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Four-wire three-phase load balancing with Static VAr Compensators

F.R. Quintela *, J.M.G. Arévalo, R.C. Redondo, N.R. Melchor

Escuela Técnica Superior de Ingeniería Industrial. Universidad de Salamanca, 37700 Béjar, Spain

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ABSTRACT

Static VAr Compensators (SVCs) can balance the phase currents of three-wire three-phase loads and compensate their reactive power. Thus, the SVC-load set becomes a balanced load with any desired power factor. This paper proposes a method to use SVCs with four-wire three-phase loads which still perform those functions: load balancing and reactive power compensation. As a result, any load connected to a three-(or-four-)wire three-phase system can be transformed into a balanced load with unity power factor, even if it is a single-phase load. Other properties that appear in particular cases are also analyzed.

1. Introduction

Static VAr Compensators (SVCs) perform a main function serving as reactive power compensators in electrical energy distribution systems. So much so, that the optimization of this function attracted, and continues to attract, the interest of researchers who provide new approaches to the subject [1,2].

But SVCs can also be used simultaneously for power factor correction of three-wire three-phase loads, and to balance their phase currents [3–6]. Those two functions are accomplished by reactance sets. The algorithms used to obtain those SVC reactances have been determined by power analysis [6], which ensures that SVCs can be used not only with passive loads connected in a star or delta configuration [3–5], but also with any kind of load, whether active or passive, and whichever its internal connections may be. Furthermore, those algorithms allow the power factor of the resulting load to be fixed at any desired value [6].

But balancing the phase currents of four-wire three-phase loads is also beneficial, not only to contribute to voltage balance, but also to decrease power loss. For example, in Fig. 1 the power factor of each four-wire three-phase load is unity, and each load absorbs the same power, 1 kW. But the currents are balanced in (a) and unbalanced in (b). If R is the resistance of each wire, $U = 400$ V the effective voltage between two phases, and I the effective value of each phase current, then the power loss in (a) is $P_{pa} = 3RI^2 = 6.25R$. The power loss in (b) is $P_{pb} = R(I_{Rb}^2 + I_{Sb}^2 + I_{Tb}^2 + I_{Nb}^2) = 21.56R$, wherein the addends in the parenthesis are the square of the effective phase currents of (b). There results a ratio of $P_{pb}/P_{pa} = 3.45$; that is to say, the power loss P_{pb} is more than three times P_{pa} just because of the unbalance of the currents. Therefore, electric system losses can be reduced by balancing the currents of four-wire three-phase loads, which, in addition, contributes to balance the system voltages. So, it seems convenient to devise a SVC for any four-wire three-phase load, which will simultaneously balance their phase currents and correct their power factor.

2. SVC for three-wire three-phase loads

This paper presents a method of creating a SVC for four-wire three-phase loads. It is an adaptation of the SVC for three-wire three-phase loads obtained through power analysis [6]. The following summarizes the characteristics of the SVC for three-wire three-phase loads, which will also be used in the design of the SVC for four-wire loads [6].

Fig. 2 shows a three-wire three-phase load, a SVC, and three identical varmeters whose readings are Q_{R1}, Q_{S1}, and Q_{T1}. If

$$\begin{aligned} Q_{RS}^C &= Q_{T1} - Q_{R1} - Q_{S1} \\ Q_{ST}^C &= Q_{R1} - Q_{S1} - Q_{T1} \\ Q_{TR}^C &= Q_{S1} - Q_{T1} - Q_{R1} \end{aligned} \tag{1}$$

then the resulting currents $\bar{I}_R$, $\bar{I}_S$, and $\bar{I}_T$ are balanced and the power factor of the SVC-load set is unity. This is true for any three-wire three-phase load connected to it [6]. The reactive power absorbed by the set is then zero. If the load-compensator set is required to absorb a particular value of reactive power, Q, whether positive or negative, then $Q/3$ must be added to each second member of (1), that is [6]

$$Q_{RS}^C = \frac{Q}{3} + Q_{T1} - Q_{R1} - Q_{S1} \tag{2}$$

* Corresponding author. Tel.: +34 923408080.
E-mail addresses: felixrq@usal.es (F.R. Quintela), jumagar@usal.es (J.M.G. Arévalo), roberrm@usal.es (R.C. Redondo), norber@usal.es (N.R. Melchor).

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