# Transformer Tapchanging Under Load:
## A Review of Concepts and Standards

An electric power system, operating as intended, is a prime illustration of slow dynamics wherein long term trends may result in less than optimal system operation. Notably, changes in the system voltage level or power losses may occur over periods of minutes or hours to an extent where action is required to improve on those parameters. Used in concert, the switching of shunt capacitors and transformer operating tap position are the principal means of maintaining proper performance in response to daily load cycles.

Very often it is required that the transformer secondary voltage be controlled in order to hold a pre-set value within a certain tolerance. This is usually accomplished by the use of a special assembly which causes a contact to move on a dial switch in a manner to place more or fewer transformer turns in the circuit and thereby regulate the voltage in a step-change manner. This assembly is called a Load Tap Changer (LTC) due to its ability to change switch positions (taps) with load current flowing.

The total range of regulation and the size of the individual step is most often specified as ±10% voltage in 32 steps of 5/8% voltage per step, although other ranges and step sizes are also used. To illustrate this on a 120V basis, with rated primary voltage applied, the output could be stepped through 110.000, 110.625, 111.250,...119.375, 120.000, 120.625...128.750, 129.375, 130.000 volts.

Many tap changer concepts and products have evolved which use different approaches to accomplish the same objective. This paper provides a description of operation of the more commonly used tap changers and illustrates the usual transformer windings with which they are used. Also included is a discussion of pertinent points treated in an IEEE standard being developed on the topic (PC57.131 - Standard Requirements for Load Tap Changers) and a brief description of the associated tapchanger control.

## TAPCHANGER OPERATION

Load tapchanging may first appear to be a trivial matter of switching a contact between taps. The first question encountered is: Should the switch operate as break-before-make or make-before-break? That is, should the switch contact part the first contact (including arc extinguish) before making on the second, or should contact be established on the second before disconnecting from the first?

### THE NEED FOR BRIDGING OPERATION

Figure 1 illustrates one phase of a step-down autotransformer and the basic problem with tapchanging under load if there is no make-before-break provision. At (a) the load is served when a command is received to raise the tap. In (b) an arc is drawn as the finger parts contact. As illustrated at (c) there must be a period of open circuit operation, after the arc has extinguished, in order to not drag the arc between adjacent stationary contacts. The resulting momentary loss of system load would be unacceptable.

Due to this problem, some means of bridging a portion of the transformer winding is required in the operation of all load tap changers. This is necessary to avoid the momentary interruption of load during tap transition. Consequently, all tap changers which operate under load accomplish a make-before-break sequence. There are numerous ways by which this may be accomplished.

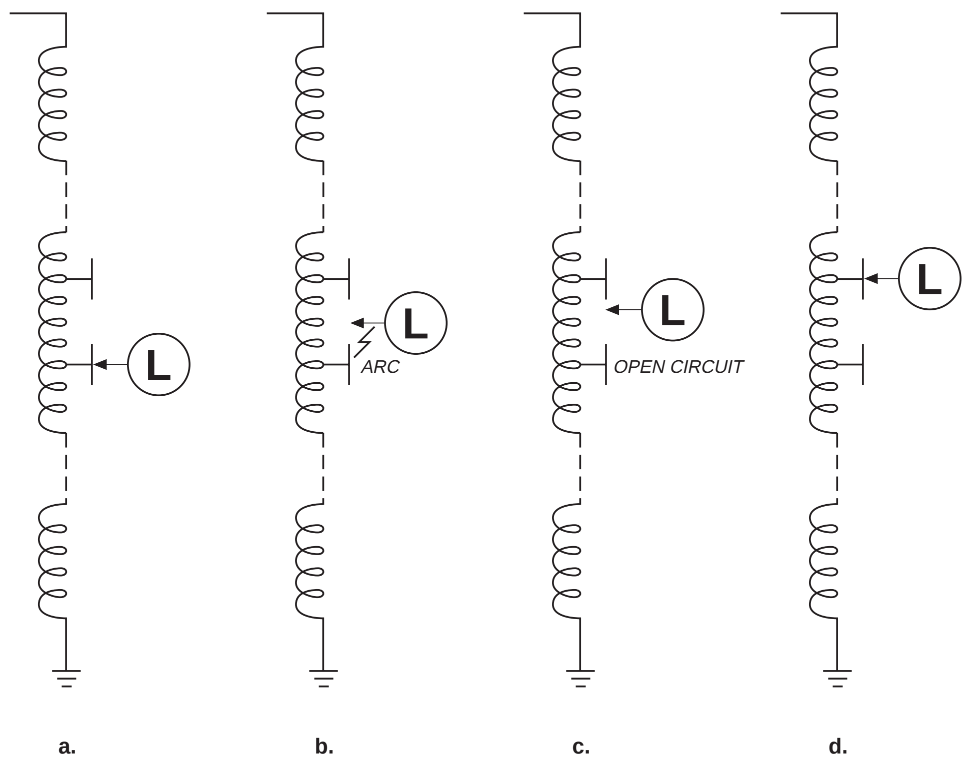



**Figure 1 - A tap transition in which there is no provision for bridging operation.**

Incorporation of a bridging step, i.e., a period during which two different moving contacts span adjacent stationary contacts will resolve the loss of load question. Figure 2 illustrates such a tap changer. For this case there is no step at which the load is disconnected. There is, however, distinctly a new problem. At step (c) the two moving finger contacts are spanning two adjacent stationary contacts, causing a direct short circuit across a portion of the tap winding. The resulting circulating current will cause excessive heat in the shorted windings and excessive wear in the arcing contacts. It is evident that the tap changer must include some provision to limit that circulating current when in the “bridging” position. This is accomplished by placing an impedance in the circulating current path which is large enough to limit the current to a manageable value, while remaining small enough to not introduce a significant voltage drop, with attendant flicker, at the load.

The impedance used to limit the current may be either a resistor or a reactor. The choice of the type of impedance used determines much about the mechanical operation of the tap changer and even the electrical design of the tap winding of the transformer.

