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# Mitigation of Power Quality Issues of Renewable Energy Sources in Electric Grid Systems Using STATCOM

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**ABSTRACT:** This study summarizes an analytical review on the comparison of three-phase static compensator (STATCOM) and active power filter (APF) inverter topologies and their control schemes using industrial standards and advanced high-power configurations. Transformer less and reduced switch count topologies are the leading technologies in power electronics that aim to reduce system cost and offer the additional benefits of small volumetric size, lightweight and compact structure, and high reliability. A detailed comparison of the topologies, control strategies and implementation structures of grid-connected high-power converters is presented.

**KEYWORDS:** FACTS devices; active powerfilter; static compensator; controlstrategies; grid-connected converter; SPWM; SVM

## I. INTRODUCTION

Nonlinear loads linked to electric power distribution Networks generate harmonic pollution. such nonlinear Masses drain currents with varying diploma of harmonic Contents. The harmonic contemporary components do not represent Useful lively power due to the frequency mismatch with the grid Voltage. but, the stream of harmonic currents via Feeders and defensive community elements produces joule losses And electromagnetic emissions that would intrude with other Gadgets linked to the Distribution community. this influences the Electric overall performance of control and verbal exchange systems Worried with the protecting factors.

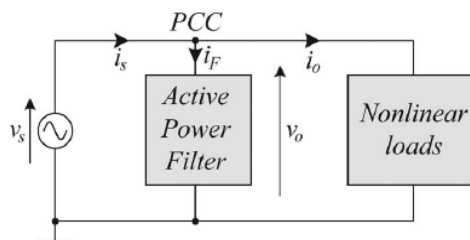


Fig. 1. APF connected in parallel with the loads—shunt-type APF. The filter current  $i_F$  supplies the load harmonic current contents.

Generated in the manipulate algorithm. then again, the Indirect manipulate methods generate the apf contemporary reference Not directly, I.e., by way of causing that the apf-plus-nonlinear-load Currents comply with sinusoidal reference modern-day indicators in phase With the percent voltages. consequently, the use of the scheme shownIn fig. 1

$$i_F^* = i_s^* - i_o = i_{s,nonactive}^* - \sum_{h=1}^{N_{h,max}} i_o(h) \quad (1)$$

In which  $i_f^*$  and  $i_s^*$  are the apf and the % reference currents, Respectively,  $i_{s,nonactive}^*$  is the nonactive contemporary thing Of the mains cutting-edge is, and  $i_o(h)$  represents the burden-side Contemporary harmonics of order h. this circumstance ensures that The best inverter repayment cutting-edge is injected even if The mains voltage affords harmonic distortion. the indirect Manage methods are commonly easier to enforce considering the fact that handiest The input variables (currents and voltages) are measured. on the Other hand, the direct strategies require state-of-the-art reference Generation mechanisms.

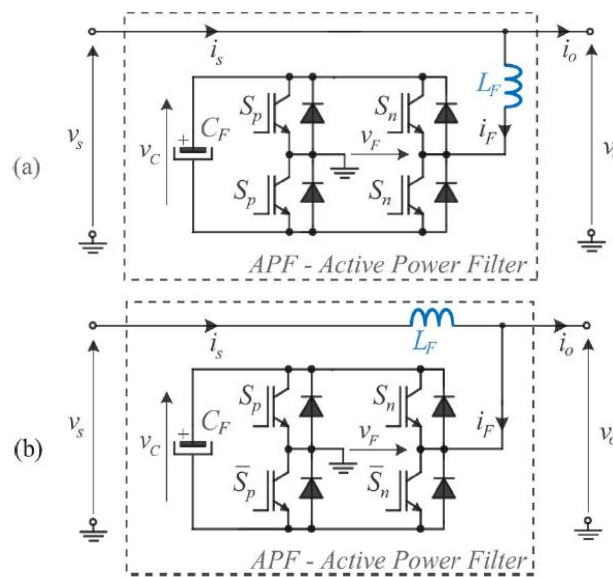


Fig. 2. (a) Typical single-phase APF system architecture. (b) APF architecture used in this work.the compensation opposite section loadHarmonic currents glide through the inductor, generating the In accordance harmonic voltages throughout the inductor in this architecture.

$$\bar{v}_o = \bar{v}_F = \hat{V} \cdot \sin(\omega_1 \cdot t + \varphi) \quad (2)$$

Wherein x represents the local common cost of x for the duration of a provider Duration, v is the peak price of the mains voltage, and  $\omega_1$  Is the mains voltage angular frequency.

