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Power Quality Issues in Smart Grid Network

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***Abstract**: This paper presents an over review of power quality in smart grid. Power quality has become the term used to describe a wide range of electrical power origin, monitoring and measurement. Power quality is also a complex subject requiring specific terminology in order to properly describe situations and issues. Understanding and solving problems becomes possible with the correct information and interpretation. An adequate power quality guarantees the necessary compatibility between all equipment connected to the grid. It is therefore an important issue for the successful and efficient operation of existing as well as future grids. One of the properties of electricity is that some of its characteristics depend not only on the electricity producer/distributor but also on the equipment manufacturers and the customer It describes the main phenomena causing degradation in Power Quality (PQ), their origins, the consequences for equipment and the main solutions. It offers a methodology for measuring the PQ in accordance with differing aims.*

***Keywords:** PQ origin, PQ improvement, monitoring, measurement, Future PQ Challenges.*

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I. Introduction

A. Smart Grid Technology

The power grid of today is a development of a system which was first used almost a hundred years ago. There have been many new requirements put on it in the last decade in particular and it is clear to many that the existing basic design will soon become inadequate. Power systems equipment, such as lines and transformers, are expensive and people are looking to communications, IT and control to enhance their performance. Hence the emphasis in this approach is on "brain" rather than "muscle". Many of the associated technologies have become cheaper in the last few years to the extent that trial demonstration sites are affordable, but it will still be very expensive to incorporate smart grid technology throughout the whole network. Some consider that each local part of the power system will have its own particular requirements and that each part will develop its own flavor of "smartness" as required. In this view, the smart grid is mainly an idealized model from which various components are to be taken and added to the real system as particular local problems arise [1].

B. The aims of the ideal smart grid are:

- Better, more efficient and more flexible use of the network,
- Price reduction for network use.
- Introduction of more customer options including time-of-day tariffs.
- Better PQ, especially in voltage control and voltage sag impact.
- Self-healing to give better reliability.

C. This is achieved by:

- Parallel communications networks with two-way communications, remote sensors, and distributed processing
- Large data storage, analysis and fast simulation capabilities.
- Some additional distributed actuators such as switches, reclosers, on-load tap changers.
- Faster protection.

II. Why Knowledge Of Power Quality Is Important

Owning or managing a concentration of electronic, control or life-safety devices requires a familiarity with the importance of electrical power quality.

Power quality difficulties can produce significant problems in situations that include:

- Important business applications (banking, inventory control, process control)
- Critical industrial processes (programmable process controls, safety systems, monitoring devices)

- Essential public services (paramedics, hospitals, police, air traffic control) Power quality problems in an electrical system can also quite frequently be indicative of safety issues that may need immediate corrective action. This is especially true in the case of wiring, grounding and bonding errors. Your electrical load should be designed to be compatible with your electrical system. Performance measures and operating guidelines for electrical equipment compatibility are available from professional standards, regulatory agency policies and utility procedures.

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IV. The Scope Of Power Quality.

Electronic Devices Many control and measurement device manufacturers recommend independent or isolated grounding rods or systems in order to provide a “low reference earth resistance”. Such recommendations are often contrary to Electrical Codes and do not make operational sense. Bear in mind that a solid connection to earth is not needed for advanced avionics or nautical electronics [3].

Uninterruptible Power Supplies (UPS) do not Provide Complete Power Quality Protection not all UPS technologies are the same and not all UPS technologies provide the same level of power quality protection. In fact, many lower priced UPS systems do not provide any power quality improvement or conditioning at all; they are merely back-up power devices. If you require power quality protection like voltage regulation or surge protection from your UPS, then make sure that the technology is built in to the device.

V. Types Of Pq Disturbances

1) Steady State Voltage (and Power Factor)

The specification for voltage at the point of connection is a range of 230V – 6% to 230V + 10%. Voltages greater than this may cause equipment insulation to degrade faster than intended resulting in a reduced life span. If voltages are less than this, equipment may fail to operate as intended. Motor-driven equipment may fail to start or motors might overheat and trip or be damaged [2].

