

Steel Facility Harmonic Filter System Application Summary

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Large Steel Mill facilities require relatively large amounts of reactive power to operate. Resultant low network efficiency decreases effective network capacity, creates overloads of network distribution equipment, and inflates Utility bills with low power factor penalties.

Power Factor Correction (PFC) system applications provide a fast solution to low power factor problems. However, several application issues need to be considered when capacitors are to be applied in industrial networks. These include load profile characteristics, network frequency responses associated with capacitor installation and correction system design based on overall objectives as well as load and power distribution system characteristics.

The following paragraphs summarize the design process and results of a Medium Voltage (MV7000) automatic PFC bank application at a Steel facility in Blytheville, AR.

Manufacturer's Load Profile

A steel pipe manufacturing facility in Blytheville, AR utilizes equipment to fabricate various diameter steel tubes. Flat steel sheets are cut, shaped, seem welded, and heat cured. The facility has a 12.47 kV Main switchgear arrangement distributing power to low voltage power centers. The manufacturing process consumes on average 3600 kW at 0.80 lagging power factor. The reactive power requirement is 2700 kVAR. Power Quality measurements indicated considerable harmonic distortion levels. The current THD (%) exceeded 16% and voltage THD(%) exceeded 4% at the Main 12.47 kV bus (*Table 1*).

Harmonic #	Voltage Distortion [%]	Current Distortion [%]
3 rd	0.14	0.61
5 th	3.85	15.21
7 th	1.02	3.87
11 th	1.22	4.41
THD	4.24	16.51

Table 1. Uncompensated load harmonic data.

Figure 1 provides voltage and current waveforms and corresponding harmonic spectra.

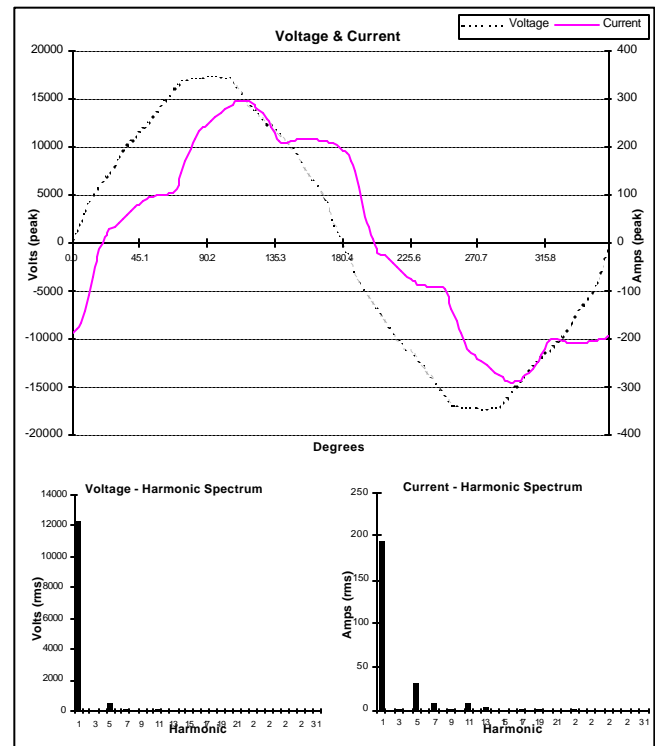


Figure 1. Uncompensated 12.47 kV Main bus - voltage and current waveforms and harmonic spectra.

PFC & Harmonics

Measured harmonic voltage distortion levels exceed IEEE 519-1992 recommended limit of 3% for each individual harmonic component. Voltage distortion is caused by current harmonics passing through network impedance. For the same amount of current harmonics, *soft* (high impedance) networks will experience higher voltage distortion than *stiff* (low impedance) networks. Medium voltage power factor correction equipment application must be evaluated based on the network frequency response and possible resonance conditions. Since power factor correction was the main objective here, 2700 kVAR automatic capacitor system was required. However, network frequency response evaluation based on the total capacitor bank kVAR size indicated possible low frequency resonance conditions which can create significant harmonic magnification. Resonance conditions may increase voltage distortion to levels high enough to cause some of the low voltage control equipment to malfunction. The manufacturing process depends on flawless and efficient operation of entire electronic control system.

Based on the above, filtered PFC system application was justified and 2700 kVAR, 12.47 kV automatic 5th harmonic filter was chosen.

