ONE *Transformer . . .*
MANY *Voltages*

A turn of the dial converts power line output into the desired voltage. Here is a review of applications for that handy electrical servant, the variable voltage transformer.

The variable voltage transformer thrives on trouble. When the value of the voltage on the AC line is incorrect, just a turn of the transformer dial operates a sliding brush that makes it right. The same dial can act like a rheostat to control the speed of motors; cutting input voltage reduces the motor speed.

Versatility of the variable transformer lies in its ability to tap in anywhere from 0 to 100% of the line voltage, plus another 17% usually available because of a few extra windings in the secondary. Depending on the frame size, the output current ranges from 1 to 50 A at 120 V or half this amperage at 240 V.

Added versatility is possible by larger size units. Some single coil variable transformers are available with output ratings as low as 0.13 kVA and 3-phase "ganged" units can reach 405 kVA.

Most common use, especially with the smaller 500 to 750 VA sizes, is to obtain AC voltages different from the normal 120 or 240 V, single or 3-phase supply. The other major use is delivering either standard or test voltages from lines where voltages fluctuate above or below the normal standard.

A sampling of specific applications include:

- Voltage correction for undervoltage or overvoltage supplies on 1, 2 or 3-phase circuits.
- Producing variable DC voltages from AC sources, usually by control of input voltage to rectifier elements.
- Heater or oven temperature control. Voltage adjustment in addition to usual thermostatic control provides more uniform heating.
- Dimming or controlling incandescent lamp circuits. Life of lamps goes down significantly when operated above rated voltage. Conversely lamp life increases significantly when operated below rated voltage.
- Operating motors and other electrical equipment at correct voltages even when supply is above or below normal. Starting characteristics at subnormal voltages and heating at higher than normal voltages are critical design factors.
- Speed control of some AC motors and of DC motors operating on rectified AC circuits. Fan and other motors with low starting torque are good applications.
- Providing voltages not commonly used for tests or operational runs.
- Calibrating electrical equipment and controls.
- Servo motor regulation.
- Varying step-up transformer output voltage by control of input voltage.

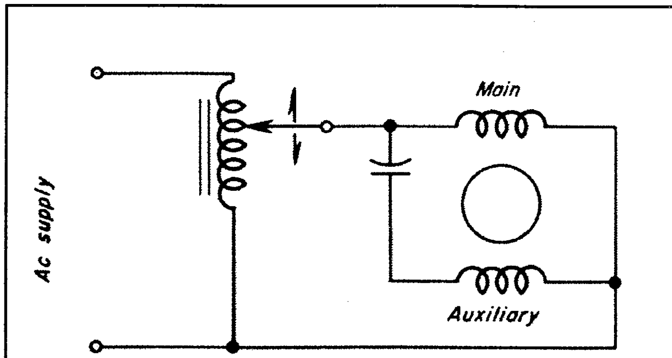

Figure A

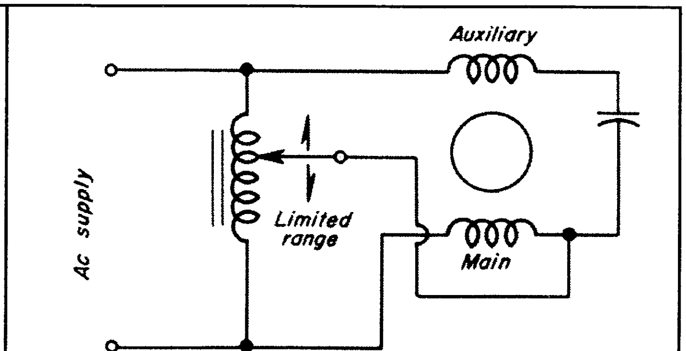

Figure B

SPEED IS REDUCED in these fan motors by a variable transformer. Figure A shows a simple control that lowers voltage to both windings. Figure B illustrates proportional voltage control that varies ratio of voltages to windings for better regulation at low speeds.

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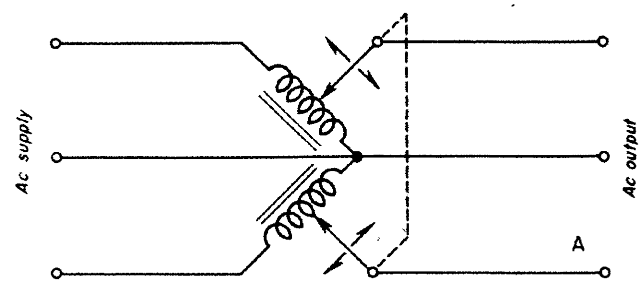


