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Data Bulletin

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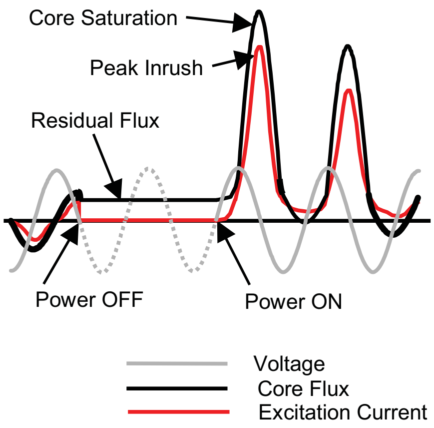
Energy Efficient Transformers Technical Data

Class 7400

Retain for future use.

Inrush Current Data

The tables in this bulletin include inrush current data for low voltage transformers. The values supplied by Schneider Electric can be plotted against the circuit breaker and fuse curves; they are RMS values. What follows is a brief description of factors affecting transformer inrush current.



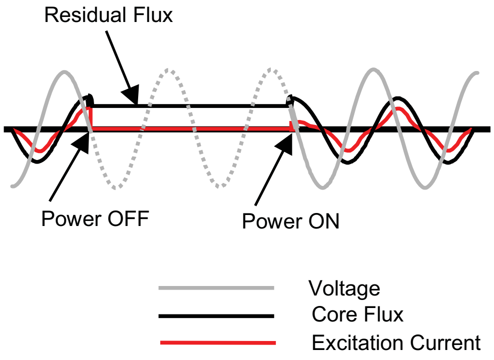
When a transformer is turned off, the core typically remains magnetized at a point called the 'residual' or 'remanent' flux level. That's because the disconnect device, typically a mechanical switch, will interrupt excitation current, which will reduce to zero when contact arcing extinguishes.

Zero current corresponds to the points of residual flux (B_r) on the core B-H curve. An exception to this is in the case of a motor on the load side of the transformer, which will generate a gradually diminishing voltage as it coasts to a stop, reducing the flux in the transformer core to essentially zero.

The residual flux point will vary with core steel material. Non-oriented steels will have lower residual flux levels than oriented grain steel. Thus, the higher the steel quality, the higher the potential inrush.

Other factors influencing inrush are coil-winding geometry, that is, the length and diameter of coils and the number of turns in the energized winding. In general, the smaller the diameter (or mean length of turn), the higher the inrush. Thus, windings that are wound on the inside of the coil are subject to higher energizing inrush than windings wound on the outside.

Typical transformer designs specify the winding that is intended as the primary to be wound over the secondary winding(s) and have the largest coil diameter. If a transformer is energized from the secondary (back-fed), then higher maximum inrush can be expected. As a general rule, back-feeding results in an inrush current two to three times higher than that of a normally-fed transformer.



Voltage waveform switching angles profoundly affect transformer inrush. Maximum inrush occurs when power is applied at voltage zero crossing. Minimum (or zero) inrush will occur when the voltage is at a point where the continuation excitation current matches direction and magnitude of the residual flux in the core.

When power is reestablished at any other point, the inrush will be less than the peak value obtained in the above formula. In fact, it could be zero given the condition that power is applied at such a time so as to not require the core flux to be driven above the saturation point.

Effects of Energy Efficiency on Inrush Current

Introduction

Effective January 1, 2007 energy efficiency regulations from DOE became mandatory. In general, the efficiencies required are higher than those under previous regulations. The efficiency requirements are also different in that:

- They are evaluated at 35% load for low voltage transformers and 50% load for medium voltage transformers;
- Although not specified as part of the regulation, the new designs needed to fit existing enclosures to make the transition as transparent and painless as possible;
- The new designs had to meet the same dielectric, impedance, temperature rise, and noise specifications as before.

These regulatory and practical requirements have changed transformer design philosophy, resulting in a significant impact on the inrush current of the new designs. The following paragraphs explore the impact of these changed parameters on the inrush currents. It should be emphasized that these parameters apply to all transformer manufacturers, so all members of the industry are basically affected the same way.

Inrush Current

The simple, historical equation used for computing maximum inrush current of a transformer is:

$$I_{max} = 2020 * h * A_c * (B_{res} + 2 * B_{max} - B_{sat}) / (N * A_s)$$

Where,

I_{max} = maximum peak inrush current in amperes

h = exciting coil height in inches

A_c = area of the core in square inches

B_{res} = residual core magnetic field in kilogauss

B_{max} = maximum operating flux density of the transformer in kilogauss

B_{sat} = saturation flux density of the transformer core in kilogauss: approximately 20.2 KG

N = excitation winding turns in series

A_s = effective area of the excitation coil in square inches

There are more accurate and improved methods available to calculate the inrush current. However, for understanding the impact of various parameters, this equation provides excellent qualitative insight.

How Energy Efficiency Affects the Parameters

In general the regulation efficiencies are higher than the pre-regulation efficiencies at the defined points, that is, a 35% load for low voltage transformers and a 50% load for medium voltage transformers. It is well known that the maximum efficiency of a transformer occurs at a load point when the core loss equals the load loss. It is natural, then, to design the transformers so that maximum efficiency occurs close to a load point where the regulation efficiency is measured. The net effect is that the loss ratio = (load loss at full load)/core loss is larger than the pre-regulation loss ratio, more so for the low voltage transformers. The upshot of this dynamic is that the core loss now needs to be considerably smaller than the pre-regulation core loss. All this needs to happen while all other constraints mentioned in the Introduction section above are met.

Here are some of the actions a designer can take:

1. Use larger cores and reduce the flux density. This approach has limitations because:
   - It increases the core and coil costs and becomes unproductive beyond a certain point where reduction in core loss is more than matched by the increase in coil loss;
   - The impedance increases. It can be reduced by increasing the coil length, but this is limited by the overall enclosure dimensions.
2. Use smaller cores while keeping the flux density approximately the same. This has limitations because load loss and impedance increase.

Both actions 1 and 2 are possible only if the original design needs only a small improvement in the core loss, and the impedance and enclosure dimensions are not a limiting factor. If the designs are changed in this manner, the affect on inrush current is minimal. However, in the majority of cases, the improvement in core loss obtainable by these actions is not sufficient. Thus, one or more of the following actions are also required:

- Use of better grade magnetic steel (lower watts/lb. at given density), typically operated at higher flux densities. This increases B_{max} which, referring to the equation on page 2, increases the inrush current.
- Change the magnetic steel from non-oriented to oriented steel. Oriented steel has much better core loss characteristics. It is possible to stay with better quality, non-oriented steel at the lower kVA end of the spectrum. The mid-kVA spectrum typically will require a switch to oriented steel, which also has a higher residual flux density. The residual flux density also increases with operating flux density. Referring to the equation on page 2 again, both of these factors increase the inrush current.
- Use of better core construction techniques such as miter joints, step lap miter cores, etc. These construction techniques allow the use of still higher flux densities while keeping the core loss within limits. The higher B_{max} increases the residual flux density further, and both together increase the inrush current.

