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Power Quality Improvement using Active Power Filter

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Abstract - *In this paper, we enhance the power quality, Harmonic reduction, Reactive power compensation. Power quality problems have become the most important concern now a days. Custom Power Devices (CPD) provides a solution for these power quality problems. Shunt active power filter is the preeminent solution against nonlinear loads, power quality problems, current harmonics. The HPF consists of a series passive filter and a thyristor-controlled-reactor-based variable-impedance shunt passive filter (SPF). A novel circuit topology for the three-phase active power filter (APF) is proposed to suppress harmonic currents. This three-phase APF is made up of a two-arm bridge power converter, a filter inductor set, a reactive power compensating capacitor set and a capacitor/resistor filtering set. The proposed topology enhances the harmonic compensation capability and provides complete reactive power compensation compared with conventional APF topologies.*

Key Words: **Harmonics; Hybrid Topology; Nonlinear Load; Power Quality (PQ); Grid-Connected System.**

I. INTRODUCTION

The nonlinear loads and equipment in the consumer side and the renewable energy sources in the generation side give birth to new problems in electrical systems. Then, power electronics appears as an essential interface to improve power quality [1]. Due to the increasing use of various nonlinear loads by the consumers the power drawn from the supply is not of good quality. These loads inject current harmonics and also reduces input power factor. Current harmonics leads to various problems like malfunctioning of sensitive equipment, feeder voltage distortions, overheating of distribution transformers etc. In order to avoid these problems, equipment like Custom Power Devices (CPD) which can suppress harmonics are needed. [2]. The active filters can be pure or hybrid active power filters. To reduce the disadvantages of passive filters and active filters and to have the advantages of both the filters, Hybrid active power filters are used, which is a combination of both active and passive filters. [2].

II. ACTIVE POWER FILTERS

Active power filters are superior than passive filters and can suppress supply current harmonics and also reactive power components. Active power filters consist of power electronic devices and can generate specific current components to mitigate the harmonic currents caused by nonlinear loads. Active power filters can be connected in series as well as in shunt to the nonlinear loads. Fig 1 shows a three-phase shunt active power filter where the active filter is connected in parallel with the load. In this paper, a three-phase shunt active power filter is used. The cost of shunt active filters is relatively high, and they are not preferable for a large-scale system because the power rating of the shunt active filter is directly proportional to the load current to be compensated. [5]

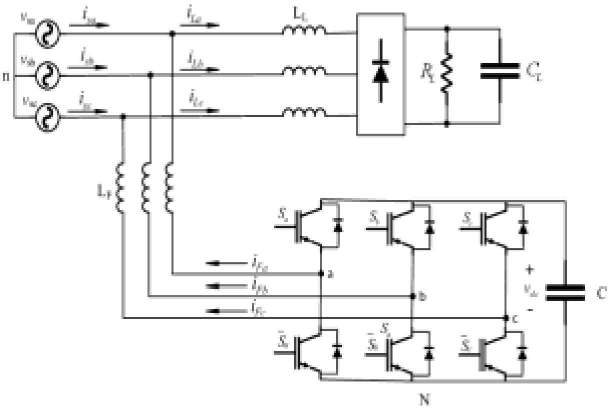

Fig.1 Three phase active power filter

III. CONFIGURATION OF CONVENTIONAL APF

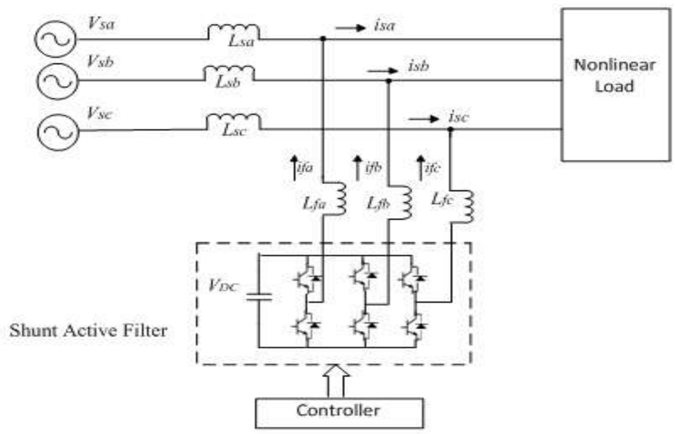

Fig.2 Configuration of conventional APF

Fig 2 shows the power circuit of the conventional APF. The passive device connecting the ac terminal of the power converter in an APF and the utility is an inductor set that acts as a switching ripple filter. Generally, this APF adopt a current mode controller to generate three-phase compensation currents. The generated compensation current of each phase in the three-phase APF is the summation of the harmonic components and fundamental reactive component of load currents. Consequently, the compensation currents are injected into the power lines, and the utility currents are sinusoidal and in phase with the utility voltages. The power converter is a three-arm bridge structure. [3]

IV. CONFIGURATION OF THE HYBRID POWER FILTER

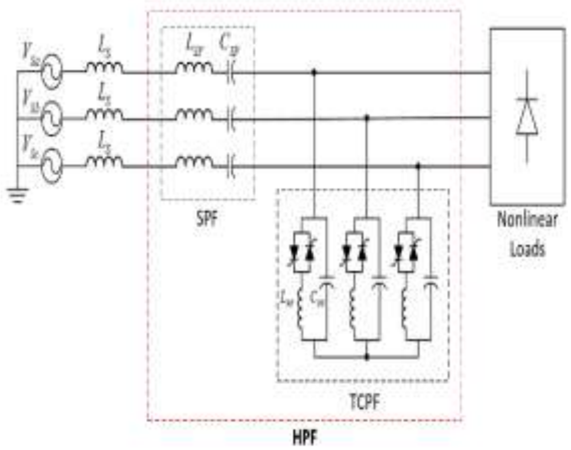

Fig.3 Configuration of the hybrid power filter

Fig. 3 replaces the passive devices of the APF, and this new filter is named the hybrid power filter [6]–[11]. The series inductor and capacitor set acts as a passive power filter. The hybrid power filter overcomes the high-capacity and high-cost problems caused by the power converter of the APF because the passive power filter can lower the capacity of the power converter. The power converter used in hybrid power filters is also a three-arm bridge structure. [3]

