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Solution Methods and Recommendations for Power Quality Analysis in Power Systems

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ABSTRACT

Power quality means to maintain or compensate the nominal size and frequency of the near sinusoidal nominal voltage and current of the power system. As an undesirable condition in the power quality, the energy loss leads to a decrease in the efficiency of the system and the failure in sustainability in energy. In most cases, the control of the power quality means that the voltage is controlled, ie, the frequency balance. This is because in most cases the tension can be more easily controlled from the current. More specifically, power quality can be explained by some parameters such as continuity of service, change of voltage magnitude in transient voltages and currents, and harmonic content. To define the importance of power quality problems, we can say that poor power quality leads to unnecessary power and economic waste. This also directly affects the risk of reliability in energy. In addition, it creates a financial burden for suppliers and consumers. Unstable voltage and frequency often create problems with the power flow in the transmission line. Several methods are used to solve basic power quality problems. In this study, energy quality solution methods, especially reserve requirements, have been examined and solution suggestions are presented.

1. Introduction

Power quality is undoubtedly one of the most important factors affecting the profitability and productivity of the industry and is of great importance for the companies working in the high-competitive business environment [1-3]. Power Quality problems; it is defined as problems that cause incorrect operation of the consumer's devices or errors in systems due to changes in voltage, current and frequency [4]. These problems, especially high technology used in the production stages can be cut and can cause huge economic losses. All types of power quality problems are described [5]. In some studies, this problem has been explained extensively and definitions and incidence frequencies of the most common power quality problems have been investigated [6]. Mains power quality will be presented and solution methods applied to solve problems arising from proceses and their superiority. Improvements are aimed at stability in process inputs, savings in energy use, prolongation of the service life of the equipment in the electricity distribution system, and reduction in breakdown labor and maintenance costs directly reflected in operating costs. These additional costs provide a positive impact on production quantities, but are reflected in product unit costs due to the burden of costs. Today, the increase in demand for electric energy has led to a more reliable and higher quality energy definition.

As in all areas, total quality is very important in electrical energy. Since the approach to power quality can be achieved through a team work between the producer, the transmitter, the distributor and the consumer company, each one needs to know and fulfill its responsibilities. The quality of the power may vary depending on the type of inspection being made or who made it. For example, the power quality for an electric generator can be defined as the reliable transmission of the electric energy, but the electric power for the generator is the electric form necessary for the tool to operate in the prescribed manner [7]. However, when the electricity generation is made for the users, it should be based on the user's point of view. For this reason, the power quality problem can be defined as "the changes in voltage, current and frequency that will cause the user's appliances to malfunction or not function at all". Since energy production systems are thought to be able to influence the voltage of the generated energy, it is seen that the determinations made on the concept of power quality are mostly concerned with system voltage. As in the case of a short circuit, large current variations may be caused by significant differentiation in tension, but the basic criterion must be voltage. The evaluation process of the problem of power quality is shown in fig.1 [1]. From the flow diagram, it can be seen that the first step of this evaluation is to define the problem category. There are basically five problem categories: voltage imbalance, voltage interruption, flicker, transient and harmonic distortion. Once the categories have been determined, the characterization of the problem is made by measuring or collecting data to find the causes and the effects of the equipment. The next step is to define the solution flow and the evaluation of the solutions. The last step is to evaluate the most appropriate solution to achieve the most economical result from all possibilities.

