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An Improved IUPQC Controller to Provide Additional Grid-Voltage Regulation as a STATCOM

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ABSTRACT

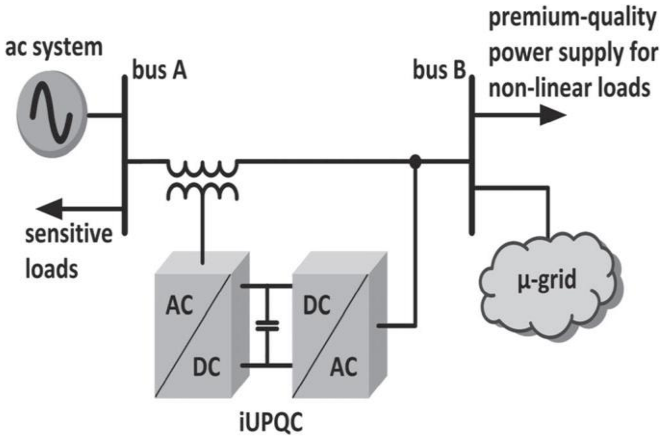
This paper presents an improved controller for the dual topology of the unified power quality conditioner (iUPQC) extending its applicability in power-quality compensation, as well as in micro grid applications. By using this controller, beyond the conventional UPQC power quality features, including voltage sag/swell compensation, the iUPQC will also provide reactive power support to regulate not only the load-bus voltage but also the voltage at the grid-side bus. In other words, the iUPQC will work as a static synchronous compensator (STATCOM) at the grid side, while providing also the conventional UPQCcompensations at the load or Micro grid side. Experimental results are provided to verify the new functionality of the equipment.

INTRODUCTION

Certainly, power-electronics devices have brought about great technological improvements. However, the increasing number of power-electronics-driven loads used generally in the industry has brought about uncommon powerqualityproblems. In contrast, power-electronics-driven loads generally require ideal sinusoidal supply voltage in order to function properly, whereas they are the most responsible ones for abnormal harmonic currents level in the distribution system. In this scenario, devices that can mitigate these drawbacks have been developed over the years. Some of the solutions involve a flexible compensator, known as the unified power quality conditioner (UPQC) and the static synchronous compensator (STATCOM).The power circuit of a UPQC consists of a combination of a shunt active filter and a series active filter connected in a back-to-back configuration. This combination allows the simultaneous compensation of the load current and the supply voltage, so that the compensated current drawn from the grid and the compensated supply voltage delivered to the load are kept balanced and sinusoidal. The dual topology of the UPQC, i.e., the iUPQC, was presented, where the shunt active filter behaves as an ac-voltage source and the series ones an ac-current source, both at the fundamental frequency. This is a key point to better design the control gains, as wells to optimize the *LCL* filter of the power converters, which allows improving significantly the overall performance of the compensator.

The STATCOM has been used widely in transmission networks to regulate the voltage by means of dynamic reactivepowercompensation. Nowadays, the STATCOM is largely used For voltage regulation, whereas the UPQC and the iUPQChave been selected as solution for more specific applications. Moreover, these last ones are used only in particular cases, where their relatively high costs are justified by the power quality improvement it can provide, which would be unfeasible by using conventional solutions. By joining the extra functionality like a STATCOM in the iUPQC device, a wider scenario of applications can be reached, particularly in case of distributed generation in smart grids and as the coupling device in grid-tied micro grids. In, the performance of the iUPQC and the UPQC was compared when working as UPQCs. The main difference between these compensators is the sort of source emulated by the series and shunt power converters.

