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Overview of Power Quality Issues and Improvement Techniques

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Abstract:

This paper will assist in identifying various energy system best problems and providing a quick idea about their solutions through a comparative study. The term "electric energy first-rate" (PQ) is commonly used to assess and maintain good electricity quality at the levels of generation, transmission, distribution, and use of AC electrical electricity. Nonlinear masses. As a result, strength gratification is expressed in terms of voltage, current, or frequency. The modelling and simulation of an electricity distribution system were accomplished using MATLAB/Simulink in this paper. The gap between the quality of power delivered and the quality of power required for reliable functioning of load equipment is defined as power quality problems in this study. The new enhanced power electronic concept is based on Custom Power Devices (CPDs) mainly distributed static synchronous compensator (D-STATCOM), dynamic voltage restorer (DVR), and unified power quality conditioner (UPQC) due to the ineffectiveness of classic compensating devices un reducing power quality disruptions, new compensating devices have been created. The major goal of this study is to look behind the resources and determine the most typical energy exceptional problems that exist in the power system, as well as the solutions that can be used to address these issues.

Keywords:

Introduction:

Along with natural causes such as lightning, flashover, equipment failure, and faults, there are also pressured causes such as voltage distortions and notches that can pollute AC transmission systems. Because they draw non-sinusoidal modern and behave as nonlinear masses, some patron's devices foul the machine. As a result, power quality is measured in terms of voltage, current, or frequency deviation in the supply system, which can lead to equipment failure or malfunction. Furthermore, a significant amount of energy is squandered because to the presence of negative charge in the supply. The existence of voltage harmonics, surge, spikes, notches, sag/dip, swell, unbalance, fluctuations, system flaws, flickers, outages, and so on are all common electrical exceptional concerns linked with the voltage on the point of unique coupling where many hundreds are connected. These issues exist in the delivery device as a result of various disturbances within the device or the existence of various nonlinear masses which are furnaces, uninterruptible power supplies (UPSs), and adjustable speed drives (ASDs). Poor power factor, reactive power burden, harmonic currents, unbalanced currents, and an excessive impartial current in polyphase structures due to unbalancing and harmonic currents generated through some nonlinear hundreds are some strength first-rate issues related to the cutting-edge drawn from the AC mains. Furthermore, due to poor power quality in the services, a significant quantity of energy is wasted. These power quality issues result in capacitor bank failure, increased losses in the distribution system and electric machines, noise, vibrations, over voltages and excessive current due to resonance, negative sequence currents in generators and motors, especially rotor heating, dielectric breakdown, interference with communication systems, signal interference, relay and breaker malfunctions, false metering, interference with motor controllers and digital control, and false metering. Power electronics devices are employed by a significant number of industrial, commercial, and residential clients at their installations, and these devices are sensitive to power quality disruptions. The difficulties can be solved in one of the following ways, according to this viewpoint: Equipment and electrical systems should be designed to prevent equipment or systems from malfunctioning due to electrical disturbances, determine the medium that is conveying the electrical disturbance and take steps to limit or eliminate its effect, Use power conditioning equipment to treat the symptoms of a power quality problem. When a power quality problem occurs, power conditioning equipment helps to reduce the situation, Determine the origin and solution of a power quality issue by analyzing the symptoms.

Transients:

It's an unexpected and fleeting occurrence. It's the abrupt transition from one functioning state to another. Transients can be divided into two groups: Impulsive and oscillatory.

Impulsive Transient: An impulsive transient is a one-directional (positive or negative) non–power frequency shift in the steady-state condition of voltage, current, or both. The peak and decay times of impulsive transients are typical characteristics. Due to the high frequency nature of impulsive transients, circuit components can quickly change their shape, resulting in significantly different characteristics when viewed from various portions of the power system. They are rarely carried out far away from the source.

Oscillatory Transient: A non–power frequency change in the steady-state condition of voltage, current, or both that contains both positive and negative polarity value is known as an oscillatory transient. The polarity of an oscillating transient varies fast based on its instantaneous value.

Short duration voltage variations: Short duration voltage variation occurs when the RMS value of voltage deviates for less than one minute. Depending on its duration, each form of variation can be classified as immediate, momentary, or temporary.

Long duration voltage variations: Long duration voltage variation occurs when the RMS value of voltage deviates for more than one minute.

Voltage imbalance: The highest divergence from the average of the three-phase voltages or currents, divided by the average of the three-phase voltages or currents, stated in percent, is known as voltage imbalance. The percent unbalance can be calculated by dividing the negative or zero sequence components by the positive sequence component. Single phase loads on a three-phase circuit are the source of voltage unbalances. Blown fuses in one phase of a three phase capacitor bank can potentially cause voltage unbalance. Single-phasing situations can cause severe voltage unbalance.

Power quality problems:

1. Voltage sags: Voltage sag is an abrupt drop in the RMS voltage of between 0.1 and 0.9 pu from its nominal value, lasting anywhere from 0.5 cycle to several seconds. Transients are defined as sags with duration of less than 0.5 cycles. There are different sorts of voltage sag: symmetrical and asymmetrical.