V. CONFIGURATION OF PROPOSED APF

The passive devices are also a series inductor and capacitor set for reducing the power capacity of the power converter in the APF. However, the function of the series inductor and capacitor set in the proposed APF is not the same as that of the hybrid power filter APF. However, the function of the series inductor and capacitor set in the proposed APF is not the same as that of the hybrid power filter. The inductor of the series inductor and capacitor set is used to filter the switching ripple due to switching operation of the power-electronic devices used in the power converter, and the capacitor of the series inductor and capacitor set supplies fixed compensation reactive power. The number of power-electronic devices employed in the proposed three-phase APF can be reduced. [3]. Power system quality is caused mainly by the use of constant growth of nonlinear loads, which essentially contain semiconductor devices [4].

VI. PROPOSED FOUR-SWITCH TWO-LEG INVERTER ANALYSIS

For simplicity of analysis, source voltage (V_{sx}=V_{xf}=V_{pcc}) and load voltage (V_x) are considered as sinusoidal waveforms (V_x=V_{pcc}), without the harmonic components (V_{sx}=V_x). The coupling passive power component is represented by (Z_{shF} =Z_{ppFf} =Z_{Fabc}) which comprises a series resistor, an inductor and a capacitor. The inductance is a short circuit path owing to the low rated value as demonstrated in Fig. 5.

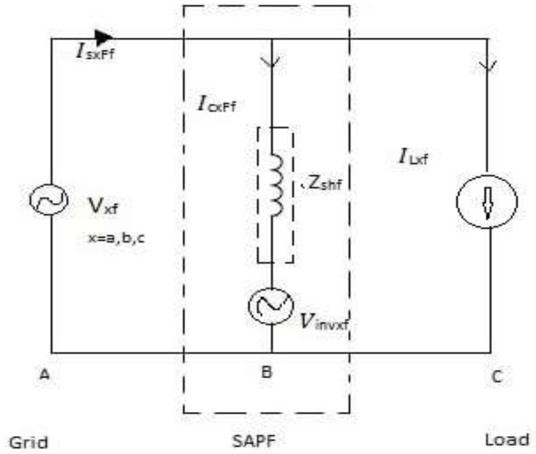

Fig.5 Fundamental equivalent circuit of the proposed APF system

Fig. 5 illustrates the single-phase fundamental equivalent reference circuit from the filter inverter fundamental voltage phasor ($V_{inv\text{-}shxf}$) to the output, where “f” shows the fundamental frequency component.

$$V_{inv\text{-}shxf} = V_x - Z_{shf} * I_{cxfF} \quad (1)$$

where the fundamental compensating current phasor (I_{cxFf}) is divided into real and reactive components as

$$I_{cxFf} = I_{cxFfp} + j\, I_{cxFfq} \quad (2)$$

where the subscripts “p” and “q” represent the active and reactive components. I_{cxFfp} is the fundamental active current component that compensates the loss and dc-link voltage control, and I_{cxFfq} is the fundamental reactive current component that compensate the reactive power in the system load. Thus, expression (1) can be simplified as follows

$$V_{inv\text{-}shxf} = V_{inv\text{-}sxfp} + V_{inv\text{-}sxfq} \quad (3)$$
$$V_{inv\text{-}sxfp} = V_x + I_{inv\text{-}sxfq} * X_{Ff} \quad (4)$$
$$V_{inv\text{-}sxfq} = -I_{inv\text{-}sxfp} * X_{Ff}$$

As shown in expression (2) and (4), the fundamental compensating active current (I_{cxFfp}) and the reactive compensating current (I_{cxFfq}) are extracted into

$$V_{cxFfp} = I_{inv\text{-}sxfp} / X_{Ff} \quad (5)$$
$$V_{cxFfq} = I_{inv\text{-}sxfp} - V_x / X_{Ff} \quad (6)$$

The value of the reactive dc current (i_{qDC}) is controlled in the quadrature axis and the value of the direct axis is set to zero to compensate the fundamental reactive power and protect the APF from being damaged. In the steady state, the active fundamental current (I_{cxFfp}) is insufficiently small (I_{cxFfp}≈0); thus, this current is generated by the inverter to maintain the constant dc-link voltage level. Therefore, with constant dc voltage level and modulation index around (m≈1), the ratio between the DC-link voltage and the load voltage (V_x) is expressed in expression (7), where ($V_{inv-sxf}$) is the inverter fundamental RMS voltage.

$$R_{v_{dc}} = \pm \frac{V_{inv-sxf}}{V_x} = \pm \frac{v_{dc}}{2\sqrt{2}V_x} \quad (7)$$

VII. CONCLUSION

In this paper, we reduce the harmonic, improve the power quality, reactive power compensation. A novel three-phase reduced switch count and transformer-less APF circuit, operating with the function of active filtering and enhanced reactive power compensation. The proposed APF system is more robust, efficient and stable to improve the feasibility and harmonic propagation of the power distribution system.

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