International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 2 ǁ 2022 ǁ PP. 72-76

A Novel Approach to Control Power Quality Issues in Microgrids

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Abstract
In this manuscript, a new concept of active power quality management (APQM) is presented. Instead of just controlling the quality of node power in a power system, power quality is considered as a network-level problem and a high-level management method is presented to deal with this problem in distribution networks. Analogous to how active network management helps increase hosting capacity for Distributed Energy Resource (DER) interconnection by managing thermal and voltage constraints, APQM maps consumer requirements, technical and regulatory standards in specific areas and actively manages the operational power quality limits rather than relying on connection planning screens. The APQM includes the restructuring of the distribution grid and the integration of renewable energy sources (RES) to increase the reliability of supply of critical loads, the intelligent management and the optimized installation of energy improvement devices to improve the distributed power quality (PQID) to improve the grid quality by adding from features to installed power electronic DER converters to increase DER cost efficiency. Finally, the coordinated control of PQIDs and high penetrating nonlinear loads is also covered in this study.
Keywords: *Power Quality Management, Renewable Energy Sources, Distributed Energy Resources.*

Date of Submission: 02-02-2022 Date of acceptance: 16-02-2022

I. INTRODUCTION

Due to the increasing penetration of power resources connected to the converter, consumer electronics, and on the other hand, the increased public awareness of power quality issues, the penetration of quality-sensitive power loads, intelligent meters, etc., power quality is becoming a matter of great concern for utilities and consumers Importance. The power quality levels required at different nodes (or areas) of the network are not the same, e.g. Critical loads such as data centers, hospitals, communication systems require a high level of power quality that includes high availability and low distortion of voltage and current [1, 2]. However, the power grid can be vulnerable to natural disasters such as hurricanes, earthquakes, and storms, and the power grid should be prepared for these events in advance to avoid serious problems. Today, the quality of energy delivered to customers' connection points is managed by static planning and regulation rules in terms of voltage delivery limits, harmonic content limits and power availability. This means that the quality of the energy supplied is within a tolerance threshold, often above or below the performance levels required by the different customers [3–5]. This standardization has historically been important for planning methods that assume passive network operation and for the most sensitive customer loads. As power electronic devices and non-linear loads become more prevalent on the power grid, these issues are increasingly impacting power systems. Customers with power quality requirements that were more stringent than grid-wide standards had to self-manage using local, site-specific PQ improvement devices. It emphasizes the importance of different power quality for different areas to survive extreme conditions or flexibly meet different customers' power quality requirements. Unlike some power system problems that originate at higher levels of the power system, power quality problems typically begin at the distribution system level, which in turn demonstrates the importance of power quality management at the distribution level. Power electronics-based devices can support power quality by locally compensating for harmonics with active and passive line filters, voltage sags and surges with uninterruptible power supplies, automatic voltage regulators, dynamic voltage restorers, reactive power compensation [synchronous static compensators (STATCOMs)]. , and similar matters [1, 6, 7]. Although this method of improving power quality has worked so far, it will not be as effective as before due to changes in consumer load due to sensitivity and power quality pollution. Aside from the financial aspect of installing Power Quality Enhancement Devices (PQIDs), since most PQIDs rely on power electronics that can cause other power system stability and protection issues, adding unique devices to improve zonal power quality is not enough. seem to be the best solution [8]. Instead, using newer technologies to actively manage devices to improve and degrade power quality would be an alternative to adding power electronics-based devices to the power system. The concept of smart grids facilitates the introduction of flexibility, resiliency, improved power quality and the integration of renewable energy sources (RES) into traditional power systems. These goals could be achieved through modern measurement and monitoring devices, fast and accurate communication systems, new renewable energy control methods based on power electronics, and distributed or centralized management systems [9]. This article introduces several solutions to this problem, including new ideas on power quality management. These solutions include the distributed and optimized installation of active or passive PQIDs based on a fundamental and harmonic analysis of the power flow [10], using different control methods to optimize the output/input power quality in the power electronics converters [11-15]. improve and maintain ancillary services from power electronics based distributed generation units to operate as PQIDs and to actively control and manage high penetration non-linear loads such as 3 .

