Introduction

This case study points out the possible problems with power factor correction of DC motors. In the presented case, after commissioning a new balancing machine (DC regulated drive), mains voltage became highly distorted, which led to unreliable functioning of the rest of sensitive equipment (PLCs, analyzers) as well as frequent tripping of protection, which prevented normal operation. Problem was succesfully analysed and solved by our engineers.

Problem description

New DC drive was connected to the same bus bars as other loads in the factory, such as variable speed drives, asynchronous motors, UPS, lighting, etc. as well as a regulated power factor correction bank with standard capacitors. Immediately upon commissioning of the new drive voltage become highly distorted: THD U > 14% and normal operation of other devices in the same network was compromised.

In order to determine the cause of the problem, measurements of power quality had been conducted on several characteristic points in the network and in different operating modes of the drive. Figure 1. shows voltage and current vaweforms during DC drive operation. Voltage is very distorted with THD factor of about 16.5 % per phase (the usual THD of voltage, as a measure of distortion, is around 1.5-2.5 %). Such distorted voltage has very unfavorable effects to sensitive loads which leads to frequent PLC and VFD resets and producton stoppage, premature ageing of insulation material, increased losses and heating (more on harmonic effects in our white paper “Effects of harmonic distortion”).

In this case the cause of the problem was the resonance between capacitors in capacitor bank and transformer secondary, creating a region of high impedance (resonance) at the frequences at which the DC drive was injecting harmonic currents (aprox. 109 A rms per phase), thus producing voltage distortions at these frequencies. Distortions were so high that voltage THD reached 16.5%. This kind of operation is uncontrollable and unstable operation mode and rise of voltage and higher harmonics currents cannot be really predicted. Such modes have to be prevented asap.

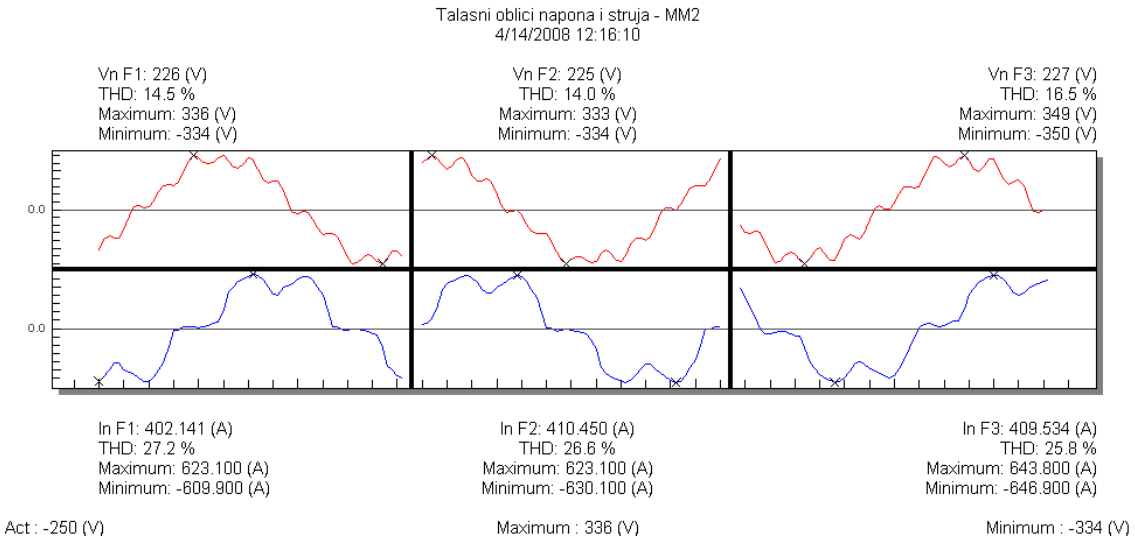

***Figure 1**. Waveforms of voltage and current in the resonance condition (capacitors connected)*

Solution

To display the effect of resonance, existing power factor correction bank had been disconnected, which efectively broke off the resonant circuit and removed the high impedance region away. Despite the same amount of harmonic currents (109 Arms) being injected, voltage distortion was reduced to 6..3%. Waveforms of voltage and currents in this mode are represented on Figure 2.

