

Transformer Terms and Definitions

A transformer is a static electrical apparatus, without moving parts, which transfers energy from one alternating current source to one or more circuits - at the same frequency (Hz). Transformers may be used to increase voltage (Step-Up), decrease voltage (Step-Down) or to keep voltage the same in electrically isolated circuits. This ability creates an effective match between the incoming line voltage and the required load voltage for a wide variety of devices in a wide variety of electrical circuits. Transformers are designed to provide a long life when used under normal conditions of load, temperature and line harmonic content. Transformers operate under the principles of electromagnetic induction.

Dry-Type Transformers:

Transformers are divided into two basic types, dry-type and oil-filled. Dry-type transformers rely on various types of solid insulation materials, both natural (paper-based and various varnishes) and synthetic (various polymers and silicones), and pass their heat directly to air or indirectly through a heat conducting encapsulant such as epoxy.

Dry-type transformers require little or no maintenance through their service life other than assuring that connections remain clean and tight, that the loading on the transformer remains within design limits, and that air flow through the transformer is not impeded by extraneous materials or dust. Dry-type transformers are therefore the primary choice for indoor locations, and can be used anywhere a transformer is required.

Oil-filled transformers, on the other hand, have a sealed or pressure-vented enclosure with the windings submersed in an oil-based fluid which serves as both insulation and a heat transfer (cooling) medium. Because the oil may pose a fire hazard, oil-filled transformers are generally limited to outdoor use. The oil and its attendant cooling devices (pumps, fans, radiators, etc.) also require regular maintenance and supervision.

Except for the very smallest sizes, all Dongan dry-type enclosed transformers are fully approved for indoor or outdoor installation under normal conditions without any accessory purchase or modification (NEMA 3R rating). Some specialized types are supplied standard in NEMA 12 enclosures. Enclosures for more severe locations, such as NEMA 4, 4X, and 12 are available on a special order basis.

Construction:

Transformers, in their simplest form, consist of two or more windings of insulated magnet wire wound around insulated forms. These forms are then

placed into an iron core consisting of thin steel plates laminated and fastened together into a single unit. Alternating current supplied to the line, or input side of the transformer creates a magnetic field which induces a voltage in the load, or output side of the transformer. This current flows even though the two windings do not physically touch each other. The change of voltage from line side to load side is proportional to the turns ratio of the two windings. This turns ratio forms the basis for the various transformer voltage combinations depicted in this catalog.

Unless noted, transformers in this catalog are wound as *isolation* or *insulating* type transformers. This means that primary and secondary windings are physically separated, and electrically isolated, from each other. This physical separation of windings makes isolation transformers distinct from *autotransformers* - whose windings are physically connected to each other. Most installations of general purpose transformers require the use of an insulating or isolating type transformer. Buck-boost applications are a noted exception.

Taps:

Installers of transformers in commercial and industrial locations frequently encounter inherent high or low voltage conditions in which the use of a transformer would result in proportionally higher or lower voltage on the output side of the transformer. This results because most transformers are designed with fixed turns ratios. Transformer taps are designed to compensate for these steady state, high or low voltage situations while still allowing the transformer to deliver full nameplate rated output current and voltage to the connected load. Taps are referred to as FCAN - *Full Capacity Above Normal* and FCBN - *Full Capacity Below Normal* and are generally furnished on the primary winding. By connecting to an above or below normal tap, the transformer's turns ratio is changed.

For example, suppose line voltage in a 480 volt to 120 volt step down installation is supposed to be 480 volts, but is measured and found to be only 432 volts (a 48 volt -10% difference). Connecting a transformer without taps would result in an output of about 10% reduced voltage, or 108 volts. While this may be acceptable for some installations, other equipment may not tolerate the low voltage. However, the same load connected to a transformer with its primary wired to a 10% below normal tap will see output of exactly 120 volts, as desired.



Transformer Terms and Definitions

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Polarity:

Polarity is the instantaneous voltage obtained from the secondary winding in relation to the primary winding.

While Alternating Current (AC) does not have polarity in the same sense as Direct Current (DC), polarity is involved whenever circuits or transformers are connected together. When two wires in AC circuits are of like polarity, the voltage is rising simultaneously in both, with the current flow in the same direction.

Polarity is normally only a consideration when connecting two or more transformers or windings in series or parallel. For example, the voltages of two windings connected in series will add together if the start of the second winding is connected to the finish of the first; if the finishes or starts are connected together, the lower voltage will subtract from the higher. This is the principle upon which Buck-Boost transformers and transformers with split primaries or secondaries operate.

Shielding:

Most transformer installations today are used to power circuits containing solid state devices sensitive to electrical "noise", transients and voltage spikes. While the possibility of voltage spikes due to lighting strikes on nearby transmission lines exists, the more frequent threat to electronic equipment comes from conducted electrical noise. Noise and transients can enter installations from distant external sources or from internal sources such as fluorescent ballasts and switch mode power supplies. Shielded transformers mitigate the harmful effects of certain types of transients.

