A Comparison of Power Quality Controllers

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Abstract

This paper focuses on certain types of FACTS (Flexibile AC Transmission System) controllers, which can be used for improving the power quality at the point of connection with the power network. It focuses on types of controllers that are suitable for use in large buildings, rather than in transmission networks. The goal is to compare the features of the controllers in specific tasks, and to clarify which solution is best for a specific purpose. It is in some cases better and cheaper to use a combination of controllers than a single controller. The paper also presents the features of a shunt active harmonic compensator, which is a very modern power quality controller that can be used in many cases, or in combination with other controllers. The comparison was made using a matrix diagram that, resulted from mind maps and other analysis tools. The paper should help engineers to choose the best solution for improving the power quality in a specific power network at distribution level.

Keywords: power, quality, controllers, matrix, diagram, FACTS.

1 Introduction

In recent decades, power quality has become topic number one. The target has been to obtain the most effective conditions for power transmission between power sources and users. The same demands arise in the construction of intelligent buildings and large public buildings. There are several ways to ensure power quality in buildings of this kind, and this paper tries to clarify them and compare them with each other.

Mind maps were used at the beginning of the analysis to define important disturbances and important controllers for the distribution level of networks. Disturbances are presented in section 2. A comparison of the controllers themselves is made section 3. The analysis points to major considerations when using controllers and should help engineers to select an appropriate solution. A SWOT analysis of the shunt Active Harmonic Filter (AHF) is also presented in section 3. AHF is a very modern way to ensure power quality, so it is studied in greater detail.

2 Power quality in power distribution networks

There are several power quality parameters that are important for transmission networks, e.g. the static and dynamic stability of the power system, voltage stability, frequency stability, etc. A very important issue here is the loop flow of power through parallel transmission lines. Only some of these parameters are important at distribution level. Users are not able to control the whole transmission network, so they cannot have much effect on the frequency stability, the power flow, or the stability of the power network. However, users are limited by the demands of their electric power supplier and by the demands of their power system. If a power network is being designed for a hospital for example, the project engineer will be very concerned about supply continuity and voltage stability. A another parameter that has to be taken into account is minimum power factor defined by the power suppliers.

Four important power quality parameters at distribution level were determined using mind maps. These parameters are graphically represented in Figure 1.

2.1 Power Factor

The power factor is defined as:

$$PF = \frac{P}{S},$$

where P is active power and S is apparent power. Poor quality of this parameter is caused by:

- inductive or capacitive load, which creates reactive power,
- by the current harmonics (nonlinear load) or
- by an unbalanced load in three-phase systems.

It is obvious that the power factor parameter is affected by the load and its currents. To compensate the effects mentioned above, the load has to be resistive, linear and balanced. Shunt compensators are therefore suitable for this purpose.

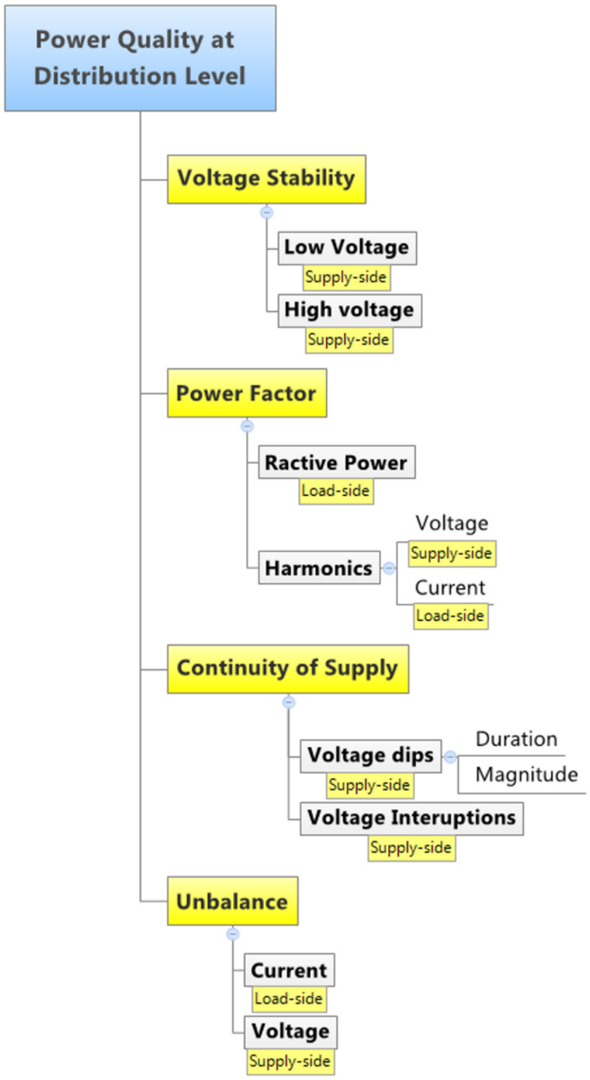

Figure 1: Important power quality parameters at distribution level.

