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An Efficient Method for Stabilizing AC Power-Electronics-Based Power Systems

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Abstract

An LC circuit, also called a resonant circuit, tank circuit, or tuned circuit, is an electric circuit consisting of an inductor, represented by the letter L, and a capacitor, represented by the letter C, connected together. The circuit can act as an electrical resonator, an electrical analogue of a tuning fork, storing energy oscillating at the circuit's resonant frequency.

This letter proposes an active damper with a series LC-filter for suppressing resonances in an ac power-electronics based power system. The added series filter capacitor helps to withstand most of the system voltage, hence allowing a lower rated converter to be used for implementing the active damper. Unlike an active power filter for mitigating low-frequency harmonics, the proposed damper dampens resonances at higher frequencies, whose values are dependent on interactions among multiple grid connected converters and reactive elements of the system. Its control requirements are therefore different, particularly in the low-frequency range, where the series LC-filter is predominantly capacitive, rather than the usual inductive characteristics that exist between voltage-source converters and the grid (or load). This low-frequency challenge can fortunately be resolved by the proposed fourth-order resonant controller, in addition to the second-order resonant controller used for resonance damping. Experimental results obtained have confirmed the effectiveness of these controllers, and hence the feasibility of the active damper.

Index Terms—***Active damper, resonances, stabilization, series LC-filter, converters, disturbance rejection.***

INTRODUCTION

AC power-electronics-based power systems are evolving, mainly driven by the increasing use of power electronic converters with renewable energy sources and energy-efficient loads. The resulting converter-interfaced sources and loads are more controllable and efficient, but they also generate more harmonics into power systems. The harmonics may, in turn, trigger resonances introduced by inductive and capacitive elements residing in the systems . Such resonances may further interact with control loops of the converters, leading to instability problems over a wide frequency range. It is thus necessary to develop effective measures for preserving stability and power quality of the ac power grids.

One possibility is to re-shape the dynamic properties of the converters by adding control loops or digital filters. Although lossless damping of resonances can be achieved by these control additions, their effectiveness is usually influenced by the variations of the system conditions. Alternatively, additional passive or active devices can be used as dampers for stabilizing the systems. Passive dampers are, in general, robust, but they incur additional power losses.Lower-loss active dampers are therefore preferred, which however require the use of the high-bandwidth converters for suppressing those high-frequency resonances burdening the power systems.

In terms of convenience, the active dampers are generally added in parallel like in, where an active damper has been added to the Point of Common Coupling (PCC), together with other paralleled grid converters. By dynamically shaping the equivalent grid impedance at the PCC, the active damper in dampens resonances effectively, thus maintaining stability of the considered system. Moreover, since the damper in focuses only on high-frequency resonances from 800 Hz to 2 kHz, its power rating is not high. It however requires switching at frequency, preferably, higher than a normal source or load converter, in order to provide the necessary control bandwidth for damping.

This requirement can be costly for the damper in because of its higher voltage rating, as compared to the source and load converters. Higher voltage rating of the damper is mainly contributed by its series ac L-filter, whose voltage drop is higher than in a traditional shunt Active Power Filter (APF) due to its higher-frequency current flow. Consequently, a higher dc-link voltage is needed, which is not attractive.

To effectively reduce its voltage rating, a series-LC-filtered active damper is proposed in this letter. The filter has an extra capacitor connected in series for withstanding most of the system voltage. The damping converter can then be realized with a lower voltage rating and a smaller filter inductor. The resulting damper is similar to the series-LC-APF proposed in However, their control requirements and challenges encountered are different with the active damper concentrating on the higher-frequency resonances damping, rather than the low-frequency harmonics compensation targeted by the APF. On the other hand, the capacitive filter characteristic in the low-frequency range challenges the stability of grid current controller for the damper. A fourth-order resonant controller is developed for the damper to reject common grid disturbances. Experimental results showing the damper ability to stabilize a grid converter have been obtained for verification.

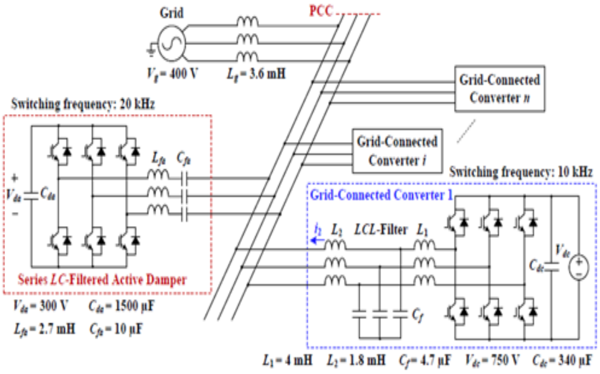

Fig.1.An example power system showing the series Lc filtered active and multiple paralleled LCL filteredgrid converters.

