Validity of Watts Loss Data for Line Reactors

This application note explains how some published watts loss data for line reactors cannot always be relied upon when sizing enclosures or cooling methods for internal heat generation.

Watts loss is an important piece of information needed to properly size enclosures and for selection of cooling methods. Due to ambiguity and lack of industry standards, one cannot simply compare the watts loss data for multiple manufacturers to get a sense of temperature rise, power losses or general performance of line reactors.
This paper explains some of the ambiguity or irrelevance of some published watts loss data for line reactors.

Definitions (terms used in this paper):
THD-v: Total Harmonic Voltage Distortion
THD-i: Total Harmonic Current Distortion
ASD: Adjustable Speed Drive
VFD: Variable Frequency Drive

Watts Loss: Internal heat generated by reactor which must be dissipated via enclosure cooling methods. For an iron core reactor, it is a function of both current squared and frequency squared.

Higher watts loss = higher temperature rise

Higher watts loss may require larger enclosure size, more ventilation or more forced air cooling in an enclosure.

Incorrect watts loss data may cause improper selection of enclosures and cooling methods and can lead to reduced reactor life.

You can rely upon Mangoldt watts loss data and use it with confidence.

General Application

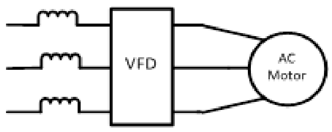
- Line side of VFD
- Protection for diodes
- Current limiting of charging currents
- Protection of motor drive electronics

Approvals / Standards

- UL Listed (E173113)
- IEC/EN60076-6 VDE0532-76-6

RoHS 2011/65/EU

c UL us LISTED



VFD with Line Reactor

Watts Loss Data for Line Reactors

The two primary causes of internal heat generated in a reactor are current and frequency. Current squared impacts the copper losses, while iron losses are a function of frequency squared. The total spectrum of current must be considered to define the total watts loss. Harmonic current will cause significantly higher watts losses than current at the fundamental frequency (60Hz or 50Hz).

The harmonic current spectrum, for typical VFD applications, is very predictable and is a function of total line reactance, including dc bus and ac line reactance, as well as power source reactance. These all provide inductive reactance with higher ohms at higher (harmonic) frequencies [X_L = 2 pi f L (ohms)]. It is the inductive ohms, more than resistive ohms that are effective at reducing harmonic current.

Table 1 illustrates the expected harmonic current spectrum for typical 6-pulse rectifiers (shown up to 25th harmonic) for various amounts of reactance (% impedance). A 5% impedance line reactor will offer effective impedance of 5%, when it is operating at 100% of its (fundamental) current rating. This means that if a 5% line reactor is properly sized for a drive, where the reactor current rating matches the actual current flow, we can expect input harmonic current distortion for that drive of about 35% THD-i.

effective % Z	3	3.5	4	4.5	5	5.5	6	7
harmonic								
5th	39.00	36.75	34.90	33.35	32.02	30.86	29.85	28.12
7th	17.43	15.72	14.37	13.28	12.38	11.61	10.95	9.88
11th	7.43	6.88	6.44	6.07	5.76	5.49	5.25	4.86
13th	4.84	4.53	4.28	4.08	3.90	3.75	3.61	3.39
17th	2.90	2.68	2.50	2.35	2.22	2.11	2.02	1.86
19th	2.28	2.10	1.95	1.84	1.74	1.65	1.58	1.45
23rd	1.49	1.36	1.25	1.16	1.08	1.02	0.96	0.87
25th	1.10	1.04	0.98	0.94	0.90	0.86	0.84	0.79
% THD-i	43.8%	41.0%	38.7%	36.8%	35.2%	33.8%	32.6%	30.5%

Table 1 Harmonic Current vs. Effective Source Reactance

The reactor effective % impedance is based upon the actual fundamental current flowing through the reactor compared to its rated current.

Effective % Impedance = % impedance (rated) x [I_f (actual) / I_f (rated)]

Where: If = fundamental current
Example: Effective % Impedance = 5% Z x [60% / 100%] = 3% effective impedance

At full rated current, a 5% impedance reactor offers effective impedance of 5% and one can expect about 35% THD-i (or less). Less is possible because other circuit devices (transformers and DC chokes) may also be contributing to the total effective input impedance for this drive. If this same drive/motor is operating at reduced load, then the effective % impedance is also reduced and a higher percentage of harmonic distortion can be expected. For example, at 60% load, a 5% line reactor will have effective impedance of only 3%. Therefore, at that load condition it will act like a 3% line reactor and the input harmonic current distortion for that drive; will be about 44% THD-i (or less). If a transformer is much larger than the rating of the drive/reactor, then the transformer effective impedance, relative to the VFD/reactor, may be extremely low, and it may not have much effect on the THD-i.

