Why is a transformer needed?

A control transformer is required to supply voltage to a load which requires significantly more current when initially energized than under normal steady state operating conditions. A control transformer is designed to provide secondary voltage stability under a short period of specific overload referred to as inrush.

What is a transformer and how does it work?

A transformer is a passive electrical device designed to convert alternating current from one voltage to another by magnetic induction. It can be designed to "step up" or "step down" voltages and works on the magnetic induction principle. A transformer has no moving parts and is a completely static solid state device, which insures, under normal operating conditions, a long and trouble-free life. It consists, in its simplest form, of two or more coils of insulated wire wound on a laminated steel core. When an alternating voltage is introduced to one coil, called the primary, it magnetizes the iron core. A voltage is then induced in the other coil, called the secondary or output coil. The change of voltage (or voltage ratio) between the primary and secondary depends on the turns ratio of the two coils and obeys the Ampère's law (N1xI1=N2xI2).

What is a control transformer?

A control transformer is an isolation transformer designed to provide a high degree of secondary voltage stability (regulation) during a short period overload condition typically referred to as inrush to an inductive load. Control transformers are also referred to as Industrial Control Transformers, Machine Tool Transformers or Control Power Transformers.

Steps for Selecting the Proper Transformer

1) Determine electrical load

- Voltage required by load
- Amperes or KVA capacity required by load
- Frequency in Hz (cycles per second)
- Verify if the load is designed to operate on a single phase supply

All of the above information is standard data normally obtained from equipment nameplates or instruction manuals.

2) Determine supply voltage

- Voltage of supply (source)
- Frequency in Hz (cycles per second)

The frequency of the line and load must be the same. Select the transformer designed to operate at this frequency, having a primary (input) equal to the supply voltage and a secondary (output) equal to the voltage required by the load.

3) If the nameplate load expresses a rating in KVA, a transformer can be directly selected from the tables. Choose from a group of transformers with primary and secondary voltages matching those you have just determined

- Select a transformer with a standard KVA capacity equal to or greater than that needed to operate the load
- The following formulae may be used to determine proper KVA size for the required transformer:

	Single phase	Three phase
KVA	$\frac{\text{Volts x Amps}}{1000}$	$\frac{\text{Volts x Amps x 1.73}}{1000}$
Amps	$\frac{\text{KVA x 1000}}{\text{Volts}}$	$\frac{\text{KVA x 1000}}{\text{Volts x 1.73}}$

EXAMPLES:

SINGLE PHASE LOADS

Select a transformer to meet the following conditions. Load is single phase lighting using incandescent lamps. Each one requires 1.3 amps @ 120 volts, 1 phase, 60 Hz, power factor of unity. The installation requires 30 units of 100 watt each. The desired circuit distributing power to the light fixtures is 120/240 volt, three wire, single phase. The supply voltage is 600 volt, 3 phase.

KVA required = <u>1.3 Amps x 120 Volts</u> = 0.156 KVA for each lighting unit
1000

Always use amps x volts to compute VA, never use lamp wattage. 0.156 KVA / unit x 30 units = 4.68 KVA. The two sizes (KVA) nearest 4.68 KVA are 4 KVA and 5 KVA. Use the 5 KVA. This will not overload the transformer and allows some capacity, 0.32 KVA, for future loads.

THREE PHASE LOADS

Select a transformer to fulfill the following conditions. Load is a three phase induction motor, 2.5 HP @ 240 volts, 60 Hz and a heater load of 1 KW @ 240 volts single phase. The supply voltage is 600Y/347, three phase, 4 wires.

Motor: 6.8 amps (2.5HP - 240V)

$$\frac{240 \text{ volts} \times 6.8 \text{ amps} \times 1.73}{1000} = 2.8 \text{ KVA}$$

Heater: 1 KVA
A three phase transformer must be selected so that any one phase is not overloaded. Each phase should have the additional 1 KVA rating required by the heater even though the heater will operate on one phase only. So, the transformer should have a minimum KVA rating of 2.8 + 1 + 1 + 1 or 5.8 KVA. A 600 volts delta primary, 240 volts delta secondary transformer may be used on a 4 wire, 600Y/347 volt supply. The fourth wire (neutral) is not connected to the transformer. To not overload the transformer, a 6 KVA transformer should be selected.

NOTE: any two wires of the 240 volts, 3 phase developed by the secondary of the transformer may be used to supply the heater. Any 2 wires of a 3 phase system is single phase.

What is meant by regulation in a transformer?