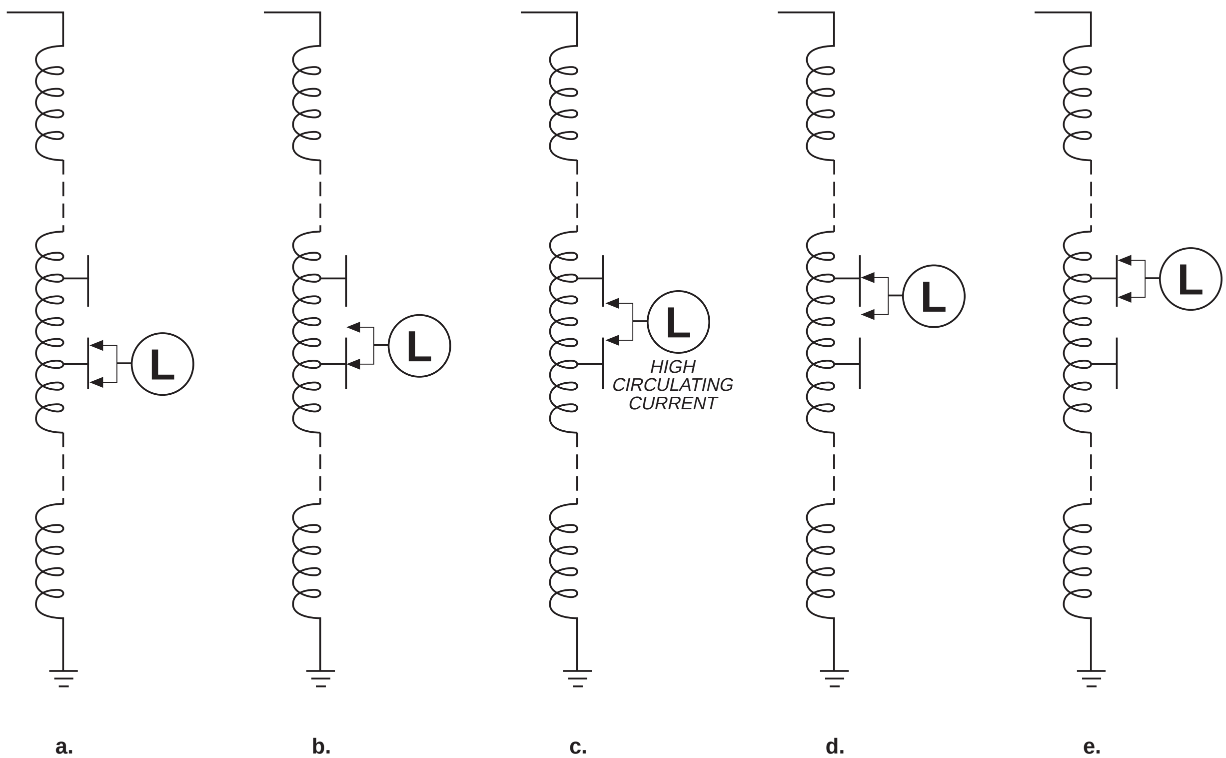


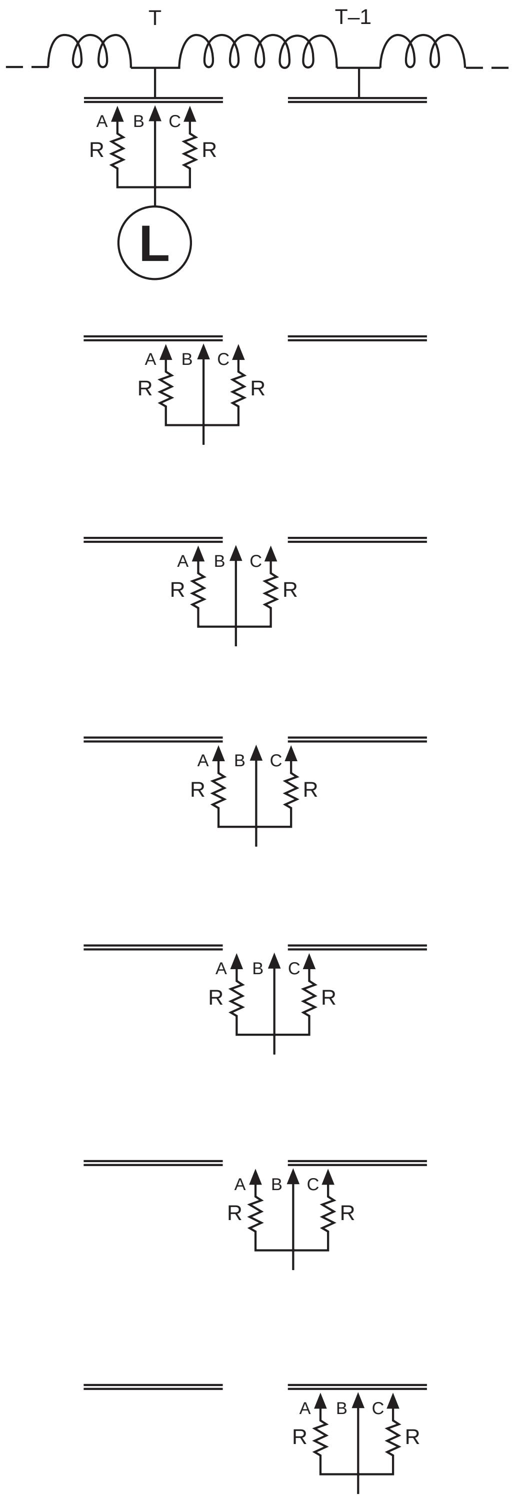

**Figure 2 - A tap transition which includes bridging operation but no provision to limit bridging circulating current.**

## RESISTANCE TYPE LTC

Resistance type load tap changers, as the name implies, use a resistive element to limit the circulating current when in the bridging position. Presuming a common 13.8kV transformer secondary where the voltage change per tap is 5/8%, one step change represents about 50V. If the resistor is sized as one ohm, it will be required to dissipate 2.5kW as due only to the circulating current. This point is the basis for the fact that LTC which use resistors transition quickly between steps, the bridging position being in the circuit only tens of milliseconds.

Tap changers employing resistors to limit the circulating current have been designed with certain differences to attempt to shift the arcing duty between particular contacts or perhaps to simplify the mechanical design. Three such configurations are treated in the pending IEEE standard C57.131. As will be seen, these are described using names suggested by the shape of the phasor diagrams which result when the interstep voltage changes are plotted:

- Arcing Tap Switch - Flag Cycle




a. LTC on tap T. All Load current via B.

b. C breaks; no current in C so no arcing. All load in B.

c. B breaks. Arcing occurs as load current transfers to A. Secondary voltage drops amount $I_{LOAD}R$. High power dissipation in $R_A$.

d. C makes on tap T–1. Arcing occurs. Load current shared by A and C. Current circulates between T and T–1, driven by tap voltage, limited by 2R. High power in $R_A$ and $R_C$.

e. A breaks with attendent arcing. All load current carried by C. High power dissipation in $R_C$.

f. B makes, shunting current away from C, with arcing.

g. A makes; tapchange is complete.

