude fluctuation of the voltage, transient voltages and currents, harmonic content and so on. Power quality problems can be caused by a variety of factors, including electrical noise, lightning strikes, power system faults, and equipment malfunction. It is important to identify and address power quality problems to ensure the safe and reliable operation of electrical equipment and devices.

Various power quality problems such as voltage imbalance, short duration voltage variation, voltage flicker, long duration voltage variation, transients, and power frequency variation and so on are shown in Fig.3. Researchers may employ the reality that poor power quality leads excessive economic and energy to demonstrate the relevance of power quality concerns. Both the producers and the consumers are forced beneath economic burden. Transmission line power flow is frequently disturbed by unstable voltage and frequency.

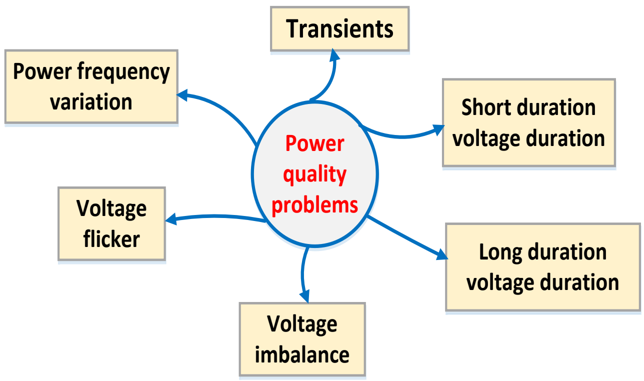

Figure 3. List of power quality problems

One of the main problems with power quality is transients which are defined as abrupt but large variations from typical current or voltage values. Normally, transients last for 200 millionths to half a second. It is usually brought on by lightning, electrostatic discharges, switching between loads, or poor wiring.

In electrical engineering, a transient refers to a sudden, temporary change in an electrical circuit that can last from microseconds to milliseconds. Transients can be caused by various factors, including the switching of electrical devices, lightning strikes, or other disturbances in the power system. Transient events can cause various problems, including equipment damage or failure, electromagnetic interference, and voltage and current waveform distortions. In some cases, transients can also pose a safety hazard to people working with electrical equipment. To address transients, power system engineers use various methods to protect electrical equipment which may involve using surge protection devices, such as surge suppressors or surge arrestors, to limit the voltage spikes caused by transient events. It may also involve using filters or other waveform conditioning devices to reduce the distortions caused by transients.

The two types of transients are namely, Impulsive and Oscillatory. Short Duration Voltage Variations (SDVV) are defined as fluctuations in the supply voltage over a period not exceeding one minute that are driven on by faults, the energization of huge loads with significant inrush currents, or changing rapidly significant reactive power requirements of the loads. SDVV are classified into two types namely, sag and swell. Over voltages or under voltages are two possible Long-Duration Voltage Variation (LDVV) caused by alterations in the system's load and system switching activities. Plots of rms voltage against time are frequently used to illustrate such fluctuations.

Voltage imbalance refers to a situation where the voltages in a three-phase power system are not equal. In a balanced three-phase power system, the voltage magnitudes and phases are equal. However, due to various factors such as unbalanced loads, faulty equipment, or uneven distribution of loads, the voltages in the three phases can become imbalanced. It can cause overheating and premature failure of equipment, as well as uneven power distribution and increased energy consumption.

Voltage flicker is a rapid, repetitive change in the voltage level of an electrical system, typically caused by sudden changes in the load on the system. It can be caused by various factors, including the operation of large loads such as motors or welding equipment, or by the switching of loads on and off. This may involve adjusting the load distribution, installing voltage regulation devices such as voltage regulators or capacitors, or improving the overall power quality of the system [4]. The international standard for voltage flicker is IEC 61000-4-15, which defines measurement methods and limits for voltage fluctuations and flicker. Power system operators and engineers use this standard to ensure that the voltage flicker level in their electrical systems is within acceptable limits [5].

Power frequency variation refers to the deviation of the electrical power frequency from its nominal value, which is typically 50 or 60 Hz, depending on the country. Frequency variations can occur due to various factors, including changes in the power demand, fluctuations in the power generation, or disturbances in the power transmission and distribution network. Power frequency variation can cause various problems, including the disruption of electrical equipment, changes in the performance and efficiency of electric motors, and the malfunctioning of electronic devices that rely on accurate frequency synchronization. In some cases, it can even cause equipment damage or failure. To address power frequency variation, power system operators use frequency control measures to ensure that the frequency remains within acceptable limits. This may involve adjusting the power generation, managing the power demand, or using frequency regulation devices such as governors or load-shedding systems. The international standard for power frequency variation is IEC 60038, which defines the nominal frequency values for electrical power systems, as well as the tolerance limits for frequency deviation. Power system operators and engineers use this standard to ensure that the power frequency in their electrical systems is within acceptable limits [6].