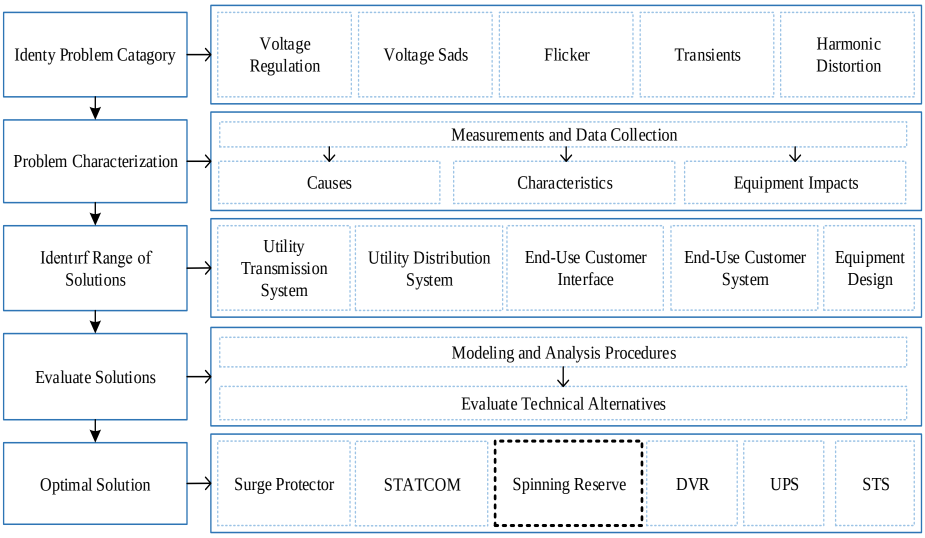

Figure 1. Flow diagram for evaluation of power quality problems [1]

Some basic problem mitigation methods are used for power quality such as Power Quality solution methods, Static Synchronous Compensator (STATCOM), Unified Power Quality Controller (UPQC), Uninterruptible Power Supply (UPS) and Spinning Reserve (SR). SR has produced different approaches to measure this parameter of renewable resources, but it does not suffer from a satisfactory outcome. A D-STATCOM with a shunt-connected special power device corrects the power factor and current harmonics [8]. It also provides filtering, voltage regulation and load balancing in the distribution bus. Sometimes referred to as an active power filter consisting of a shunt-coupled voltage source converts IGBTS and driven by PWM [9-11]. IGBTs with high switching frequencies are often used to improve speed. The capacitor is used for energy storage and acts as passive filter based on condenser. UPQC is an integration of series and shunt active filters connected in series [13]. The serial components compensate for feed-side disturbances such as voltage sags, vibration, voltage imbalance and harmonics [14-16]. These methods are compared with advantages and disadvantages and the most effective solution method for increasing the quality of the power is determined. Consequently, the aim is to provide quality and sustainable energy.

2. Impacts Of Power Qualıty Issues

The most important problem with regard to power quality is voltage fluctuations, which generally show changes in voltage amplitude. This problem, which means an instantaneous increase in voltage beyond normal tolerance levels, refers to the decrease in supply voltage magnitude [17]. There are many variations of this problem. In general, the longest deterioration lasts less than a few seconds [18]. The main cause is the sudden change, such as fluctuations, and the voltage, current, or both can be in a steady state.

Another problem of power quality is the long-term voltage interruption. Approximately a few milliseconds are defined as meaning a total interruption or reduction in the load current and cause a fault in the data processing process. In addition, another common problem in the system is a noise that is defined as noise. This problem is the high-frequency signal overlapping with the main waveform of the power system, which causes data loss in the system [19]. Another problem that is investigated in the study and identified as Flicker is the fluctuation of voltage between 90% and 110% of nominal from the power supply and generally damages the load side of the system [20]. The shape distortion of the frequency wave is defined as a stable deviation from the ideal frequency wave frequency and is characterized by the spectral content of the slice. Variations in the system frequency are deviations of the power system from the nominal value of the fundamental frequency (50 Hz for our national power system).

The electrical line noise is usually expressed in the form of Electromagnetic Interference and Radio Frequency Interference. These problems also cause unacceptable events in the circuitry of computer systems. The causes of the disturbances include motors, relays, motor control devices, broadcast transmissions, microwave radiation and distant electric storms [21]. The interruptions experienced in the power system are long-running and zero-voltage conditions over two cycles. It may be due to interruption of the power distribution in the circuit breaker in an electrical system or by interruption of the mains electricity. A blackout directly leads to data loss or quality deterioration and damage to the equipment used in the system [22]. These are generally divided into two groups; very short interrupts and long interrupts. Short interruptions occur when the source lasts from a few milliseconds to one or two seconds. This is usually due to the opening of protection devices and automatic reclosure to disable a faulty part of the network. But the main interrupt causes the main error causes insulation failure, lightning and isolator flashover [23]. Another interruption is that the power supply lasts longer than 1 to 2 seconds. At this point, the hardware of the power system network is out of order, storms and objects. If this interruption occurs, the equipment on my site can be stopped [24].