**Figure 3 - A tap transition sequence based on the arcing tap switch- flag cycle (Resistance Type LTC).**

- Arcing Switch - Flag Cycle
- Arcing Switch - Symmetrical Pennant Cycle

### Arcing Tap Switch - Flag Cycle

The power circuit components required for an arcing tap switch operating on a flag cycle are as illustrated in Figure 3, the sequence of seven steps defining a one-step tap change.

At Figure 3a, the transformer is in operation at tap position T. A command is given to transition to position T-1.

A phasor diagram illustrating the load voltage at each of the steps is instructive.

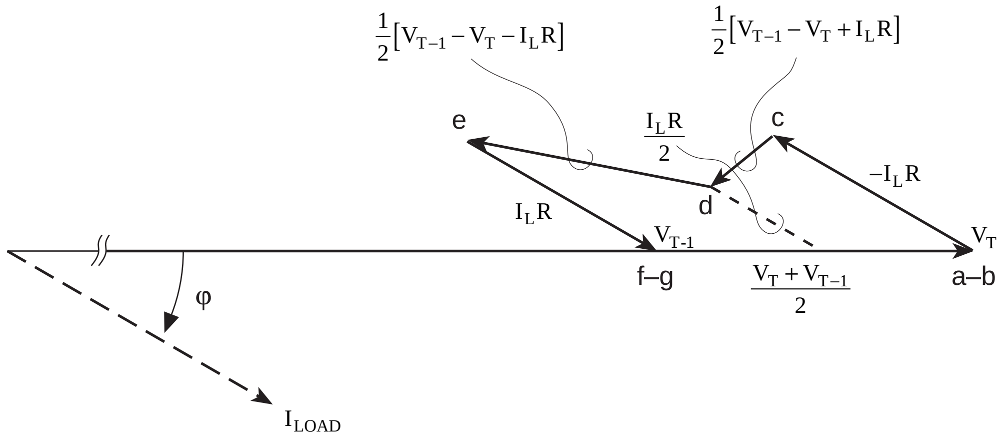



**Figure 4 - Phasor diagram relating to arcing tap switch - flag cycle (Resistance Type LTC).**

In Figure 4, the voltage phasor is the reference for a system operating at about 0.87 lagging power factor, i.e. $\varphi = 30½$.

The voltage at each step coinciding to Figure 4 is:

a) The load voltage is initially that at tap T

b) The load voltage remains that at tap T

c) From the voltage at tap T is subtracted $I_L R$

d) This is the bridging tap position. The load voltage is

$$\frac{V_T + V_{T+1}}{2} - \frac{I_L R}{2} \quad [1]$$

so in transition from c to d, the voltage change is $V_d – V_c$ or

$$\left[\frac{V_T + V_{T-1}}{2} - \frac{I_L R}{2}\right] - [V_T - I_L R] = \frac{1}{2}[V_{T-1} - V_T + I_L R] \quad [2]$$

e) The voltage at the load is

$$V_{T-1} - I_L R \quad [3]$$

so in transition from d to e, the voltage change is $V_e – V_d$ or

$$\left[V_{T-1} - I_L R\right] - \left[\frac{V_T + V_{T-1}}{2} - \frac{I_L R}{2}\right] = \frac{1}{2}\left[V_{T-1} - V_T - I_L R\right] \quad [4]$$

f) The load voltage becomes that at tap T–1

g) The load voltage remains that at tap T–1

Other sources depict Figure 4 without the load current phasor plotted and with the voltage phasor shown vertically. Then the trace a-b,c,d,e,f-g recalls the shape of a flag, hence the name "flag cycle."

The currents and recovery voltages are also important. At step c it is clear that the main contact (B) breaks the load current and that the recovery voltage is $I_L R$ (as the load current moves into A). The duty on the transition contacts (A and C) is as illustrated in Figure 5 for step d.

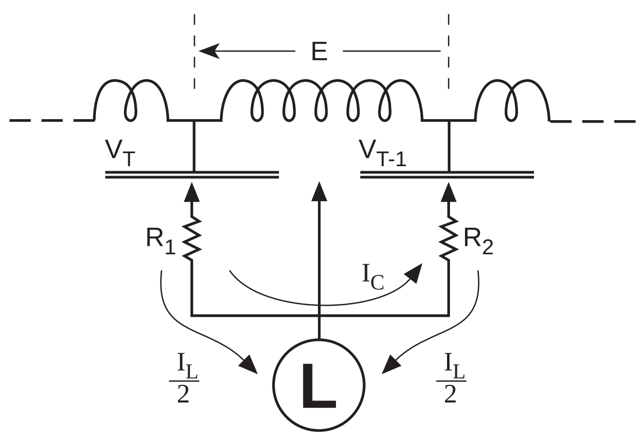



**Figure 5 - Paths of load and circulating current in mid tap position.**

Where

$$I_{CIRCULATING} = \frac{E}{2R} \quad [5]$$

and $I_{LOAD}$ is shared equally in the two paths:

$$I_{R_1} = \frac{I_L}{2} + \frac{E}{2R} = \frac{1}{2}\left[I_L + \frac{E}{R}\right] \quad [6]$$

$$I_{R_2} = \frac{I_L}{2} - \frac{E}{2R} = \frac{1}{2}\left[I_L - \frac{E}{R}\right] \quad [7]$$

The recovery voltage, i.e., the voltage appearing between the parting contact and $R_1$ finger at the moment of arc extinguish is E – IR. In the opposite direction, this will be E + IR.

### Arcing Switch

The arcing switch differs in principle from the arcing tap switch first described. The arcing switch employs additionally a set of main contacts which select the new tap, but accomplishes the procedure while carrying no load, for example as shown in Figure 6.