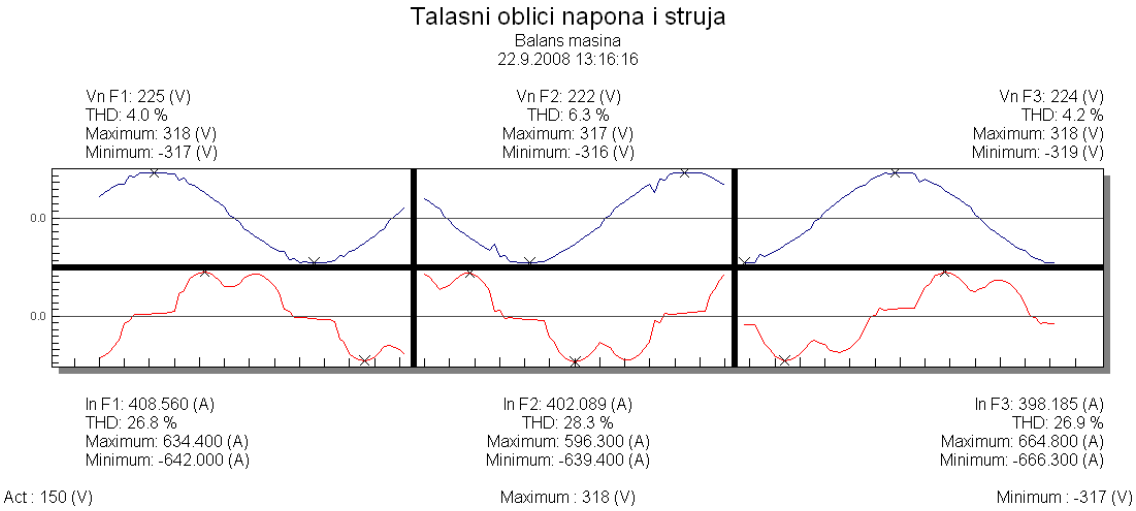

Figure 2. Waveforms of voltage and currents of DC adapter (capacitor batteries off)

It was clear that standard capacitors could not be used for power factor correction of the DC drive. Likewise, higher harmonics currents injected by the drive were extremely high, so neither the standard detuned filter PFC fc=189 Hz could be used, as the distortions would remain high. To solve the problem, it was necessary to design a dedicated hybrid filter for this drive, with resonant frequency of the filter steps selected in such way as to achieve the following objectives:

- prevention of forming a resonance,
- reduction of emission of higher harmonics currents,
- reduction of mains voltage distortion, i.e. stable operation of equipment and the drive,
- power factor correction, i.e. savings of the electricity bill.

Avalon Partners engineers designed such a filter, produced the complete unit, delivered and comissioned it. Power quaity results had been verified with a final measurement of voltage and current vaweforms, as shown in Figure 3.

Figure 3 shows that, in nominal operation of the drive and hybrid filter, the distortions of currents are reduced to about 38 A, i.e. distortion of about 9% (normalized to current of the machine of 470 A). THD V factor is 3.3%, and any sensitive equipment in the drive can operate reliably.

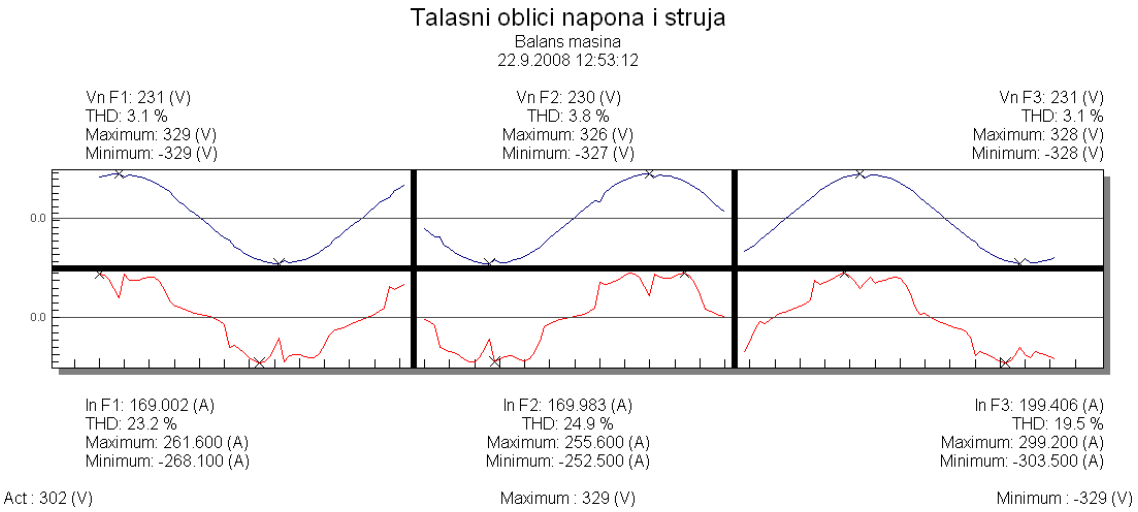

Figure 3. *Waveforms of voltage and current of DC adapter after installing the hybrid filter*

The following table compares different operating modes of DC motors and PFC/Filter equipment.

Operating modes	P [kW]	Q [kVAr]	I [A]	THD I* [%]	THD U** [%]
DC adapter only (PFC off)	151	250	437	14.9	6.9
	40	290	420	24.5	4.9-6.9
	110	170	312	19.2	4.5
DC adapter and capacitor banks (resonance)	160	224	424	23.8	16.5
DC adapter and hybrid filter	124	**10**	187	**9**	**3.3**

* Value normalized to nominal current of the drive - 470 A.
** Value normalized to nominal mains voltage - 400 V.

By comparing the values of the table, it can be concluded that the designed filter has fulfilled its task. The higher harmonics currents have been reduced to a minimal value (9%), distortion of voltages have been reduced from 6.9% to 3.3%. Resonant phenomena were eliminated and the drive operated stabile. Power factor of the factory is corrected, and reactive energy consumption expenses have been minimized.

Conclusion

DC machine is a significant source of higher harmonic currents and cannot work in parallel with the classic PFC equipment (capacitor banks), since such arrangement creates a resonance. The result of resonance is a significant worsening of the voltage quality, thereby deteriorating the conditions for a reliable and long-lasting operation of the entire electrical equipment and the drive. In order to maintain the quality of the voltage at an acceptable level, while achieving savings of good power factor correction, a dedicated harmonic hybrid filter has been designed and installed, which solved the power quality problem in DC motor operation.

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