Under no load, the voltage at the output it is slightly higher than the nameplate voltage. When a load is applied, the voltage will drop slightly. The difference in the output voltage under load vs unloaded is referred to as the transformer's output regulation and is normally expressed as a percentage. If under no load a transformer had an output voltage of 240 volts but under load the output voltage was 230 volts, the difference would be 10 volts and the regulation would be 10/240 or 4.17%. The power factor of the load can impact the transformer's regulation. General purpose transformers can be used with a variety of loads, the most common being inductive motor loads and resistive loads. For that reason, it is common to express transformer regulation at 100% power factor and also at 80% power factor.

Dry-type distribution transformers generally have regulation from 2% to 10%, depending on the size and the application for which they are used.

Which is the effect of load on a transformer?

A control transformer is designed to provide rated output voltage at full output VA. As the load decreases, the output voltage will go up. Conversely, increases in load will result in lower output voltages. Typically, the smaller the VA size of the unit, the greater difference there is between no-load and full-load voltage.

Will a control transformer regulate output voltage?

Control transformers are not voltage regulating. Because voltage changes are a function of the transformer's turns ratio and its internal impedance, variations in input voltage will be proportionally reflected to the output.

What is meant by "impedance" in transformers?

Impedance is defined as the vector sum of resistance and reactance which limits the current flow in an AC circuit. When dealing with a transformer, impedance indicates the current limiting effect if you have a short circuit on the secondary. Expressed as a percentage and usually designated as %IZ, impedance along with X/R ratio is used for coordination of fuses and/or circuit breakers. It's expressed in percentage.

Why is impedance important?

It is used for determining the interrupting capacity of a circuit breaker or for sizing the fuse employed to protect the primary of a transformer.

Is one insulation system better than another?

Not necessarily. It depends on the application and the cost benefit to be realized. Higher temperature class insulation systems cost more and larger transformers are more expensive to build. Therefore, the more expensive insulation systems are more likely to be found in the larger KVA units. Small KVA transformers use insulation class 130°C. Compound filled transformers use insulation class 180°C. Larger ventilated transformers are designed to use 220°C insulation. All of these insulation systems will normally have the same number of years operating life. A well designed transformer, observing these temperature limits, will have a life expectancy of 20-25 years.

What is "Temperature Class" in insulation?

Insulation class was the original method used to distinguish insulating materials operating at different temperature levels. Letters were used for different designations. Letter classifications have been replaced by insulation system temperatures in degrees Celsius. The system temperature is the maximum temperature at the hottest spot in the winding (coil). We can obtain it by adding ambient temperature, average winding temperature rise (winding resistance method) and the hot spot differential temperature. The insulation systems recognized by Underwriters Laboratories Inc. (UL1446) are shown on the following table:

Ambient temperature	Average winding temperature rise	Hot spot temperature	Temperature class (max)
40°C	55°C	10°C	A (105°C)
40°C	80°C	10°C	B (130°C)
40°C	100°C	15°C	F (155°C)

40°C	120°C	20°C	H (180°C)
40°C	160°C	20°C	R (220°C)

What does "ambient temperature rating" mean?

Ambient temperature rating refers to the relationship between the label power rating, the application ambient operating temperature, and the actual power capacity after required derating if necessary. Many manufacturers list their power ratings based upon a 40°C ambient. This means that the nameplate rating (i.e. 60 watts) only applies if the unit is operated within an environment with ambient temperatures at or below 40°C. If the unit is operated above 40°C, the unit power capacity must be significantly reduced, with full derating usually occurring at 50°C. In this example, a 60 watt 40°C design would be revalued at 30 watts in a 45°C ambient, and inoperable at 50°C. This is important in two respects. First, the specifying engineer must match the ambient operating temperature to an appropriate power supply design to avoid overloading the power supply. Second, the purchaser of the power supply must pay attention to the differences in operating temperature ratings so as to make an intelligent buy decision, as the performance differences between the 40°C and 60°C designs are significant, hence the lower unit cost for the lesser design.

What is temperature rise in a transformer?

Temperature rise is the difference between the average temperature of the transformer windings and the ambient (or surrounding) temperature.

What is hot spot?

The hot spot is an allowance selected to approximate the difference between the highest temperature inside the transformer coil and the average temperature of the transformer coil.

How does transformer temperature relate to losses and enclosures?

Transformers generate heat! They all do. There is no way of getting around it. Heat is a by-product of the transformation process and heat is due to losses in both the core and coils of the transformer. For most applications, the heat generated is of little concern. But it becomes a concern when determining how much cooling must be provided to compensate for the heat or when the temperature of the enclosure could become a problem.

Transformer losses are dependent on loading. A transformer operating at its nameplate KVA generates maximum losses. This is considered to be 100% losses at 100% load, full load losses.

A transformer loaded at less than 100% doesn't generate as many losses, but it is not in direct proportion to the amount of the load as indicated in the table below. Transformer losses are expressed in watts.