2.2 Voltage stability

The voltage in a power system may vary due to changes in the load. Low voltage at a point of heavy load is caused by a voltage drop on the series impedance of the power network. Similarly for low loads the voltage can rise and make higher stress on the load. This effect can be compensated by changing the ratio of the distribution transformer or by changing the series impedance of the network. Compensation can also be make by changing the character of the load. This effect is shown in Figure 2. Shunt compensators can be used for this purpose. If low voltage is detected, reactive power should be supplied as a countermeasure (capacitive load).

2.3 Continuity of supply

The primary sources of voltage dips are load switching events and short circuits occurring in the power

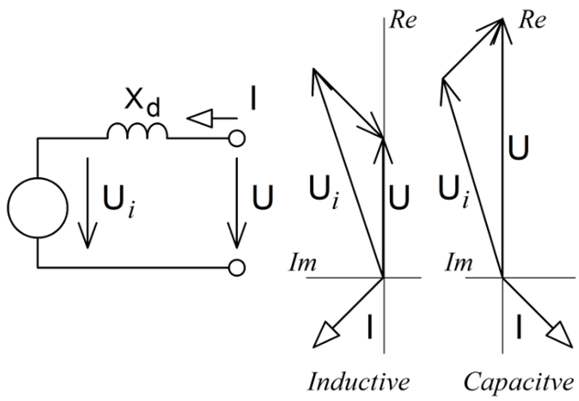

Figure 2: The dependency of voltage on the character of the load.

network. Short circuit events also lead to unbalanced supply voltage. Moreover the system can be disconnected from the supply by the fuse due to short circuits. Electric power users within the disconnected segment of the network suffer an interruption of supply.

Voltage dips and interruptions are the problems on the power supply side. Much standard electrical equipment has to be designed to overcome a short interruption of the power supply. The duration of the effect is therefore a major parameter. For example, computers and a much other equipment can deal supply interruption lasting more than 1 ms. However some special loads, e.g. measuring systems, are very sensitive to voltage changes and therefore have to be controlled.

2.4 Voltage and current imbalance

Unbalanced phase voltage is closely connected to phase currents. If phase currents are unbalanced, ther a different voltage drop in each phase. As a result, the phase voltages are also unbalanced. In three-wire systems, unbalanced loads create reactive power even though the loads are resistive. This phenomenon is less significant in a four-wire system. However, in large buildings it can be useful to compensate unbalanced loads in oder to ensure proper utilization of the power network.

Imbalances at fundamental frequency can be caused by negative sequence and zero sequence components. However, a zero sequence component can only appear in a three-phase grounded system, which induces current flow through the neutral wire. This part of the imbalances can be compensated by transformers in connection D/yn or Y/yn.

Strenghts	Weaknesses
Campensation of harmonics	Difficult control algorithms
Possibility of selective compensation of harmonics	High hardware requirements
Selective P, Q compensation	For nonselective compensation is the power rating of the converter the same order as the load
Compensation of unbalanced currents	Continuous operation - aging
Can be used in 3 and 4 wire system	Switching losses
Compensate currents only for defined load	Need filtration chokes
Oscilation damping	
Opportunities	**Threats**
The same control can be used for active rectifier	High frequency interference
Combination with other instruments - make the resulting solution cheaper	The network voltage magnitude has to be lower than the voltage on DC capacitor
Can be designed as multilevel converter - high voltage	The transformer is needed for high voltage systems
Combination with series active harmonic filter	
By controlling of reactive power can be compensated voltage drops	

Figure 3: SWOT analysis of shunt Active Harmonic Filter.

3 A Comparison of Controllers

Various types of controllers are compared in Figure 4. The controllers have been divided into two groups according to their connection to the power network. Only controllers intended for use in a power distribution network, were selected for the comparison:

AHF — An Active Harmonic Filter is a power converter that is able to compensate harmonics and reactive power. It is used as a shunt or as a series compensator, according to whether current or voltage is being controlled. AHF can also improve the stability of the network or the efficiency of passive filters.

STATCOM — A static compensator is a solid state synchronous condenser connected in shunt with the power network. The output current is adjusted to control the reactive power. The output waveform is close to a sine wave, so it injects only a small amount of harmonics. If connected to a source of power, it can also provide active AC power and can compensate the imbalances.

SVC — A static VAR compensator is a thyristor-controlled reactor connected in parallel with a capacitor. It changes the firing angle in order to control the reactive power in the power network. It is one of the most common types of compensation.

Pass. Filter — This column includes mechanically switched capacitor banks and passive LC filters. This type of compensation has only low ability to adapt to changes in the power network. The main advantage is that the solution is very simple and can fit to stable loads. Some other controllers can be combined with LC filters and the compensation may better meet the requirements.

DVR — A dynamic voltage restorer is a converter which can protect sensitive loads from all supply-side disturbances other than outages. It operates like a series voltage source. DVRs are usually less than costly UPS requirements.