K-factor Rated Transformers and Low Temperature Rise Transformers

Both K-factor and low temperature rise transformers are required to meet the same energy efficiencies as the conventional transformers, with minor differences: K-factor rated transformers have to meet the efficiencies at a K-factor of 1 and low temperature rise transformers have to meet them at a slightly lower temperature.

Typical Performance Data

Data is supplied for informational purposes only; no guarantee of losses or performance is implied or made. Actual losses and performance may vary from values shown.

Units are UL Listed to Standard 1561 and Certified to CSA Standard C22.2 No. 47-M90 in UL file E6868.

Table 1: Ventilated Energy Efficient Dry Type Transformer; 480 Delta Primary to 208Y/120 Secondary; Aluminum Wound

	Losses in Watts						IZ Related Data			
Catalog Number	**Coil Loss (load loss)**	**Core Loss (no load)**	**25% Load**	**50% Load**	**75% Load**	**100% Load**	**%IZ**	**%IX**	**X/R**	**Inrush x Rated Primary Current**
150 °C Rise										
EE15T3H	652	95	136	258	462	747	5.1	2.7	0.6	10.1
EE30T3H	1170	133	206	426	791	1303	5.5	3.9	1.0	7.5
EE45T3H	1836	171	286	630	1204	2007	6.0	4.4	1.1	6.3
EE75T3H	2518	253	410	883	1669	2771	3.7	1.6	0.5	10.0
EE112T3H	3366	379	589	1221	2272	3745	5.2	4.2	1.4	7.8
EE150T3H	4385	467	741	1563	2934	4852	6.0	5.2	1.8	6.9
EE225T3H	5108	633	952	1910	3506	5741	6.5	6.1	2.7	9.8
EE300T3H	6584	831	1243	2477	4535	7415	5.9	5.5	2.5	8.7
EE500T68H	8662	1320	1861	3486	8358	9982	6.1	5.9	3.4	9.1
EE750T68H	9495	1925	2518	4299	9640	11420	5.4	5.2	4.1	8.2
EE1000T77H	22000	1700	3075	7200	19575	23700	5.7	5.3	2.4	4.2
115 °C Rise										
EE15T3HF	561	102	137	242	418	663	5.3	3.8	1.0	8.0
EE30T3HF	1148	149	221	436	795	1297	5.3	3.7	1.0	7.4
EE45T3HF	1430	202	291	560	1006	1632	5.2	4.1	1.3	6.9
EE75T3HF	2463	274	428	890	1659	2737	6.3	5.4	1.6	5.3
EE112T3HF	2800	407	582	1107	1982	3207	5.3	4.7	1.9	12.2
EE150T3HF	3341	506	715	1341	2385	3847	5.1	4.6	2.7	10.5
EE225T3HF	4811	644	945	1847	3350	5455	6.0	5.6	2.6	8.9
EE300T68HF	3439	1320	1535	2180	3255	4759	3.7	3.5	3.1	14.6
EE500T68HF	8147	1334	1843	3371	7954	9481	6.6	6.4	4.0	11.1
EE750T68HF	10492	1618	2274	4241	10143	12110	5.5	5.3	3.8	7.8
80 °C Rise										
EE15T3HB	503	102	133	228	385	605	5.1	3.8	1.1	8.0
EE30T3HB	664	171	212	337	544	835	3.7	2.9	1.3	9.5
EE45T3HB	822	253	304	458	715	1075	2.1	1.0	0.5	16.7
EE75T3HB	1356	379	464	718	1142	1735	3.3	2.8	1.5	11.7
EE112T3HB	1806	477	590	928	1493	2283	3.7	3.3	2.1	15.0
EE150T3HB	2241	524	664	1085	1785	2766	3.1	2.7	1.8	17.2
EE225T3HB	3013	776	964	1529	2470	3788	4.2	4.0	3.0	11.8
EE300T68HB	3530	1006	1227	1889	2992	4536	4.8	4.7	4.0	10.7
EE500T68HB	3432	1925	2140	2783	4714	5357	3.6	3.5	5.1	12.3

Table 2: Ventilated Energy Efficient Dry Type Transformer; 480 Delta Primary to 480Y/277 Secondary; Aluminum Wound

Losses in Watts							IZ Related Data			
Catalog Number	**Coil Loss (load loss)**	**Core Loss (no load)**	**25% Load**	**50% Load**	**75% Load**	**100% Load**	**%IZ**	**%IX**	**X/R**	**Inrush x Rated Primary Current**
150 °C Rise										
EE15T1814H	628	96	135	252	449	723	4.8	2.3	0.6	11.0
EE30T1814H	1149	155	227	442	801	1304	4.7	2.7	0.7	10.1
EE45T1814H	1677	196	301	615	1139	1873	5.7	4.3	1.2	8.0
EE75T1814H	3170	187	385	980	1970	3357	4.5	1.6	0.4	9.6
EE112T1814H	3472	356	573	1224	2309	3828	5.1	4.1	1.3	11.9
EE150T1814H	3888	488	731	1459	2674	4375	3.3	2.1	0.8	19.7
EE225T1814H	5739	574	932	2009	3802	6313	4.0	3.1	1.2	11.9
EE300T1814H	5789	864	1226	2312	4121	6654	4.9	4.5	2.3	12.3
EE500T1814H	9176	1385	1959	3679	8841	10561	5.8	5.5	3.0	8.5
EE750T1814H	12811	1562	2363	4765	11971	14373	6.2	6.0	3.5	7.5
115 °C Rise										
EE15T1814HF	647	95	135	257	459	742	5.7	3.7	0.9	9.1
EE30T1814HF	676	196	238	365	576	871	3.7	2.9	1.3	12.0
EE45T1814HF	1040	213	278	473	798	1253	2.5	1.0	0.4	16.0
EE75T1814HF	1407	356	444	707	1147	1762	3.3	2.7	1.5	17.9
EE112T1814HF	1993	488	612	986	1609	2481	2.4	1.6	0.9	26.2
EE150T1814HF	2427	557	709	1164	1922	2984	2.6	2.1	1.3	16.9
EE225T1814HF	2968	864	1050	1606	2534	3832	3.6	3.4	2.5	13.9
EE300T76HF	4759	952	1249	2142	3629	5711	4.5	4.2	2.6	10.8
80 °C Rise										
EE15T1814HB	580	95	131	240	421	675	5.4	3.7	1.0	9.1
EE30T1814HB	606	196	234	347	537	802	3.5	2.9	1.4	12.0
EE45T1814HB	939	213	271	447	741	1152	2.3	1.0	0.5	16.0
EE75T1814HB	1270	356	435	673	1070	1625	3.2	2.7	1.6	17.9
EE112T1814HB	1788	488	599	935	1493	2275	2.2	1.6	1.0	26.2
EE150T1814HB	2044	557	685	1068	1707	2601	2.5	2.1	1.5	16.9
EE225T1814HB	2662	864	1030	1530	2362	3526	3.6	3.4	2.9	13.9

Table 3: Ventilated Energy Efficient Dry Type Transformer; 208 Delta Primary to 480Y/277 Secondary; Aluminum Wound

