Consumption analysis method for optimizing reactive compensation at MV

Abstract

Many times we find the question that how many reactive power to be compensated must be chosen after making a measurement with a network analyzer. This situation is crucial in determining proper reactive compensation system in MV.

The presence of harmonics in the electrical system may also influence considerably, not only upon the operation of the capacitor bank, but the entire system power quality.

This article will explain how to define the power and steps that power factor correction in MV should be, using a simple statistical method, and assess risks to the presence of harmonics in the electrical system.

Electrical measurements

We must start any analysis of reactive power compensation with a measure carried out with a network analyzer (CIR-e3, AR5L or AR6), where we record the consumption of reactive power to compensate of the installation.

We should proceed according to the following principles so that a correct data logging is achieved for further accurate analysis:

- Period: The period for registration must be large enough to be considered as a representative and realistic sample of normal consumption of the installation. It is advisable for at least a period of one week.

- Sampling frequency: It is recommendable to use a sampling rate as low as possible to observe more closely the fluctuations of loads. If we consider a system with little load variations one can use a higher sample rate. It is suggested to use a sampling rate between ten seconds and fifteen minutes, also considering the memory capacity of the recording data logger.

- Seasonality: Depending on the facility activity sector, the power consumption may differ depending on the time of year, even between days along a week. It is, therefore, essential to assure the recorded values are as representative as possible of the real profile consumption of the installation.

- Existing capacitor bank: The presence of a capacitor bank will interfere with the acquired data and distort the data collected. So, ensure that during the registration period no kind of power factor correction equipment is connected.

Analyzing the measurements

After obtaining the data, we must analyze them. We will use a very simple but yet very useful statistical method such as histograms.

A histogram is a graphical representation of a frequency distribution given values. The distribution of values is divided into intervals. These intervals could be selected as one decides, but too short or too large intervals could be impossible to analyze.

One method to determinate the optimal interval size is with the following formula [1.1]:

$$S = \frac{(X_{MAX} - X_{MIN})}{k}$$

X_{MAX} is the maximum value, X_{MIN} is the minimum value, and k is the number of intervals calculated according to the Velleman method, $k = 2 \cdot N^{1/2}$, where N is the number of values. To avoid deviations you can delete outliers that could affect the correct approach.

Let we go through an example of analysis using reactive power histogram. We can observe the three-phase inductive reactive power consumption at a voltage of 6,6 kV in an industry, where they are paying penalties for low power factor, in Figure 1.