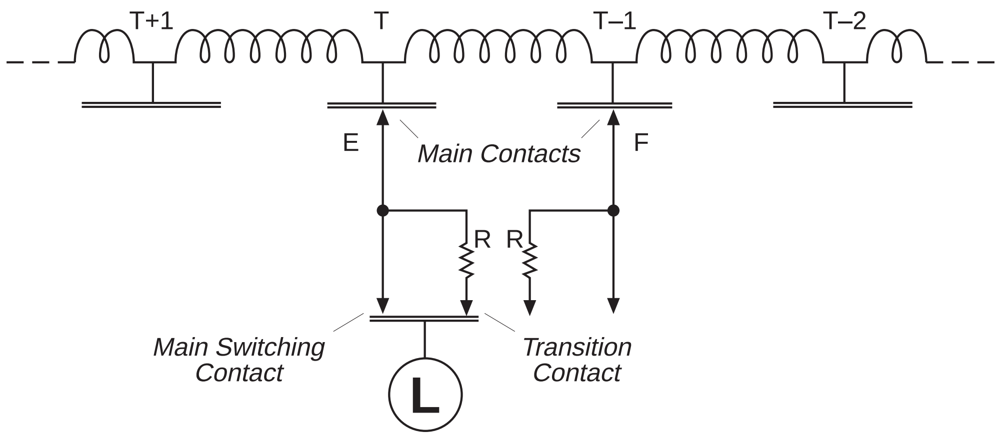



**Figure 6 - Arcing Switch Configuration (Resistance Type LTC)**

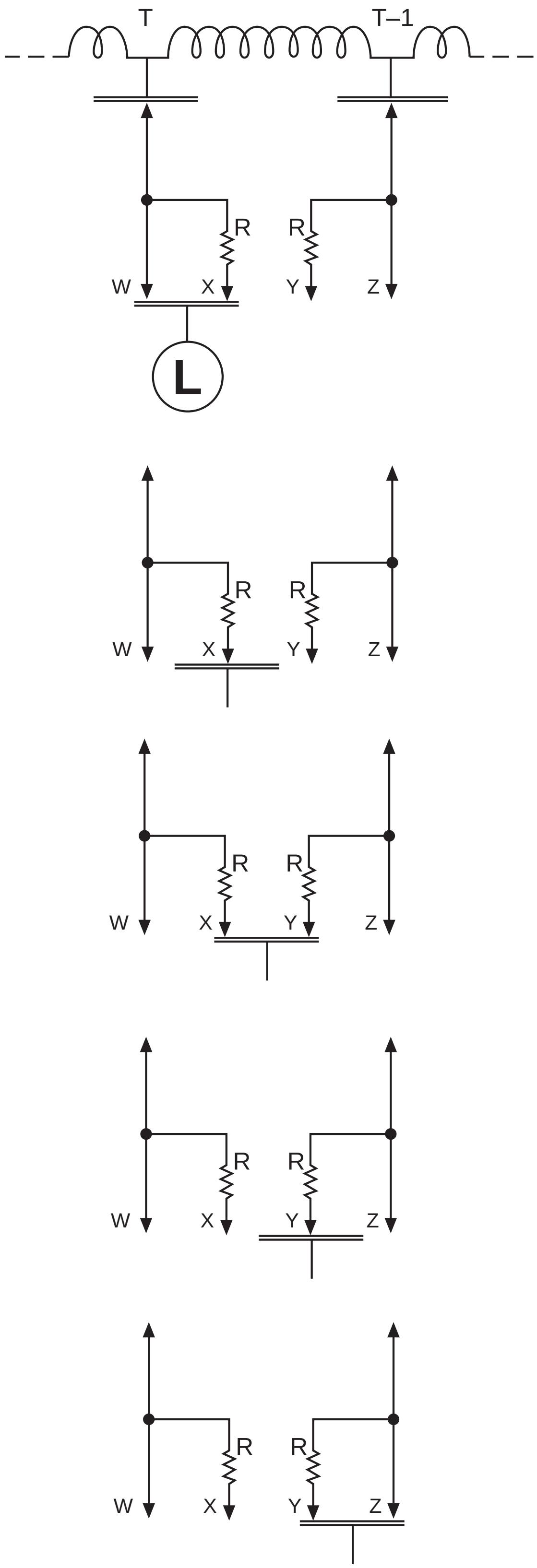
Figure 6 shows that the LTC is operating on tap T. If the next tap is required to be T – 1, finger F is already in position and there will be no main contact change required. If, however, the next tap is to be T + 1, finger F must move to tap T + 1 before there is any movement of the main switching contacts or transition contacts. Finger F can move to tap T + 1 with no arcing involved as there is no current in that finger while the load is on tap T.

The arcing switch may be designed to operate on different cycles. All involve main contacts which operate under no load and consequently are not of particular interest when describing contact duty.

### Arcing Switch - Flag Cycle

A one step transition for an arcing switch operating on a flag cycle is shown in Figure 7. The tap changer is on tap T, moving to tap T – 1. As illustrated, the main contacts are already in the proper position for the pending tap change.

A phasor diagram of the operation shows that another “flag” is created, per Figure 8.




a. LTC on tap T. All load current via W.

b. W breaks with arcing. All load current via X, through $R_X$. Large power dissipation in $R_X$.

c. Y makes with arcing. Load is divided between X and Y and there is circulating current between taps and large power dissipation in $R_X$ and $R_Y$.

d. X breaks with arcing. All load current via Y, through $R_Y$. Large power dissipation in $R_Y$.

e. Z makes, shunting current from Y.

**Figure 7 - A tap transition sequence based on the arcing switch-flag cycle (Resistance Type LTC).**

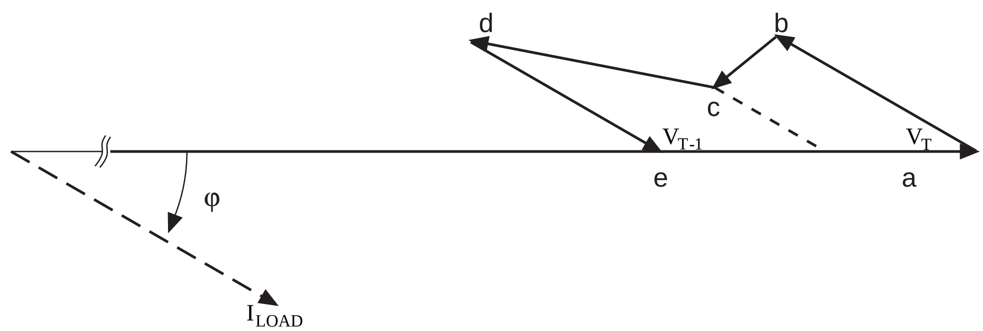



**Figure 8 - Phasor diagram relating to arcing switch-flag cycle (Resistance Type LTC).**

a) The load voltage is initially that at tap T

b) The load voltage is that at tap T, less the drop due to load current in R

c) This is the bridging tap position. The load voltage is

$$\frac{V_T + V_{T-1}}{2} - \frac{I_L R}{2} \qquad [8]$$

so in transitioning from b to c, the operation is the same as earlier described as c to d.