In practice, the increase in voltage occurs as an instantaneous increase in the voltage experienced beyond normal tolerances, and the duration is more than one cycle and is typically less than a few seconds. Consequently, a general list of power quality problems is shown in Table I. The right order of four, the four most effective sorting according to the severity of the effect of quality, is shown in Table I below.

Table 1. Problem of Power Quality Issues

Power Quality Issues	Causes	Effects
Voltage Fluctuations	Load switching	Over/Under voltages, flickering of lighting
Voltage Sag	Fault in the system, starting of large loads, excessive network loading, Source Voltage Variation, Inrush current, Inadequate wiring	Overloading problems. Intermittent Lock-up, Grabbled data
Voltage Swell	Start/stop of heavy loads, Source Voltage Variation, Inrush current, Inadequate wiring	Data loss, Damage of equipments, Intermittent Lock-up, Grabbled data
Long Time Voltage Interruption	Failure of protecting devices, insulation failure or control malfunction	Malfunction in data processing equipments
Noise	Electromagnetic interference, improper grounding	Disturbances in the sensitivity of the equipments, data loss

Waveform distortion	Noise in the system	Overheating and saturation of the transformers
Power frequency variations	Heavy load	Mainly affects the motors and sensitive devices
Harmonics	If a sinusoidal voltage is applied across the nonlinear load	Losses in electrical equipments, Overheated transformers or motors, Lock-up, Grabbled data
Voltage spike	start/stop of heavy loads, badly dimensioned power sources or badly regulated transformers	Data loss, flickering of lighting and screens, stoppage or damage of sensitive equipment,
Transient	PE commutation, RLC snubber circuits, Lightning	Disturbance in electrical equipments
Flicker	Fluctuation of supply voltage	Damage the equipments at the load side
Spinning Reserve	Load shedding	used by system operators as a response to unforeseen events such as sudden load changes and outages

3. Factors Of Dısturbıng Power Qualıty

Since energy production systems are thought to be able to influence the voltage of the generated energy, it is seen that the determinations made on the concept of power quality are mostly concerned with system voltage. As in the case of a short circuit, large current variations may be caused by significant differentiation in tension, but the basic criterion must be voltage. Table 2 shows some effects that impair the power quality.

Table 1. Factors Affecting On Power Quality

Category			Spectrum of Frequency	Time	Voltage on The Top
Ttransients	An impact	Nano sec.	5 ns rise	<50ns	
		Micro sec.	1 mics rise	50 ns-1 ms	
		Milli sec.		>1 ms	
	Oscillatory	Low frequency	< 5 kHz	0,3-50 mic. Sec.	0-4 p.u
		Medium frequency	5-500 kHz	20 mikro sec.	0-8 p.u
		High frequency	0,5-5 MHz	5 mikro sec.	0-4 p.u
Short-term changes	Sudden	Drop		0.5-30 period	0,1-0,9 p.u
		Rise		0.5-30 period	1,1-1,8 p.u
	Short-term	Cessation		0.5-3s	< 0.1 p.u.
		Drop		30 period-3s	0,l-0.9 pu
		Rise		30 period-3s	l.l-1.4p.u.
	Temporary	Cessation		3 s- 1 min.	< 0.1 p.u.
		Drop		3 s- 1 min.	0.1-0.9 p.u.
		Rise		3 s- 1 min.	1.1-1.2 p.u
Long-term changes		Permanent interruption		> 1 min.	0.0 p.u.
		Allowances		> 1 min.	0.8-0,9p.u.
		Height		> 1 min.	1.1-1.2 p.u.
		Imbalance		Persistent state	0-%0.1

As seen in Table II, transient events are used to describe unwanted but short-lived events in the analysis of power system changes. Damped oscillations due to the construction of energy systems in drenched capacitor and coil circuits are the most common words heard by power engineers as a transient phenomenon. Commonly used shapes and transient events are changes that occur during the transition of a system from one permanent state to another. However, this definition needs to be classified, searched, and unexplained because it can be used for all unusual events that occur in power systems.

3.1. Short-term changes

Temporary events in transient events are defined as transient, brief and transient according to their duration. Faults in the power system, the disconnection of loads with high starting currents, and the disconnection in the distribution system can be shown as the basis for short-time voltage changes. The voltage increase is 1.1 p.u. for a period of 0.5 period to one minute of the effective value of the voltage at the frequency of the power system. to 1.8 p.u. is a rising value.