Transients are high energy, short duration bursts of electrical energy covering a wide range of frequencies other than the nominal domestic 60 Hz distribution frequency. These bursts range from a high of 20 kHz to a low or about 25 Hz. Distribution systems encounter two types of transient noise: transverse mode and common mode noise. Differences in the two are found in their reference to ground.

Transverse mode noise is noise occurring between circuit supply lines. Shielded isolation transformers have no significant effect in combating transverse noise. Generally, though, transverse mode noise transients dissipate when loads are placed across the lines on which they appear.

Common mode noise, on the other hand, contains transients appearing between the wires of the distribution system and ground. Common mode noise is typically passed to the secondary, or output side of the transformer through a capacitive link between the primary and secondary windings. Circuits containing substantial common mode noise will eventually cause failure to sensitive components.

Shielded isolation transformers attenuate common mode noise transients by providing a barrier, called a Faraday Shield, to the capacitive linking of the primary and secondary windings. The barrier reduces, or attenuates, the amount of non 60 Hz frequencies passed through the transformer in either direction. This is accomplished by connecting the Faraday Shield to ground, effectively reducing transmission of frequencies other than 60 Hz.

Typical attenuation levels of 50:1 (34 DB) are achievable with Dongan shielded isolation transformers. This attenuation provides noise levels generally considered to solve many noise and transient caused problems. Most Dongan General Purpose transformers are furnished with shields at no additional cost. Shielded transformers are designated by the suffix SH or the prefix ES.

Regulation:

A transformer will generally provide a higher output voltage when no load is attached to it than when the transformer is fully loaded at nameplate capacity. Stated differently, under load, a transformer's output voltage drops slightly. Regulation is the ratio of the difference between a transformer's no load output voltage to its full load output voltage expressed as a percentage.

For example, suppose a transformer has a no load voltage of 124 volts and a full load voltage of 120 volts. The transformer's regulation is calculated as follows:

$$\text{Regulation} = \frac{(\text{No Load Voltage} - \text{Full Load Voltage})}{(\text{No Load Voltage})}$$

$$\text{Regulation} = \frac{124 - 120}{120}$$

$$\text{Regulation} = 3.33\%$$

Temperature and Insulation

Ambient Temperature:

The ambient temperature is the average temperature of the air in the immediate area surrounding the transformer. The transformer dissipates its heat into this ambient air.

All Dongan transformers are designed to operate in ambient temperatures of 40°C (104°F) maximum. Derating of transformers is necessary when ambients exceed 40°C (See Operations Section)

Temperature Rise:

Temperature rise refers to the difference in temperature between the ambient air temperature and the actual temperature of the windings or enclosure.

Transformer Terms and Definitions

Insulation System:

An insulation system is a collection of insulating components used to protect the transformer from the effects of heat and dielectric stress occurring during the normal operation of the transformer. Typically these components include insulation coatings on magnet wire, insulation between winding layers and between windings, tape, and other components.

Hot-Spot Temperature:

The hot-spot temperature refers to the highest temperature found inside the transformer winding. Hot-spot temperature allowances vary with insulation classes. See the Total Winding Temperature, Chart 1.1, for a graphical representation of hot spot temperature values.

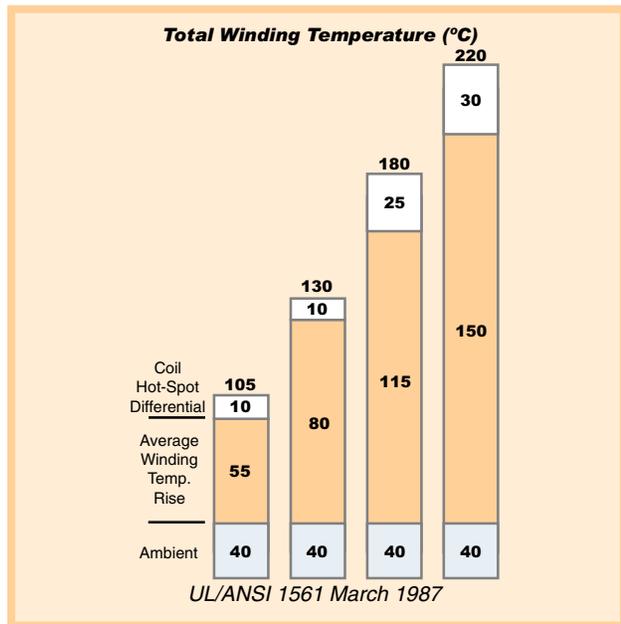


Chart 1.1

Insulation System Temperature and Class:

The insulation system temperature indicates the insulation system's maximum operating temperature in service. This temperature is determined by the temperature rating of the insulation components in a particular design including tape, layer insulation, magnet wire insulation coatings and impregnation materials. The system temperature is determined by adding the ambient temperature, rise and the hot spot temperature. Transformers operated under normal operating conditions will not exceed this temperature, and will enjoy a long service life.