In the UPQC approach, the series converter is controlled as a no sinusoidal voltage source and the shunt one as a no sinusoidal current source. Hence, in real time, the UPQC controller has to determine and synthesize accurately the harmonic voltage and current to be compensated. On the other hand, in the iUPQC approach, the series converter behaves as a controlled sinusoidal current source and the shunt converter as a controlled sinusoidal voltage source. This means that it is not necessary to determine the harmonic voltage and current to be compensated, since the harmonic voltages appear naturally across the series current source and the harmonic currents flow naturally into the shunt voltage source. In actual power converters, as the switching frequency increases, the power rate capability is reduced. Therefore, theiUPQC offers better solutions if compared with the UPQC in case of high-power applications, since the iUPQC compensating references are pure sinusoidal waveforms at the fundamental frequency. Moreover, the UPQC has higher switching losses due to its higher switching frequency this paper proposes an improved controller, which expands the iUPQC functionalities. This improved version of iUPQCcontroller includes all functionalities of those previous ones, including the voltage regulation at the load-side bus, and now providing also voltage regulation at the grid-side bus, like astaticism to the grid. Experimental results are provided to validate the new controller design. This paper is organized in five sections. After this introduction, in Section II, the iUPQC applicability is explained, as well as the novel feature of the proposed controller. Section IIIpresents the proposed controller and an analysis of the power flow in steady state. Finally, Sections IV and V provide the experimental results and the conclusions, respectively.



Example of applicability of iUPQC.

Static Compensator (STATCOM)

A static VAR compensator is a set of electrical devices for providing fast-acting reactive power on high-voltage electricity transmission networks. SVCs are part of the Flexible device family, regulating voltage, power factor, and harmonics and stabilizing the system. Unlike a synchronous condenser which is a rotating electrical machine, a static VAR compensator has no significant moving parts (other than internal switchgear). Prior to the invention of the SVC, power factor compensation was the preserve of large rotating machines such as synchronous condensers or switched capacitor banks. The SVC is an automated impedance matching device, designed to bring the system closer to unity power factor. SVCs are used in two main situations:

- Connected to the power system, to regulate the transmission voltage ("Transmission SVC")
- Connected near large industrial loads, to improve power quality ("Industrial SVC")

In transmission applications, the SVC is used to regulate the grid voltage. If the power system's reactive load is capacitive (leading), the SVC will use reactors to consume VARs from the system, lowering the system voltage. Under inductive (lagging) conditions, the capacitor banks are automatically switched in, thus providing a higher system voltage. By connecting the thruster-controlled reactor, which is continuously variable, along with a capacitor bank step, the net

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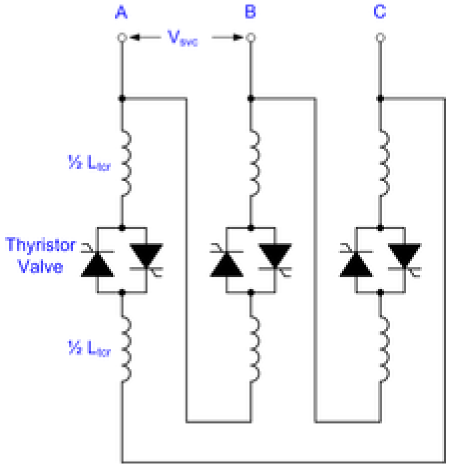
result is continuously variable leading or lagging power. In industrial applications, SVCs are typically placed near high and rapidly varying loads, such as arc furnaces, where they can smooth flicker voltage.

The emergence of FACTS devices and in particular TO thruster-based STATCOM has enabled such technology to be proposed as serious competitive alternatives to conventional SVC [21] A static synchronous compensator (STATCOM) is regulating device used on alternating current electricity transmission networks. It is based on power electronics voltage-source converter and can act as either a source or sink of reactive AC power tan electricity network. If connected to a source of power it can also provide active AC power. It is a member of the FACTS family of devices. Usually aSTATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation. There are however, other uses, the most common use is for voltage stability. From the power system dynamic stability viewpoint, the STATCOM provides better damping characteristics than the SVC as it is able to transiently exchange active power with the system