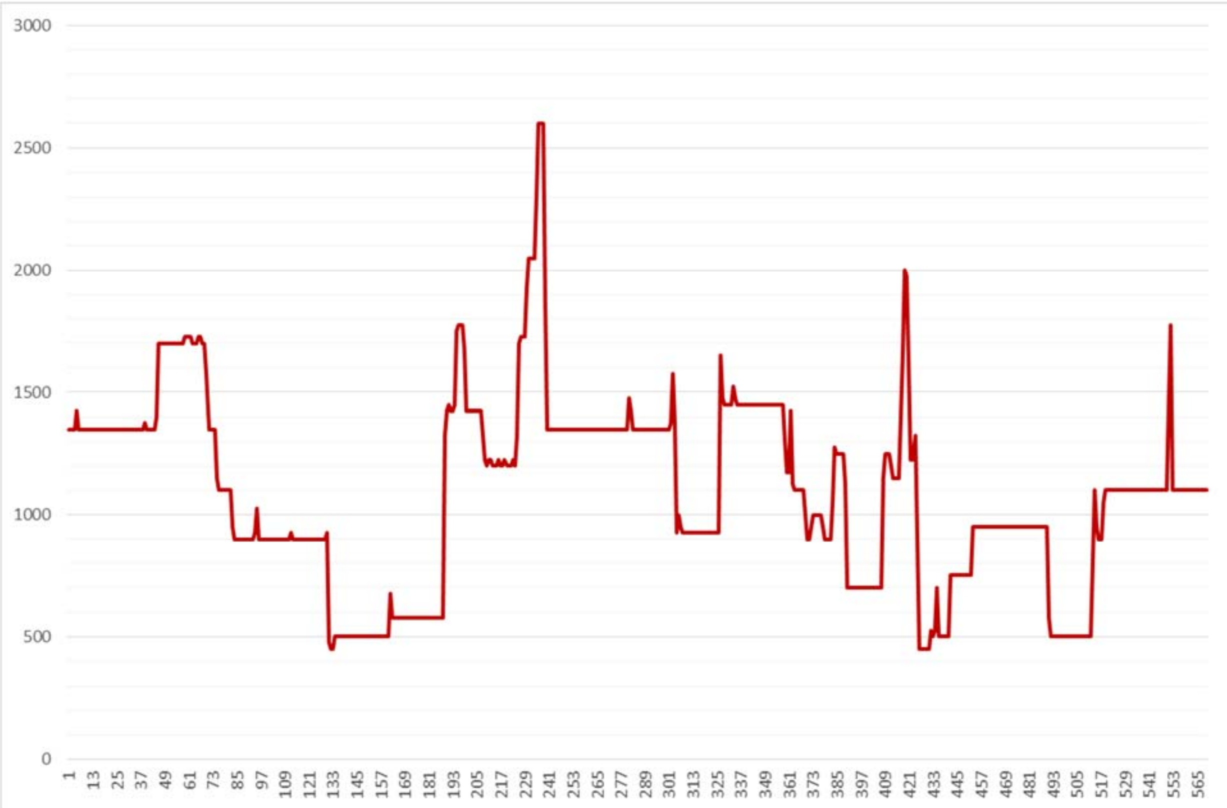


Figure 1. Three-phase Inductive reactive power consumption in kvarL

By applying formula [1.1], the proposed interval value that is got would be:

$$S = \frac{(2600 - 450)}{48} = 45$$

Anyway, since usually, M.V. automatic capacitor banks are based on 100 kvar multiples, in this case we choose this interval of 100 kvar, which will better suit to the compensation requirements of this installation. Thus, the result of applying this interval is the histogram of Figure 2.

Interval	*Frequency*	*% accumulated*
100	0	0,00%
200	0	0,00%
300	0	0,00%
400	0	0,00%
500	65	11,40%
600	29	16,49%
700	20	20,00%
800	12	22,11%
900	52	31,23%
1000	73	44,04%
1100	66	55,61%
1200	21	59,30%
1300	17	62,28%
1400	115	82,46%
1500	48	90,88%
1600	3	91,40%
1700	23	95,44%
1800	14	97,89%
1900	1	98,07%
2000	3	98,60%
2100	4	99,30%
2200	0	99,30%
2300	1	99,47%
2400	0	99,47%
2500	0	99,47%
2600	3	100,00%

Figure 2. Results of histogram (100 kvarL interval)

