POWER FACTOR CORRECTION

DWD - 12

Filtering Reactors

Twelve electric

www.twelvee.com.pl

Introduction

The variety of power-electronic devices used in the industry brought a significant decrease in the quality of supply voltage. Frequency regulating and voltage wave forming nonlinear converters have found wide use in soft-starters and devices for precise control of high-power motors rotational speed. Near the end of the 20th century, the share of nonlinear loads in the overall balance of power consumed by an individual user increased to the level at which new problems and phenomena arise: neutral line overloads, higher harmonics and asymmetries. This state even deepened since traditional sources of light have begun to be replaced with energy-saving equivalents on a massive scale. As a consequence, it became almost impossible to compensate reactive power using the traditional method which is a standard capacitor bank energised with deformed voltage. Distortions in supply networks are measurable and can be decomposed into higher harmonics, that is voltage/current components at frequencies being integer multiples of the base frequency (50Hz). Deformed voltage/current wave is defined by the sum of all of the harmonic components. Because the reactance of a capacitor is inversely proportional to the frequency, it decreases with the appearance of higher orders of harmonics. This way for the 5th harmonic (250Hz) a capacitor's reactance will be five times lesser than it is for 50Hz. It causes current flowing through the capacitor to be higher than that resulting its reactance at 50Hz. Higher current flow causes operating temperature increase and, as an effect, higher power losses. Due to strong dependence of dry capacitor lifetime from the operating temperature, presence of higher harmonics shortens the time of proper operation. Hence, it is necessary to protect capacitors against the influence of higher harmonics. It helps to avoid capacitor faults and the financial burden of frequent replacements. Protection against higher harmonics is also important because energy solicitation contracts include a supplier's requirement for the customer to maintain a particular tgφ in the supply system. That means power factor correction process has to remain uninterrupted, even with higher harmonics in the supply voltage. A filtering reactor is the device allowing continuous compensation in a deformed voltage system. A circuit with a capacitor and a filtering reactor (correctly matched) makes a filter which protects the capacitor and enables power factor correction with higher harmonics in voltage/current..

Construction

Twelve Electric offers DWD-12 reactors in three-phase version. Types and sizes match the power range of capacitors they are to be used with, that is from 2.5kvar to 60kvar. For individual orders we can provide lower or higher ranges of power. The reactor's core is made from ferromagnetic plates. The windings are made from copper coil wire of adequate size and shape. In cheaper versions of the reactor, the copper wire has been replaced with aluminium tape. The whole structure is protected from the environment by impregnation in high-vacuum conditions. High quality black artificial resin with increased thermal radiation and high dielectric strength is used as the impregnant to ensure safe operation. The reactor has a built-in thermal switch that opens the contacts and disconnects the reactor from the power supply in case of temperature threshold override. It prevents melting of windings that might be caused by an uncontrolled temperature surge. Power supply is connected to the connection block in low-power reactors, while high-power ones use Cu busbar bolt-clamps.

Operation principles

Ensuring long lasting, fault-free operation of PFC capacitors working with strong voltage deformations is only possible thanks to filtering reactors in a low-pass filter circuit (LC). A filtering reactor combined with a power factor correcting capacitor separates higher harmonics and prevents their penetration into the capacitor circuit. The principle of filters operation is such a coupling of reactor and capacitor that will ensure the smallest possible impedance at a particular frequency (resonance frequency). For frequencies exceeding resonance frequency, the circuit will have higher impedance. Another words, it will attenuate higher frequencies. The key parameter of a higher harmonics filtering reactor is its attenuation coefficient described by the relation: in which:

$$p\% = 100 * \frac{U_L}{U_C} = 100 * \left(\frac{f}{f_r}\right)^2$$

where:

U_L - voltage on the inductance

U_C - voltage on the capacitance

f - network frequency

f_r - resonance frequency

The attenuation coefficient identifies the resonance frequency too, so it determines the part of frequency spectrum that will be attenuated. For example: for a reactor with attenuation coefficient at p=7% the resonance frequency is 189Hz, which in practice means that efficiently filtered components of the wave will be those from the 5th harmonic up. For the right choice of a reactor to be combined with a capacitor, specialistic measurements must be carried out to determine the harmonics spectrum, that is the level of voltage and current waves deformation with each harmonic. Because of the specifics of the reactor-capacitor circuit, these measurements differ from traditional higher harmonics analysis for purposes of power supply quality examination.