By means of phase angle modulation switched by the thrusters, the reactor may be variably switched into the circuit and so provide a continuously variable MVAR injection (or absorption) to the electrical network. In this configuration, coarse voltage control is provided by the capacitors; the thyristor-controlled reactor is to provide smooth control. Smoother control and more flexibility can be provided with thyristor-controlled capacitor switching. The thrusters are electronically controlled. Thyristors, like all semiconductors, generate heat and deionized water is commonly used to cool them. Chopping reactive load into the circuit in this manner injects undesirable odd-order harmonics and so banks of high-power filters are usually provided to smooth the waveform. Since the filters themselves are capacitive, they also export MVARs to the power system. More complex arrangements are practical where precise voltage regulation is required. Voltage regulation is provided by means of aclosed-loop controller. Remote supervisory control and manual adjustment of the voltage set-point are also common. Generally, static VAR compensation is not done at line voltage; a bank of transformers steps the transmission voltage (for example, 230 kV) down to a much lower level (for example, 9.0 kV).[5] This reduces the size and number of components needed in the SVC, although the conductors must be very large to handle the high currents associated with the lower voltage. In some static VAR compensators for industrial applications such as electric arc furnaces, where there may be an existing medium-voltage bulbar present (for example at 33kV or 34.5kV), the static VAR compensator may be directly connected in order to save the cost of the transformer. Another common connection point for SVC is on the delta tertiary winding of Y-connected auto-transformers used to connect one transmission voltage to another voltage. The dynamic nature of the SVC lies in the use of thyristors connected in series and inverse-parallel, forming "thruster valves"). The disc-shaped semiconductors, usually several inches in diameter, are usually located indoors in a "valve house".



The main advantage of SVCs over simple mechanically switched compensation schemes is their near-instantaneous response to changes in the system voltage. For this reason they are often operated at close to their zero-point in order to maximize the reactive power correction they can rapidly provide when required. They are, in general, cheaper, higher-capacity, faster and more reliable than dynamic compensation schemes such as synchronous condensers. However, static VAR compensators are more expensive than mechanically switched capacitors, so many system operators use a combination of the two technologies (sometimes in the same installation), using the static VAR compensator to provide support for fast changes and the mechanically switched capacitors to provide steady-state VARs.

Unified Power Flow Controller (UPFC)

A unified power flow controller (UPFC) is the most promising device in the FACTS concept. It has the ability to adjust the three control parameters, i.e. the bus voltage, transmission line reactance, and phase angle between two buses, either simultaneously or independently. A UPFC performs this through the control of the in-phase voltage, quadrature voltage, and shunt compensation. The UPFC is the most versatile and complex power electronic equipment that has emerged for the control and optimization of power flow in electrical power transmission systems. It offers major potential advantages for the static and Dynamic operation of transmission lines. The UPFCwas devised for the real-time control and dynamic compensation of ac transmission systems, providing multifunctional flexibility required to solve many of the problems facing the power industry. Within the framework of traditional power transmission concepts, the UPFC is able to control, simultaneously or selectively, all the parameters affecting power flowing the transmission line. Alternatively, it can independently control both the real and reactive power flow in the line unlike all other controllers.

CONCLUSION

In the improved iUPQC controller, the currents synthesized by the series converter are determined by the average active power of the load and the active power to provide the dc-link voltage regulation, together with an average reactive power to regulate the grid-bus voltage. In this manner, in addition to all the power-quality compensation features of a conventionalUPQC or an iUPQC, this improved controller also mimics aSTATCOM to the grid bus. This new feature enhances the applicability of the iUPQC and provides new solutions in future scenarios involving smart grids and micro grids, including distributed generation and energy storage systems to better deal with the inherent variability of renewable resources such as solar and wind power. Moreover, the improved iUPQC controller may justify the costs and promotes the iUPQC applicability in power quality issues of critical systems, where it is necessary not only aniUPQC or a STATCOM, but both, simultaneously. Despite the addition of one more power-quality compensation feature, the grid-voltage regulation reduces the inner-loop circulating power inside the iUPQC, which would allow lower power rating for the series converter. The experimental results verified the improved iUPQC goals. The grid-voltage regulation was achieved with no load, as well as when supplying a three-phase nonlinear load. These results have demonstrated a suitable performance of voltage regulation at both sides of the iUPQC, even while compensating harmonic current and voltage imbalances.

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