d) The voltage at the load is

$$V_{T-1} - I_L R \qquad [9]$$

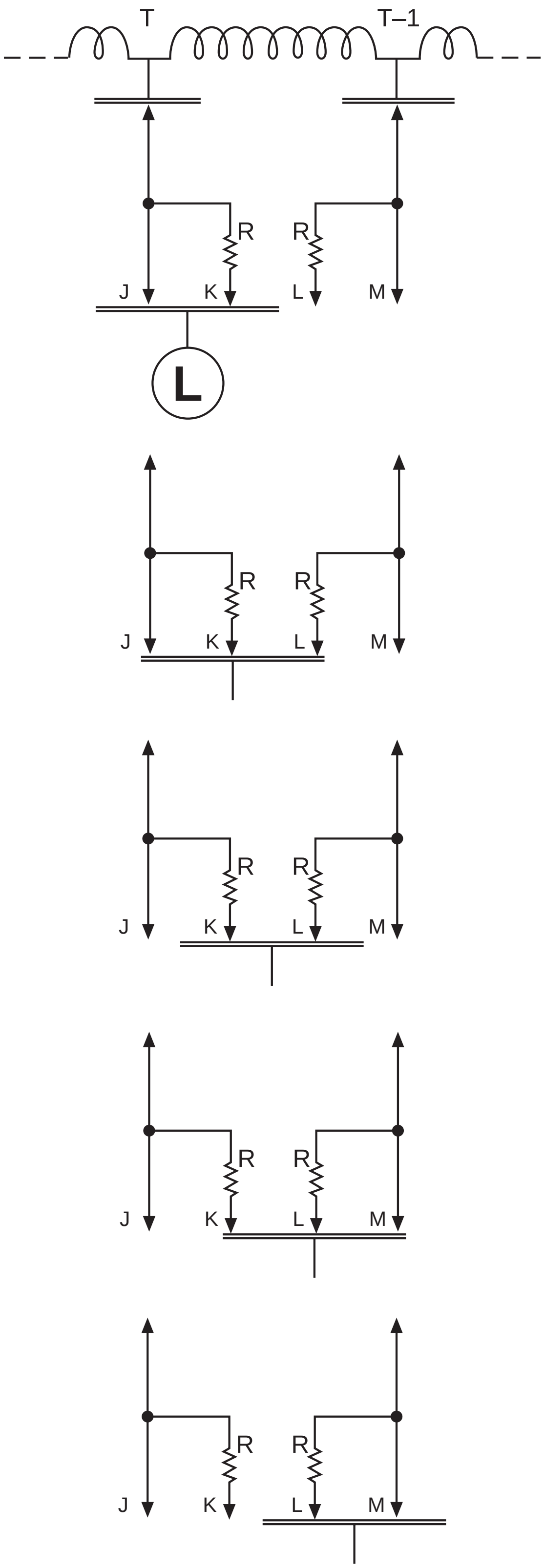
e) The load voltage becomes that at tap T – 1.

In fact, the only difference between Figures 4 and 8 is the step at which a situation exists. The difference of the two is that the tap selection is made with either the same (arcing tap switch) or a separate (arcing switch) switch.

## Arcing Switch - Symmetrical Pennant Cycle

Another operating cycle is sometimes used with the arcing switch. The applicable illustration is very similar to Figure 7, but the contact operating order is different, as shown in Figure 9.

The voltage phasor diagram will differ, as developed in Figure 10.




a. LTC on tap T. All load current via J.

b. L makes with arcing. Ciculating current dissipates power in $R_L$. Load is served via J and L.

c. J breaks with arcing. Load served by K and L. $R_K$ and $R_L$ dissipate power due to load and circulating current.

d. M makes with arcing. Circulating current dissipates power in $R_K$. Load is served by K and M.

e. K breaks with arcing. All load served by M.

**Figure 9 - A Tap transition sequence based on the Arcing Switch - Symmetrical Pennant Cycle (Resistance Type LTC).**

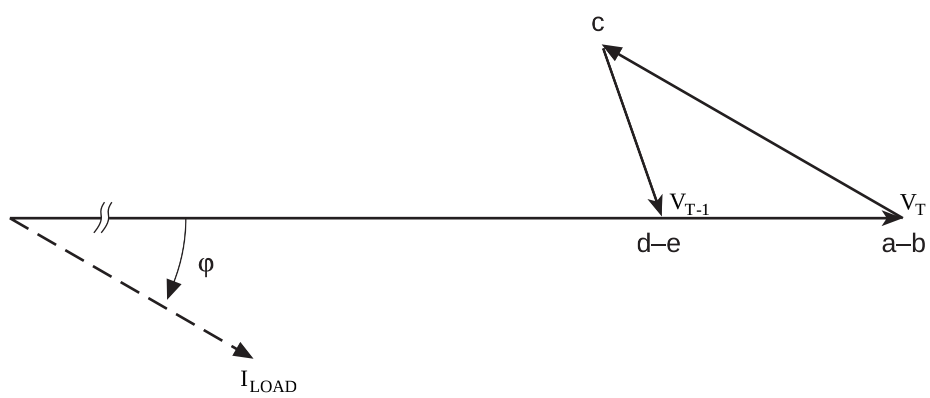



**Figure 10 - Phasor diagram relating to arcing switch - symmetrical pennant cycle (Resistance Type LTC).**

a) The load voltage is that at tap T

b) While there will be some circulating current, the load voltage remains that at tap T

c) The load voltage will be

$$\frac{V_T + V_{T-1}}{2} - \frac{I_L R}{2} \quad [10]$$

so the voltage change from b to c is $V_c - V_b$ or

$$\left[\frac{V_T + V_{T-1}}{2} - \frac{I_L R}{2}\right] - V_T = \frac{1}{2}\left[V_{T-1} - V_T - \frac{I_L R}{2}\right] \quad [11]$$