Losses in Watts							IZ Related Data			
Catalog Number	**Coil Loss (load loss)**	**Core Loss (no load)**	**25% Load**	**50% Load**	**75% Load**	**100% Load**	**%IZ**	**%IX**	**X/R**	**Inrush x Rated Primary Current**
150 °C Rise										
EE15T212H	568	105	140	247	424	672	4.2	1.9	0.5	11.5
EE30T212H	1554	112	209	501	986	1666	6.5	4.0	0.8	6.8
EE45T212H	1734	199	308	633	1174	1933	6.0	4.6	1.2	6.9
EE75T212H	2516	215	373	844	1631	2732	6.9	6.0	1.8	8.8
EE112T212H	3412	371	584	1223	2289	3782	5.4	4.5	1.5	11.7
EE150T212H	3942	473	719	1459	2691	4415	6.4	5.8	2.2	10.0
EE225T212H	6285	581	974	2153	4117	6867	4.7	3.7	1.3	13.9
EE300T212H	5986	839	1213	2335	4206	6825	5.1	4.7	2.4	9.6
EE500T212H	8894	1271	1827	3495	8498	10165	6.5	6.3	3.5	8.9
EE750T212H	11132	1716	2412	4499	10761	12848	5.5	5.3	3.6	8.1
115 °C Rise										
EE15T212HF	517	105	137	234	396	622	3.9	1.9	0.6	11.5
EE30T212HF	699	199	243	374	592	898	3.8	3.1	1.3	10.3
EE45T212HF	821	215	267	421	677	1037	4.1	3.6	2.0	14.7
EE75T212HF	1382	371	457	716	1148	1752	3.5	3.0	1.6	17.6
EE112T212HF	2021	473	599	978	1610	2494	4.7	4.4	2.4	13.4
EE150T212HF	2534	546	704	1179	1971	3080	2.7	2.1	1.2	20.8
EE225T212HF	3069	839	1030	1606	2565	3907	3.8	3.5	2.6	12.8
EE300T212HF	4109	1036	1293	2063	3347	5145	3.3	3.0	2.2	12.1
EE500T212HF	7711	1279	1761	3207	7544	8990	6.2	6.0	3.9	8.0
80 °C Rise										
EE15T212HB	462	105	133	220	364	566	3.6	1.9	0.6	11.5
EE30T212HB	627	199	238	356	552	826	3.7	3.1	1.5	10.3
EE45T212HB	745	215	262	402	635	961	4.0	3.6	2.2	14.7
EE75T212HB	1240	371	448	680	1068	1610	3.4	3.0	1.8	17.6
EE112T212HB	1843	488	603	949	1525	2331	4.2	3.9	2.4	12.7
EE150T212HB	2300	546	689	1120	1839	2845	2.6	2.1	1.4	20.8
EE225T212HB	2771	839	1012	1531	2397	3609	3.7	3.5	2.9	12.8
EE300T212HB	4137	968	1227	2002	3295	5105	6.0	5.8	4.2	7.4
EE500T212HB	5099	1488	1807	2763	5631	6587	4.5	4.4	4.3	9.2

Table 4: Ventilated Energy Efficient Dry Type Transformer; 480 Wye Primary to 240 D with 120 CT Secondary; Aluminum Wound

Losses in Watts							IZ Related Data			
Catalog Number	**Coil Loss (load loss)**	**Core Loss (no load)**	**25% Load**	**50% Load**	**75% Load**	**100% Load**	**%IZ**	**%IX**	**X/R**	**Inrush x Rated Primary Current**
150 °C Rise										
EE15T151HCT	697	71	115	246	463	768	5.3	2.5	0.5	13.0
EE30T151HCT	1282	134	214	454	855	1416	5.6	3.7	0.9	11.9
EE45T151HCT	1677	185	290	604	1128	1862	5.7	4.3	1.1	11.0
EE75T151HCT	3149	226	423	1014	1998	3375	4.7	2.0	0.5	7.4
EE112T151HCT	3008	396	584	1148	2088	3404	4.3	3.4	1.3	18.6
EE150T151HCT	3876	456	698	1425	2636	4332	3.1	1.7	0.7	12.0
EE225T151HCT	5106	650	969	1927	3522	5756	3.8	3.1	1.4	18.7
EE300T151HCT	6074	863	1242	2381	4280	6937	4.6	4.2	2.1	14.6
EE500T151HCT	7350	1178	1637	3016	7150	8528	5.1	4.9	3.3	11.7
EE750T151HCT	12341	1556	2327	4641	11583	13897	5.6	5.3	3.2	10.3

Table 5: Ventilated Energy Efficient Dry Type Transformer; 600 Delta Primary to 208Y/120 Secondary; Aluminum Wound

Losses in Watts							IZ Related Data			
Catalog Number	**Coil Loss (load loss)**	**Core Loss (no load)**	**25% Load**	**50% Load**	**75% Load**	**100% Load**	**%IZ**	**%IX**	**X/R**	**Inrush x Rated Primary Current**
150 °C Rise										
EE15T65H	573	101	137	244	424	674	4.5	2.4	0.6	10.7
EE30T65H	1374	134	220	478	907	1508	5.9	3.8	0.8	7.3
EE45T65H	1922	180	300	660	1261	2102	6.4	4.8	1.1	6.4
EE75T65H	2370	258	406	851	1591	2628	3.6	1.7	0.5	8.6
EE112T65H	3313	361	568	1189	2224	3674	5.0	4.1	1.4	10.6
EE150T65H	4457	457	735	1571	2964	4913	3.7	2.2	0.8	15.2
EE225T65H	6546	549	958	2185	4231	7095	5.1	4.2	1.4	12.2
EE300T65H	6925	826	1259	2558	4722	7751	5.6	5.1	2.2	8.7

Table 6: Ventilated Energy Efficient Dry Type Transformer; 208 Delta Primary to 208Y/120 Secondary; Aluminum Wound

Losses in Watts							IZ Related Data			
Catalog Number	**Coil Loss (load loss)**	**Core Loss (no load)**	**25% Load**	**50% Load**	**75% Load**	**100% Load**	**%IZ**	**%IX**	**X/R**	**Inrush x Rated Primary Current**
150 °C Rise										
EE15T211H	675	99	141	268	479	774	5.1	2.3	0.5	11.7
EE30T211H	1392	105	192	453	888	1497	6.1	4.0	0.9	7.1
EE45T211H	1693	212	318	636	1165	1905	5.7	4.3	1.2	7.3
EE75T211H	2576	258	419	902	1707	2834	3.8	1.7	0.5	9.5
EE112T211H	3465	355	572	1222	2304	3820	5.3	4.3	1.4	10.7
EE150T211H	4181	481	742	1526	2832	4661	3.6	2.3	0.8	18.7
EE225T211H	6583	542	953	2188	4245	7125	4.9	4.0	1.4	11.7
EE300T211H	6356	768	1165	2357	4343	7124	5.2	4.8	2.3	8.7
EE500T211H	8554	1387	1921	3525	8337	9941	6.2	6.0	3.5	9.2
EE750T211H	11676	1511	2240	4430	10997	13187	6.1	5.9	3.8	7.3

Table 7: Ventilated Energy Efficient Dry Type Transformer; 480 Delta Primary to 208Y/120 Secondary; Copper Wound