Reactor types

Twelve Electric offers DWD-12 reactors in a wide range of available powers and with following attenuation coefficients: 5.67%, 7% and 14%. These correspond to resonance frequencies of 233Hz, 189Hz and 133Hz respectively For each reactor the efficiently attenuated harmonics will be those of frequencies greater than the resonance frequency. Using a reactor with attenuation coefficient p=14% for example, ensures wide span of filtration and decent attenuation from frequencies as low as the 3rd harmonic (150Hz). Inductances of DWD-12 reactors match typical sizes of power capacitors. While ordering, it is enough to specify just the power of the capacitor to be used with the reactor, the reactor's attenuation coefficient (p) and nominal voltage of the power supply system.

Usage benefits

Filtration of higher harmonics by using filtering reactors has many advantages. Higher harmonics in a system cause an increase in the power flow and energy intake at frequencies greater than the supply frequency. It is linked to greater current flows and, consequently, bigger power losses that lead to more intense heating of transformers and power cables. In addition, the skin effect appears which has negative impact on the energy flow. For the same reason higher losses in transformers and harmful conditions in electric motors arise. This is why all of the rational and technically grounded methods should get incorporated into decreasing, or at least preventing an increase of higher harmonics level in a supply system..

The theory and the evidence of actual measurements show that connection of a capacitance to voltage with distortions, especially in systems of low breaking capacity, leads the capacitor to so called higher harmonics absorption that brings reduction of the resultant of a system's impedances. Energising a capacitor with distorted voltage causes an increase of distortions magnitude in the current, and subsequently to a "boost" in the magnitude of distortions in the system's voltage. When THD of the voltage is at the threshold allowed by energy regulations, then installation of a capacitor bank without reactors could cause it to exceed the limit and effect in an introduction of nonlinear distortions to the network. It becomes clear that equipping a capacitor bank with filtering reactors is not only necessary to protect the capacitors, but also to prevent increasing of the harmonics level by the capacitor bank and to decrease total distortions in the supply system.

Installation principles

Correct installation of reactors should concern the need for removal of notable heat they produce. Capacitor banks with reactors installed should consist in a separate automatic ventilation system controlled by the temperature level in the reactors chamber. Because of negative effects of magnetic (surrounding reactors) and electric (surrounding capacitors) fields interpenetration, reactors have to be separated from capacitors inside of a capacitor bank's structure. Reactors, as the components of higher operating temperature (800ºC-1200ºC), should always be fitted above capacitors. Voltages magnitudes in a reactor-capacitor circuit, especially if seen on a vector graph, show that the capacitor to be used in this kind of connection should have the nominal voltage increased (440-480V). A reactor is seen as an inductance by the system. Every attempt to break a circuit consisting in an inductance results in a sudden voltage increase at the circuit's ends. This transient state can activate overcurrent protection or cause damage to power electronic elements. Therefore, it is recommended to fit filtering reactors with surge arresters to protect the system against overvoltages caused by a disconnection of the reactor-capacitor circuit..

Standards:

VDE 0550, PN – IEC 61558, PN – IEC 60938

Q [kvar]	p [%]	L (per phase) [mH]	I for 50 Hz [A]	I_{th} [A]	Losses for 50 Hz [W]	Total losses [W]	Weight [kg]
5	5,67	6,13	7,65	9,2	21	40	6,0
	7	7,67		8,4	32	49	5,0
	14	16,59		8,1	51	53	7,5
10	5,67	3,06	15,3	18,4	31	68	12,0
	7	3,84		16,9	47	65	7,5
	14	8,29		16,2	77	78	16,0
12,5	5,67	2,45	19,12	23,0	34	80	16,0
	7	3,07		21,1	47	69	12,0
	14	6,64		20,2	89	93	16,0
15	5,67	2,04	22,95	27,6	43	100	16,0
	7	2,56		25,3	54	76	16,0
	14	5,53		24,3	81	89	20,0
20	5,67	1,53	30,6	36,8	38	101	20,0
	7	1,92		33,7	68	100	16,0
	14	4,15		32,3	108	118	23,0
25	5,67	1,22	38,25	46,0	42	114	20,0
	7	1,53		42,2	90	130	20,0
	14	3,32		40,4	111	120	23,0
30	5,67	1,02	45,9	55,2	58	142	23,0
	7	1,28		50,6	80	116	20,0
	14	2,76		48,5	129	140	26,0
40	5,67	0,77	61,2	73,6	65	162	26,0
	7	0,96		67,5	93	138	23,0
	14	2,07		64,6	166	181	33,0
50	5,67	0,61	76,5	92,0	69	200	48,0
	7	0,77		84,3	101	160	33,0
	14	1,66		80,8	167	190	48,0

Table 1. Filtering reactors technical parameters.