II. CONCEPT DEFINITION

Figure 1 shows the current power grid, where a mix of different types of loads and consumers have different power quality requirements that are supplied by the same power supply and therefore experience the same level of power quality. As power electronic devices and non-linear loads become more prevalent on these grids, these issues will have a greater impact on consumers, either through higher costs or lower power quality levels. On the other hand, power electronics based devices can support power quality by locally compensating for harmonics, voltage sags and swells, reactive power compensation and similar problems, but as already mentioned, this may not be the best solution (Fig. 1). Starting from the distribution level, a coordinated control method could be applied to high intruding non-linear loads such as EVSE or HP. This coordinated control, in contrast to previously proposed intelligent load management methods for EVSEs, which focused on voltage and demand management [16], takes into account the power quality limitations in the control of the mentioned units. A general explanation of coordinated EVSE control is shown in Fig. 2. The Active Power Quality Management (APQM) concept, shown in Fig. 3, combines a set of planning and management tools to provide different levels of power quality. to different customers, with minimum costs and maximum reliability. At the device level, there are a few

Fig. 1 . Today's power system with new power quality challenges

Fig. 2 . Sample power system with coordinated EVSE management

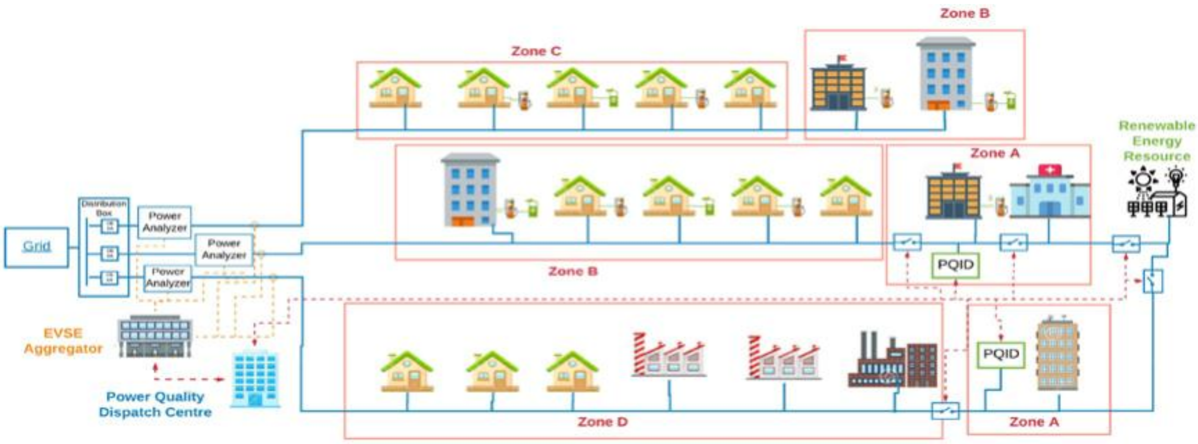

Fig. 3 . Sample power system with APQM concept applied

Solutions to maintain the required power quality, such as minimizing the output/input distortion of power electronic devices, new control methods are applied to new converter topologies. Passive filters are among the less expensive PQIDs, but may not be as effective as they could be when used in isolation. A combination of passive, active and hybrid filters helps to suppress harmonics and compensate for distortion locally. Recently, the idea of using Distributed Energy Resource (DER) converters for auxiliary services has been introduced and deployed to support the power system by local harmonic compensation [17]. With the cost of information and communication technologies falling and the proliferation of metering and control capabilities, power quality planning and operational paradigms need to be revised to ensure they are optimal for today's network demands. Not only are new solutions available to improve power quality, e.g. smart impedances, electric springs or multifunctional decentralized generation units [18, 19], but thanks to measurement and control, a variable and actively controlled level of power quality could be provided to meet the specific needs of customers within a grid area. In a world of increasing loads and DERs connected to converters, it is questionable whether it is cost-effective to actively monitor and manage power quality compared to passive operation governed by device regulations and thresholds. Therefore, APQM could use planning and management tools to coordinate highly distorted loads, such as B. charging stations for electric vehicles (EV) and HPs, ensure that the power quality levels of specific areas are kept within defined limits.

III. METHODOLOGY OF APQM

The APQM, as shown in Fig. 3, uses existing and new power quality improvement solutions to improve the power quality of electrical systems in a cost-effective manner. As can be seen in