Losses in Watts							IZ Related Data			
Catalog Number	**Coil Loss (load loss)**	**Core Loss (no load)**	**25% Load**	**50% Load**	**75% Load**	**100% Load**	**%IZ**	**%IX**	**X/R**	**Inrush x Rated Primary Current**
150 °C Rise										
EE15T3HCU	550	73	107	210	382	623	4.6	2.8	0.8	5.5
EE30T3HCU	1019	160	224	415	733	1179	4.6	3.2	0.9	7.8
EE45T3HCU	1390	210	297	558	992	1600	4.4	3.2	1.0	7.7
EE75T3HCU	2477	253	408	872	1646	2730	3.5	1.3	0.4	8.3
EE112T3HCU	2566	346	506	988	1789	2912	3.9	3.2	1.4	14.0
EE150T3HCU	3566	482	705	1374	2488	4048	4.7	4.1	1.7	11.5
EE225T3HCU	5264	529	858	1845	3490	5793	3.8	3.0	1.3	12.7
EE300T3HCU	6014	831	1207	2335	4214	6845	4.8	4.3	2.2	10.3
EE500T68HCU	6629	1367	1781	3024	6753	7996	4.1	3.9	3.0	10.3
EE750T68HCU	9196	1511	2086	3810	8983	10707	4.7	4.6	3.7	8.7
EE1000T77HCU	21000	1790	3103	7040	18853	22790	6.3	5.9	2.8	4.2
115 °C Rise										
EE15T3HFCU	578	90	126	234	415	668	5.0	3.2	0.8	9.0
EE30T3HFCU	562	210	245	350	526	772	2.8	2.1	1.1	11.5
EE45T3HFCU	811	253	304	456	709	1064	2.0	0.8	0.4	14.4
EE75T3HFCU	2115	230	362	759	1420	2345	3.4	1.9	0.7	8.3
EE112T3HFCU	2106	353	485	880	1538	2459	3.7	3.2	1.7	12.7
EE150T3HFCU	2177	481	617	1025	1705	2658	2.5	2.0	1.4	19.8
EE225T3HFCU	4015	575	826	1578	2833	4590	3.8	3.4	1.9	13.2
EE300T68HFCU	5006	833	1146	2084	3648	5838	4.8	4.5	2.7	12.2
EE500T68HFCU	6026	1367	1744	2874	6263	7393	4.1	3.9	3.3	10.5
EE750T68HFCU	8914	1617	2174	3846	8860	10531	4.7	4.5	3.8	8.7
80 °C Rise										
EE15T3HBCU	520	90	123	220	383	610	4.7	3.2	0.9	9.0
EE30T3HBCU	505	210	242	336	494	715	2.7	2.1	1.3	11.5
EE45T3HBCU	729	253	299	435	663	982	1.8	0.8	0.5	14.4
EE75T3HBCU	933	346	404	579	871	1279	2.5	2.1	1.7	21.0
EE112T3HBCU	1568	434	532	826	1317	2003	2.2	1.7	1.2	25.2
EE150T3HBCU	2015	509	635	1013	1642	2524	2.3	1.9	1.4	17.9
EE225T3HBCU	2712	608	778	1286	2134	3320	3.6	3.4	2.8	13.2
EE300T68HBCU	3381	968	1179	1813	2870	4349	4.3	4.1	3.7	11.9
EE500T68HBCU	4619	1440	1728	2594	5192	6058	5.0	4.9	5.3	9.8
EE750T77HBCU	6534	1691	2099	3325	7000	8225	5.4	5.3	6.1	7.7

Table 8: Ventilated Energy Efficient Dry Type Transformer; 480 Delta Primary to 480Y/277 Secondary; Copper Wound

	Losses in Watts						IZ Related Data			
Catalog Number	**Coil Loss (load loss)**	**Core Loss (no load)**	**25% Load**	**50% Load**	**75% Load**	**100% Load**	**%IZ**	**%IX**	**X/R**	**Inrush x Rated Primary Current**
150 °C Rise										
EE15T1814HCU	597	88	125	237	424	685	5.0	3.0	0.8	8.0
EE30T1814HCU	977	117	178	361	666	1093	4.8	3.6	1.1	6.2
EE45T1814HCU	1509	184	278	561	1032	1692	4.5	3.0	0.9	9.6
EE75T1814HCU	2050	309	437	822	1462	2359	3.2	1.6	0.6	12.7
EE112T1814HCU	2647	381	546	1043	1870	3028	3.8	3.0	1.3	9.9
EE150T1814HCU	3845	428	668	1389	2590	4273	3.4	2.2	0.9	17.3
EE225T1814HCU	4872	561	866	1779	3302	5433	3.4	2.6	1.2	9.6
EE300T1814HCU	6054	782	1160	2295	4187	6835	5.6	5.2	2.6	8.5
EE500T76HCU	5567	1137	1485	2529	5660	6704	4.9	4.8	4.3	8.9
EE750T76HCU	10636	1632	2297	4291	10274	12268	4.2	4.0	2.8	8.5
115 °C Rise										
EE15T1814HFCU	601	87	125	237	425	688	5.7	4.1	1.0	3.3
EE30T1814HFCU	613	184	222	337	528	796	2.9	2.0	1.0	14.4
EE45T1814HFCU	671	309	351	477	686	980	1.8	1.0	0.7	22.1
EE75T1814HFCU	1075	381	448	650	985	1456	2.5	2.0	1.4	14.8
EE112T1814HFCU	1976	428	551	922	1539	2403	2.4	1.7	1.0	23.0
EE150T1814HFCU	1998	525	649	1024	1648	2522	5.1	5.0	3.7	13.3
EE225T1814HFCU	3095	782	975	1555	2523	3877	4.1	3.9	2.8	11.3
EE300T76HFCU	1822	1137	1251	1592	2162	2959	2.9	2.9	4.7	14.8
EE500T76HFCU	4913	1306	1613	2534	5298	6219	4.9	4.8	4.9	9.2
80 °C Rise										
EE15T1814HBCU	541	87	121	222	391	628	5.5	4.1	1.1	3.3
EE30T1814HBCU	555	184	218	322	496	738	2.7	2.0	1.1	14.4
EE45T1814HBCU	604	309	347	460	649	913	1.7	1.0	0.7	22.1
EE75T1814HBCU	973	381	442	624	928	1354	2.4	2.0	1.5	14.8
EE112T1814HBCU	1769	428	538	870	1423	2197	2.3	1.7	1.1	23.0
EE150T1814HBCU	1808	525	638	977	1542	2333	5.1	5.0	4.1	13.3
EE225T1814HBCU	2785	782	956	1478	2348	3567	4.1	3.9	3.1	11.3
EE300T76HBCU	3350	893	1102	1731	2777	4243	4.9	4.8	4.3	10.4

Table 9: Ventilated Energy Efficient Dry Type Transformer; 240 x 480 Primary to 120/240 Secondary; Aluminum Wound

