POWER FACTOR CORRECTION OF FAST DYNAMICS INDUSTRIAL LOADS

(Power Electronics applied to Power Quality)

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ABSTRACT

In many industrial plants (as well in some large commercial buildings), it's possible to find some kinds of electrical loads that presents, simultaneously, *low power factor* and *fast operational dynamic* (what means *fast and ciclic changes in active and reactive power demmanded from the grid*).

The main target of this paper consists in evaluating power factor correction methods and technics based on conventional compensation systems (*relays-based* controllers and capacitors switched by eletromechanical contactors) and dynamic compensation systems (*transistors-based* controllers and capacitors switched by power tyristors modules) in order to compare both general performances and to analyse the possible impacts regarding to energy billing.

The paper emphasasis the benefits of applying "*real-time*" (dynamic) correction systems, discuss the inherent limitations associated to conventional systems and presents some results and conclusions about this subject, based on a real case study developed for an automotive industry in Brazil, with a large number of welding equipments.

1. INTRODUCTION

Initially, it's important to inform that, in Brazil, electrical energy bills of medium, large and intensive industrial and commercial consumers are structured based on two main registered parameters : *Demmand* (kW) and *Energy* or *Electricity Consumption* (kWh). However, there's a third (indirect) billing parameter that can impose hard penalties to these consumers if a minimum value (depending on the period of the day) is not achieved : the *Power Factor*.

Nowadays, and for a while, only the *displacement power factor* (regarding to 60 Hz currents and voltages) has been effectively monitored by energy suppliers electronic measurement systems. The allowed range is situated between *0,92 inductive* and *0,92 capacitive*. Acording to brazilian billing legislation, the power factor must be measured hourly. From 06:00 AM to 12:00 PM, capacitive values are allowed (without limits) and inductive values may not be inferior to 0,92. Similarly, from 00:00 AM to 06:00 AM, inductive values are allowed (without limits) and capacitive values may not be inferior to 0,92. See Figure 1.

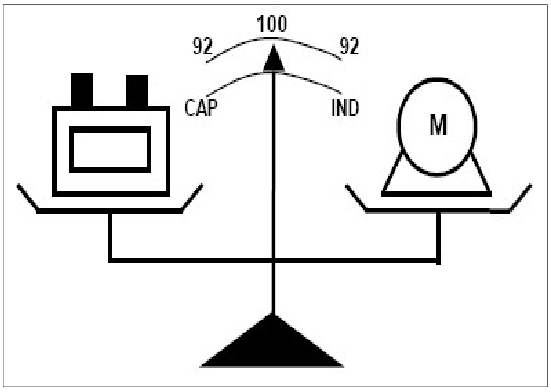


Figure 1

As the suppliers energy electronic meters are able to capture instantaneous values in one milisecond (or less) and calculate active and reactive powers based on RMS values of voltages and currents in one second (in accordance with brazilian standards), it becomes relevant to analyse the application of power factor correction systems when fast dynamic electrical loads are involved (note that this kind of load operate imposing fast and ciclic changes in active and reactive power from the grid, what can occur in a few hundreds of milliseconds or less).

In these situations, generally the conventional correction systems are not fast enough to response adequately to operational dynamic of the load. Otherwise, the dynamic systems (or "*real time*" compensation systems) are able to develop the necessary task.

The expected contribution of the analysis presented forward, based on results of a case study, is to clarify a little more (specially for electricians engineers that work with projects, consulting and maintenance), some important aspects regarded to power factor correction and to alert about necessary cautions when choosing and applying compensation systems involving fast dynamic loads.

3. POWER FACTOR CORRECTION – A GENERAL VIEW OF CONVENTIONAL AND DYNAMIC AUTOMATIC SYSTEMS

Power factor correction systems whose capacitors are switched by eletromechanical contactors are usually named "*conventional systems*". In these systems, it´s usual to adopt automatic controllers with relays outputs. Figure 2 presents an electric schematic of a complete system and shows a contactor (electric connections and a picture) specially developed for capacitors energization (pre-insertion resistors incorporated), that provides low inrush currents.