Q [kvar]	p [%]	Connection	a_1 [mm]	b_1 [mm]	c [mm]	a_2 [mm]	b_2 [mm]	a_3 [mm]	b_3 [mm]
5	5,67	clamps	150	115	190	106	76	7	13
	7	clamps	150	101	190	106	61	7	13
	14	clamps	180	106	207	106	66	7	13
10	5,67	clamps	180	125	207	106	86	7	13
	7	clamps	180	106	207	106	66	7	13
	14	clamps	228	110	260	176	71	7	13
12,5	5,67	clamps	228	110	260	176	71	7	13
	7	clamps	180	125	207	106	86	7	13
	14	clamps	228	110	260	176	71	7	13
15	5,67	clamps	228	110	260	176	71	7	13
	7	clamps	228	110	260	176	71	7	13
	14	clamps	228	134	260	176	95	7	13
20	5,67	Cu busbar	228	150	210	176	95	7	13
	7	Cu busbar	228	125	210	176	71	7	13
	14	Cu busbar	264	140	240	200	76	10	18
25	5,67	Cu busbar	228	150	210	176	95	7	13
	7	Cu busbar	228	150	210	176	95	7	13
	14	Cu busbar	264	140	240	200	76	10	18
30	5,67	Cu busbar	264	140	240	200	76	10	18
	7	Cu busbar	228	150	210	176	95	7	13
	14	Cu busbar	264	167	240	200	102	10	18
40	5,67	Cu busbar	264	167	240	200	102	10	18
	7	Cu busbar	264	140	240	200	76	10	18
	14	Cu busbar	300	155	290	224	94	10	18
50	5,67	Cu busbar	300	180	290	224	119	10	18
	7	Cu busbar	300	155	290	224	94	10	18
	14	Cu busbar	300	180	290	224	119	10	18

Table 2. Filtering reactors dimensions.

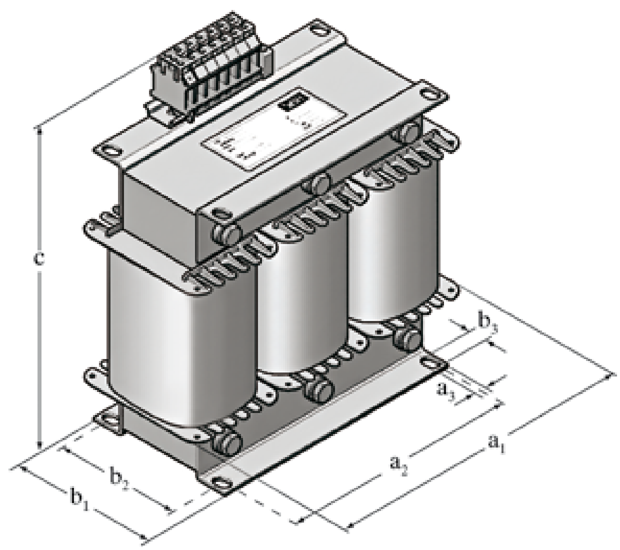

Fig. 1. Basic dimensions of the reactor.

NOTES

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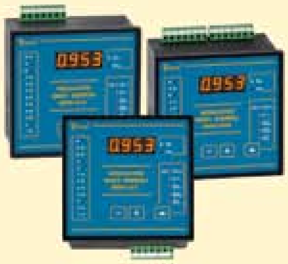
POWER FACTOR CORRECTION

MRM - 12
power factor regulators



BK - T - 95
capacitor banks

K.99/3
LV power capacitors

IKT – 12
individual compensator

NETWORK QUALITY MONITORING

- **AS – *3plus***
  Network Parameters Analyser with graphical display

- **AS – *3mini***
  DIN – mounted Network Parameters Analyser

- **AS – *3energia***
  energy costs Analyser with elements of ener-gy quality analysis

- **AS – *3diagnoza***
  porte Network Parameter Analysers with set of measuring clamps

- **AS – Multi 2002**
  system software for data transfer, visualisation, reports and alarms

Twelve Electric Sp. z o.o.
04 – 987 Warszawa, ul. Wał Miedzeszyński 162
tel. +48 (22) 872 20 20, fax. +48 (22) 612 79 49
skype: t12e_1, t12e_2, t12e_3
e – mail: twelvee@twelvee.com.pl
www.twelvee.com.pl