The proposed control strategy is much simpler to implement than conventional strategies, such as the ones listed in the following. Perhaps, the most widespread method is the average current mode control [12], which presents an outer voltage control loop and an internal current control loop. Large control bandwidths are typically required with this approach. Hysteresis current control is also employed and demands a single outer voltage control loop to generate the current references. This scheme leads to very fast dynamics but brings all disadvantages inherent to variable switching frequency. Examples of digital control strategies using intern model principles are the adaptive [13] and the dead-beat control. One of the main control challenges faced in all these strategies is the generation of current references. Among the theories to compute the compensation reference current are the  $p-q$  theory [14], [15], the synchronic reference frame [16], the discrete Fourier transform [17], adaptive neural networks [1], [13], and Lyapunov-function-based control [18], [6]. These techniques, While having an acceptable performance for achieving input unity power factor, are relatively complex to implement. In the case of digital programming, powerful digital signal processors (DSPs) are required in addition to analog-to-digital converters, phase-locked loops, and other demanding software tasks. Novel APF control indirect strategies are proposed here as alternative to the cited techniques. These novel indirect methods are based on the concept of virtual impedance emulation through inverters to achieve unity input power factor. A key feature is that either mains-side current or voltage sensor is used, leading to sensorless strategies. The APF implicit current reference does not contain high-order harmonic components to ensure unity power factor at the mains, and thus, the control function is greatly simplified, leading to the control methods derived in Section II. The system is theoretically analysed in Section III. The strategies can be implemented with both analog and digital electronics, demanding minimum hardware and data processing capabilities. The achieved performance is similar or superior to that

attained with conventional strategies as shown through the simulation and experimental results given in Sections IV and V. The main contribution of this work lies on the use of very simple implicit current controllers to control an APF.

## II. APF INDIRECT CONTROL STRATEGY CONCEPTS

### A. Current Sensorless Strategy

Applying Kirchhoff's second law to the circuit in Fig. 1 gives

$$v_s - L_F \cdot \frac{di_s}{dt} - \underbrace{(s_p - s_n)}_{=s_F} \cdot v_c = 0 \quad (3)$$

where  $s_p$  and  $s_n$  are the switching functions for switches  $S_p$  and  $S_n$ , respectively. These are defined as +1 if a switch is closed and 0 while it's miles off. the ensuing switching function For the clear out comprehends both of these into  $s_f = s_p - s_n$ . The Switching signals are generated with the aid of a proper modulation scheme.

$$\bar{s}_F = \frac{1}{T_s} \int_{t-T_s}^t s_F dt = d_F \quad (4)$$

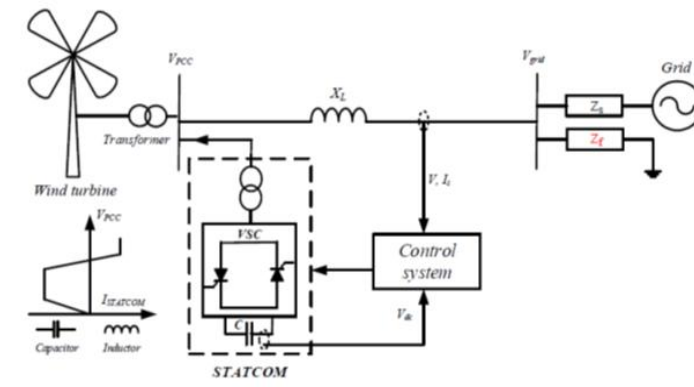
where  $d_F$  is the resulting APF duty cycle. This is to be generated by the control strategy. Applying (4) to (3) results in