Dongan transformers use UL approved insulation systems whose constituent parts have been extensively tested for compatibility and long life.

Insulation Class:

This is an older letter classification reference to an insulation material's ability to protect a transformer operating at different temperature rises and various total operating temperatures. The original letter designations have given way to numerical Centigrade insulation system temperatures, the most popular of which are 105°C, 130°C, 180°C, 200°C, and 220°C. Please see Chart 1.2 to see how these classes and temperature ratings are derived.

Former Designation	Limiting Temperature	Average Temperature Rise
Class A	105° C	55° C
Class B	130° C	60° C
Class F	155° C	85° C
Class H	180° C	115° C
Class N	200° C	135° C
Class R	220° C	150° C
Class C	240° C	150° C

Chart 1.2

A transformer operating within its insulation system will have the same life expectancy as any other insulation system. In other words, a high temperature rise system is designed for the same service life as the low temperature rise system.

Basic Impulse Level (BIL) and Transformer Insulation Systems:

Basic Impulse Level (BIL) refers to a series of dielectric tests performed on the transformer's insulation system. These tests measure the insulation system's ability to withstand line surges from such sources as the network grid and lightning.

These tests are performed by applying a high frequency voltage between windings and between windings and ground to look for weaknesses in the insulation system.

Dongan transformers comply with NEMA standard 10 kV BIL ratings.

Enclosure Temperatures:

The temperature of the enclosure of enclosed transformers is not equivalent to the temperature of the transformer inside. In air-cooled transformers, much of the heat produced by the transformer is transferred to the air flowing through the cabinet. This allows the enclosure surface to be much cooler than the transformer element inside.



Transformer Terms and Definitions

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In epoxy encapsulated transformers, the transformer's heat is conducted by the epoxy to the enclosure. Because the surface area of the enclosure is greater than that of the transformer, the temperature at the enclosure surface tends to be significantly less than that found on the surface of the transformer element inside.

UL and CSA standards strictly regulate the highest temperature which the case can reach. The enclosure temperature rise shall not exceed 50°C in a 40°C ambient at full rated current. While these temperatures are quite warm to the touch, they are completely within the allowed parameters of the insulation system, UL and NEMA standards. All Dongan transformers comply with these standards.

Enclosure Ratings:

NEMA and NEC® standards provide enclosure ratings which classify the degree of protection afforded by enclosures against various environmental conditions. The chart to the right indicates some of the most common ratings and their protection characteristics.

Excitation Current, Losses and Efficiency:

Excitation current in transformers is the amount of current needed to magnetize and maintain the field in the transformer's core whether a secondary load is connected or not. Excitation current is normally expressed as a percentage of the full rated current of the winding in which it is measured and is frequently referred to as "no load current", although this term is not technically correct.

Typical excitation current values range from about 10% in small, fractional kVA transformers to lows of 1% or 2% in larger dry-type transformers.

Excitation current has two components: a magnetizing component and a core loss component. Core losses are comprised of eddy current and hysteresis losses and are observed as dissipated heat. These losses (and heat) are constant whether the load is connected or not.

Under load conditions, energy is also consumed in the windings due to the winding's resistance. These losses, converted to heat, are called winding losses and are proportional to the amount of load. The sum of core losses and winding losses constitute the total losses developed by a transformer.

Transformer efficiency is a reflection of the amount of total losses inherent in the transformer. It is calculated as follows:

$$\% \text{ Efficiency} = \frac{\text{Nameplate kVA}}{\text{Nameplate kVA} + \text{Total Losses}} \times 100$$

In a typical enclosed, ventilated, dry-type transformer, air flow through and around the enclosure transfers and dissipates the heat from the core and windings. This assures that enclosure temperatures will remain well below internal winding temperatures.

Inrush Current:

All transformers consume a higher amount of amps than rated current for a very short duration when first energized. This "inrush current" is highest when

Enclosure Rating	Provides a Degree of Protection Against:	May be Used
NEMA 1	Incidental contact and falling dirt.	Indoor
NEMA 2	Limited amounts of falling water and dirt.	Indoor
NEMA 3	Rain, sleet, and windblown dust, and ice resistant.	Outdoor
NEMA 3R	Rain, sleet, and ice resistant.	Outdoor
NEMA 4	Windblown dust and rain, splashing or hose directed water and ice resistant.	Indoor / Outdoor
NEMA 4X	Same as NEMA 4 plus corrosion resistant	Indoor / Outdoor
NEMA 6	Entry of water during temporary, limited submersion and damage from external ice.	Indoor / Outdoor
NEMA 6P	Entry of water during prolonged, submersion at a limited depth and damage from external ice.	Indoor / Outdoor
NEMA 11	Oil immersion, corrosion resistance.	Indoor
NEMA 12	Circulating dust, falling dirt, and dripping noncorrosive liquids.	Indoor
NEMA 12k	Same as NEMA 12 - with knockouts.	Indoor
NEMA 13	Dust, spraying water and oil, and noncorrosive coolant fluids.	Indoor

the transformer is energized under conditions of no secondary load. The magnitude of the inrush current is also affected by the point in the AC sine wave in which the transformer power is switched on.

