Low-voltage Harmonics Filters for Power Plants

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Summary
During the commissioning phases of a Siemens combined cycle power plant project (750 MW), problems were experienced with power quality on the internal 11 kV and 415 V auxiliary power supply systems. Siemens PTI was consulted to analyze the cause of the problem and to propose suitable mitigation equipment. This was extremely important for the successful commissioning and handover of the complete power plant to the end-client. The proposed solution was in the form of passive high-pass harmonics filters on the low-voltage (415 V) supply system. The filters were installed and commissioned successfully and measurements showed that the filters functioned as intended.

Problem description
Problems were being experienced with equipment failure and malfunction on certain 415 V auxiliary supply circuits of the power plant. In one instance, uninterruptable power supplies tripped on overvoltage conditions and in another case, critical air conditioning units malfunctioned. A Siemens PTI consultant visited the site with power quality analyzers to perform measurements under various system operating conditions and to investigate the problem.

Repetitive transient voltage oscillations were detected on the 11 kV and 415 V supplies (see Figure 1 below) and high levels of harmonics distortion existed in the range between 3 kHz and 4.5 kHz. Analysis of the network showed that this was due to a parallel resonance that existed between the connected 11kV cable capacitance and the system impedance (see impedance plot in Figure 1 below). The commutation notches caused by the large Startup Frequency Converters (SFCs) and the Static Excitation Equipment (SEE) excited oscillations in this critical frequency range.

Figure 1 - Auxiliary Supply Diagram, Voltage Wave Shape and Impedance Plot Showing the Parallel Resonance
Solution
By constructing a detailed model of the auxiliary supply system in PSS®SINCAL and PSS®NETOMAC, the disturbance could be analyzed in detail and mitigation measures in the form of passive harmonics filters could be designed and tested. Two solutions were developed and compared; a single high-pass filter for the 11 kV side versus two smaller high-pass filters on the 415 V side (low voltage – LV). The pros and cons of the two designs were compared and the low-voltage filters were chosen as the preferred solution.

Implementation
The LV filters were in the form of three standard indoor panels with standard series filter modules and an additional panel with the resistors required, to realize high-pass damped filters. The filter configuration is shown in figure 2 below:

![LV Filter Single Line Diagram and Panel Arrangement](image)

Figure 2 - LV Filter Single Line Diagram and Panel Arrangement
An external contractor was tasked with the manufacture and supply of the filters, delivery to site, installation and commissioning. This was done in a fairly short period of time and the measurements during commissioning of the filters showed a marked improvement in the voltage wave shape (see figure 3 below). The harmonics distortion levels were reduced to acceptable levels and the connected equipment now operated trouble free.
Achievements

In the past, this type of problem was solved by installing a high-pass filter of between 2 and 6 Mvar on the medium-voltage (11 kV) supply. This is, after all, where the disturbances come from. Such a medium-voltage filter requires a lot of space (4 m x 8 m as an outdoor filter) and is expensive. In this specific case, the effects of the disturbances were limited to a specific low-voltage supply, making the LV filters an attractive option. By using the much smaller and cheaper low-voltage filters, the disturbance levels could successfully be reduced to acceptable levels.