d) The load voltage will be that at $V_{T-1}$. There will be circulating current

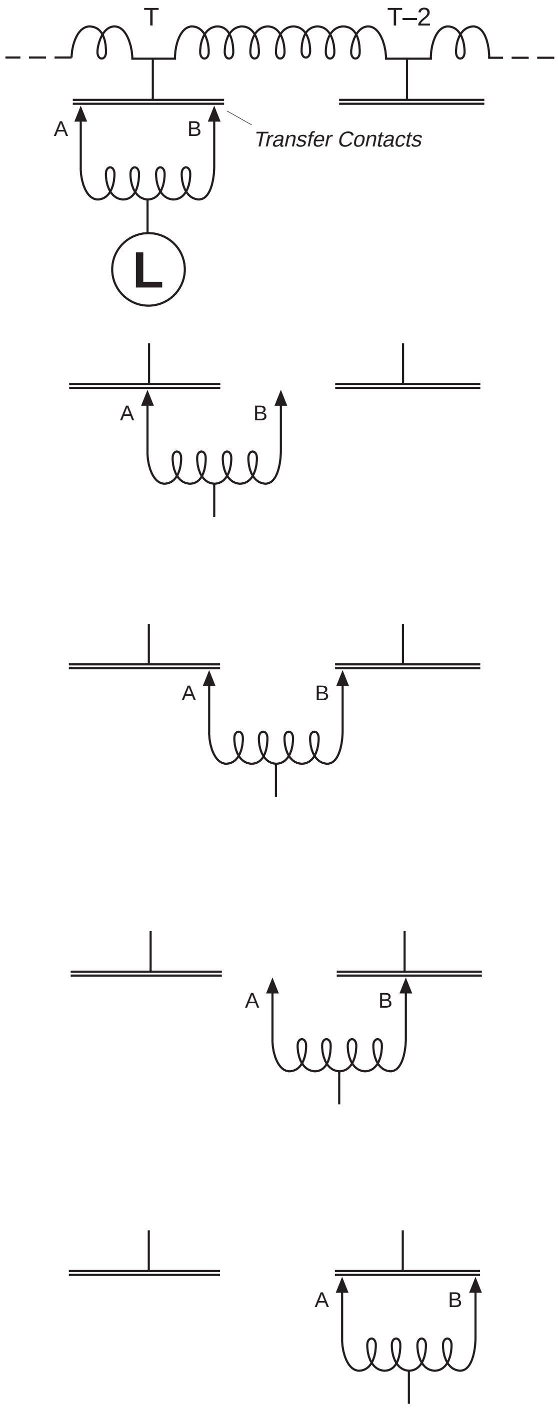
e) The load voltage remains that at $V_{T-1}$

If the earlier illustrations (Figures 4 and 8) could be construed as a “flag,” perhaps Figure 10, when raised, becomes a “pennant.”

## REACTANCE TYPE LTC

Reactance type tap changers use an inductance, rather than a resistance, to limit the circulating current. The impedance of the inductor may be very similar to that of the resistor in the resistance type LTC, but being essentially lossless, it can remain in the circuit indefinitely. Those who provide reactance type LTC take advantage of this by providing only one-half as many main winding taps and using a bridging position continuously for one-half of the tap positions.

The commonly used reactance type switching results in an arcing tap switch, flag cycle. The operating sequence is as illustrated in Figure 11 where the resistance in the reactor is considered to be negligible. Note that now the voltage between tap T and the next tap is twice as large as was illustrated with resistive type tap changers, and is thus designated T – 2.




a. The voltage at the load is that of T. Flux cancellation in the reactor minimizes the voltage drop.

b. B parts with arcing. The voltage at the load is that of T, less the impedance drop resulting from one-half of the reactor.

c. B makes at tap T – 2. The voltage at the load is the average of that at T and T – 2. A one-step tapchange is complete; the tapchanger may operate here indefinitely.

d. A parts with arcing. The voltage at the load is that of T – 2, less the impedance drop of one-half of the reactor.

e. A makes on tap T – 2. The voltage at the load is that of T – 2. The LTC is on a tap position two steps lower than at a.

**Figure 11 - A two tap (1.25%) transition sequence based on the arcing tap switch - flag cycle (Reactance Type LTC).**

The voltage phasor diagram for the reactance tap changer is illustrated in Figure 12. Recall that the reactor will introduce a 90½ shift into the voltage drop in steps b and d.

a) The voltage at the load is $V_T$

b) The voltage at the load is $V_T$ less the drop due to load current in the reactor half

c) The voltage at the load is the average of $V_T$ and $V_{T-2}$

d) The voltage at the load is $V_{T-2}$ less the drop due to load current in the reactor half

e) The voltage at the load is $V_{T-2}$

An important point to note is that, unlike the resistor type tap changer, transformer action in the reactor results in a voltage doubling across the total coil when one end is free. Consequently, while the voltage drop introduced into the load circuit is $I_L \frac{X}{2}$ at b, the voltage across the total reactor is $I_L X$ plotted as ab' and ed' for the two operations. Thus, a phasor ad' is the recovery voltage encountered at d) when the trailing finger parts the stationary contact. (In the reverse direction a phasor eb' represents the recovery voltage). The flag is ready to be raised.

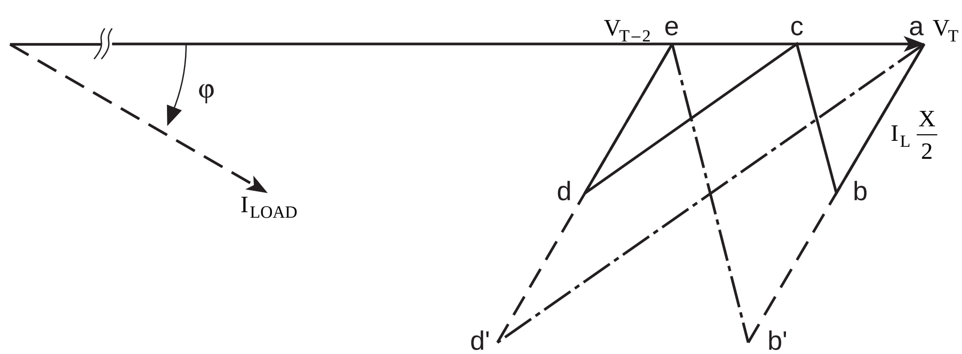
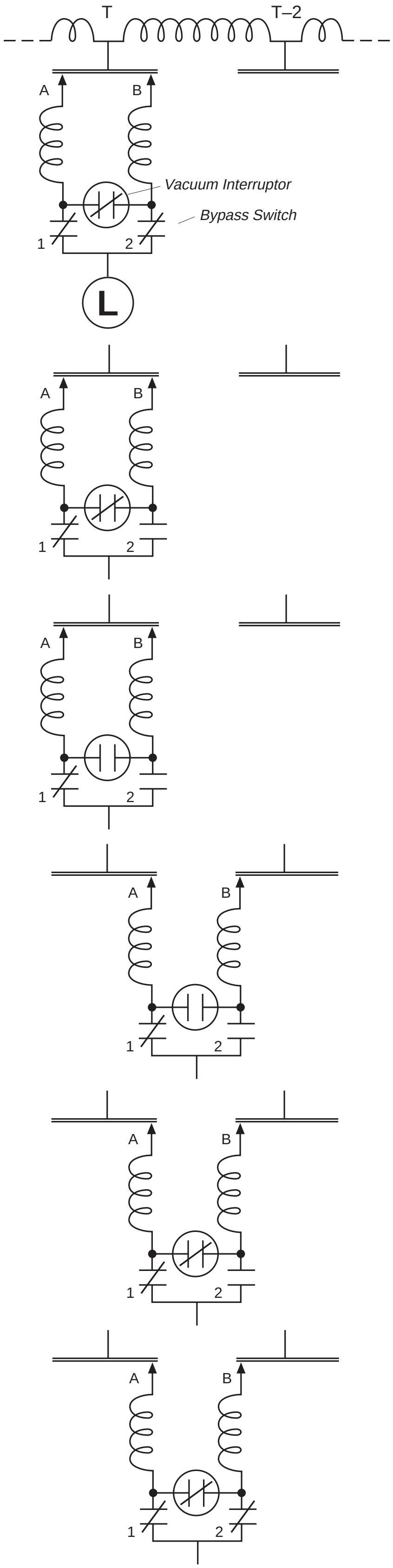