Because of this short duration burst, overcurrent protective devices supplying transformer primaries should be of the time-delay type. Proper overcurrent protection will minimize "nuisance" trips attributed to transformer inrush. Please consult your Dongan Representative or Dongan Customer Service for further advice on any inrush related questions.

Computations with Impedance:

Impedance is the vector sum of the reactance and resistance limiting current flow in an AC circuit. Impedance in transformers is expressed as a percentage and is indicated on nameplates as % IZ. Most distribution transformers have impedance ranges of from 3% to 8%. Impedance is determined

Transformer Terms and Definitions

by inherent characteristics of the transformer including kVA, wire size, and other design considerations.

The most important calculations using impedance are those used in determining interrupting capacity of primary overcurrent devices (fuses and circuit breakers). For example, suppose you are required to determine the interrupting capacity of a single phase, 15 kVA transformer with 5% impedance connected to a 480 volt supply.

Determine:

Full Load Amps (FLA):

$$FLA = \frac{\text{Nameplate kVA} \times 1000}{\text{Primary Supply Voltage}}$$

$$FLA = \frac{15 \times 1000}{480}$$

$$FLA = 31.25 \text{ Amps}$$

Next Determine:

Maximum Short Circuit Current

$$= \frac{\text{Full Load Amps}}{\text{Impedance}}$$

$$= \frac{31.25}{5\%}$$

$$= \frac{31.25}{.05}$$

$$= 625 \text{ Amps}$$

This calculation confirms that the minimum interrupting capacity of the fuse or circuit breaker must be no less than 625 amps at 480 volts.

Now suppose you are required to determine the interrupting capacity of a three phase, 30 kVA transformer with 6% impedance connected to a 480 volt supply.

Determine:

Full Load Amps (FLA):

$$FLA = \frac{\text{Nameplate kVA} \times 1000}{\text{Primary Supply Voltage} \times 1.732}$$

$$FLA = \frac{30 \times 1000}{480 \times 1.732}$$

$$FLA = 36.08 \text{ Amps}$$

Next Determine:

Maximum Short Circuit Current

$$= \frac{\text{Full Load Amps}}{\text{Impedance}}$$

$$= \frac{36.08}{6\%}$$

$$= \frac{36.08}{.06}$$

$$= 601.3 \text{ Amps}$$

This calculation confirms that the minimum interrupting capacity of the fuse or circuit breaker must be no less than 601.3 amps at 480 volts.

Transformer Operations

Overloading Transformers:

The life of a transformer is dependent on the life of its insulation. Transformers loaded in excess of nameplate rated kVA develop excessive heat. Excessive heat will lead to degradation of the insulation system and premature failure of the transformer. For this reason, transformers should not be overloaded. Transformers should be sized with future loads in mind to reduce the possibility of overloading and consequently reducing service life.

Operation of transformers in ambient temperatures exceeding 40°C:

Operating transformers in ambient air exceeding 40°C will reduce operational life unless the transformer is allowed to operate under conditions of reduced maximum load. The chart below indicates recommended derating for various ambient temperatures. While special designs for high ambient temperatures can be supplied, standard transformers derated are both more economical and more readily available. Consult the factory for ambient temperatures exceeding 60°C.

Maximum Ambient Temperature	Maximum Percentage of Loading
40° C (104° F)	100 %
50° C (122° F)	92 %
60° C (140° F)	84 %

Chart 1.3

Transformer Terms and Definitions

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Operation of transformers at frequencies other than 60 Hz:

Any transformer rated for use with 50 Hz, or 50/60 Hz distribution systems, is suitable for operation at either 50 Hz or 60 Hz. Transformers rated for operation at 60 Hz only are **not** suitable for operation at 50 Hz due to core saturation. This causes higher losses and excessive heat inherently created in transformers not engineered for 50 Hz applications.

Dongan transformers rated 50/60 Hz and 60 Hz are suitable for operation at frequencies up to and including 400 Hz provided supply voltages do not exceed rated nameplate voltages. Transformers used at 400 Hz will have output voltages slightly higher than output voltage at standard frequency ratings, and voltage regulation at 400 Hz will be slightly less accurate.