Description	% Load			
	25%	50%	75%	100%
% of total heat losses generated (approx)	20%	30%	60%	100%
% of maximum top enclosure temperature (approx)	10%	30%	60%	100%

Secondary overcurrent protection

Overcurrent devices are used between the output terminals of the transformer and the load for three reasons:

- Protect the transformer from load electrical anomalies
- Since short circuit current is minimized, a smaller gauge wire may be used between the transformer and the load
- Per NEC, a larger primary fuse may be used to reduce nuisance tripping

What do the terms "peak inrush current" and "exciting current" mean and how do they relate to transformers?

Exciting current is the amount of amperage a transformer draws under a no load condition. Another way to look at it is that exciting current is the transformer's "idling" current. Exciting current could also be referred to as no load current although this is not technically accurate. Exciting current is actually made up of two components: no load losses (normally expressed in watts) and reactive power (normally expresses in KVAR). Exciting current varies as a percent of the transformer's nameplate rating depending upon the transformer size. It is not unusual to have an exciting current of approximately 10% on very small transformers (under 1 KVA). On larger transformers, exciting current could be as low as a half of one percent.

Peak inrush current is the amount of amperage a transformer draws instantaneously when it is turned on. A transformer has an iron core and works under the principle of magnetic induction. Alternating current flows through a coil of wire (primary winding) and generates a magnetic field. The iron core of the transformer contains most of the magnetism and conducts this magnetism to where it passes through a second coil of wire (secondary winding).

Since alternating current travels in the form of a sine wave, the amount of magnetism will fluctuate depending upon the point in the sine wave. As this magnetism cuts through the path of the second coil of wire, it induces a voltage into it. When the transformer is turned off, the iron core retains an amount of residual magnetism depending on where in the sine wave the unit was when turned off. When the transformer is turned on, the greater the difference in the sine wave from the "turn off" point to the "turn on" point determines the amount of inrush current. Inrush current could be very small if everything was in phase, or it could be as high as 20 to 30 times full load current. Although this inrush condition disappears rapidly (in 6 to 10 electrical cycles - one tenth to one sixth of a second) it is the first half electrical cycle that sees the peak amount of inrush. This condition can cause problems with overcurrent devices. If the fuse or breaker is of a "quick trip" variety or not properly sized according to the National Electric Code, the inrush may cause it to trip falsely.

What is the effect of altitude on a transformer?

A transformer may be used at full nameplate capacity up to 3300 feet (1000 meters). Above that altitude, the capacity of the transformer should be derated by 0.3% for each 300 feet of elevation above 3300 feet.

How can transformer sound be controlled?

All energized transformers "hum". This "hum" is due to the alternating flux in the core producing a phenomenon known as magnetostriction. Transformer "hum", commonly referred to as "noise", is primarily produced by the core at a fundamental frequency of twice the applied frequency. Noise is an inherent characteristic of the core and cannot be completely eliminated. NEMA Publication n° ST20 and ANSI Standard C89.2 establish maximum sound levels for dry type transformers. These levels are:

KVA range	Maximum sound level
up to 9 KVA	40 dB
10 to 50 KVA	45 dB
51 to 150 KVA	50 dB
151 to 300 KVA	55 dB
301 to 500 KVA	60 dB

One of the major reasons for transformer noise complaints is improper installation. Improper installation and location can increase transformer sound levels 10 decibels or more. Considering that a 3 decibel increase in sound level has the effect of approximately doubling the sound volume as detected by the human ear, a 10 decibel increase in sound level cannot (in most cases) be tolerated.

The first step in low sound level transformer installation is specifying the proper location. With the increased popularity in cost saving advantages of high voltage distribution in modern buildings today, it is necessary to locate small dry type transformers relatively close to (or within) occupied areas. Transformers should be located in areas where the noise would be the least objectionable. The maximum sound limit of the transformer to be installed should be compared to the ambient sound level of the installation location. If the transformer is expected to be louder than the ambient of the site, it should be located elsewhere.
Don't place a transformer near multiple reflective surfaces. An example of a poor transformer location would be in a corner near the ceiling or the floor. Either of these locations presents three reflecting surfaces, and these surfaces will act as a megaphone for the transformer sound. Halls are undesirable too, because of the short distance between opposing reflecting surfaces.

When the best possible location has been found, the next step is mounting. Transformers should be mounted on a floor, wall or structure with as great a mass as possible. One guideline is that the mounting surface should weigh at least ten times as much as the transformer. Take care not to mount a transformer on a thin wall (i.e. plywood or a curtain wall) as they amplify the noise much like a drumhead. The prime noise source in the transformer is in the core and coil. The noise from this source is amplified and reflected by any structure solidly connected to it. This includes incoming conduit and conductors. (Flexible devices may be used for this purpose). Good transformer installations try to isolate the transformer from all other components and structures.