Losses in Watts							IZ Related Data			
Catalog Number	**Coil Loss (load loss)**	**Core Loss (no load)**	**25% Load**	**50% Load**	**75% Load**	**100% Load**	**%IZ**	**%IX**	**X/R**	**Inrush x Rated Primary Current**
150 °C Rise										
EE15S3H	592	60	97	208	393	652	6.1	4.7	1.2	10.3
EE25S3H	831	73	125	281	540	904	5.9	4.9	1.5	9.1
EE37S3H	1321	108	191	438	851	1429	6.1	5.0	1.4	7.9
EE50S3H	1295	164	245	488	892	1459	5.1	4.4	1.7	9.6
EE75S3H	1968	187	310	679	1294	2155	5.7	5.0	1.9	7.6
EE100S3H	2100	265	396	790	1446	2365	4.7	4.2	2.0	9.9
EE167S3H	2963	426	611	1166	2092	3389	3.9	3.5	2.0	16.7
EE250S3H	4431	596	873	1704	3088	5027	5.7	5.4	3.0	12.2
EE333S3H	4513	828	1110	1956	4495	5341	6.3	6.2	4.6	9.5
115 °C Rise										
EE15S3HF	271	73	90	141	226	344	3.5	2.9	1.6	15.1
EE25S3HF	532	108	141	241	407	640	4.0	3.4	1.6	11.9
EE37S3HF	2087	164	294	686	1338	2251	6.5	3.3	0.6	12.8
EE50S3HF	793	187	237	385	633	980	3.7	3.4	2.1	11.3
EE75S3HF	1071	265	332	533	867	1336	3.5	3.2	2.2	14.9
EE100S3HF	1409	327	415	679	1120	1736	3.5	3.2	2.3	17.9
EE167S3HF	1918	547	667	1027	1626	2466	3.9	3.7	3.2	17.6
80 °C Rise										
EE15S3HB	248	64	79	126	203	312	1.7	0.0	0.0	12.3
EE25S3HB	478	108	138	227	377	586	3.9	3.4	1.8	11.9
EE37S3HB	1872	164	281	632	1217	2036	6.0	3.3	0.7	12.8
EE50S3HB	711	187	231	365	587	898	3.6	3.4	2.4	11.3
EE75S3HB	961	265	325	505	805	1226	3.4	3.2	2.5	14.9
EE100S3HB	1264	327	406	643	1038	1591	3.4	3.2	2.5	17.9
EE167S3HB	1721	547	655	977	1515	2268	3.8	3.7	3.6	17.6

Table 10: Ventilated Energy Efficient Dry Type Transformer; 240 x 480 Primary to 120/240 Secondary; Copper Wound

Losses in Watts							IZ Related Data			
Catalog Number	**Coil Loss (load loss)**	**Core Loss (no load)**	**25% Load**	**50% Load**	**75% Load**	**100% Load**	**%IZ**	**%IX**	**X/R**	**Inrush x Rated Primary Current**
150 °C Rise										
EE15S3HCU	406	79	104	181	307	485	4.8	4.0	1.5	13.6
EE25S3HCU	807	85	135	287	539	892	4.9	3.7	1.1	10.3
EE37S3HCU	1004	129	192	380	694	1133	4.6	3.7	1.4	6.6
EE50S3HCU	1455	136	227	500	954	1591	6.8	6.1	2.1	7.9
EE75S3HCU	2046	153	281	664	1304	2199	4.9	4.1	1.5	10.2
EE100S3HCU	2750	216	388	904	1763	2966	6.1	5.5	2.0	7.3
EE167S3HCU	3133	432	628	1215	2195	3566	4.1	3.6	1.9	11.6
EE250S3HCU	3943	532	778	1518	2750	4475	5.9	5.7	3.6	11.6
115 °C Rise										
EE15S3HFCU	264	85	102	151	234	349	2.8	2.2	1.3	17.2
EE25S3HFCU	406	129	154	230	357	535	3.0	2.5	1.5	9.8
EE37S3HFCU	744	136	182	322	554	880	5.0	4.6	2.3	10.5
EE50S3HFCU	827	153	205	360	618	980	3.2	2.7	1.7	15.3
EE75S3HFCU	1144	245	316	531	888	1389	4.4	4.1	2.7	11.1
EE100S3HFCU	2011	274	400	777	1405	2285	5.1	4.7	2.3	13.2
EE167S3HFCU	1599	532	632	932	1432	2131	3.9	3.8	4.0	17.4
80 °C Rise										
EE15S3HBCU	238	85	100	144	219	323	2.7	2.2	1.4	17.2
EE25S3HBCU	365	129	152	220	334	494	2.7	2.5	2.5	9.9
EE37S3HBCU	669	136	178	303	513	805	4.9	4.6	2.6	10.5
EE50S3HBCU	744	153	199	339	571	897	3.1	2.7	1.8	15.3
EE75S3HBCU	1271	245	324	563	960	1516	4.4	4.1	2.4	11.1
EE100S3HBCU	919	432	489	662	949	1351	2.3	2.2	2.3	19.4
EE167S3HBCU	1439	532	622	892	1342	1971	3.9	3.8	4.4	17.4

Table 11: Ventilated Energy Efficient K4 Rated Transformer; 480 Delta Primary to 208Y/120 Secondary; Aluminum Wound

Losses in Watts							IZ Related Data			
Catalog Number	Coil Loss (load loss)	Core Loss (no load)	25% Load	50% Load	75% Load	100% Load	%IZ	%IX	X/R	Inrush x Rated Primary Current
150 °C Rise										
EE15T3HISNL	546	107	141	244	414	653	4.3	2.3	0.6	10.7
EE30T3HISNL	897	175	232	400	680	1072	4.8	3.8	1.3	8.3
EE45T3HISNL	1442	221	311	581	1032	1663	4.7	3.4	1.1	8.9
EE75T3HISNL	1356	379	464	718	1142	1735	3.3	2.8	1.5	7.8
EE112T3HISNL	3050	375	565	1137	2090	3425	5.0	4.2	1.5	15.8
EE150T3HISNL	2836	524	702	1233	2119	3360	3.5	2.9	1.5	17.0
EE225T3HISNL	3662	776	1004	1691	2835	4437	4.3	4.0	2.4	7.4
EE300T68HISNL	4550	989	1273	2127	3548	5539	4.7	4.5	3.0	10.9
EE500T68HISNL	8336	1277	1798	3361	8050	9613	5.7	5.5	3.3	10.3
115 °C Rise										
EE15T3HFISNL	497	107	138	232	387	605	4.0	2.3	0.7	10.7
EE30T3HFISNL	813	175	226	379	633	989	4.6	3.8	1.4	8.3
EE45T3HFISNL	921	232	289	462	750	1153	3.3	2.6	1.3	8.6
EE75T3HFISNL	1972	292	415	785	1401	2264	4.4	3.5	1.3	14.4
EE112T3HFISNL	3004	401	589	1152	2091	3405	5.2	4.5	1.7	12.7
EE150T3HFISNL	2584	524	686	1170	1978	3109	3.4	2.9	1.7	18.1
EE225T3HFISNL	3375	831	1042	1675	2729	4206	4.4	4.1	2.7	11.8
EE300T3HFISNL	3521	1006	1226	1886	2987	4527	4.8	4.7	4.0	10.7
EE500T68HFISNL	6909	1499	1931	3226	7113	8408	4.2	4.0	2.9	10.3
80 °C Rise										
EE15T3HBISNL	449	107	135	220	360	556	3.8	2.3	0.8	10.7
EE30T3HBISNL	664	171	212	337	544	835	3.4	2.5	1.1	9.5
EE45T3HBISNL	689	258	301	430	646	947	3.0	2.6	1.7	9.5
EE75T3HBISNL	1691	353	459	776	1304	2044	3.6	2.8	1.2	11.7
EE112T3HBISNL	1850	482	598	945	1523	2332	4.7	4.4	2.7	9.0
EE150T3HBISNL	2333	524	670	1108	1837	2857	3.3	2.9	1.9	17.3
EE225T3HBISNL	3006	831	1019	1583	2522	3837	4.3	4.1	3.1	11.8
EE300T68HBISNL	2830	1101	1278	1809	2693	3931	3.9	3.8	4.0	12.0