Operational Principle

Fig. 1 shows an example power system with the proposed series-LC-damper added to the PCC, together with other LCL- filtered grid converters. Like in for a series-LC-APF, the added filter capacitor Cfa is used for withstanding most of the PCC voltage, allowing a lower rated converter and a smaller filter inductor Lfa to be used, in turn. However, as an APF, the topology is mainly designed for mitigating dominant low- frequency harmonics, whose bandwidth and other control demands are therefore less stringent. The LC-filter resonance frequency of the APF is also usually tuned close to the low- frequency harmonics, which is different from an active damper.

Filter resonance frequency formed by Cfa and Lfa of the active damper should in fact be slightly lower than the smallest system resonance frequency1. An immediate compromise will then be the tougher rejection of the common 5th and 7th grid voltage harmonics. The predominantly capacitive filter characteristic at those frequencies (instead of the usual inductive characteristic demanded between a voltage-source converter and the grid or load) challenges the use of usual harmonic current controllers. It is therefore nontrivial to design the damper control scheme, whose general representation is provided in Fig. 2 for realizing three capabilities to be described next.

PROPOSED SYTEM MODELLING

The operation principle of a voltage-source converter coupled with a series capacitor to the power grid is presented here. The synthesis of the proposed current control scheme for a capacitive filter “plant” is illustrated as follows.

Fig. 2 shows the overall control diagram for a three-phase grid-connected voltage-source converter with an LC filter and a coupling capacitor at the Point of Connection (PoC). The PoC voltage Vpoc is measured for the grid synchronization by using a Phase-Locked Loop (PLL) in the synchronous reference frame [1]. The grid current that flows through the coupling capacitor is controlled in the stationary αβ-frame.

Table I lists the main electrical parameters of the system. Fig. 3 depicts the frequency response of the filter “plant” of the grid current control loop, which can be obtained based on the transfer function of the converter voltage to grid curren t where it clearly shows that the “plant” has a phase shift of 9 below the resonance frequency of the filter, which indicates a capacitive characteristic at the fundamental frequency and the low-order (5th and 7th) harmonic frequencies. To avoid the influence of the coupling between the dc-link voltage and reactive power compensation, the following two operating scenarios are considered in this work:

Controlled dc-link voltage with reactive current

The dc-link voltage is controlled by a PI controller, whose output is used as the reactive current command i* gq. The active current command i* gp is set to zero. In this case, the grid current cannot be controlled with Zero steady-state error at the fundamental frequency, which will be discussed next. Hence, the proposed current controller is only applied to compensate the low-order be controlled with zero steady-state error at the fundamental frequency, which will be discussed next. Hence, the proposed current controller is only applied to compensate the low-order harmonics.

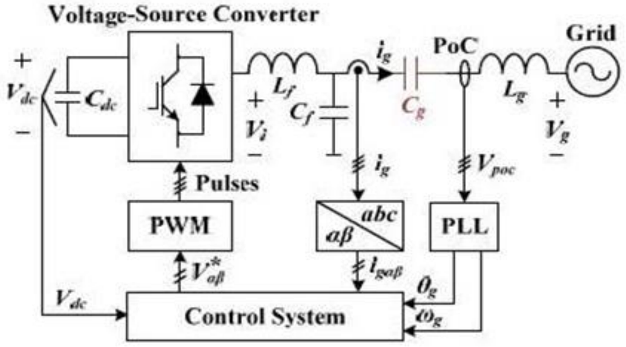

Fig-2: The proposed system architecture with series AC Capacitor

Constant dc-link voltage

The dc-link voltage is in this case kept as constant by an external dc power source . Hence, the reactive current commands i*gq is merely used for dynamic reactive power compensation. The fundamental frequency grid current can then be controlled with zero steady-state error. Fig. 3 illustrates the block diagram of the Control System in Fig. 2, including the controllers for the dc-link voltage and reactive power, as well as the proposed fourth-order resonant current controller at the fundamental and low-order harmonics frequencies. These controllers are explained in the following.

Control of DC-Link Voltage and Reactive Power

Unlike the normal grid-connected converters coupled with the inductor, the dc-link voltage control here is realized by the closed-loop output admittance Yoc(s) reactive current aligned to the orthogonal q-axis, rather than the active current along with the d-axis which the PoC voltage is aligned to. This is because the coupling capacitor is supposed to withstand most of the grid voltage, and the reactive current thus dominates the current injected into the grid [5]- [7]. However, it is

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important to note that the active current still exists to keep the dc-link voltage constant. Thus, even though the active current command is set to zero, there is still an active component in the actual grid current. Hence, the current control schemes with zero steady-state tracking error cannot be used at the fundamental frequency.