One should not get too excited however that THD-i increases as the load is reduced. The fact is that harmonic current and fundamental current both decrease when load is reduced. However, fundamental current decreases at a faster rate than the harmonic current. As load is reduced, less harmonic current flows and voltage distortion will typically reduce as well.

To be useful, line reactor watts loss data should be based upon the spectrum of current associated with the reactor rated current and % impedance. A recent review of literature of various reactor suppliers revealed misleading or invalid watts loss data. Watts losses for line reactors that include the correct harmonic current can be as much as 50% higher than pure 60% losses. For harmonic filter reactor applications, harmonic heating can be even more severe – as much as 300-500% of fundamental current losses.

One supplier (A) includes a note in their literature that for watts loss calculation, their harmonic current levels were derived from a typical 6-pulse converter as follows: 5th: 17%, 7th: 11%, 11th: 4.5% (20.7% THD-i). This current spectrum however, would only be valid for about 20% impedance, not for 3% or 5% impedance. This current spectrum is irrelevant, and therefore their watts loss data is invalid. This may explain why some customers have difficulty with excessive heat in VFD panels having multiple reactors.

One supplier (B) noted that their published watts loss data is based upon pure 60Hz current. Since line reactors are intended for use in VFD applications, where harmonic current is prevalent, 60Hz watts loss data offers no useful information at all. 60Hz current is irrelevant for watts loss calculation and therefore the watts loss data is invalid and essentially of no use if not considering the full impact of harmonic current.

Mangoldt determines watts loss for each reactor based upon real world harmonic current and reactor rated current and % impedance (and assuming an infinite power source). This provides worst case data. They also confirm watts loss data through extensive type testing which includes the harmonic currents (3rd thru 13th) using 1MVA programmable harmonic current generator. Mangoldt reactor UL Testing was also performed using the programmable harmonic current generator with specified harmonic currents. The following tables illustrate the current spectrum basis for watts loss calculations for 3% and 5% impedance reactors.

Current Spectrum for 3% Impedance Reactors at full load										
3%	I (1)	I (5)	I (7)	I (11)	I (13)	I (17)	I (19)	I (23)	I (25)	I(rms)
% rms	94.0%	35.7%	16.0%	6.8%	4.4%	2.6%	2.1%	1.4%	1.0%	100.0%
% fund	100%	39.0%	17.4%	7.4%	4.8%	2.9%	2.3%	1.5%	1.1%	109.2%

Table 2: Harmonic Current Spectrum for Watts Loss Calculations (3% impedance reactors)

Current Spectrum for 5% Impedance Reactors at full load										
5%	I (1)	I (5)	I (7)	I (11)	I (13)	I (17)	I (19)	I (23)	I (25)	I(rms)
% rms	94%	30.2%	11.7%	5.5%	3.7%	2.1%	1.6%	1.0%	0.8%	100.0%
% fund	100%	32.0%	12.4%	5.8%	3.9%	2.2%	1.7%	1.1%	0.9%	106.0%

Table 3: Harmonic Current Spectrum for Watts Loss Calculations (5% impedance reactors)

You can rely upon Mangoldt published watts loss data and use it with confidence.

MANGOLDT

The Global Reactor Brand

Hans von Mangoldt GmbH

Hans von Mangoldt GmbH (HvM), an ISO-9001 registered company, is appropriately equipped to meet the demands of the most rigorous reactor applications.

They have earned a leadership position in the international reactor markets and currently export, on a regular basis, to over thirty countries. A highly motivated and experienced workforce makes a vital contribution to the success of the company. The use of state-of-the-art production systems, together with self-defined high demands for quality and reliability enables our customers to have absolute confidence and trust in the products supplied by HvM. The management of MANGOLDT looks to the future, firmly determined to maintain its success in meeting this quality objective. Today the entire company group HvM has a 120 people strong workforce at two production sites in Germany, two international manufacturing sites (Taiwan and India) and two regional technical sales offices (China and USA).

MANGOLDT has two production facilities with complete reactor manufacturing capabilities. Both factories include everything from lamination cutting, computerized winding, assembly and vacuum and pressure impregnation systems.

1980 marked the introduction of MANGOLDT's exclusive core construction method, appropriately named PolyGap®, for its use of numerous air gaps.

PolyGap® core construction is designed to optimize the core's ability to handle harmonic frequencies and to minimize losses.

MANGOLDT has the capability to design reactors with the precise number of air gaps, length of each individual gap and location of each gap to maximize the overall performance of the reactor, based on the specified harmonic current spectrum.