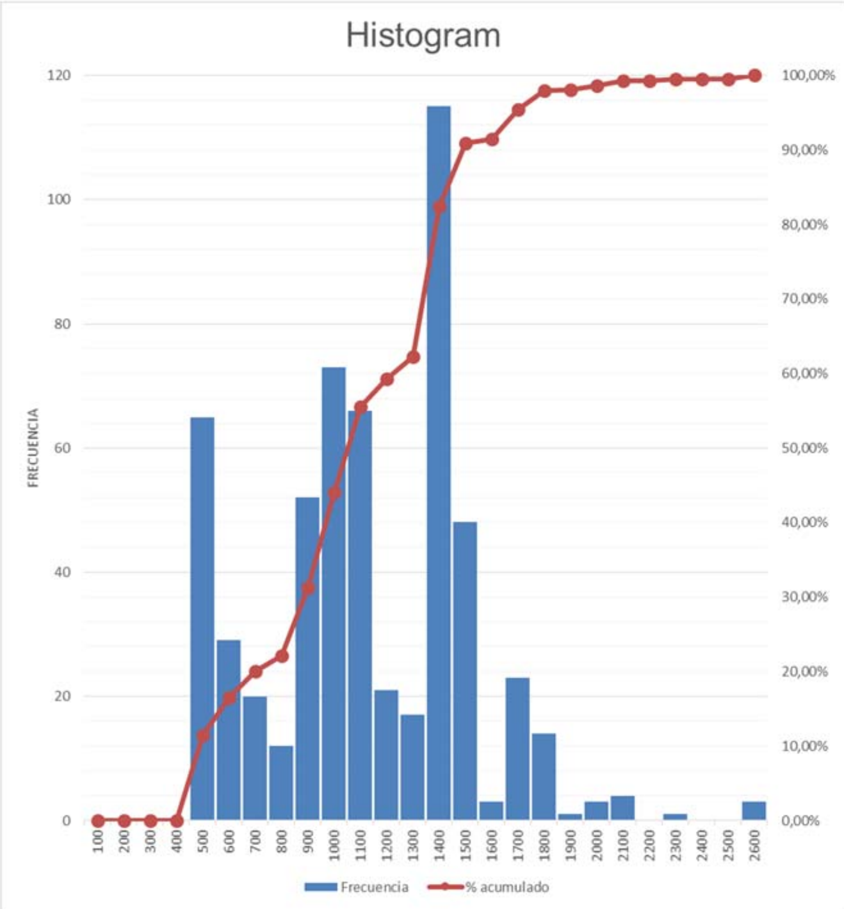


Figure 3. Histogram Graph (Frequencies and %Accumulative)

As you can see from the results, most of the consumption of reactive power is 1400 kvar, followed of 1000 kvar and 500 kvar. Therefore, with a configuration of steps will be 1x500 and 1x1000 kvar.

In this way, we can choose an optimized configuration of the capacitor bank that we could compensate the installation more than 98% of the time.

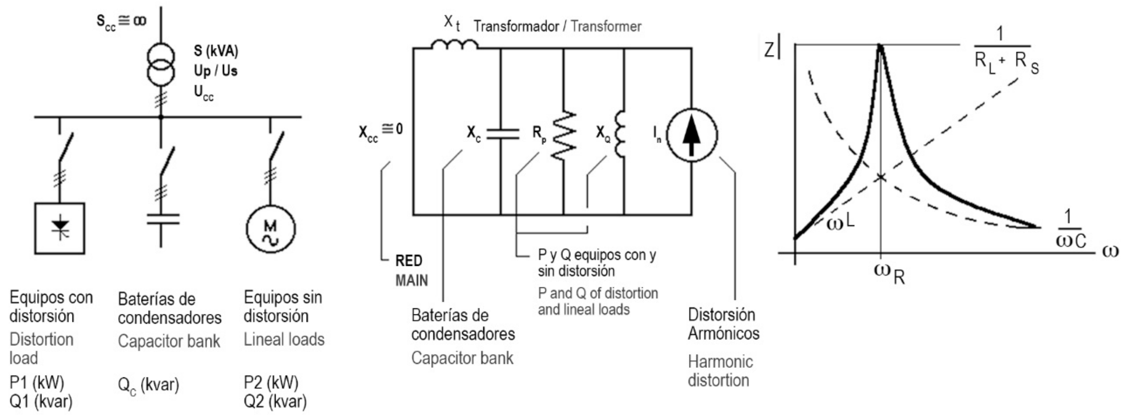
Presence of harmonics in the installation

Obviously this method allows us to determine the steps to form the capacitor bank, but we must not forget other factors that may influence the selection of the capacitor bank.

The presence of harmonics can affect the performance of the equipment and the power quality of the entire installation.

When we carry out inductive reactive power compensation, the incorporation of a parallel capacitor bank is logical to attenuate this demand in order to bring the demanded apparent power (kVA) nearest to the active power (kW), which is really used to carry out to the purpose it is designed for. This simple concept can be summarized as a parallel circuit with inductance (L – Transformer and Grid) and capacity (C – Capacitor bank).

If we observe the frequency response of the system, we see that for a frequency f_R the impedance of the system is much greater than its normal performance.



The existence of current with frequencies higher than the fundamental frequency at 50 or 60 Hz, mean that the resonance conditions could be complied with. This would basically cause:

- Amplification of the distortion in voltage for the entire installation (this could affect the equipment and sensitive electrical elements).
- Greater absorption of current by the capacitors, with their consequential overheating, reduction of their capacity and useful life, and in some cases the destruction of the capacitor.