Figure C

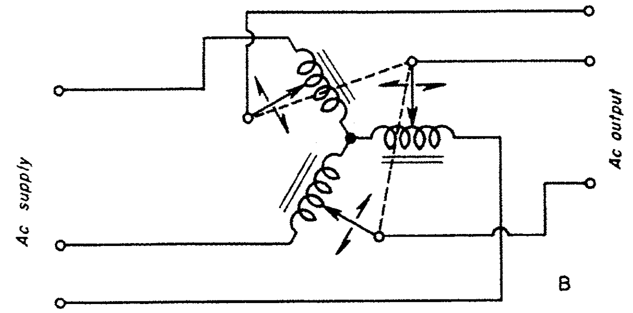


Figure D

FOR 3-PHASE SUPPLY, the open-delta output in Figure C is easily controlled by two variable transformers with ganged brush arms. The Y connection in Figure D requires three variable transformers for controlling a 3-phase output. Brush arms are mechanically connected in both systems.

Motor Speed Regulation

Variable voltage transformers are useful for controlling the speed of universal AC and DC motors and some types of split phase, capacitor run motors that do not use centrifugal switches for starting. The applied voltage is lowered below rated maximum motor voltage to obtain reduced speeds.

When the speed of an AC motor is to be changed by voltage adjustment, it should be kept in mind that the speed regulation and starting torque characteristics of the motor change. For example, if a 1/4 HP motor has a normal full-load speed of 1750 RPM, its no-load speed might approach 1800 RPM. This increase of only 50 RPM from full-load to no-load is considered good speed regulation. If the voltage to this motor is reduced, the no-load speed might be, for example, 1000 RPM. When the motor is loaded, the speed could drop to 600 or 700 RPM, a poor speed regulation value. Initial operation with reduced voltage results in low starting and pullout torque.

A DC motor operated from an AC source can be controlled by a variable voltage transformer. In this application, rectifiers are required to change the AC to DC for motor field and armature as shown in Figure E.

Some Types and Features

Air cooled open construction or screened variable voltage transformers are the most common. NEMA 1 enclosed types are also available. Some considerations when selecting a variable transformer are:

- Higher frequencies (400 to 2000 Hz) can be provided but generally at lower ratings.
- Motor driven variable transformers allow remote adjustment.
- Variable voltage transformers with separate primary and secondary windings allow windings to have voltage ranges independent from each other. The primary may be wound for a number of input voltages and the secondary for either a limited or wide range of output voltages.
- Voltages considerably above the supply voltage are available by including a variable transformer in the primary circuit of a high voltage transformer.
- It is also possible to control kVA loads greater than variable transformer rating by the arrangement shown in Figure F. The variable transformer excites the primary of the fixed step-down transformer known as a buck-boost transformer. Depending on the brush position, the secondary of the buck-boost transformer either adds or subtracts voltage from the line.

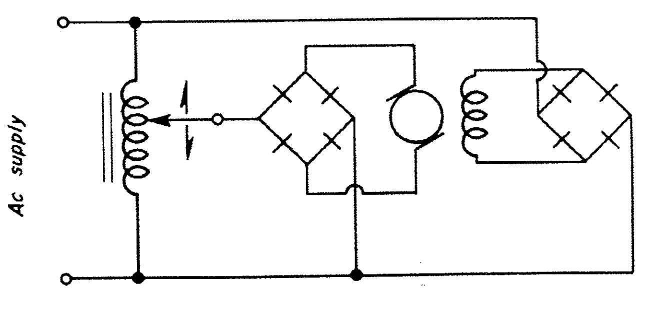


Figure E

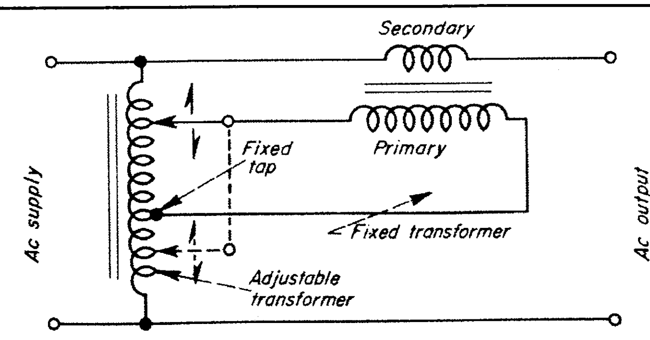
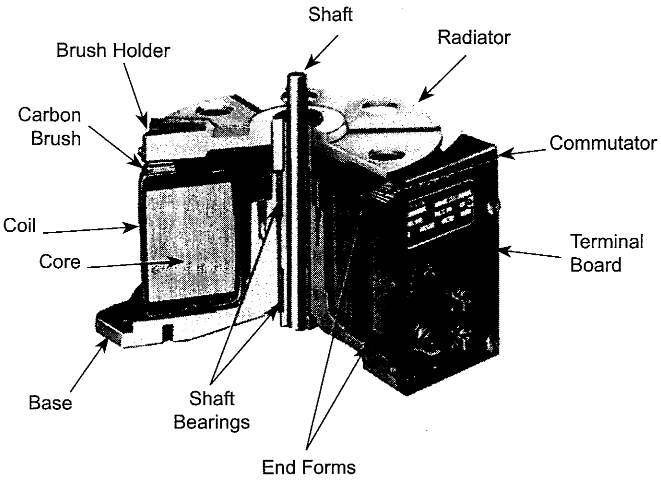