2) Unbalance

The three voltages of the active conductors are ideally similar in magnitude and time-shifted by 1/3 of a period or 6.7 ms. If the single-phase residences are drawing roughly equal current and are properly distributed across the three-phases, the voltages will be balanced along the LV supply line. In practice this is hard to achieve and the downstream voltages will in general be different in the three active conductors. Such a set of voltages is said to be unbalanced and can cause three-phase induction motors to overheat [4].

3) Voltage fluctuations

Some loads such as welders and rolling mills change in a cyclic manner with a period from a fraction of a second to several minutes. This gives an approximately cyclical change in the voltage magnitude over a similar timescale.

4) Voltage Sags (also known as Voltage Dips)

Voltage sags are short term reductions in the rms voltage.

5) Harmonics

Modern equipment is mainly electronic and draws a current with a wave shape which is usually a series of positive and negative pulses which are narrower than would be expected from a sinusoid. The effect is to both reduce the voltage as before and also to change the wave shape, an effect called harmonic distortion. The resultant voltage wave shape is usually like a sinusoid which has been flattened slightly [2].

6) Transients

A very high current is injected into a power line during a direct lightning strike causing high voltages of up to several hundred kV for duration of 100 µs or more.

VI. Different Power-Quality Issues

A. Emission by new devices

When smart grids are introduced, we expect growth both in production at lower voltage levels (distributed generation) and in new types of consumption (for example, charging stations for electric vehicles, expanded high-speed railways, etc.). Some of these new types of consumption will emit power-quality disturbances, for example harmonic emission. Preliminary studies have shown that harmonic emission due to distributed generation is rather limited. Most existing end-user equipment (computer, television, lamps, etc) emit almost exclusively at the lower odd integer harmonics (3, 5, 7, 9 etc), but there are indications that modern devices including certain types of distributed generators emit a broadband spectrum [5].

B. Interference between devices and powerline-communication.

Smart grids will depend to a large extent on the ability to communicate between devices, customers, distributed generators, and the grid operator. Many types of communication channels are possible. Power-line communication might seem an obvious choice due to its easy availability, but choosing power-line communication could introduce new disturbances in the power system, resulting in a further reduction in power quality. Depending on the frequency chosen for power line communication, it may also result in radiated disturbances, possibly interfering with radio broadcasting and communication.

C. Immunity of devices

Simultaneous tripping of many distributed generators due to a voltage-quality disturbance (like a voltage dip) is the subject of active discussion [6]. This problem is far from solved. As a smart grid attempts to maintain a balance between production and consumption, mass tripping of consumption could have similar adverse consequences. This should be further investigated.

D. Weakening of the transmission grid.

The increased use of distributed generation and of large wind parks will result in a reduction of the amount of conventional generation connected to the transmission system. The fault level will consequently be reduced, and power-quality disturbances will spread further.

VII. Steps To Rectify Pq Problems

- Continuous and extensive monitoring of different power system quantities.
- Detection and identification of power quality related disturbances and categorizing hem.
- Analysis of the identified problems to their probable causes.
- Prevention and corrections of the probable causes either automatically or manually.

VIII. Power Quality Monitoring.

PQ monitoring is an integral part of overall system performance assessment procedures. A simple classification of power quality monitoring could be:

1) Local monitoring: Its objective consists of determining the quality of power that is delivered to a single customer.
2) System monitoring**:** Its objective consists of determining the quality of power and the behavior of the electrical system globally. From a pure measurement view point there is no difference between PQ measurement and the measurement of voltages and currents, for protection and control purposes. The difference is in the further processing and application of the measured signals.

A. Objectives of PQ Monitoring

- Continuous evaluation of the electric supply system for disturbances and power quality variations.
- Performance of power conditioning equipment, such as static switches, UPS systems, other ride through technologies, and backup generators.
- Evaluation of power quality characteristics of the equipment within the facility like harmonic interaction between loads and power conditioning equipment and inrush characteristics for loads.
- Complete documentation of disturbances and power system conditions for any event that actually disrupts facility operation.