Image 1. Blow-up MV capacitor due a resonance effect

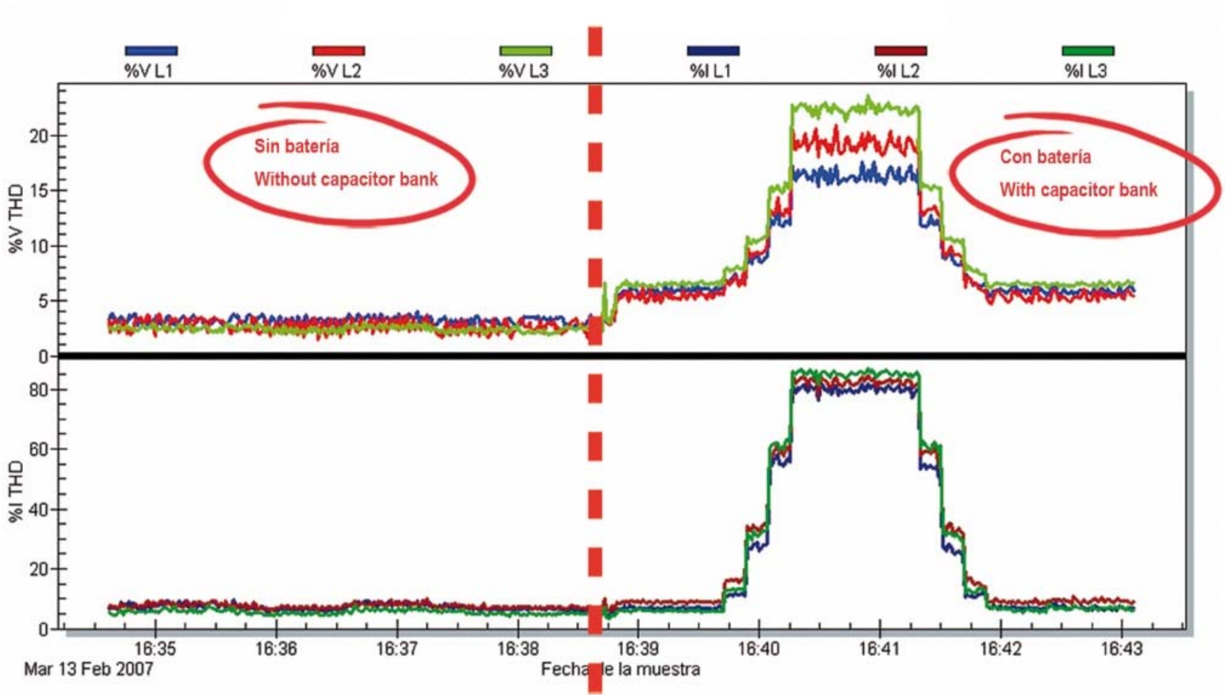
There are two methods to check or detect the risk of resonance. First method is to calculate the frequency of resonance with the following formula:

$$f_R = f \cdot \sqrt{\frac{S_{SC}}{Q}}$$

Where S_{SC} is the short-circuit power of the power transformer (kVA), Q is the reactive power of the capacitor bank (kvar) and f is the rated frequency of the system (50 or 60 Hz).

Then you can check if the frequency of resonance could be close or not to harmonic current presence in the installation, therefore could produce a resonance between the capacitor bank and the network.

The second method is to detect if the capacitor bank is producing or not a parallel resonance with a measurement. We just need to take measurements with and without the capacitor bank connected, and see the performance of THDU%.



If the THDU% increases so much when you connect the capacitor bank, it will means that exists an important resonance and it will damage the capacitor bank, as well as, the whole equipment connected in that installation.

The only way to avoid this risk of resonance is to install a detuned capacitor bank that reject the parallel resonance this the most common harmonics presence in the installation.

Final conclusion

A brief summary of this paper may conclude that the right choice of a capacitor bank to compensate any M.V. must take into account two essential points:

- The accurate selection of the stages that compose the capacitor bank, trying to get the most cost-effective arrangement.
- A thorough analysis of the need of using detuned reactors to avoid possible harmonic amplification phenomena.