MV7000 Bank Characteristics

The manufacturing process and load profiles dictated an automatically switched correction system. Therefore, three stage filtered bank configuration was chosen with 1x560 kVAR and 2x1120 kVAR stages, respectively. Each stage utilizes 400A, 13.8 kV, three-pole vacuum contactor for switching. Three single-phase iron core reactors tuned to 4.7th harmonic are placed in series with capacitors for each stage. Single phase, 7.62 kV rated, individually fused capacitor cells are used in ungrounded Wye configuration. The Square D *VarLogic* controller automatically controls stage operation. Each stage is protected against phase unbalance and phase loss by three-phase current unbalance relay (46D). All of the above components are housed in NEMA 1 enclosure equipped with front doors, rear removable panels, and viewing windows. Main incoming section features Square D *HVL* non-load break disconnect switch (unfused) and houses 12,470:120 V control power transformer (CPT). The entire assembly is Kirk key interlocked to prevent unauthorized and out of sequence entry into the bank.

Harmonic Filter Effect

The 5th harmonic filter application, equipped with 4.7th harmonic reactors, not only prevents harmonic magnification but also provides significant harmonic filtering. *Table 2* below summarizes harmonic levels with filter bank in full operation.

Harmonic #	Voltage Distortion [%]	Current Distortion [%]
3 rd	0.20	1.60
5 th	0.51	6.58
7 th	0.70	1.92
11 th	0.58	1.52
THD	1.45	7.38

Table 2. Compensated load harmonic data.

Over 50% of 5th harmonic current is removed together with overall power factor improvement to 0.97 lagging. The voltage distortion levels dropped well below IEEE 519 recommended limits. Figure 2 provides pictorial representation of voltage and current waveforms and harmonic levels after filter installation. Note voltage magnitude rise associated with capacitor applications. This voltage increase, based on total PFC bank size and network short circuit availability, can cause overvoltage even during heavy load periods. Maximum voltage magnitudes with capacitor bank fully energized need to be evaluated prior to capacitor installation to assure that overvoltage will not cause problems. In cases when voltage magnitudes may exceed allowable limits, it is necessary to adjust upstream transformer taps to keep voltage magnitudes within acceptable limits. Therefore, it is beneficial to work closely with local utility when medium voltage PFC bank installation is planned to coordinate possible utility distribution equipment adjustments.

Conclusion

Square D *ReactiVar* MV7000 harmonic filter application proved to be a successful solution for low power factor and harmonic problem at the Blytheville facility. In this case the automatically controlled, metal enclosed medium voltage harmonic filter installation proved to be relatively economical way not only to achieve power factor improvements but also for harmonic filtering purposes.

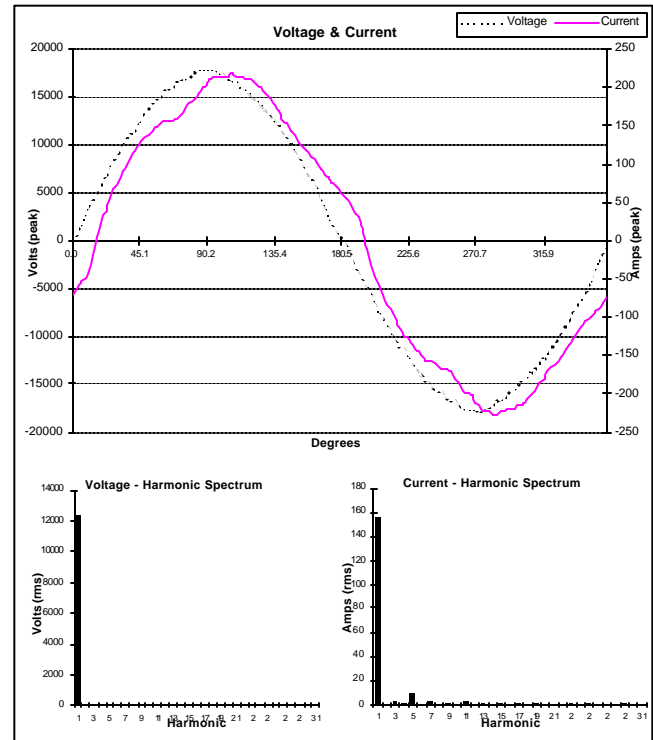


Figure 2. Compensated 12.47 kV Main bus - voltage and current waveforms and harmonic spectra.

References

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