2. Voltage swell: A voltage swell is a sudden increase in the RMS voltage at a point in the electrical system between 1.1 and 1.9 pu that can last anywhere from 0.5 cycle to several seconds. Transient swells are defined as those that last shorter than a cycle.

3. Harmonics: Harmonics are spectral components that occur at integer multiples of the fundamental frequency. Nonlinear loads are the primary source of harmonic voltage distortion. Additionally, there are various factors that contribute to voltage harmonics, which are, Because of tiny variations from the ideal geometry of the machine, the voltage generated by a synchronous machine is not exactly sinusoidal. The transmission of electrical energy from generation stations to loads is not totally linear in the power system. The power transformer, for example, has non-linearity due to magnetic flux saturation in the iron core of the transformer. The high voltage direct current (HVDC) connection is a good example of a non-linear power system component. Power-electronics components that only conduct for a portion of a cycle are used to convert AC to DC and vice versa. Harmonic heating and torque pulsation are two impacts of harmonics. The equipment is eventually damaged as a result of these effects. Harmonics are particularly vulnerable in transformers and other industrial equipment. Harmonic voltage distortion can cause equipment malfunction and control mistakes.

4. Poor load power factor: The power factor of a power system is the ratio of real power flowing to the load to visible power in the electric circuit. It is a crucial term in the power system. Real power is the capacity of a circuit to do work in a given amount of time, while apparent power is the product of current and voltage. Because of the numerous uses of semiconductor devices or nonlinear loads in power systems, the wave shape of voltage and current is distorted, resulting in apparent power being greater than real power and a low power factor in the circuit. In an electric power system with a low power factor, the amount of current flowing in the circuit consumes greater for the same amount of useable power delivered than a load with a high power factor. When a circuit has a high current, the amount of energy wasted in the circuit is greater, necessitating the use of longer cables and other electrical equipment.

5. Notching in low voltage: Voltage notching is a disruption in the voltage waveform that occurs when current is transferred from one phase to another. This is an example of a power quality issue. The voltage notch disrupts the voltage waveform and stimulates the system's natural frequency, which is normally in the radio frequency range, introducing higher harmonic and non harmonic frequencies than those seen in higher voltage systems. The high frequency fluctuations in the voltage of the converter circuit are caused by the precision frequency. Overloading in electromagnetic filters is caused by voltage notch damage to capacitor banks, parallel resonance, signal interference in logic and communication circuits, and voltage notch damage to capacitor banks.

6. Voltage imbalance: The ratio of maximum departure from the average of three phase voltage and current to the average of three phase voltage and current is known as voltage imbalance or unbalance. Unbalanced incoming supply lines, non-equable transformer tap settings, large single phase distribution transformers on the system, faults in power transformer grounding, open delta connected transformer banks, unequal impedance in conductors of power supply wiring, and heavy reactive single phase loads such as welders are all factors that contribute to voltage imbalance.

7. Power supply disturbance: A complete sin wave of voltage and current was necessary for optimum power quality in a power system. However, disturbances in supply power such as interruption, distortion, sag, swell, flicker, overvoltage, under voltage, and so on cause many types of power loss in the system. Short-term voltage interruptions cause relay tripping, overheating in the system, power supply burnout, semiconductor component damage, and other issues.

Power quality improvement techniques:

The gap between the quality of power delivered and the quality of power required for reliable functioning of load equipment is known as power quality difficulties. Over the years, a variety of power enhancement devices have been created to safeguard equipment against power outages. The following are some examples of effective and cost-efficient measures:

I. Power conditioning devices
II. Custom power devices.

I. Power conditioning devices:

i. **Lighting and Surge arrestors**: Arrestors are used to protect transformers from lightning and voltage surges; however they are far from adequate in terms of reducing voltage disturbances and protecting sensitive electronic circuits from voltage surges.
ii. **Transient Voltage Surge Capacitors (TVSC)**: The spikes are clamped to a safe level for the sensitive loads in these units. The electrical system will be protected against most transients if an overall facility protection strategy is implemented.
iii. **Filters**: Protect against low-voltage noises with a high frequency. Filters are designed to allow the fundamental frequency to pass through while rejecting higher frequency noise such as EMI and Radio Frequency Interference (RFI). Harmonics filters keep nonlinear loads' harmonics from returning to the power source.
iv. **Isolation transformer**: Filtering and isolation are provided to some extent. Isolation transformers reduce electrical noise by magnetically isolating the primary and secondary coils. Noise and harmonics are reduced by using an isolation transformer, but it does not compensate for power interruptions or voltage variations.
v. **Voltage regulators**: Under significant input voltage changes, voltage regulators keep the output voltage at the nominal level. Regulators are divided into three categories:
    a) Tap changing transformer: Designed to automatically transfer taps on a power transformer to adapt for varying voltages. When compared to alternative voltage control technologies, tap changers have the following advantages: high efficiency, wide input range, high over load current capability, and effective noise isolation. Noise is produced when changing taps, and there is no waveform correction. The tap-changing transformer is slow to respond, has contact erosion, requires routine maintenance of its parts, is large, and requires frequent transformer oil replenishment.
    b) Buck boost: The transformer is not isolated, thus it works in a similar way to the changers. It has the ability to endure high in-rush currents, which is one of its advantages. Noise is created when changing taps, there is inadequate noise isolation, and there is no waveform correction.
    c) Constant Voltage Transformer (CVT): Ferro resonant transformer is another name for it. The CVT is a static regulator that maintains a nearly constant output voltage even when the input voltage varies widely. Superior noise isolation, very precise output voltage and current limiting for overload protection are among the benefits. The transformer requires low maintenance due to its lack of moving parts. Large size, noticeable noise, and low efficiency are all disadvantages.
vi. **Uninterruptible Power Supply (UPS)**: In the event of a complete power outage, UPS systems provide protection. Off-line UPS, Line interactive UPS, and on-line UPS are the three main UPS topologies, each giving varying levels of protection. According to the load need, topology can be considered based on efficiency, cost, and transfer time. Furthermore, UPSs necessitate a high level of maintenance due to battery leaking and require replacement every five years.