**Figure 12 - Phasor diagram relating to arcing tap switch - flag cycle (Reactance Type LTC)**

## VACUUM INTERRUPTOR LTC

The basic arcing tap switch, flag cycle reactance tap changer has been adapted, to avoid arcing under oil, by the addition of a vacuum switch circuit. The circuit becomes that of Figure 13.

It will be noted that the operation is the same as described earlier, albeit without the arcing. The flag will appear as in Figure 12.




a. The voltage at the load is that of T. The vacuum interruptor and bypass switches are closed.

b. Bypass switch (2) is opened. There is no arcing because a parallel path exists for load current. The load voltage remains that at tap T.

c. The vacuum switch opens, forcing all load current into one half of the bridging reactor. The load voltage is that at T minus the impedance drop of the reactance.

d. With no current in path B, the B finger can move without arcing. There is no change in the load voltage.

e. The vacuum switch recloses, permitting a circulating current. The load voltage is the average of that at T and T – 2.

f. Bypass switch (2) closes, fully completing the bridging operation. The LTC is on a tap position one lower than at a.

**Figure 13 - A tap transition sequence based on vacuum interruption used in Reactance Type LTC.**

## TRANSFORMER WINDING CONFIGURATIONS

A transformer will be designed to operate at a level of core induction which results from a particular voltage excitation, or a particular design level volts per turn. The transformer can be continuously operated at the designed volts per turn (and designed no-load loss) if the number of turns is adjusted in conformance with the voltage fluctuation. Thus, if the primary system voltage is stable, and the secondary requires regulation, the taps will usually be on the secondary winding.

Two circuits are illustrated in Figure 14 which depict how the tap section might be included to accommodate a varying HV or LV circuit with an autotransformer. Both circuits involve the tap changer at the low voltage winding.

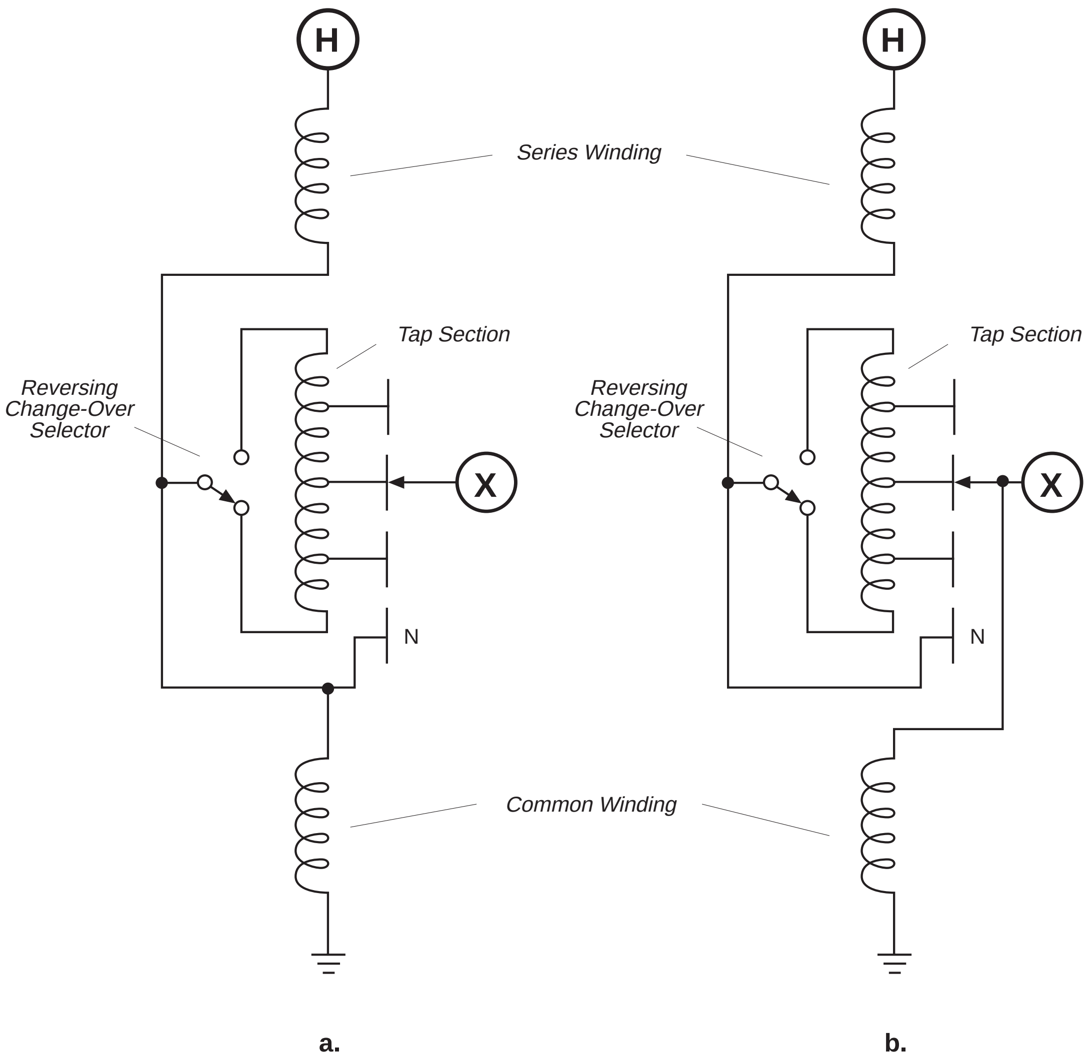



**Figure 14 - Two basic circuits for tap winding of autotransformer, including reversing changeover selector switch.**

In Figure 14a the number of turns H to neutral is fixed. Thus the operating volts per turn will be stable if H voltage is stable. Figure 14b shows an alternate scheme where the corresponding number of turns is adjusted. This may be preferred if the HV winding experiences the greater voltage change.