Power Quality Issues Due to Changes Adopted in Generation

Changes in methods of generation can cause various power quality issues. Here are some of the most common ones:

Voltage fluctuations: When large amounts of renewable energy sources such as wind or solar power are connected to the grid, it can cause voltage fluctuations due to their intermittency. This can lead to voltage sags [7] or swells, which can damage sensitive electronic equipment.

Harmonic distortion: Power electronics devices such as inverters, rectifiers, and switching power supplies used in renewable energy systems can produce harmonic distortion in the power grid. This can result in increased heating in equipment, reduced efficiency, and interference with communication systems [8].

Transient overvoltage: The sudden disconnection of large loads or the rapid switching of capacitors can cause transient overvoltage, which can damage equipment.

Frequency variations: Changes in the frequency of the power grid can also occur due to variations in the generation of power. This can lead to synchronization issues, tripping of protective relays, and failure of motors and other equipment [9].

Power factor issues: The use of renewable energy sources can cause power factor issues, which can affect the efficiency of the power system. Power factor is a measure of the amount of real power versus reactive power in a system. To address these power quality issues, power utilities can use various mitigation techniques such as power conditioning equipment, reactive power compensation, and harmonic filters. They can also implement advanced monitoring and control systems to ensure the stable operation of the power grid [10].

Power Quality Issues from transmission

Changes in methods of transmission can have significant impacts on power quality. Power quality refers to the characteristics of the electricity supply that affect the performance of electrical equipment. Any changes in the transmission system that cause variations in the voltage, frequency, or waveform of the electricity supply can lead to power quality issues.

The sources of energy can introduce fluctuations in voltage and frequency, leading to power quality issues such as voltage sags, voltage swells, and harmonics. However, the use of HVDC systems can introduce new power quality issues, such as electromagnetic interference and voltage instability [11].

To mitigate these power quality issues caused by changes in transmission methods, various technologies such as voltage regulators, capacitors, and filters can be employed. Additionally, standards and regulations such as the IEEE 519 standard for harmonic distortion and the IEC 61000 series for electromagnetic compatibility can provide guidelines for designing and operating transmission systems to ensure acceptable power quality levels.

Power Quality Issues from Consumption

Consumption methods can have a significant impact on power quality. Here are a few ways in which changes in consumption methods can lead to power quality issues:

Increased use of electronics: With the proliferation of electronic devices, the amount of harmonic distortion in the power system has increased. This can lead to voltage fluctuations, flicker, and overheating of equipment [11].

Use of renewable energy sources: While the use of renewable energy sources can reduce carbon emissions, they can also cause power quality issues. Solar and wind power can cause voltage fluctuations and instability in the power grid.

Electric vehicle charging: The widespread adoption of electric vehicles can cause power quality issues, especially during peak charging times. The sudden demand for power can cause voltage sags, flicker, and harmonic distortion.

Distributed generation: The use of distributed generation, such as rooftop solar panels, can cause voltage fluctuations and instability in the power grid [12,13].

Energy efficiency measures: The use of LED lighting and appliances that are energy efficient, can cause power quality issues due to their non-linear loads.

Overall, changes in methods of consumption can lead to a variety of power quality issues. It is important for power system operators to monitor and manage these issues to ensure a reliable and stable power supply.

3. Potential Solutions to Address Power Quality Issues

- Voltage regulation: Ensure that the voltage at the power source is stable and within the acceptable range. This can be achieved through the use of voltage regulators or power conditioners.

- Harmonic filtering: Install harmonic filters to reduce the level of harmonic distortion in the electrical system.

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- Surge protection: Install surge protectors to prevent equipment damage from voltage surges or lightning strikes.

- Grounding: Ensure that the electrical system is properly grounded to reduce the risk of electrical noise and electromagnetic interference.

- Power factor correction: Install power factor correction equipment to improve the efficiency of the electrical system and reduce the risk of power quality issues.

4. Conclusion

The power system modernization has led to new power quality problems due to changes in methods of producing energy, transmitting, and consuming. These problems can lead to voltage sags, interruptions, transients, harmonics, and other issues that can disrupt power supply and cause equipment damage.

Great suggestion for a study topic!

- Power quality is a critical aspect of power system operation, as it directly impacts the reliability and performance of the electrical equipment and the overall system. As power systems become more complex and interconnected, they are also increasingly susceptible to various disturbances and failures.

- Evaluating and understanding the harmonics profile of renewable energy systems and new types of consumer loads can help ensure that these systems are designed and operated in a way that minimizes their impact on the power system.

- A harmonics level analysis is therefore important to identify and quantify the presence of harmonics in a power system, especially if the transmission line is lengthy. This analysis can help determine the source of the harmonics and their potential impact on the system.

- The management and mitigation of power quality problems during the changeover of a microgrid to and from isolated mode and the grid tied mode is an active study topic in the field of microgrid design and operation.

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