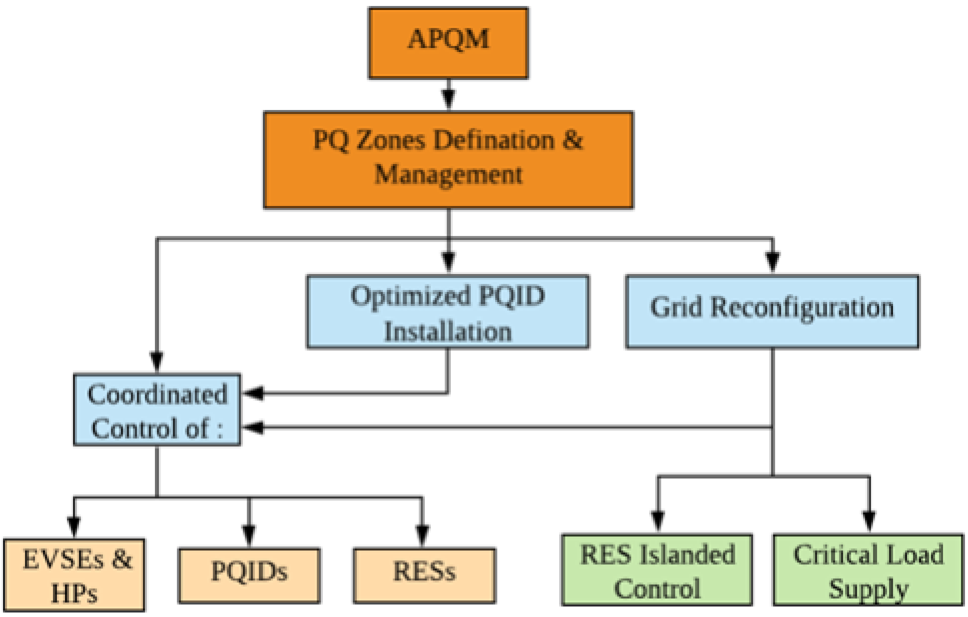

Fig. 4 . APQD simple principle

Figure. 4, the solutions in APQM include various steps summarized as follows:
† Customer and zone assignment of required power quality levels assigned by design and engineering teams.
† Coordinated management of influence loads (e.g. non-linear or unbalanced loads such as EVSE), PQID and RES with ancillary services.
† Active control and optimization of local/zonal PQIDs.
† Prioritize serving critical and sensitive loads during emergencies by reconfiguring the network.
† Proactive islanding of operational areas during grid instability and low power quality events.

3.1 Power quality zones definition

Different areas of the electrical system require different power qualities, e.g. The electrical quality required for a hospital is not the same as for an industrial area. Power quality can be managed more flexibly in an area network to satisfy individual customers. By defining different power quality zones within electrical systems, the focus on improving power quality in areas with critical loads is significantly increased, while for other areas an acceptable level of power quality is achieved and costs are kept within reasonable bounds. Power quality levels would be defined based on power availability, voltage and frequency stability, voltage and power distortion, and resilience to natural disasters of any kind.

3.2 Coordinated control of EVSEs, PQIDs, and RESs

Coordinated management of non-linear loads such as EVSEs or HPs is a planning and active management tool to support the proliferation of EVSEs before the nominal level of grid harmonic stress is reached. Similar to the EV smart charging scenario, this method manages the charging processes in an area and has a two-way communication system with the EVSEs to read their data and send the signals needed for coordinated operation. The main benefit of this EVSE-coordinated management is to integrate energy quality concerns into the optimized management. The concept of coordinated EVSE management was presented in Fig. 2, which could be applied to any example network, even with different EVSE aggregators.

3.3 Optimised local PQID installation

Mapping the locations of impacting loads facilitates implementation of power quality design decisions when necessary. If there is enough information about the distribution of the type of load, this provides good support for local management of power quality problems. Active monitoring and optimization of local zonal PQIDs improves device performance and maximizes efficiency through aggregated PQID management.

3.4 Grid reconfiguration and RES ancillary services

In this concept, DERs based on power electronics would have a great influence to increase the reliability of the power supply as well as provide power quality improvement services as an ancillary service. Any unused capacitance of the converters could be used as active power filters to locally compensate for current/voltage distortions. During emergencies and outages, DER converters can act as grid-forming converters, powering critical loads with high priority and supporting black/grey start of the power grid. All layers mentioned are controlled by a central controller, which does not replace the local controller, but supports the definition of different power quality zones in the distribution network. This concept gives the power system design team more flexibility to address today's power quality issues. As in Fig. 3. Different solutions can be applied to each zone to improve the power quality individually without affecting the power quality of other zones. Existing PQIDs will continue to work. In order to meet the power quality requirement of the specified area, the only difference would be the additional overall control of the power quality dispatch unit.

IV. CONCLUSION

This article introduces the concept of APQM in distribution networks. In order to have a power grid with multiple levels of power quality, it is essential to have a management unit (distribution) that exercises coordinated control over high-penetration non-linear loads, PQIDs, RES, as well as power supply to critical loads through reconfiguration of the power grid. In this way, a hierarchical control approach is applied to manage the power quality in the distribution network. This hierarchy starts at the lower levels with the coordinated control of loads and PQIDs and ends with the high-level control via the central power quality management that guarantees different levels of power quality to satisfy different customers according to their requirements.

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