Implementation and Control of an Anti-Resonance HybridShunt Capacitor System for Power Factor Correction

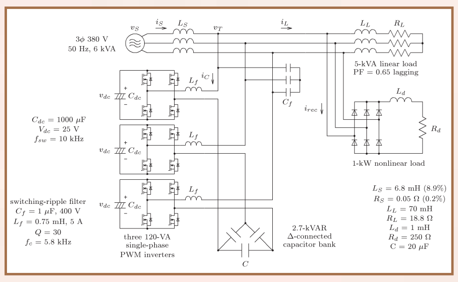
ชื่อผู้วิจัย/หน่วยงาน

Pichai Jintakosonwit — Sirindhorn International Institute of Technology, Thammasat University

Sunt Srianthumrong — National Electronics and Computer Technology Center

Pichit Jintakosonwit — Metropolitan Electricity Authority

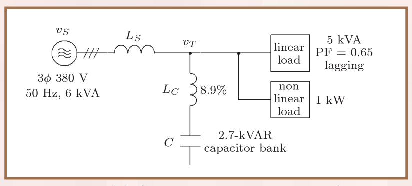
ABSTRACT



This research proposes design and control of a three-phase anti-resonance hybrid capacitor bank for power factor correction in low-voltage industrial power systems. In general, shunt capacitors connected in series with reactors should be designed carefully before installation in order to avoid series and/or parallel harmonic resonance between the capacitors and line inductances. However, the system parameters are dynamically changed according to the power system configurations and loads. Consequently, harmonic resonance might occur after the capacitors have been installed. The main objective of the proposed hybrid capacitor bank is to compensate for reactive power without any harmonic resonance. The hybrid capacitor bank is a combination of delta-connected capacitors connecting in series with three small-rating single-phase inverters without any matching transformer. The inverter is used to improve the characteristics of the capacitors. As a result, no harmonic resonance occurs under any system condition. In this poster, simulation results verify the viability and the effectiveness of the proposed anti-resonance hybrid delta-connected capacitor bank for reactive power compensation.

Introduction

Shunt power capacitors are commonly used in industrial and utility power distribution systems for power factor improvement and voltage control. Even though the capacitors do not generate harmonics, they can influence harmonic levels on the distribution systems. One of the most serious problems is the so-called "harmonic resonance," which contributes to a significant amplification of voltage and current harmonics. This phenomenon is caused by series and/or parallel harmonic resonance between line inductances and capacitors. Several real cases of harmonic resonance problems have been reported. In addition, it has been known that the harmonic resonance might occur seriously under light-load conditions at night.



In general, individual customers should design shunt capacitors carefully before installation on their industrial distribution systems, so as to avoid the system resonance. A common solution is to add reactors in series with existing capacitors. This combination forms a tuned filter with a tuned frequency below the most dominant harmonic frequency, usually the fifth harmonic frequency. However, the system parameters are dynamically changed with the power system configurations and loads. Therefore, the harmonic resonance might occur even if a combination of capacitors connected in series with reactors has been installed.

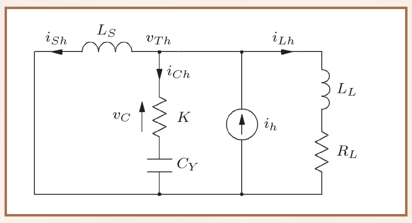
Even though a static var compensator (SVC) can compensate for reactive power effectively, the cost of SVC is much more expensive than that of a shunt capacitor. Recently, hybrid passive-active filters have been extensively investigated for achieving higher efficiency and reducing the kVA-ratings of the active filters. The hybrid filters can provide various functions such as power factor correction, harmonic compensation and/or harmonic damping. Nevertheless, the shunt capacitor in the hybrid filter should be capable of continuous operation including harmonic currents. The voltage and current ratings of the capacitor might be larger than the nominal ratings. Moreover, in low-voltage industrial power systems, delta-connected capacitors are commonly used. This makes the system configuration and control of a hybrid filter complicated. No literature has been published concerning a transformerless hybrid filter equipped with delta-connected capacitors.