Table 12: Ventilated Energy Efficient K13 Rated Transformer; 480 Delta Primary to 208Y/120 Secondary; Aluminum Wound

Losses in Watts							**IZ Related Data**			
Catalog Number	**Coil Loss (load loss)**	**Core Loss (no load)**	**25% Load**	**50% Load**	**75% Load**	**100% Load**	**%IZ**	**%IX**	**X/R**	**Inrush x Rated Primary Current**
150 °C Rise										
EE15T3HISNLP	546	107	141	244	414	653	4.3	2.3	0.6	10.7
EE30T3HISNLP	892	175	231	399	677	1068	4.8	3.8	1.3	8.3
EE45T3HISNLP	1442	221	311	581	1032	1663	4.7	3.4	1.1	8.6
EE75T3HISNLP	2164	292	427	833	1509	2456	4.5	3.5	1.2	14.4
EE112T3HISNLP	2275	482	624	1051	1761	2757	4.81	4.36	2.16	9.0
EE150T3HISNLP	2817	549	725	1253	2134	3366	3.5	2.9	1.5	17.0
EE225T3HISNLP	6584	831	1243	2477	4535	7415	6.2	5.5	1.9	11.8
EE300T3HISNLP	3521	1006	1226	1886	2987	4527	4.8	4.7	4.0	10.7
EE500T68HISNLP	7620	1499	1975	3404	7690	9119	4.2	4.0	2.6	10.3
115 °C Rise										
EE15T3HFISNLP	497	107	138	232	387	605	4.0	2.3	0.7	10.7
EE30T3HFISNLP	813	175	226	379	633	989	4.6	3.8	1.4	8.3
EE45T3HFISNLP	921	232	289	462	750	1153	3.3	2.6	1.3	17.5
EE75T3HFISNLP	1356	379	464	718	1142	1735	3.3	2.8	1.5	11.7
EE112T3HFISNLP	2062	482	611	998	1642	2544	4.7	4.4	2.4	9.0
EE150T3HFISNLP	2568	549	709	1191	1993	3117	3.4	2.9	1.7	18.1
EE225T3HFISNLP	3370	832	1043	1675	2728	4202	4.4	4.1	2.7	11.8
EE300T68HFISNLP	5868	1101	1468	2568	4402	6969	4.4	3.9	2.0	12.0
EE500T68HFISNLP	11577	1562	2286	4456	10968	13139	5.0	4.5	1.9	8.1
EE750T68HFISNLP	13219	2012	2838	5316	12752	15231	5.5	5.2	3.0	9.3
80 °C Rise										
EE15T3HBISNLP	479	100	130	220	369	579	4.2	2.8	0.9	9.1
EE30T3HBISNLP	554	185	220	323	497	739	3.7	3.2	1.7	11.5
EE45T3HBISNLP	1116	265	335	544	893	1381	4.1	3.3	1.3	10.0
EE75T3HBISNLP	1384	385	472	731	1163	1769	3.6	3.1	1.7	15.6
EE112T3HBISNLP	1194	479	554	778	1151	1673	4.3	4.2	3.9	13.7
EE150T3HBISNLP	1225	679	756	986	1368	1904	4.2	4.1	5.0	15.6
EE225T3HBISNLP	3147	804	1001	1591	2574	3951	4.0	3.8	2.7	14.5
EE300T68HBISNLP	2830	1101	1278	1809	2693	3931	3.9	3.8	4.0	12.0

Table 13: Ventilated Energy Efficient K4 Rated Transformer; 480 Delta Primary to 208Y/120 Secondary; Copper Wound

	Losses in Watts						IZ Related Data			
Catalog Number	Coil Loss (load loss)	Core Loss (no load)	25% Load	50% Load	75% Load	100% Load	%IZ	%IX	X/R	Inrush x Rated Primary Current
150 °C Rise										
EE15T3HISCUNL	555	73	108	212	385	628	5.0	3.4	0.9	5.5
EE30T3HISCUNL	697	146	190	320	538	843	3.5	2.6	1.1	11.4
EE45T3HISCUNL	1522	221	316	601	1077	1743	4.3	2.7	0.8	11.8
EE75T3HISCUNL	2425	290	442	897	1655	2716	4.4	3.0	0.9	10.8
EE112T3HISCUNL	2806	394	569	1096	1972	3200	4.2	3.4	1.4	12.7
EE150T3HISCUNL	3369	509	719	1351	2404	3878	4.8	4.2	1.9	12.3
EE225T3HISCUNL	3895	546	789	1520	2737	4441	5.3	5.0	2.9	6.6
EE300T68HISCUNL	5041	927	1242	2187	3763	5968	4.7	4.4	2.6	14.2
EE500T68HISCUNL	5526	1500	1845	2882	5990	7026	4.5	4.3	3.9	10.3
115 °C Rise										
EE15T3HFISCUNL	520	90	123	220	383	610	4.7	3.2	0.9	9.1
EE30T3HFISCUNL	637	146	186	305	504	783	3.4	2.6	1.2	11.4
EE45T3HFISCUNL	1654	199	302	612	1129	1853	5.2	3.7	1.0	13.7
EE75T3HFISCUNL	2818	251	427	956	1836	3069	6.5	5.3	1.4	10.7
EE112T3HFISCUNL	2252	433	574	996	1700	2685	3.8	3.2	1.6	17.8
EE150T3HFISCUNL	2157	563	698	1102	1776	2720	4.6	4.2	2.2	10.6
EE225T3HFISCUNL	2800	833	1008	1533	2408	3632	3.6	3.4	2.7	12.6
EE300T68HFISCUNL	5496	871	1215	2245	3963	6367	4.7	4.4	2.4	11.0
EE500T68HFISCUNL	4618	1440	1729	2595	5192	6058	5.0	4.9	5.3	8.3
80 °C Rise										
EE15T3HBISCUNL	468	90	119	207	353	558	4.5	3.2	1.0	9.1
EE30T3HBISCUNL	626	185	224	341	537	811	3.6	2.9	1.4	11.4
EE45T3HBISCUNL	888	258	313	480	757	1146	3.0	2.3	1.2	12.5
EE75T3HBISCUNL	2536	251	410	885	1677	2787	6.3	5.3	1.6	10.7
EE112T3HBISCUNL	1250	398	476	710	1101	1648	4.2	4.1	3.7	10.5
EE150T3HBISCUNL	2638	563	728	1223	2047	3201	4.6	4.2	2.4	13.4
EE225T3HBISCUNL	2209	774	912	1326	2017	2983	4.6	4.5	4.6	11.8
EE500T68HBISCUNL	8224	1439	1953	3495	6065	9663	5.5	5.3	3.2	10.6