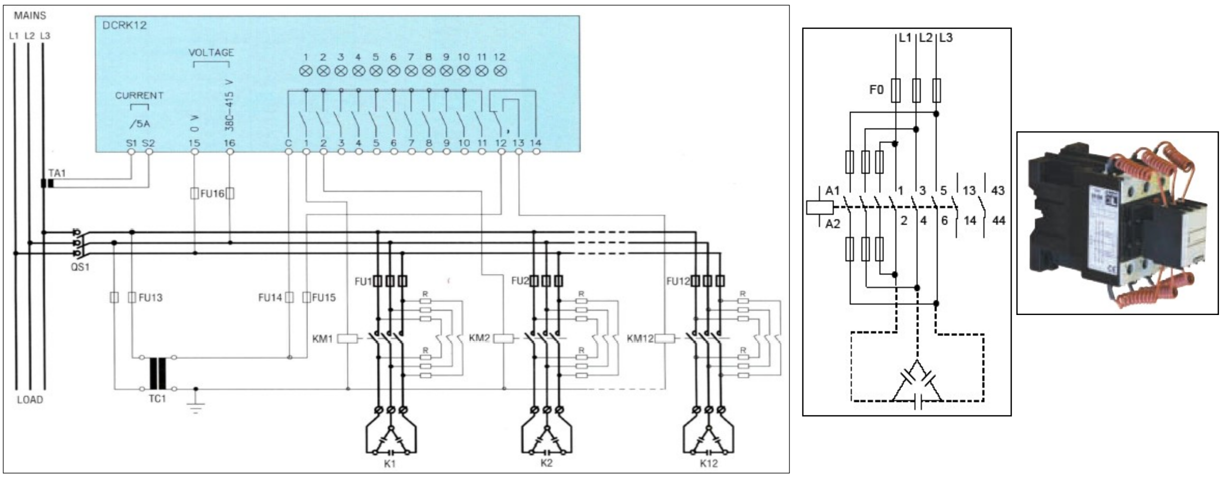


Figure 2

The main characteristics of a commercial conventional system are :

.reduction of inrush currents to, at about, one fourth of the inrush currents that would flow without the presence of pré-insertion resistors;

.it´s necessary to wait capacitors discharging time before reenergizations (generally, something at about one minute), what is provided by adjusting the "reconnection time" on the controller;

.aplliable to any kinds of loads, specially to reactive compensation (and power factor correction) involving fast dynamic loads;

.high maintenance costs and low acquisition costs, if compared to dynamic systems.

In dynamic systems (or “*real time*” compensation systems), capacitors are switched by tyristors modules. The switching times are extremely short, varying, generally, from a half cicle to one cicle and a half (from 8 to 25 miliseconds in 60 Hz). In these systems, it´s usual to adopt automatic controllers with transistors outputs. Figure 3 presents an electric schematic of a complete system and shows a tyristor switching module (picture) and a graphic that ilustrates the instant of reenergization of a capacitor after the activation signal sent by the controller (note that the system waits for the momment when both grid and residual capacitor voltages are equal).

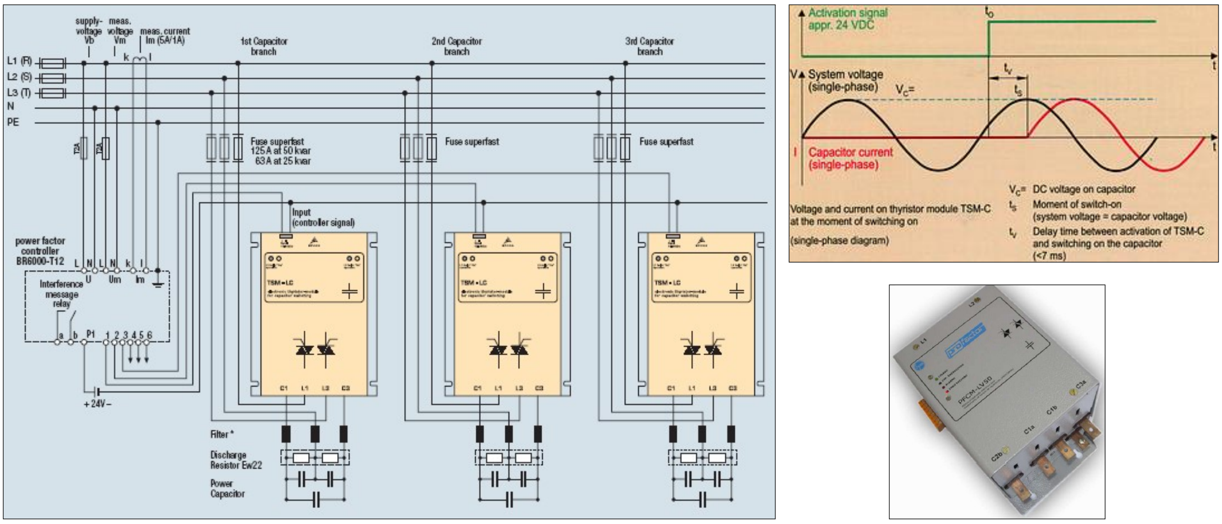


Figure 3

The main characteristics of a commercial dynamic system are :

.no inrush currents;

.possibility of immediate reenergizations (reenergizations occur with zero volts between the grid and the capacitors);

.reconnections ins a very short time (25 miliseconds or less);

.aplliable to any kinds of loads, specially to reactive compensation (and power factor correction) involving fast dynamic loads;

.low maintenance cost and high acquisition costs, if compared to conventional systems.

