

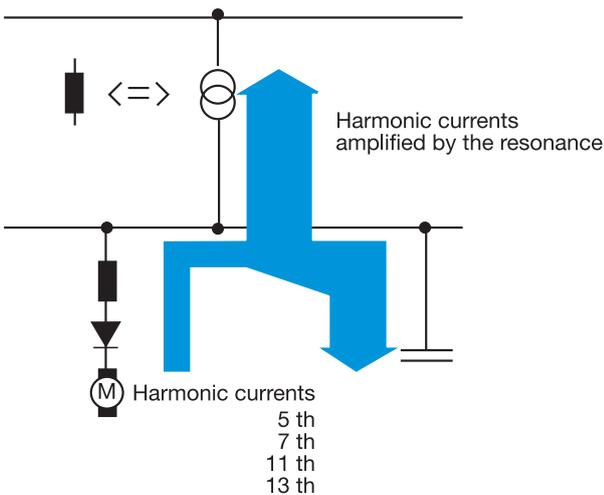
Harmonic filters for high voltage

Power transmission and distribution systems are designed for operation with sinusoidal voltage and current waveforms at a constant frequency.



However, when non-linear loads - such as thyristor drives, converters and arc furnaces - are connected to the system, excessive harmonic currents are generated, and this causes both current and voltage distortion. Harmonic filtering is the best way to eliminate this distortion from the power system.

Harmonic filtering makes electrical power work more efficiently

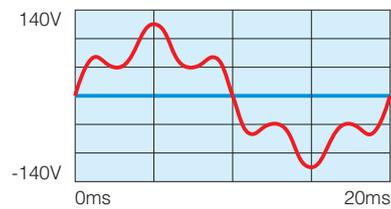


The capacitor bank and network may form a parallel resonant circuit.

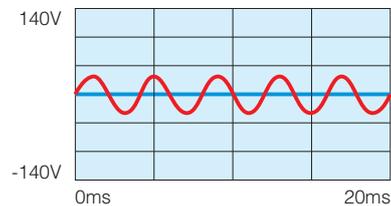
Harmonic distortion - an increasingly common problem

Harmonic distortion problems are becoming increasingly common and, ironically, the cause can be traced back to the "electronic revolution". Modern electronic power control devices provide many advantages over conventional control methods, and are widely used in industrial processes. Their major disadvantage, however, is that they also generate harmonics.

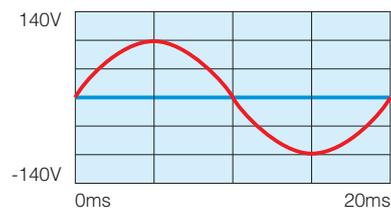
Problems are most often caused by the 3rd, 5th, 7th, 11th and 13th order harmonics.



1. Voltage waveform distorted by 5th harmonic.



2. 5th harmonic (250 Hz).



3. Pure 50 Hz sine wave.

High frequency harmonic currents often give rise to unexpected problems. Excessive heat loss occurs in transformers, cables and other components. Control, protection and metering systems fail to function as required. Telecommunications and data networks are subject to interference and disturbance.

Particular problems are experienced when the network contains power factor correction capacitors. The capacitor bank and the inductance of the network may form a parallel resonant circuit at the harmonic frequency, with the result that harmonics are amplified to such an extent that the voltage becomes unsuitable for most applications.

With increasing reactive power charges, adequate reactive power compensation has become an economic necessity. Power factor correction systems pay for themselves in only 12-36 months through reduced costs. In many countries regulations concerning the quality of electricity supplies also sets limits on the amount of distortion permitted.

Harmonic filters keep the voltage and current distortion within allowed limits

Harmonic filters represent the optimum solution to distortion problems. Consisting of capacitors, reactors and resistors, filter circuits provide a low impedance for harmonics. Distortion is reduced to the required levels. Single-tuned, double-tuned and high-pass filters are all available. At the fundamental frequency (50 or 60 Hz) the filter acts as capacitor and produces reactive power, functioning in the same way as a conventional capacitor bank.

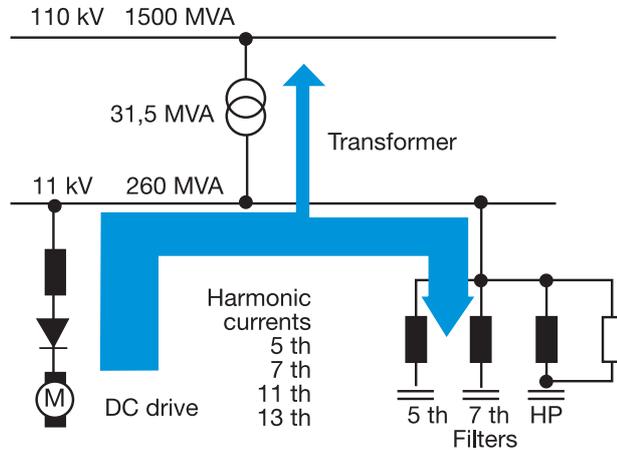
For the best results, the capacitor and reactor must be properly matched. Nokian Capacitors is the only filter manufacturer in the world with its own capacitor and air-core reactor production. Nokian Capacitors filters contain perfectly matched components for trouble-free operation.