General purpose transformers are designed to change voltage. They are **not** capable of changing, or converting frequency from one value to another. Frequency converters or generators are necessary if frequency conversion is required.

Operation of transformers at other than nameplate voltages:

Transformers must **not** be operated at voltages higher than indicated on the nameplate. The only exception to this rule is when Full Capacity Above Normal (FCAN) taps are provided to accommodate higher voltage.

Transformers may be operated at lower than nameplate voltage provided the transformer's capacity is derated in the same ratio as the voltage reduction. For instance, suppose a 5 kVA transformer with a 480 volt primary and 240 volt secondary is connected to a 240 volt source, resulting in a 120 volt output. Since the transformer capacity must be derated in the same ratio as the voltage, the capacity for this example will be 2.5 kVA, or a 50% reduction.

Balanced Loading of Single Phase, 120 / 240 Volt Secondaries:

Many single phase transformers are wound with 120 / 240 volt secondaries suitable for 3 wire, 120 / 240 volt service. This feature means that the transformer is wound with 2 separate 120 volt windings designed for series or parallel connection. When these 120 volt windings are connected in series, the transformer is capable of delivering both 120 and 240 volts simultaneously. It is important to assure that each 120 volt winding is not overloaded since each 120 volt winding is designed to carry only one-half of the nameplate kVA of the transformer.

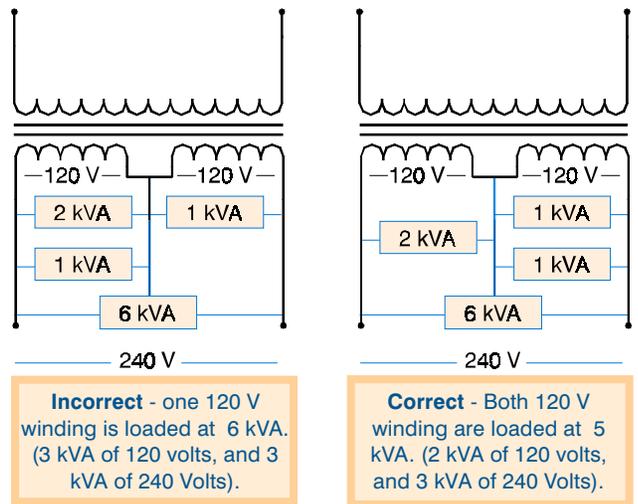
Loading on each 120 volt winding is determined by adding the 120 volt load(s) plus one-half of the 240 volt load.

Example:

Suppose we have a 10 kVA transformer with multiple single phase loads of both 120 and 240 volts as follows:

- 120 volts, 2 kVA
- 120 volts, 1 kVA
- 120 volts, 1 kVA
- 240 volts, 6 kVA

The load must be divided so as not to overload any winding. The diagrams below indicate correct and incorrect connection methods.



Balanced Loading of Three Phase Transformers:

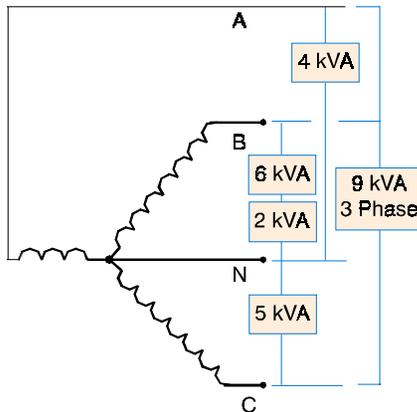
Three phase transformers have balanced loading considerations similar to single phase in that no phase can be overloaded. Each phase must not be loaded at more than one-third of the nameplate kVA of the transformer. For example, a 30 kVA transformer may be loaded at no more than 10 kVA per phase (one-third of 30 kVA). Load per phase is determined by adding the single phase load on any phase plus one-third of the total three phase load.

Suppose we have a three phase, 30 kVA transformer with a 208 Y/120 secondary and multiple single and three phase loads as follows:

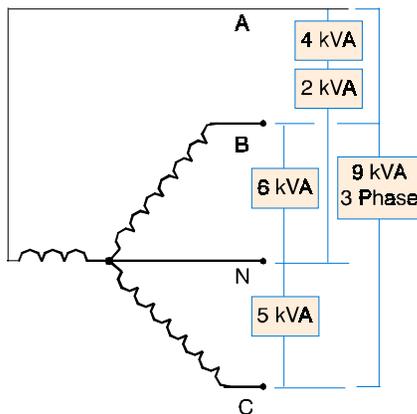
- 120 volts, 4 kVA, single phase
- 120 volts, 2 kVA, single phase
- 120 volts, 6 kVA, single phase
- 120 volts, 5 kVA, single phase
- 208 volts, 9 kVA, three phase

The load must be divided so as not to load any phase at more than 10 kVA. The diagram on the next page indicates correct and incorrect connections.