4. MAIN RESULTS OF A REAL CASE STUDY – WELDING EQUIPMENTS IN AUTOMOTIVE INDUSTRY

In 2007 and 2008, a study / project was developed in an automotive plant (Brazil) in order to define, size and specify a power correction system to be apllied in industrial areas with hundreds of fast dynamic welding machines presenting aleatory and intermitent operation, and with individual operative cicles of, at about, 500 miliseconds (time between starting and finishing one effective welding cicle). Measurements and calculations were perfomed and the study, project and specification of a dynamic compensation system were concluded. Afterwards, the measurement results obtained for one of the four existing welding stations feeders (*bus-ways* electrically fed by two parallel 440 V buses) were used for aditional analysis and simulations. The target was to compare, based on the load dynamic behaviour, the performance of both *conventional* and *dynamic* power factor correction systems. For this specific evaluation, a 800 kVAr (16 x 50 kVAr) capacitors bank was sized. The simplified one-line diagram is shown in Figure 4.

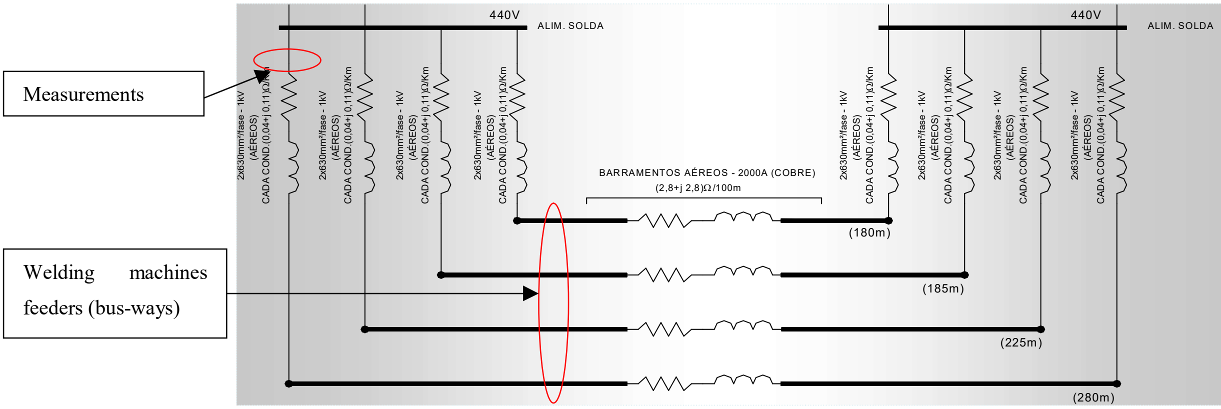


Figure 4

The operational power factor, before any correction procedure (average value = 0,62), is shown in Figure 5. Note that the sampling time interval is equivalent to 30 minutes (total of 18.000 subintervals of 100 miliseconds).

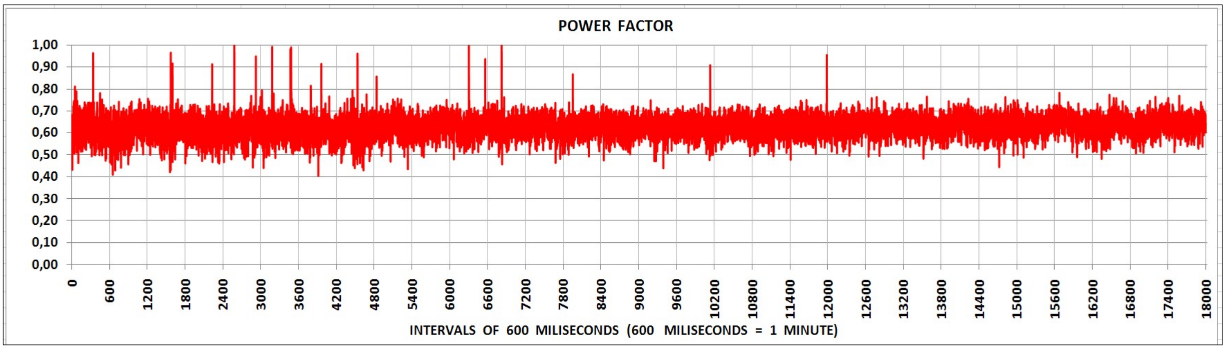
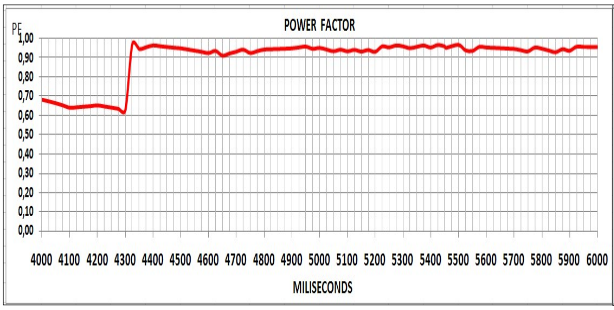


Figure 5

The main results of comparative analysis are summarized by the graphics and by the comments presented forward (item 5). In the simulations, the target power factor was defined as 0,95.