Table 14: Ventilated Energy Efficient K13 Rated Transformer; 480 Delta Primary to 208Y/120 Secondary; Copper Wound

Losses in Watts							IZ Related Data			
Catalog Number	**Coil Loss (load loss)**	**Core Loss (no load)**	**25% Load**	**50% Load**	**75% Load**	**100% Load**	**%IZ**	**%IX**	**X/R**	**Inrush x Rated Primary Current**
150 °C Rise										
EE15T3HISCUNLP	506	100	132	227	385	606	4.0	2.2	0.7	11.3
EE30T3HISCUNLP	697	146	190	320	538	843	3.5	2.6	1.1	11.4
EE45T3HISCUNLP	1811	199	312	652	1217	2009	5.5	3.7	0.9	13.7
EE75T3HISCUNLP	2750	251	423	939	1798	3001	6.5	5.3	1.5	10.7
EE112T3HISCUNLP	2443	433	586	1044	1808	2877	3.8	3.2	1.5	14.1
EE150T3HISCUNLP	2362	563	711	1154	1892	2925	4.5	4.2	2.7	13.4
EE225T3HISCUNLP	3065	833	1024	1599	2557	3898	3.7	3.4	2.5	12.6
EE300T68HISCUNLP	5041	927	1242	2187	3763	5968	4.7	4.4	2.6	9.9
EE500T68HISCUNLP	6816	1367	1793	3071	6905	8183	4.8	4.6	3.4	9.8
115 °C Rise										
EE15T3HFISCUNLP	460	100	129	215	359	560	3.8	2.2	0.7	11.3
EE30T3HFISCUNLP	637	146	186	305	504	783	3.4	2.6	1.2	11.4
EE45T3HFISCUNLP	1113	198	268	476	824	1311	4.5	3.8	1.5	13.7
EE75T3HFISCUNLP	2729	230	401	912	1765	2959	6.5	5.3	1.5	10.5
EE112T3HFISCUNLP	2232	433	573	991	1689	2665	3.7	3.2	1.6	14.1
EE150T3HFISCUNLP	2157	563	698	1103	1777	2721	4.4	4.2	2.9	13.4
EE225T3HFISCUNLP	2800	833	1008	1533	2408	3632	3.6	3.4	2.7	12.6
EE300T68HFISCUNLP	3900	1038	1282	2013	3232	4938	3.5	3.3	2.5	12.3
EE500T68HFISCUNLP	8224	1439	1953	3495	8121	9663	5.5	5.3	3.2	10.6
EE750T68HFISCUNLP	11159	1562	2260	4352	10629	12722	6.0	5.8	3.9	7.8
80 °C Rise										
EE15T3HBISCUNLP	481	96	126	216	367	577	3.8	2.1	0.7	11.0
EE30T3HBISCUNLP	554	185	220	323	497	739	3.7	3.2	1.7	11.5
EE45T3HBISCUNLP	867	241	295	458	729	1108	3.6	3.0	1.6	11.5
EE75T3HBISCUNLP	972	385	446	628	932	1357	3.4	3.1	2.4	15.6
EE112T3HBISCUNLP	1194	479	554	778	1151	1673	4.3	4.2	3.9	13.7
EE150T3HBISCUNLP	1225	679	756	986	1368	1904	4.2	4.1	5.0	15.6
EE225T3HBISCUNLP	2209	774	912	1326	2017	2983	4.6	4.5	4.6	11.8
EE300T68HBISCUNLP	3696	1038	1269	1962	3117	4734	3.3	3.1	2.5	12.3
EE500T68HBISCUNLP	3177	1708	1907	2502	4289	4885	3.1	3.1	4.8	12.9

Glossary of Terms

Impedance

Definition	Impedance, usually designated as %IZ, is a way of expressing the amount of current-limiting effect the transformer will represent if the load side of the transformer short-circuits. Considered along with the X/R ratio, the information is used for systems analysis to determine proper interrupting ratings and coordination of protective devices.
Use of Impedance to Determine Interrupting Capacity	Knowing the maximum current available on the load side of a transformer is necessary to properly choose current interrupting values for disconnects and overcurrent protective devices. Here is a simple method of estimating short circuit current: $\text{Secondary short circuit current} = \frac{\text{Transformer secondary full load rating}}{\text{Transformer impedance}}$
Example	For a transformer with 208 A full load current and 5% impedance: $\text{Secondary short circuit current} = \frac{208}{.05} = 4160\ \text{A}$ Others factors besides impedance affect short circuit current. Primary system capacity and motor current contribution from the load side will change the short circuit value obtained using the above simplified method. Make sure to take all factors into account to ensure that device interrupting ratings are properly coordinated. Contact your local Schneider Electric representative for information on system analysis service.

High Inrush Loads

Overview	Many loads served by transformers can momentarily draw high peak currents when power is applied to them. Transformers, of course, are one of these. Others include motors, relays, contactors, and certain electronic devices. Other types of loads can draw repeated high current surges during their normal operation. These include DC drives, electronic phase control, welders, X-ray equipment, and many kinds of cyclic process equipment. Often the transformer is called upon to supply momentary currents far in excess of the nameplate full load rating. One concern when supplying these loads is the supply transformer’s ability to withstand the current both mechanically and thermally. Another is the voltage drop (regulation) on the transformer secondary caused by these high current demands.
Thermal Effects	For loads that have a high inrush on energizing, and where such high current loads occur infrequently, the thermal affects on the supply transformer can typically be ignored. For repetitive overloads, however, it may be necessary to calculate the thermal effect on insulation life expectancy. A good guide for such calculation is ANSI/IEEE C57.96 “IEEE Guide for Loading Dry-Type Distribution and Power Transformers.”
Mechanical Effects	Low voltage transformers are designed mechanically to withstand full, bolted fault conditions on the secondary for 1–2 seconds. So, since the load could never exceed the current achieved by a bolted fault, and since typical inrush only lasts for a fraction of a second, mechanical concerns are not generally an issue in low voltage transformers.

Regulation Effects

The majority of electrical equipment is designed to function with an input voltage variation of +/- 10%. If we assume the customer has at least nominal voltage to begin with, we can allow a voltage drop maximum of 10% on the transformer secondary during peak current conditions. Under those conditions, we can be reasonably confident these currents will not cause malfunction of other equipment on the load side because of low voltage conditions. Calculation of regulation on a transformer is complex, requiring information about load power factor as well as amperage. Since complete information is often lacking, a worse case calculation, as shown below, is often used to provide conservative results:

$$\text{Voltage drop (\%)} = \frac{\text{Maximum load current}}{\text{Transformer secondary full load rating}} \times \text{Impedance (\%)}$$

Simply choose a transformer of sufficient full load capacity to result in a voltage drop of less than 10%. The transformer impedance can be obtained either from the nameplate or from Schneider Electric engineering. Industrial control transformer literature typically includes regulation charts that relate peak load VA and power factor to voltage drop, so that approximation calculations such as shown above are not necessary.