Figure F

RECTIFIED AC runs DC motor with speed controlled by a variable transformer that varies armature current.

HIGH kVA is controlled with a variable transformer exciting fixed transformer primary to adjust line voltage within setting.

Construction and Operation of a POWERSTAT® Variable Transformer



The core of a variable voltage transformer does not have to be of stacked-flat laminations as in usual transformers. It is usually a continuous ribbon of electrical sheet steel tightly wound in the shape of a hollow cylinder. The cross-section of this laminated core often approximates a square.

For the usual autotransformer type, a single layer of copper magnet wire is wound over the core to form a toroid. The top of each turn is bared to form a commutator for the carbon brush. When the AC input is applied to the coil, the brush can slide from turn to turn, tapping off the desired AC voltage. Action is that of a true transformer because transformation, not resistance, provides the voltage change.

Some variable transformers have primary and secondary windings isolated from each other. The primary is placed nearest the core and the secondary is placed over the primary. The adjustable feature is still the ability to tap the desired voltage off the secondary with a sliding brush which follows an axial or circumferential track. Contact area of the brush spans more than one wire turn so the output circuit is unbroken as the brush moves. Voltage change is virtually stepless since voltage between turns is very low, never more than a volt. Electrical losses are low for several reasons: a completely closed path confines magnetic flux to core and winding, thin sheet steel with treated surfaces forms fine laminations that prevent flow of eddy currents and low resistance copper conductors have low power loss. For instance, the no-load loss for a 120 V, 7.5 A unit is only 6 W.

- For operation on 2- or 3-phase circuits, two or three single phase units are ganged with a single shaft to control the output. An open-delta circuit is 3-phase but requires only two variable transformers as shown in Figure C. A 3-phase Y-connection uses three variable transformers as shown in Figure D.

Some Advantages

The range of voltage output extends from zero to maximum input voltage for "line connection". Boost connection increases the range of output voltage to values above the input. A typical boost connection provides output to approximately 17% above line voltage. Greater boost is also obtainable. For example, a 120/240 V variable transformer can have an output range of 0 to 280 V with an input of 120 V. However, at any output over 150 V the output current must be reduced according to published curves. Other advantages include:

- Good regulation. Within the rating of the variable transformer, output voltage is nearly independent of the load.
- Excellent efficiency and low losses at low and maximum rated loads. Little heat has to be dissipated.
- Voltage change by small increments over at least 320° dial rotation. Dials are indexed for output voltages.
- Significant transient overload capability. Published curves show the maximum time units can be subjected to various overloads.
- Quiet in operation, little hum, small external magnetic field.
- Low inherent phase shift and little waveform distortion.
- 60 Hz units are adaptable for 25 Hz with reduced output.
- Minimal required maintenance.
- Moderate cost

Comparison with Other Methods

Solid state voltage controls "chop" the input voltage using a semiconductor switch called a triac to connect the input to the load for a variable portion of each AC half cycle. The devices are smaller per controlled kVA but produce significant current harmonics because of the nonsinusoidal voltage applied to the load. By nature of the time chopping control method, solid state controls cannot serve constant current loads as a variable transformer can. In addition, triacs do not have the same overload capability as variable transformers of equal load ratings and may have to be significantly derated for loads with short term overloads or inrush currents.

When a rheostat reduces line voltage supplied to an electrical device, the voltage drop in the rheostat must be dissipated in heat. If the line voltage or the load varies, the rheostat must be continually readjusted. With a variable transformer, heat loss is negligible and output voltage is not affected appreciably by the load.

A reactor, which is an impedance of small resistance and large inductance, is sometimes inserted in series with a load to vary current and voltage. In contrast with a variable transformer, it has some heat loss and a low power factor. The inductance has to be adjusted to take care of input and output variations.

Other type transformers with tapped primary and secondary windings usually require opening the circuit while changing from one tap to another. Tap changing mechanisms are relatively expensive and voltage changes are not likely to be in small increments. ❑