Transformer Terms and Definitions



Incorrect - Phase B has a total load of 11 kVA when the maximum allowed is 10 kVA



Correct - Phase A Load = 9 kVA,
Phase B Load = 9 kVA, and
Phase C Load = 8 kVA

Balanced Loading of a Three Phase Transformer with a Center Tapped 240 Volt Delta Winding:

A common application for three phase transformers with a 240 volt Delta, center tapped winding is to provide power for three phase 240 volt loads and single phase 120 volt lighting loads at the same time. Balanced loading is essential to assure transformer life is not compromised.

For example, suppose a 45 kVA, three phase transformer is to have 36 kVA of three phase load. We know that each phase can carry one-third of the total nameplate kVA (15 kVA), and that the three phase load splits one-third per phase. In this example, each phase would see one-third of 36 kVA, or 12 kVA per phase. This means that no more than 3 kVA of single phase load can be applied to the center tapped leg.

Additionally, the single phase load must be equally divided on either side of the center tap so that 1.5 kVA is connected between X0 and X2 and 1.5 kVA is connected between X0 and X3.

As you can see, applications of this type can severely limit three phase capacity. For this reason, we recommend single phase loads not exceed 5% of nameplate capacity. Installers should consider the use of a separate single phase transformer when single phase loads are excessive.

Duty Cycle:

Transformers produce heat during the course of normal operations. Some of the heat produced is directly related to the amount of load amps drawn on the transformer. Duty cycle refers to the percentage of time the transformer is loaded to its maximum capacity as opposed to not supplying a load.

Duty cycle is usually expressed over a period of an hour, not including continuous shutdown periods (overnight, weekends, etc.). Therefore, the duty cycle refers to the amount of time the transformer is producing maximum heat output vs. the amount of time it has to cool off again. The most severe duty cycle is, of course, 100%. In some cases, transformers must be oversized in severe duty cycle applications, and in a few cases they can be down sized for light duty cycles.

The most important application of duty cycle is in motor operation, where duty cycle must be considered along with motor starting cycles. A situation where a motor runs almost continuously, (say, 85%) but starts several times per hour will require an oversized transformer. This is because the starting current will cause a momentary overload, with attendant heat buildup, which cannot be cleared from the transformer due to the high duty cycle percentage.

Dongan's technical and customer service staff can advise you on proper transformer sizing where severe duty cycle and/or frequent motor starts are involved.

Operating Transformers with Motor Loads:

Transformers are well suited for providing power for motor load applications provided a few sizing considerations are followed.

Typical motors have inrush loads of 5 to 10 times their running load requirements. Momentary inrush loads of this magnitude will cause a similar momentary transformer output voltage drop.

Lower transformer output voltage results in lower torque and lower horsepower output of the motor proportionate to the square of the voltage drop. For example, if the voltage drops to 90% of normal, torque and horsepower would be 81% of normal ($90\%^2 = 81\%$)

Should the output voltage seen by the motor fall below 50% of nameplate requirements, overheating and even failure of both motor and/or transformer

Transformer Terms and Definitions

could result. Overheating and failure can occur even in cases where correctly sized overcurrent devices employed in the circuit do not trip.

For this reason, transformers should be sized with a few rules in mind.

- For applications where one transformer is powering one motor, size the transformer so that the motor's running amps do not exceed 66% of the transformer's maximum full load amps.
- For applications of more than one motor being powered by the same transformer, motor start up should be sequenced so that the motors do not start at the same time. If sequencing is not practical, size the transformer so that the combined running amps of all motors do not exceed 66% of the transformer's maximum full load amps.
- Increase transformer kVA by 20% when motors are started more than once per hour.
- Derate transformer kVA by .3% for each 330 feet over 3300 feet above sea level.

Parallel Operation:

Transformers may be operated in parallel banks to achieve higher ampacities under the following circumstances:

- Transformer winding voltages must be exactly equal. If there is an imbalance in voltage, excessive current caused by the voltage imbalance will circulate through the transformer bank, creating heat which will quickly destroy the transformer bank.
- Transformer impedances must be the same.
- Internal and external polarity must be identical on all connections.
- Ampacities of the transformers add arithmetically: two 3 kVA transformers in parallel give a 6 kVA capacity.
- In addition to the above, three phase transformers must have the same angular displacement and phasing.

In short, the safest way to achieve parallel operation is to use identical transformers of the same manufacturer.

Single-Phase Transformers used for Three-Phase Banks:

Single phase, stock, general purpose transformers may be banked to achieve a variety of three phase voltage combinations. These combinations are achieved by connecting two or three identical 240/480 volt, or 600 volt primary, single phase transformers into three phase banks. These *banks provide isolation between primary and secondary* just as a three phase, general purpose transformer would.