For effective harmonic filtration, call the professionals

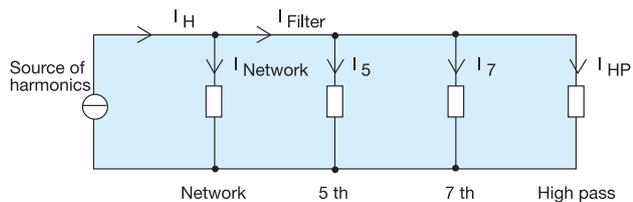
The effective solution of distortion problems demands a high level of power transmission and distribution know-how. For many years Nokian Capacitors' professional team has successfully been designing filters to eliminate harmonic distortion problems for customers in countries all over the world. Nokian Capacitors' expertise has been further enhanced by cooperation with major industrial companies and electrical utilities. Nokian Capacitors uses the latest computer software for system simulation and design purposes. With accurate modelling techniques, the optimum solution can be quickly and reliably found.

Each filters is custom designed; the input data for the design process is obtained from on-site measurements or from a computer model. If requested by the customer, Nokian Capacitors performs the necessary measurements on the system and provides a report detailing the type of compensation or filtering necessary.

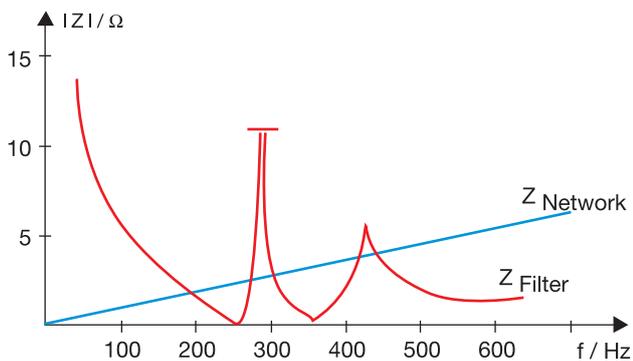
The data required for filter design is listed on the back cover of this brochure.



On-line diagram

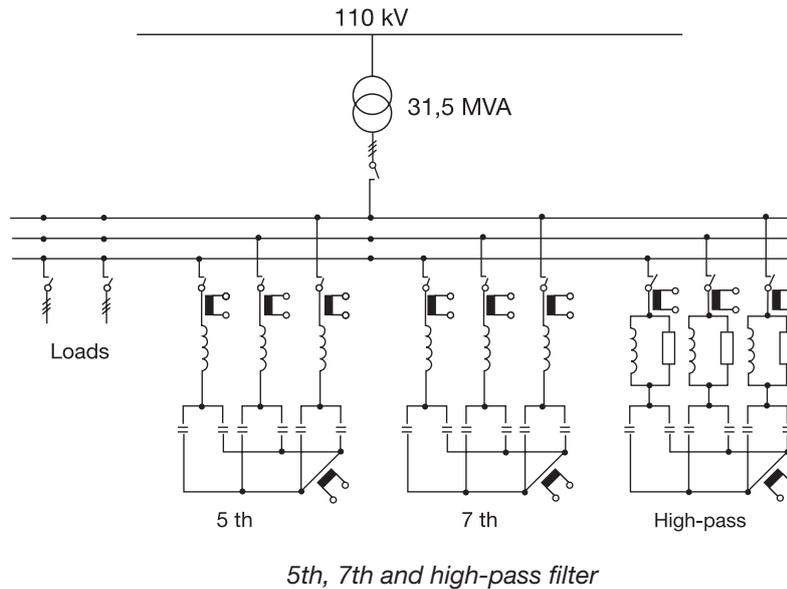


Equivalent circuit



Impedance curves for network and filter

Figure 1



Harmonic filters in practice

Nokian Capacitors harmonic filters are most commonly used in cases where reactive power is required, but conventional capacitor banks would tend to amplify existing distortion to excessive levels.

In a typical application (figure 1), Nokian Capacitors custom designed filters represented the best solution to reactive power and distortion problems at a paper mill. In the system, a number of 6-pulse rectifiers (total rating 10.5 MW) were connected to an 11 kV bus supplied by a 31.5 MVA transformer. A total of

three filters - two single tuned filters for 5th and 7th harmonics plus a high-pass filter for higher order harmonics - were connected to the busbar. Together the filters produced a total reactive power output of 13 Mvar, while the harmonics entering the system were reduced by 70 %. This problem could not have been solved by the use of capacitor banks alone, because the resulting parallel resonance would have amplified the harmonics and exacerbated the distortion problem.

Data required for harmonic filter design

1. Rated voltage, operating voltage and duration of voltage variations in system.
2. Reactive power requirement at fundamental frequency.
3. Harmonic currents flowing in network (normal and "worst case"), or information on harmonic generating loads (e.g. 6-pulse rectifier 10 MW).
4. Existing short-circuit level of network and range of variation (for calculation of impedances at different frequencies).
5. Permitted level of harmonic currents and voltages.
6. Required insulation level of filters.
7. Environmental conditions (outdoor/indoor installation, ambient temperature).

In line with our policy of on-going product development we reserve the right to alter specifications.