UPS — Uninterruptible power supplies are the only type of equipment that is able to compensate outages. There are many technologies based on batteries, flywheels etc. Depending on the solution it can protect the loads from all supply-side disturbances. The main disadvantages are that UPS occupy a relatively large area and are relatively expensive.

As can be seen from the analysis in Figure 4 and from the diagram in Figure 1 shunt compensators are suitable for load-side disturbances and series compensators are suitable for source-side disturbances should one of these be supply-side. Outages are the most important supply-side disturbances in most cases. UPS devices are the only equipment that can overcome this problem. In a suitable solution, UPS can protect sensitive loads very well. Other series equipment, e.g. AHF or DVR, is suitable only in special cases, e.g. some voltage sensitive loads like loads requiring constant power. This can be important in industrial applications.

For users, the power factor which is given by their loads, is an important consideration. Power suppliers require this factor to be kept close to 1. As stated above, the power factor depends on the reactive power, the harmonics and, in the case of three-wire systems, also on imbalances. These effects are caused especially by currents, because supply voltages are sinusoidal and are in most cases balanced.

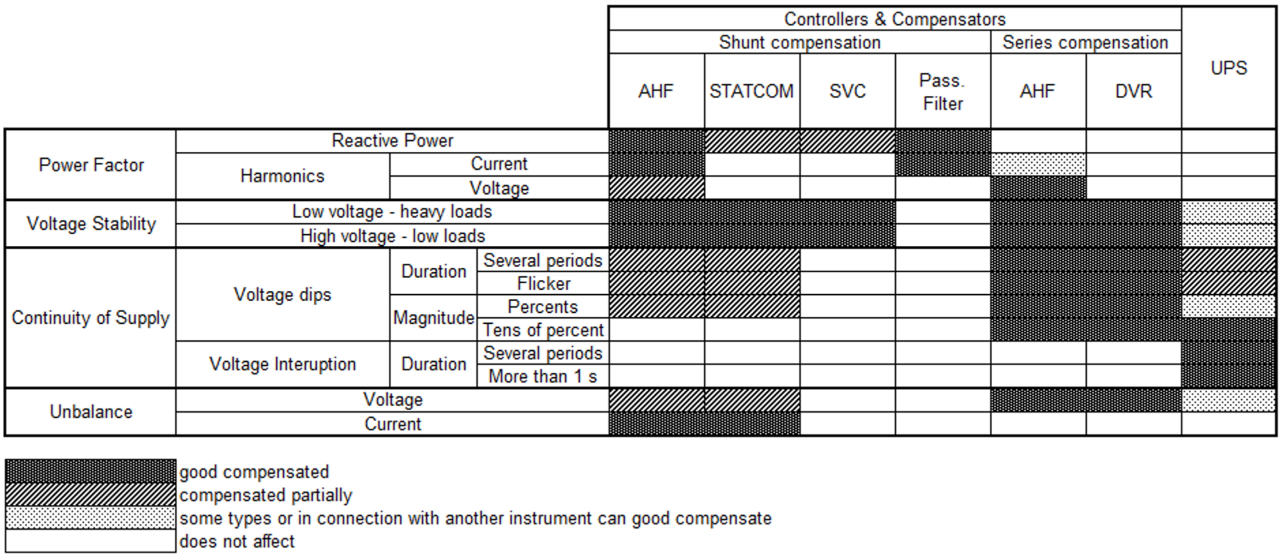

Figure 4: Abilities of controllers.

In the simplest case, only inductive reactive power has to be compensated. A capacitor bank, SVC or STATCOM is suitable for this purpose depending on the required precision of the control. SVC and STATCOM are very suitable in buildings that are equipped with solar cells or other sources of energy.

Intelligent buildings are crammed with electrical equipments and devices, which are major sources of harmonic disturbances. Harmonics decrease the power factor and increase the power loss in the network. A passive filter, or a combination of a passive filter with a series active harmonic filter, can be used to compensate the current harmonics. A disadvantage is that this solution is relatively comprehensive.

The best solution for improving the power factor is to use a shunt active harmonic filter. This equipment alone can meet many of the requirements for power quality. A SWOT analysis of Active Harmonic Filters is presented in Figure 3. The main advantage is, that the reactive power, the current harmonics and the imbalances can be compensated by a single device. However, in many cases it is suitable to combine the AHF with other instruments to suppress its weaknesses. If AHF is combined with a capacitor bank, the main part of the reactive power is compensated by the capacitors and the AHF can be less rated. The resulting solution is then cheaper.

4 Conclusion

With the expansion of intelligent buildings, more emphasis will be placed on power quality. Some equipment for ensuring power quality has been presented in this paper, and comparisons have been made. The shunt Active Harmonic Filter seems to be most promising, and can be used in most of the cases presented here. The paper presents one aspect of our research on constructing and testing this type of compensation equipment.

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