<u>Application of a *Dynamic ("real-time") Correction System*</u>



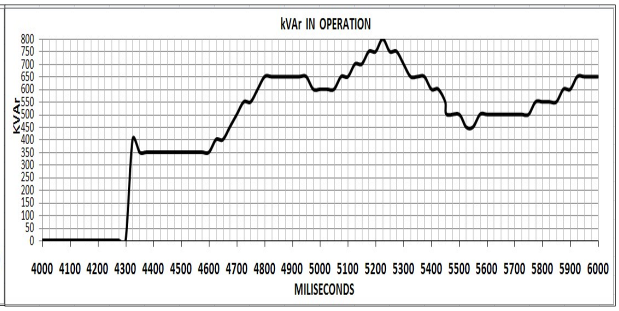
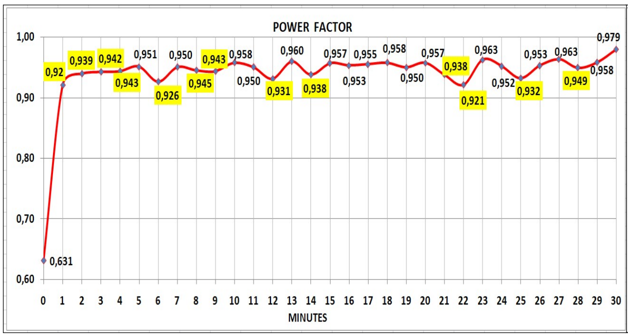


Figure 6 ***Figure 7***

Figures 6 and 7 show, respectively, power factor behavior and capacitive reactive power in operation on a period of 2 s or 2000 ms (to match more clearly the operational dynamic of the "*real time*" system), considering correction steps of 50 kVAr and reconnection times of 25 ms.

<u>Application of a *Conventional System*</u>



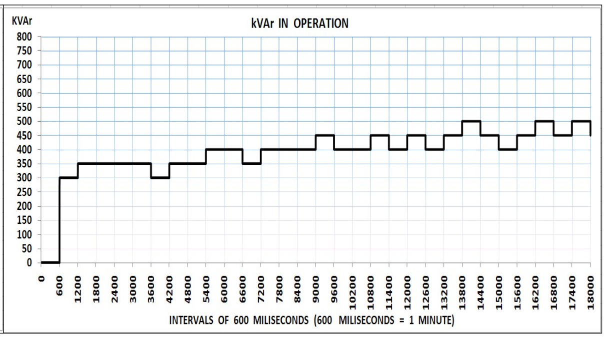


Figure 8 ***Figure 9***

Figures 8 and 9 show, respectively, power factor behavior and capacitive reactive power utilization on 30 minutes (to match more clearly the operational dynamic of the conventional correction system), considering correction steps 50 kVAr and safe reconnection times of 1 minute. In Figure 8, the insatisfactory power factor levels are highlighted in yellow.

5. GENERAL COMMENTS AND PRELIMINARY CONCLUSIONS

Considering the operational dynamic of the load, the main preliminary conclusions of these evaluations may be described as follows :

.the considerable stability and accuracy in power factor correction obtained with the tyristors-based systems because of the fast reactive compensation (it's not necessary to wait capacitors discharging to proceed with reconnections, as in conventional systems);

.the optimal usage of capacitive banks when they are switched by "real time" systems (considering the presence of fast dynamic loads, the necessary delay between two consecutive reconnections in conventional systems may demmand only a partial usage of the installed capacitors);

.the absence of inrush currents when applying dynamic systems (what provides a better voltage regulation and avoid transitory overvoltages) and the reduced maintenance costs.

.the guarantee of a secure power factor correction provided by dynamic systems (the simulations for conventional systems showed that, on a period of 30 minutes, several occurrences of low power factor were detected; so, in this case, and depending on the active and reactive consumption characteristics of the load along the time, it's possible for the energy suppliers measurement systems to registrate low power factors).

REFERENCES

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.Starosta, J. , IEEE member – “*Real Time Reactive Energy Static Compensation*” – VII Brazilian Power Quality Conference - 2007
.Notes and results of real case studies developed by the author.