Voltage drop is the instantaneous drop in an electrical power system, resulting in a short recovery of the voltage after a few cycles to a few seconds. The voltage drop is characterized by calculating root mean square, over a cycle in each half cycle, and each cycle exceeds one half of the previous cycle. The voltage increase is related to the system fault as well as the voltage drop. Voltage rise occurs in faultless phase during single phase - ground short circuit. Voltage surge can occur when switching large loads or switching large capacitors on.

Voltage drops and interruptions are a problem in many devices connected to the plant. These cause Power Quality problems very often. A voltage drops or interruption of several hundred milliseconds can cause harmful consequences for a few hours.

The most sensitive applications are:

- The complete and uninterrupted production line (printing, steel works, paper mills, petrochemicals, etc.) that the process can not condone for any temporary closing of any item in the chain
- Illumination and security systems (hospitals, airport lighting systems, public buildings and high buildings, etc.)
- Computers (data processing centers, banks, telecommunication, etc.)
- Auxiliary facilities required for power plants.

3.2. Long-term changes

Long term voltage changes refer to the effective value changes in the power frequency that lasts longer than 1 minute. Long-term voltage changes may be overvoltage, undervoltage and permanent voltage interruption. Over voltage and low voltage are caused by system faults and not by changes in load on the system. Such changes are usually shown in the effective value - time graphs. The situation that occurs when the upper value exceeds the limit values specified in a standard or specification when voltage is applied to a device is called overvoltage. There are three types of overvoltages as Temporary power frequency, Switching and Lightning.
These disorders occur when:

- In differential mode (between electrically charged conductors: phase / phase-phase / neutral),
- In common mode (between electrically charged conductors and exposed conductive parts or ground.

3.3. Unbalanced Voltage

If the phase angles of phase voltages are not equal to the rms value or the phase angle between successive phases, then a 3-phase system is unbalanced. The level of the imbalance is defined using the Fortescue's Theorem (1), with the base negative component (U_{1i}) (or zero component (U_{10}) compared to the base positive component).

$$\Delta U_i = \frac{\overline{|U_{1i}|}}{|U_{1d}|} \; and \; \Delta U_0 = \frac{\overline{|U_{10}|}}{|U_{1d}|} \quad (1)$$

The reverse component (or zero component) voltage is produced by voltage drops due to negative sequence (or zero sequence) currents across the network, produced by unbalanced loads leading to undetermined currents in the internal phase (single-phase or two-phase MV loads such as LV loads connected between phase and neutral or welding machines and induction furnaces). The effects of voltage imbalance can be explained as follows: The most significant effect is overheating of 3-phase asynchronous machines. In fact, an asynchronous motor equals zero-order resistance, the resistance in the order of the operating phase. The current imbalance factor will thus be a multiple of the supply voltage imbalance factor. The phase currents can vary greatly in this way. This increases the overheating of the active phase / phases through the current and reduces the working life of the machine.

In practice, a long-term voltage imbalance factor of 1% and an overvoltage imbalance factor of 1.5% over several minutes can be considered. Distortions caused by voltage imbalance can be corrected as follows:

- Balancing single-phase loads entirely in three phases,
- The power system of the devices which cause the unbalance by increasing the transformer ratio power and cable cross-sectional area, reducing the impedance network side,
- Mounting suitable protective device for machines,
- Using carefully connected LC loads (Steinmetz connection).

4. Implementation Requirements for Improving Power Quality

Industrial system performance assessments are directly related to the earthing and bonding quality of components included in the system. If the grounding and bonding process is inadequate, it will result in poor performance in the power system. Grounding is the most important application in power systems. It is very important to distinguish the functions of the grounded conductor (neutral) from the earthing system (safety ground) in equipment connected to the power system. In the case of grounding in these lines, there is a limitation of the voltage potential in the equipment with reference to the grounded components. Neutral and soil must only be combined at the service entrance or after a separately derived source. One of the most common mistakes made in a power system is that neutrals are attached to the soil in more than one place. Proper grounding and bonding reduces the costliest discomforts.