Typically, banks of three single phase transformers are connected in a Delta Primary and Delta Secondary, or a Delta Primary and Wye Secondary configuration. The capacity of the three unit, three phase bank is equal to the sum of the individual

single phase kVA ratings. For example, three single phase 10 kVA transformers connected in this manner will have a capacity of 3 x 10 kVA - or 30 kVA, three phase.

Conversely, two transformer banks are connected almost solely in an Open Delta (Delta Primary and Delta Secondary) configuration. The capacity of the 2 unit, three phase bank is equal to the sum of the individual single phase kVA ratings multiplied by 86.6% (.866). For example, two single phase 10 kVA transformers connected in this manner will have a capacity of 2 x 10 kVA x .866 - or 17.3 kVA, three phase.

Three Phase to Single Phase:

Transformers will not "convert" three phase to single phase.

A single phase transformer may be connected to a three phase source to furnish single phase power. The primary of the single phase transformer is connected to any two of the three phase lines, or in the case of a wye service, to any phase line and the neutral. Primary voltage of the single phase transformer must be chosen appropriately to match phase-to-phase or phase-to-neutral voltages of the three phase source.

Caution must be exercised to avoid unbalanced loading of the three phase system supplying power to these types of circuits. Examine all connected loads at the three phase source before proceeding.

Single Phase to Three Phase:

Three phase power requires a three phase source. You cannot use any combination of transformer "magic" to produce three phase power from a single phase source. When this is required, a rotating phase adder or a special inductive/capacitive device called a phase converter must be used. This is a highly specialized area, and equipment for this purpose should be specified with the advice of firms supplying the phase change equipment.

Single-Phase Transformers used for Two-Phase Operation:

While it is seldom seen, there are areas, particularly on the East Coast, where two phase power is still supplied by utility companies. Three phase equipment can be operated from a two phase service by using a specialized transformer system called a "Scott-connected two-to three phase transformer bank".

Dongan Electric designs and builds these special-order units for customers on a regular basis. If two-phase power is found or suspected, please consult with our Engineering Department, because there are several different wiring configurations found, and transformer banks designed for each may be incompatible with the others.

Transformer Terms and Definitions

Reverse Connecting Transformers:

Because transformers are based on the ratio of turns between two windings insulated from each other, it would appear that there should be no problem with using what is designated as the primary for the secondary, and vice versa. For instance, someone needing 480 volts from a 120 volt source should be able to use a transformer designed to transform 480 volts to 120 volts wired backwards.

Most transformers sized 1 kVA and above in this catalog can be used in this manner. However, because of certain design limitations inherent in transformers below 1 kVA, these should not be reverse connected without checking with our engineering staff. Small transformers are usually made with a "turns compensation" to help offset losses. This compensation will result in an output voltage that is significantly lower than the primary voltage shown on the nameplate if the transformer is reverse connected.

Single Phase Transformers used for Autotransformer Zig-Zag Ground Connections:

Three single phase isolation transformers may be connected into a three phase, Zig-Zag bank to obtain 277 volts by creating a neutral from an existing 480 volt, three phase, three wire service. Please see Page 45 for details on this convenient and economical hookup.

Other Autotransformer Connections:

There are many applications where single phase transformers are conveniently used as autotransformers for both single phase connections and three phase banked connections. Typical three phase autotransformer banks may be found in this catalog in the Three Phase Specialty Application Section on Page 42 and include 600 to 480, 480 to 240, and 380 to 240.

Common single phase applications include using a standard General Purpose transformer with a 240 x 480 volt primary and a 120 / 240 volt secondary to step 480 to 240, single phase, autotransformer connected. When used in this manner, the transformer's nameplate kVA doubles from its original isolation transformer rating. For example, when autoconnected, a 3 kVA transformer will have a capacity of 6 kVA.

Harmonics:

Most electrical and electronic equipment that is not a pure resistive or pure inductive load generates some amount of harmonic distortion of the basic sine wave of the power system. These nonlinear devices can generate levels of harmonic distortion that are significant enough to cause problems for three phase transformers with wye-connected

secondaries. The SCR's found in switchmode power supplies commonly found in all types of electronic equipment today are a major source of this harmonic distortion. Electronic equipment is often connected between a phase and the neutral, and the harmonic currents generated vary between the phases.

This imbalance in harmonic current generates heat in the transformer because of extra neutral currents and eddy current losses in the core. The effect of these nonlinear loads is expressed as a K-factor, with a totally linear load having a K-factor of 1. Loads generating harmonics can have K-factors ranging from K=4 to K=50, with K=20 being the most severe load commonly encountered. Dongan transformers can be custom-made to serve three phase wye loads with K-factors; please contact us for details.

Motor Drive Isolation Transformers:

Transformers for Motor Drive Isolation are specifically designed with additional cooling; the windings are designed with additional support so as to better withstand the constant physical stress on them caused by the heavy loads that occur each time the thyristors in the drive fire. They are also shielded to keep the electrical noise created by the drive unit from radiating back through the transformer into the building's power system.