Typical Customer Issue Relating To This Topic

A contracting firm is ordering a 300 kVA 480 Delta – 240 Delta transformer, which has a 721 A nameplate full load current capacity on the secondary and 5.1% impedance. They want to use it to directly supply a 200 hp motor with 2700 A locked rotor current.

Explanation and Solution

Applying our voltage drop estimating formula:

$$\text{Voltage drop (\%)} = \frac{2700}{721} \times 5.1 = 19\%$$

Since the result exceeds 10%, this transformer’s capacity is too low, or its impedance too high for this application.

There are two solutions:

1. Choose a larger transformer (in this case, a 500 kVA with no more than 4.4% impedance, or a 750 kVA with no more than 6.6% impedance).
2. Purchase a reduced voltage starter, or a soft start unit, to reduce the motor locked rotor current to near full load motor rating. These devices eliminate the need for transformer over-sizing.

Transformer Loss

Core Loss (No-load Loss)

When a transformer is energized on the primary side, the laminated steel core carries a magnetic field or flux. This magnetic field causes certain losses in the core, generating heat and dissipating real power from the primary source, even when no load is on the secondary side of the transformer.

For a given level of magnetic flux, various core steel materials have a constant Watts/pound characteristic. So, at a given flux level, the more pounds of a specific core lamination used in a design, the higher the losses.

Core loss (sometimes referred to as a no-load loss) can be a major concern in the total operating cost of a transformer, particularly over very light loading, where it becomes the predominant energy cost associated with the operation of the transformer. A transformer designer can reduce the core loss in a a transformer either by using a better grade of magnetic steel material or by reducing the level of magnetic field in the core. Core loss in Watts is available for all Schneider Electric low voltage transformers, and is required by NEMA ST20 to be reported on all electrical test reports.

Coil Loss (Load Loss)

Under load, a transformer loses energy in the form of heat within the winding conductors. That’s because these conductors have a certain amount of resistance. Nearly all of the coil loss can be accounted for by the simple I^2R (current in A^2 x resistance in ohms) formula for Watts. There is a small amount of what are called “stray losses,” and the sum of these and I^2R Watts equals total coil loss. These losses raise the temperature of the coils in a transformer to a variable degree, depending on loading. Conductor loss in Watts is available for all Schneider Electric low voltage transformers, and is required by NEMA ST20 to be reported on all electrical test reports.

Since the losses vary approximately with the square of load current, they accelerate rather rapidly as full load is approached, and can become the most significant loss in a transformer.

Coils are typically wound with either aluminum or copper conductors. Assuming that transformers are designed economically for a given maximum temperature rise, both materials have the same approximate loss. That’s because, even though copper is a better conductor that aluminum, designers use smaller conductor sizes in copper windings to reduce material cost.

As stated earlier, coil losses vary approximately with the square of load current. So a transformer operating at half of its rated load can be expected to have approximately 25% of its reported full load coil loss. Since the resistance of conductors reduces as temperature goes down, the reduced load loss will actually be somewhat less than that calculated with this method:

Coil Loss at particular load

Full Load Loss x (percent load)^2

The sum of core loss and coil loss equals the total loss of a transformer for a given load. The core loss remains constant for a given applied voltage, and the coil loss is variable with load. These losses are typically reported by engineering in Watts. Many contractors interested in air conditioning requirements of a building will request the BTU/HR (British Thermal Units per hour) equivalent, which can be determined as follows:

BTU/HR = 3.414 x Losses in Watts

Efficiency

Overview

Transformer efficiency can be defined as the percentage of power out compared to the power in. A perfect, zero loss transformer would have the same power in as out and would be 100% efficient. Modern transformers are amazingly efficient, with some larger transformers exceeding 99% in efficiency. However, no transformer is without some loss in both the core steel and the conductors within the coils. Percent full load efficiency is typically calculated by:

$$\text{\% Efficiency} = \frac{100 \text{ x VA}}{\text{VA + Core Loss + Coil Loss}}$$

Example: A 75 kVA (75000 VA) transformer has a core loss of 467 Watts and a coil loss of 2491 Watts. What is the full load efficiency?

$$\text{\% Efficiency} = \frac{100 \text{ x } 75000}{75000 + 467 + 2491} = 96.21\%$$

Conventional reporting in transformer test data records consists of efficiencies at 25%, 50%, 75%, and 100% load points. In order to calculate reduced load efficiencies, the formula needs to be modified as shown:

$$\text{\% Efficiency} = \frac{100 \text{ x P x VA}}{\text{(P x VA) + Core Loss + (}P^2\text{ x Coil Loss)}}$$

Where:

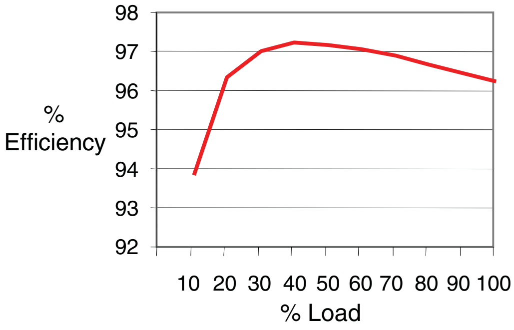
P = Per unit load

Example: What is the efficiency at 50% load for the same 75 kVA transformer in the previous example?

$$\text{\% Efficiency@ 50\% Load} = \frac{100 \text{ x } 0.5 \text{ x } 75000}{(0.5 \text{ x } 75000) + 467 + (0.25 \text{ x } 2491)} = 97.17\%$$

The complete efficiency report for the example transformer would look like this:

Efficiency @100% load = 96.21%
@ 75% load = 96.79%
@ 50% load = 97.17%
@ 25% load = 96.79%



Transformers reach their highest efficiency at a load point that results in coil loss equaling core loss. In the example transformer, this would be at about 43% load, where the efficiency would be 97.20%. The peak efficiency point will vary depending on the relationship between core loss and conductor loss.

Typical Customer Issue Relating to This Topic

A facility engineer has compiled complete loading profile information for a proposed service, and wishes to purchase a transformer that will present the lowest energy costs over the life of the transformer.

Explanation and Solution

Given the daily, 24-hour average load on the transformer, Schneider Electric engineering can design transformers with the most economical first cost, as well as optimize the efficiency at a point which provides the owner with maximum long term energy savings.

Detail

The typical test reporting of efficiency in transformers may neglect the influence of temperature changes in the coils as load is varied. This omission always results in conservative efficiency numbers, and the results are satisfactory for most general use, such as estimating air conditioning, room ventilation, etc. However, it’s recognized that more exact values may be needed in cases such as calculating ownership costs.

NEMA Standard TP1 addresses the necessary corrections in temperature reference for specific daily average loading. It recognizes that copper and aluminum conductors change resistance at different rates with temperature, so that correction factors change with winding material. An example calculation shows a specific instance assuming 35% average loading on a 150 °C rise transformer.

$$\% \text{ Efficiency} = \frac{100 \times P \times VA}{(P \times VA) + \text{Core Loss} + (P^2 \times \text{Coil Loss} \times T)}$$

Where:

P = Per unit load

T = 0.8152 for aluminum
0.8193 for copper

For further details on temperature correction for accurate efficiency data, refer to NEMA Standard TP1.

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