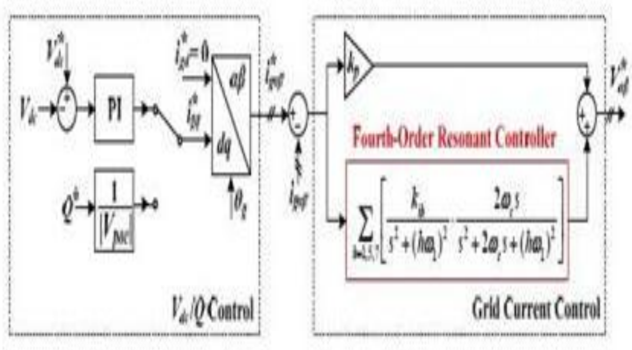

Fig-3: Control System block of the grid-connected converter

WORKING PRINCIPLE

Active power filter is used to mitigating low frequency harmonics. Active damper is used to increase high frequency.

Why we are taken series lc filter instead of remaining filters, because lc filters are exist in between voltage source converters. In active dampers losses are less in particular system, but in passive dampers losses are more. Active dampers are used to high bandwidth converters for suppressing those high frequency resonances burdening the power systems.

There are two types of converter controls are there
1. Active damper converter control
2. Grid converter control

Active damper filter added parallel to point of common coupling to grid converters. High frequency resonances from 800hz to 2khz its power rating is not high, it requires switching frequency. Active damper is costly ,because its higher voltage rating.L filter voltage drop is greater than active power filter so automatically higher frequency current will flow, so we have higher dc link voltage should be needed. So effectively to reduce voltage rating, A series lc filtered active damper is proposed in this scheme.LC filter is used to increase system voltage, active damper is used to lower voltage rating. Damping converter is used to produce reactive power. Finally with help of series lc filtered active damper at grid side the disturbance will be rejected so pure form of active power will be supplied to grid.

Simulation results:

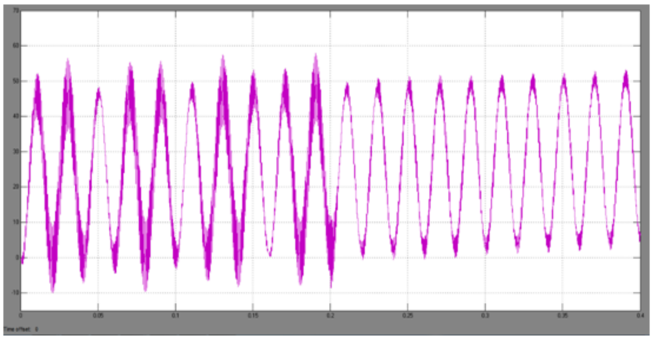

Fig.4 Ac current of the active damper

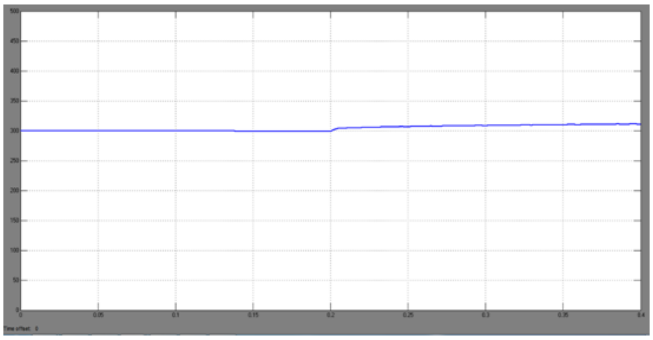

Fig.5 Measured dc link voltage

Fig 4 and 5 shows measured dc link voltage and output current of the active damper. At the instant of enabling the active damper, the dc link voltage rapidly falls from its pre-charged value through anti-parallel diodes of the damping converter to the regulated value of 300v.Compared with the dc voltage of 750v needed by the grid converter, dc voltage of the damper is clearly reduced by the added series filter capacitor. This reduction can further be increased by using higher rated filter capacitor depending on requirements.

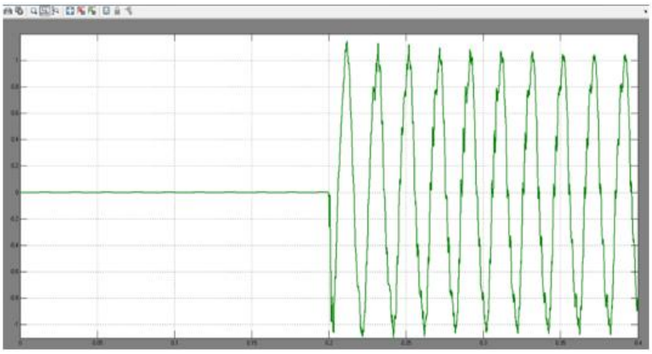

Fig.6 Active damper with dc link voltage at 0.2

CONCLUSION

This letter presents a series-LC-filtered active damper for stabilizing ac power-electronics-based power systems. Performance of the damper has been verified in experiment with the series filter capacitor demonstrated to withstand most of the system voltage. The damping converter can then be rated low in voltage, allowing for a faster switching operation. Stability of the proposed damper has been analyzed over a wide frequency range with appropriate controllers recommended for each requirement, including the fourth-order resonant controller developed for grid disturbance rejection. With its low- and high- frequency control coordinated, the proposed active damper is thus a promising solution for addressing multiple concerns faced by the newer power systems.

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