$$\bar{v}_s - L_F \frac{d\bar{i}_s}{dt} - d_F \bar{v}_c = 0. \quad (5)$$

Assuming that a unity input power factor is to be achieved, the system should emulate a resistive behavior. Thus

$$\bar{i}_s = \frac{\bar{v}_s}{R_e^*} \quad (6)$$

## III. THE STRUCTURE OF THE WT BASED FSIG CONNECTED TO STATCOM:



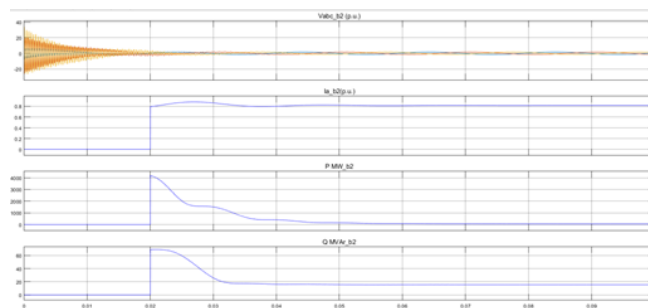
## IV. EQUIVALENT-CIRCUIT-BASED ANALYSIS

In which the parameters  $L_{eq}$ ,  $R_e$ , and  $C_{eq}$  are the equivalent Circuit elements that model the controlled system. the equivalent. This expression indicates that the Equal enter impedance of the active filter with the proposed Manage method includes a chain connection of a resistance  $R_e$  And a capacitance  $C_{eq}$ . the resistance is chargeable for the Lively strength transference to the burden, whereas the series capacitance Compensates for the filter out inductance If a Frequency domain Evaluation is applied to the equivalent circuit.

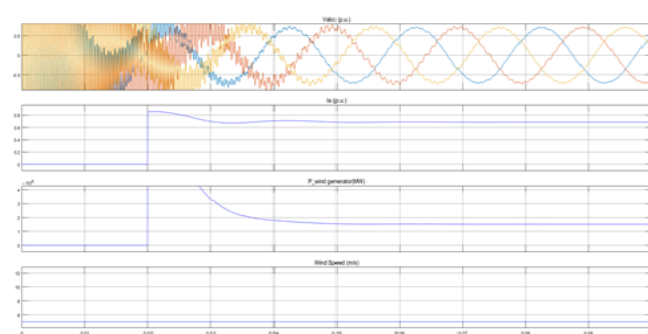
### A. Equivalent-Feedback-Control-Based Analysis

The proposed manage strategies do not present a specific Current loop manage. the modern-day control is truly implicit Within the manage legal guidelines that decide the Apf obligation cycle. that is understood within the following. a classic Feedback control loop is in which  $c(s)$  represents A cutting-edge controller,  $g(s)$  is the device model, and  $h(s)$  is The transfer function of the size chain.

### V.SIMULATION RESULT



(a) Bus Ioutput



(b) Wind generator

### VI.CONCLUSION

Novel control strategies for a modified shunt APF architecture have been proposed here. The proposed strategies were able to guarantee close-to-unity power factor. Both current and voltage sensorless versions have been presented, where the voltage sensorless control has been analyzed in detail regarding its performance, equivalent circuits, and stability.

The main feature of the strategies is their extreme simplicity since no complex current reference computations are required. The implicit control loop is another innovative characteristic. In this sense, it was proven that the proposed strategies are equivalent to explicit current control strategies employing a resonant-type controller. This explains the excellent sinusoidal tracking performance. In addition to the resistive behavior, the APF emulates virtual capacitance and/or negative inductance. Thus, zero mains-side current phase displacement is achieved. These characteristics were verified through circuit simulation and in an experimental setup including a nonlinear rectifier load, with the APF being switched at 5 kHz. This is a very low switching and highlights the achievable performance. The concepts can be easily extended to the control of PFC rectifiers and three-phase systems.

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