Ordering a Transformer:

Several parameters must be established when specifying a transformer:

1. Phase Requirements (single or three phase).
2. Line Voltage from source.
3. Load Voltage of load connected to transformer.
4. Frequency (in Hertz) of current source. This must match frequency requirements of connected load!
5. Load amps of connected load.
6. Type of service: General Purpose, Industrial Control, in which the transformer is either open or enclosed.

In most cases, transformers may be selected by answering these six questions. Additional help in sizing transformers is provided in each section of this catalog.

Special applications may require additional information for sizing. Such cases might include installations where the power factor is less than unity, harmonics are present in significant amounts, motors are started and stopped frequently, high ambient temperatures (above 40°C), or special a temperature rise is desired.

In such instances, your Dongan Representative will assist you or you may contact Dongan Customer Service for additional help.



Transformer Terms and Definitions

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Receipt and Handling:

Upon receipt of shipment, dry type transformers should be thoroughly inspected for any external or hidden damage. In the event a product is found to be damaged, contact the delivering carrier to file a claim and notify your local Dongan Representative. Save all shipping cartons, crates, and/or skids for inspection by the delivering carrier.

Transformers may be extremely heavy. Care must be taken when moving, lifting, and handling to avoid damage to either the transformer or the lifting apparatus. Ventilated, cabinet style transformers must not be tipped over during movement. Lift truck forks should be placed under the skid provided to avoid enclosure damage.

Lifting provisions are provided on many transformers. In some cases, the enclosure top cover must be removed to access lifting provisions provided on the core brackets.

Installation:

Dry-type transformer installations must comply with all applicable national and local codes for overcurrent protection, enclosure bonding, grounding, etc. Particular attention must be given to assure all installations are provided with adequate clearance from walls and ceilings, and ventilation is sufficient to provide for free air circulation in and around each transformer. Transformers installed in rooms must have enough ventilation to maintain ambient air temperatures within established insulation temperature limits when measured at or near the transformer ventilation openings or enclosure.

Accessibility to the transformer must be considered when locations for transformers are selected. Whenever possible, installation should be away from high traffic areas. Placement must allow unrestricted access to covers and panels for inspection, maintenance, and testing. In addition, area must be provided to allow installation of guards for maintenance personnel and, if necessary, for the removal of the transformer without major disassembly of other components.

Outdoor applications should be in areas where water will not pond or flood into or around the enclosure or connections. Enclosure ratings must be appropriate for outdoor use.

Grounding:

The *National Electric Code*[®], Articles 250 and 450, NEMA ST 20 and local electrical codes mandate methods and practices for providing adequate and appropriate conductor grounds and enclosure bonds.

Grounding is important because it increases the safety of the installation by permitting a path to ground should the transformer's coil make contact with the transformer core or enclosure and for passing accumulated static charge buildup to

ground. Proper grounding in transformer installations is essential in increasing the safety of personnel.

Grounding conductors are sized in accordance with the above cited codes. All ground connections must be free of paint and nonconductive materials including rust, dust and corrosion. In addition, connections must be tight at all points in order to maintain adequate bonds throughout.

Installing to minimize "Hum":

All energized transformers hum due to the alternating magnetic field in the transformer's core. Dongan transformers are designed to minimize this noise. While transformer noise is not avoidable, certain installation techniques will reduce noise complaints.

A transformer should be installed where it will be the least objectionable. This is generally away from quiet areas of a facility. If the ambient sound levels are required to be quieter than the transformer's rated sound output, move the transformer to a remote or noisier area. In addition, transformers should be installed where sound will not reflect from close surfaces such as nearby walls, ceilings or floors.

Installations should not be chosen that will resonate sound. This might occur on thin walls or structures on which the transformer is mounted or from rigid conduit connections. The best installations are those that most effectively isolate the transformer from its surrounding support structures and connections.

Dongan transformers comply with ANSI and NEMA standards for sound requirements. These standards establish maximum sound levels for various transformer kVA ratings as listed in the chart.

Transformer kVA Range	Average Sound Level (Decibels)
0 - 9	40
10 - 50	45
51 - 150	50
151 - 300	55
301 - 500	60

Maintenance:

Periodic maintenance should be performed by qualified personnel only. Ventilated openings and transformer enclosures must be kept free of dust and debris so as not to restrict the free flow of air throughout the transformer. Periodically the unit should be de-energized and checked for loose connections and internal collections of dust and dirt. Dust may be removed with the use of compressed air or with a vacuum cleaner.

In addition, when de-energized, the transformer may be periodically checked for terminal alignment, pitted or corroded terminals or wires, and tightness and condition of ground connections, mounting bolts and all other hardware.