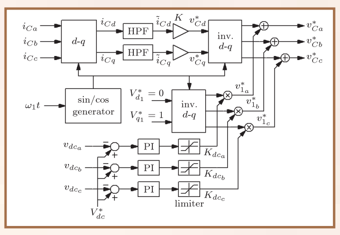
Objectives

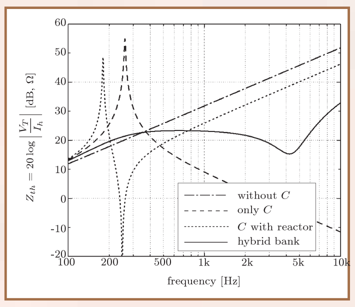
1. To compensate for reactive power (energy conservation)
2. To improve power quality (system stability and reliability)
3. To reduce voltage and current ratings of shunt capacitor (cost reduction)

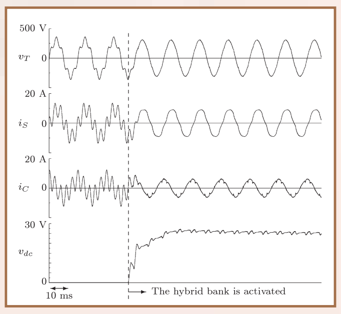
Proposed Hybrid Capacitor System

The hybrid capacitor system is a combination of delta-connected capacitors connecting in series with three small-rating single-phase inverters without any matching transformer. The main purpose of integrating the inverters is to make the capacitors compensate for reactive power without harmonic resonance. Each capacitor is characterized by behaving like a high impedance for the fundamental frequency, so that the VA and voltage ratings of the inverters can be much reduced. Each inverter acts as an infinite impedance for harmonic frequencies, whereas it behaves like a zero-ohm impedance for the fundamental frequency. As a result, no harmonic resonance occurs between the capacitors and line inductances, irrespective of system conditions.



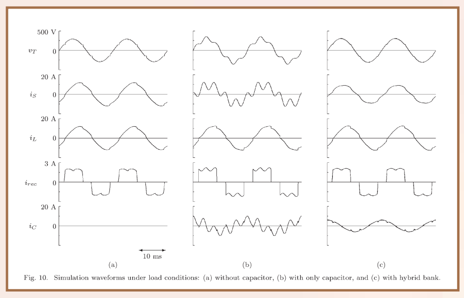






Simulation Results

The following simulations are performed under full-load and no-load conditions by a software "PSCAD." The control gain K is set to 15 (.In case of full-load conditions, the source voltage is assumed to be a pure sinusoidal voltage. Therefore, there is no harmonic voltage in the source. The harmonic current generated by the nonlinear load is taken into account. In case of no-load conditions, both linear and nonlinear loads are disconnected.



The 5th- and 7th-harmonic voltages, each of which has a constant value of 3.11 V (1%), exist on the source for the purpose of taking background harmonic voltage into account.

Conclusion

This research has proposed an anti-resonance hybrid delta-connected capacitor bank for power factor correction in low-voltage power distribution systems. As a result, the hybrid capacitor bank can compensate for reactive power and damp harmonic resonance, irrespective of load conditions and harmonic sources. The voltage and current ratings of shunt capacitors can be reduced. No matching transformer is required and the required dc bus voltage of the inverter is only 25 V for the power distribution system rated at 380 V. This leads to practical use for low-voltage systems, because of low-cost MOSFETs and small size. Moreover, it is easy to modify the existing delta-connected capacitor banks to the hybrid capacitor banks by adding or replacing the reactors with three single-phase inverters.

TABLE II

TOTAL RMS VALUES, INPUT POWER FACTOR AND LOAD POWER IN FIG. 10.

conditions	V_T	I_S	I_L	I_{rec}	I_C	DPF	PF	P_o
no capacitor	207 V	8.3 A	8.3 A	1.6	0 A	0.74	0.74	3822 W
only capacitor	218 V	7.4 A	8.6 A	1.6	5.3 A	0.96	0.85	4098 W
hybrid bank	216 V	6.6 A	8.6 A	1.6	4.1 A	0.97	0.97	4143 W

Note: all values of DPF and PF are lagging power factors.

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