Control of the general components is crucial for making proper connections in a power system. The entire electrical system must check for loose, missing or improper connections to the panel, cups and equipment. Article 300 of the National Electrical Code covers cabling methods and should be followed to ensure safe and reliable operation. There are many common circuit tester types that can be used to check for inappropriate conditions, such as reverse polarity, open neutral, or sliding floors. Be sure to isolate panels carrying sensitive electronic loads from heavy inductive loads or other electrically operated equipment such as air compressors or refrigeration equipment. Voltage fluctuations and noise are defined as common power interruptions that are present in any electrical environment that directly affects electronic equipment. These disturbances arise in various forms such as transitions, sags, amplitudes, overvoltages, voltages, harmonics, interruptions, frequency changes and high frequency noises. Due to the increased use of electronic equipment in power systems, harmonic distortion appears to be an important problem. These electronic components used draw nonlinear current in the voltage waveform. This non-linear current causes high neutral current, overheated neutral conductors, overheating transformers, voltage distortion and opening of the cutter.

4.1. Solution Suggestions for Improving Power Quality

In addition to energy storage systems and distributed generators, many methods can be used to solve power quality problems. Using the right interface devices, the load can be isolated from network-related anomalies. In addition, a number of power-up devices have been developed to protect the components included in the system from the adverse effects of power failures. These developed devices play a crucial role in developing an effective power quality strategy.

Temporary Voltage Surge Suppressors are one of the best examples of these devices. It provides the simplest and cheapest way to supply power, and these units compress the temporary impulses to a safe level for the electronic load. The use of the entire plant protection strategy will protect the electrical system against many passages. Multistage protection requires the use of Temporary Voltage Surge Suppressors on the bottom panel at the point of service entry at the point of use. This coordination of the devices provides the lowest possible discharge voltage to the equipment. Temporary voltage surge suppressors are used as an interface between the power supply and sensitive loads, so that the transient voltage is clamped by Temporary Voltage Surge Suppressors before reaching the load. Transient Voltage Surge Suppressors usually include a component that limits the over-line voltage and includes a non-linear resistor that transmits excess impulse energy to the ground.

Noise filters are another example of these devices and are used to prevent unwanted frequency currents or voltage signals from reaching sensitive equipment. These devices utilize a combination of capacitors and inductances that form a low impedance path to high frequencies, that is, a fundamental frequency and a high impedance to a low pass filter, and should be used when frequency noise is significant in the 1 KHz range. Harmonic filters are used to reduce unwanted harmonics and can be divided into two groups, passive filters and active filters. Passive filters consist of a low-impedance path to the frequencies of harmonics that are weakened using passive. The active filters also analyze the current consumed by the load and generate a current that cancels the harmonic current generated by the loads. Active filters have been applied at a rather high cost in the past, but now they are cost-effectively balanced for unknown or varying harmonics.

Finally, the other widely used tool to recommend is Isolation transformers. These tools are used to isolate temporary loads from transient loads and noise from the network. In some cases, in the power system, isolation transformers prevent harmonic currents generated by loads from entering the transformer upstream. Isolation transformers feature a grounded system made of non-magnetic foil between primary and secondary. Any noise or transient from the source, primary and transmitted through the capacitance between the shield and earth and not reaching the load. Provides a degree of isolation and filtration. In addition, these devices effectively reduce the electrical noise generated by physical separation by primary and secondary via magnetic isolation. Isolation transformers reduce normal and common mode noises, but they do not compensate for voltage fluctuations and power cuts.

UPQC is widely used as a special power device that reduces power quality problems related to voltage and current in power distribution systems. These devices are also referred to as a DC energy storage capacitor, also used as two voltage source converters connected to UPQC, DSTATCOM and Dynamic Voltage Regulator. This combination provides simultaneous compensation of the load currents and supply voltages so that the balancing current from the network and the balanced supply voltage to the load are sinusoidal and balanced as desired.

4. Conclusion

For energy components used in the power system of developed and developing countries, it is very important to have high power electrical power. If all consumer types are satisfied with the quality of the power provided by the production plants, they will feel comfortable providing energy. In order to avoid huge losses in power quality problems, the most demanding consumers must take all the necessary remedial steps to prevent problems. The choice of less sensitive equipment may play an important role in such measures. Temporary Voltage Surge Suppressors, noise filters, UPQC, Isolation transformers and DSTATCOM make power quality improvements very simple and practical. In addition, for the sustainable energy in power systems, the necessary power capacity needed in unexpected situations must also be kept as SR. Finally, problems with power quality can be easily avoided if you are using an application that does not have a power quality problem.

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