B. Objectives of Power Quality measurement.

The measurement parameters and accuracy may differ depending on the application.

1) Contractual application

   Within the context of a deregulated market, contractual relations may exist not only between the electricity supplier and the end user, but also between the power Production Company and Transmission Company or between the Transmission company and Distribution Company. A contractual arrangement requires that terms are defined jointly and mutually agreed upon by all parties. The parameters for measuring quality must therefore be defined and the values compared with predefined, i.e. contractual limits. This arrangement frequently requires the processing of significant quantities of data.

2) Corrective maintenance

   Even where best practice is observed (single line diagram, choice of protective devices and neutral point connection, application of appropriate solutions) right from the design phase, malfunctions may occur during operation:

- Disturbances may have been ignored or under-estimated.
- The installation may have changed (new loads and/or modification).

Troubleshooting is generally required as a consequence of problems of this nature.

The aim is frequently to get results as quickly as possible, which may lead to premature or unfounded conclusions. Portable measurement systems (for limited periods) or fixed apparatus (for continuous monitoring) make it easier to carry out installation diagnostics (detection and archiving of disturbances and triggering of alarms).

C Optimizing the operation of electrical installations

To achieve productivity gains (operational economies and/or reduction of operating costs) correct operation of processes and sound energy management are required, both of which are factors dependent on PQ. Operating, maintenance and management personnel of service sector and industrial sites all aim for a PQ which matches their requirements.

Complementary software tools to ensure control-command and continuous monitoring of the installation are thus required.

D. Advanced Applications for Monitoring Systems

EPRI's Power Quality (PQ) program has identified issues relating to PQ data and monitoring as fundamentally important to the success of electric utilities in the coming years Power quality monitoring systems capture significant amounts of data that describe the performance of the power system and the condition of power system equipment. These data have traditionally been available only for historical analysis and reporting. However, advances in communications systems are making these data available in near real-time, and the integration of data from additional intelligent devices in the system is resulting in the ability to collect data from across the system. However, considerable barriers to realizing the benefits of these advances remain.

Research Approach may increase the value of PQ monitoring systems through the development of advanced applications that can directly benefit system operation and maintenance. The applications build on existing monitoring system platforms to minimize the additional investment required to achieve these benefits. They also take advantage of the data available in PQ monitoring systems that can be used to assess equipment and system condition with appropriate analytical methods and system interfaces [7]. This expands the value of PQ monitoring systems by using the data to develop important information about the health of the overall system and individual components. Alarms and reports can then be integrated with system maintenance procedures and operations to more efficiently resolve problems and improve equipment reliability. The net effect can be a dramatic improvement in system reliability and a reduction in maintenance and operation expenses—the most important justifications for monitoring systems in the future.

- New data visualization techniques
- Better methods to port useful PQ information to mobile devices (smart phones and tablets) New waveform compression and analysis techniques
- New fault analysis and incipient fault identification techniques
- Data mining for equipment and hardware problems
- New indices and performance modules
- Fault protection and coordination assessment module
- Customer information modules.

E. Future PQ Challenges

1) Voltage

Voltage control is expected to be the major issue. The new Australian voltage standard will require extensive retuning of the whole distribution system. Voltage retuning has to be done simultaneously at the zone-substation and downstream distribution transformers since there are interactions both upstream and downstream. Embedded generation at all voltage levels will give power flows and voltage increases for which the present system is not designed. At LV, the dominant PV solar cell units will encourage high voltages in the day time, particularly at times of light load. Conversely, electric vehicle charging will reduce the voltage at night. The length and cross-section of LV conductors will need to be re-evaluated for future LV system construction. The use of distributed voltage regulators simplifies the technical challenges but may impose an unacceptable additional cost in most situations [2].

2) Unbalance

It is pointed out in that if electric vehicle chargers are single-phase units, they will constitute a load with little diversity but which might impose significant unbalance on the system. This could limit the maximum power taken through the distribution transformer below the firm capacity. He gives the results of a probabilistic simulation which shows that for 50% of the charging scenarios the maximum power taken from the network is no more than 50% of the maximum available under balanced conditions. This is an issue which could be addressed to some extent with smart grid features.