II. Custom power devices:

Customers are demanding high-quality electrical electricity from electric companies. Power quality issues can be solved with custom power devices. Custom power is based on the employment of power electronic controllers in the distribution system to provide reliable and high-quality power to sensitive equipment that is susceptible to power quality variations. Custom power devices are divided into two categories:

I. Network reconfiguring type
II. Compensating type

I. Network reconfiguring type:

Static current breakers (SCB), static current limiters (SCL), and static transfer switches are examples of devices used to improve power quality (STS).

i. **Static Current Limiter (SCL)**: By promptly injecting a series inductance into the fault line, SCL restricts the fault current. It comprises of a current limiting inductor and a pair of anti-parallel gate turns off thyristors switches with snubbers (RC circuit). In the event of a fault downstream, the currents limiter is linked in series with a feeder to limit the current. The opposing poled switch remains closed in a healthy state. When a problem is detected, these switches open, allowing the fault current to flow through the current limiting inductor.
ii. **Static Circuit Breaker (SCB)**: A faulty circuit is broken significantly faster by a SCB than by a mechanical circuit breaker. The limiting inductor is linked in series with an opposite poled thyristor pair in a SCB, which is nearly identical to that of a SCL. The standard current carrying elements are Gate Turn Off Thyristors (GTO). When a fault is discovered, the thyristor pair is turned on at the same time that the bidirectional switch GTO is turned off. The fault current will be forced to flow through the limiting inductor as a result of this. If the fault persists after a few cycles, the thyristor pair is blocked. At the next possible zero crossing of the current, the current through the thyristor pair will start to flow.
iii. **Solid-State Switch Based on the Thyristor Device (STS)**: The ON-state and OFF-state features of a thyristor are used to create an intelligent switch that can select between two power sources and deliver the best available power to the electrical load [9]. By moving loads from the afflicted feeder to a backup feeder, the STS can usually keep voltage sags and interruptions to less than 0.5 cycles in most circumstances. STS has a very fast response time, but when both feeders are afflicted by voltage disturbances, STS is no longer acceptable.

II. Compensating type:

Voltage regulation, power factor correction, load balancing, and active filtering are all done using this device. Distributed Static Compensator (DSTATCOM), Dynamic Voltage Restorer (DVR), and Unified Power Quality Conditioner (UPQC) are examples of compensating types.

i. **Dynamic Voltage Restorer**: DVR stands for compensating custom power. A compensating voltage is generated by the DVR's Voltage Source Inverter (VSI), which is then injected into the distribution system via a series injection transformer. The higher order harmonic components are removed from the inverter output voltage by a passive filter installed between the VSI and the injection transformer. The active power for the compensation is provided by an energy storage device connected to the VSI. The ability of DVR to compensate for sags is determined on the range of sags and the quantity of the energy storage.

ii. **DSTATCOM**: Small voltage variations can be compensated with shunt devices, which can be controlled with reactive power injection. The ability to control the fundamental voltage at a given point is determined by the supply impedance and the load's power factor. Because the supply impedance is usually low and the injected current must be quite strong to improve the load voltage, current injection compensation of a voltage dip is particularly difficult to achieve.

Conclusion:

The numerous power quality enhancement strategies and solutions were explored in this study. Poor power quality can have serious consequences for our power system, such as overheating in system equipment, overloading, harmonic generation, waveform distortion, and so on, which can be mitigated using a variety of techniques such as filters, fact devices, and power factor corrected circuits, among others. The FACTS devices are used to increase the transmission line's power transfer capacity and stability margins. Under various faults and nonlinear load conditions, the bespoke power devices are effective in restoring the sensitive load voltage to its pre-fault value and smoothing it out. DSTATCOM, UPQC, and DVR are just a few of the bespoke power devices available. Researchers, users, and suppliers of electrical power will benefit from this paper's guidance on power quality.

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