3) Voltage Fluctuations

At present the most significant impact of voltage fluctuations is on incandescent lamps. As these are phased out, it is expected that higher levels of voltage fluctuations will be able to be tolerated on the network. There has been some discussion suggesting that CFLs might show a low immunity to inter harmonics

4) Voltage Sags

It needs to be stressed that the voltage sag immunity of a complex system is determined by the least immune part, not the most immune part. The increasingly sophisticated equipment within residential customer installations in particular, being made up of many components, is expected to show a greater susceptibility to voltage sags. Grid developments of both the smart and strong type have the improvement of Reliability as one of their goals and this should improve sag rates as well. Voltage sag durations will be greatly reduced if the smart grid is developed to give unit protection with fast breaker operation for MV feeders.

5) Harmonics

The harmonic situation is rather complex. One needs to think separately about low frequency (LF) harmonics (up to about the 20th order) and high frequency (HF) harmonics. There will be some growth in lf harmonics due to increasing use of electronics with front-end capacitor-filtered rectifiers. The use of embedded generation will lead to a growth in harmonic generating loads without a corresponding increase in fault level. This will increase the system impedance relative to the total load giving an increase in harmonic voltages [8]. If power factor correction is widely used without detuning inductors, there will be harmonic resonances at the important harmonic orders 5-9.

IX. Future Developments Of The Electricity Supply Network

It is difficult to forecast the immediate future of the grid because of competing forces. Many technical developments in power system equipment, instrumentation and communication systems are now becoming more affordable and offer many advantages in terms of efficiency and reliability. However increasing electricity tariffs and accusations of “gold-plating the network” may mean that these developments will not occur as rapidly as was thought a couple of years ago. Factors which will lead to changes in the network are discussed in the following sub-sections. There are strong connections between some of these items and they are not as independent as the discussion might suggest [2].

A. The Need to Reduce Greenhouse Gas Emissions

This is prompting utilities to look for alternative renewable generation sources. Power systems need to be operated with lower losses. Assets need to be operated with greater utilisation prompting a drive to reduce system peak demand encouraging demand management. Customer loads will incorporate power electronics for higher efficiency.

B. Embedded Generation

This comes about because of the need for sustainable generation and regulator pressures to give open access to the grid. The main forms at present are wind at MV and solar photovoltaic units (PV) at LV [6]. These forms of generation are not generation-on-demand and give greater uncertainty as to the load to be met by the large power stations. There are voltage control issues at MV as wind generation is often situated away from load centers where the transmission system is weak. There are different voltage control issues at LV as the system is designed for power flow only in one direction. When PV reverses this flow, there can be undesirable voltage rises and these may be sufficient to trip out some PV inverter units. Embedded generation is often connected to the system via power electronics and this may give increasing harmonic issues particularly at the higher frequencies associated with power switching. Protection systems are not designed to account for embedded generation and may need redesign. There are opportunities for embedded generation to support the system during large disturbances and this may contribute to reducing sag severity.

C. Customer Load Technologies

More power electronics is being introduced to make appliances with higher efficiency, smaller volume and lower weight. There is greater use of digital control operating at lower signal levels [8]. This may result in a greater sensitivity to voltage sags. This can be avoided with adequate design if the extra cost is acceptable. Higher harmonic frequencies and inter harmonics may result from this growth in power electronics depending on the choice of front-end power conversion technology. Demand management may give customers access to more information from utilities through smart meters and this might result in some customers having overall energy management systems which control lighting, heating and non-critical loads to optimise time-of-day tariff charges. Such systems may be very susceptible to PQ issues from voltage sags, harmonics and transients unless very well designed.

X. Conclusion

This paper presents a brief review of the power quality disturbances, issues and its effect on efficiency and reliability of grid power supply. So PQ monitoring plays an important role in an integral part of overall system performance. Hence there is a need to adopt recent advance communication technology to address and monitor the PQ problems to get quality and reliable power supply in the smart gird environment

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