Figures 14a and 14b also reveal the operation of a reversing change over selector switch. This switch is operated only when the tap changer is on the N (or neutral) tap position and the switch is carrying no load. The reversal of the switch results in a polarity reversal of the tap section of winding. By this means, a given tap section can be used to accomplish plus and minus regulation.

The circuits of Figure 14 use the tap changer at the potential of the X circuit. It is noted that the insulation requirements of the tap changer would be reduced if the tap changer could be operated at ground, as in Figure 15. Indeed this is an accepted configuration, but note that the number of HV turns is variable with tap position, as with Figure 14b, and is therefore probably not preferred for most systems where the HV will be the more stable.

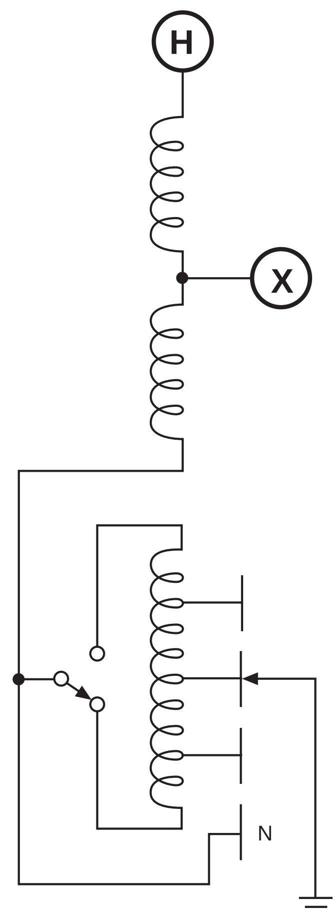



**Figure 15 - Basic circuit for tap section at ground potential.**

All tap changers are capable of switching a certain maximum current. In spite of this, a tap changer may be used in a transformer to switch several times its rating if used in conjunction with a series transformer. The primary of the series transformer is in series with the load; the secondary, operating at lower current, is switched by the tap changer.

Consider the circuit of Figure 16. If the series transformer is of a 1:3 ratio, a tap changer rated for 600A may be used in a transformer rated to 1800A.

Note that when the tap changer is on neutral that the secondary of the series transformer is shorted, there is no core excitation and no series transformer core loss. The loss in the series transformer will increase as the tap position digresses from neutral.

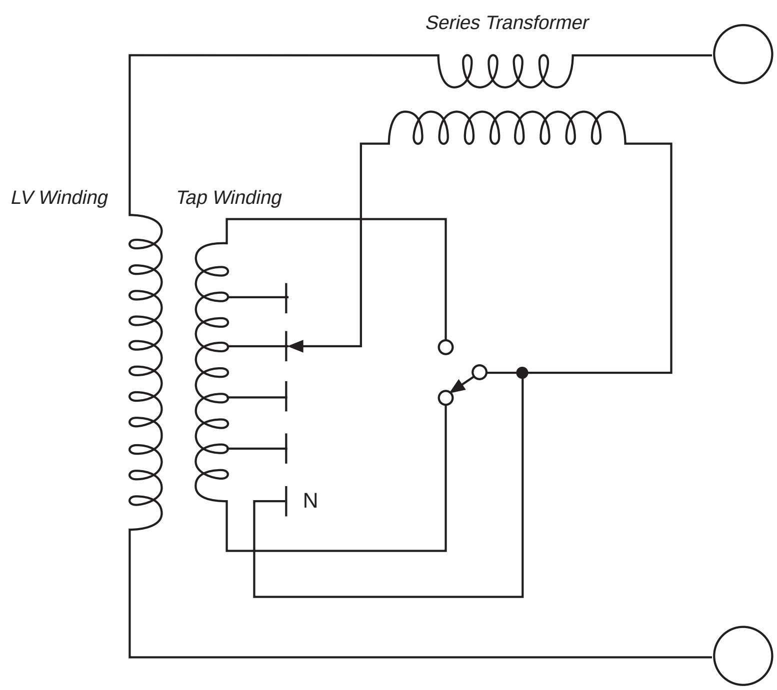



**Figure 16 - Basic circuit for incorporation of series transformer with tap winding including reversing changeover selector switch.**

## PROPOSED IEEE STANDARD C57.131 "STANDARD REQUIREMENTS FOR LOAD TAP CHANGERS"

There is, at present, no IEEE or ANSI Standard which defines the operation or performance of a transformer load tap changer. A Working Group of the IEEE PES Transformers Committee is developing such a standard which will be patterned from IEC-214, "On-Load Tap Changers"; IEC-214, however, deals only with resistance type LTC.

The main purpose of C57.131 will be to provide standard performance and test requirements for both resistance and reactance type load tap changers. The proposed IEEE standard compliments the IEC standard by providing additional performance and test criteria for reactance type LTC while essentially adapting, sometimes with modification, the IEC requirements for resistance type LTC. The standard will also include a section of pertinent definitions, some of which are included in this paper as Appendix A. Note that the standard is not yet an approved document; some of the following information may change before the standard is issued.

Perhaps of most interest are the six design tests required by the standard.

1. **Temperature Rise of Contacts**

   Under particular operating conditions, including a load current of 120% of the stated maximum rated through current of the tapchanger, the contact temperature rise above the temperature of the insulating fluid surrounding the contact shall not exceed 20½C.

2. **Switching Tests**

Switching tests include service duty tests and breaking capacity tests.

- **Service Duty Test**. The service duty test is to demonstrate satisfactory operation of all arcing contacts equivalent to 50,000 tapchange operations when carrying the maximum rated through current at the relevant rated step voltage. Further, the results of this test may be used by the manufacturer to demonstrate that the contacts used for making and breaking current are capable of performing, without replacement of the contacts, the number of tapchange operations guaranteed by the manufacturer at the rated through-current and at the relevant step voltage.

- **Breaking Capacity Test**. Tapchange operation is made forty times at twice the maximum rated through current and at the relevant rated step voltage. In this test, the arcing time must be such as to not endanger the operation of the apparatus, e.g., dragging the arc across the stationary contacts must not occur. The performance of this test will typically result in a curve such as that of Figure 17 where a plot of points of 40 consecutive successful switching operations defines the breaking capacity. Recall that the curve plots a current which is twice the maximum rated through current.

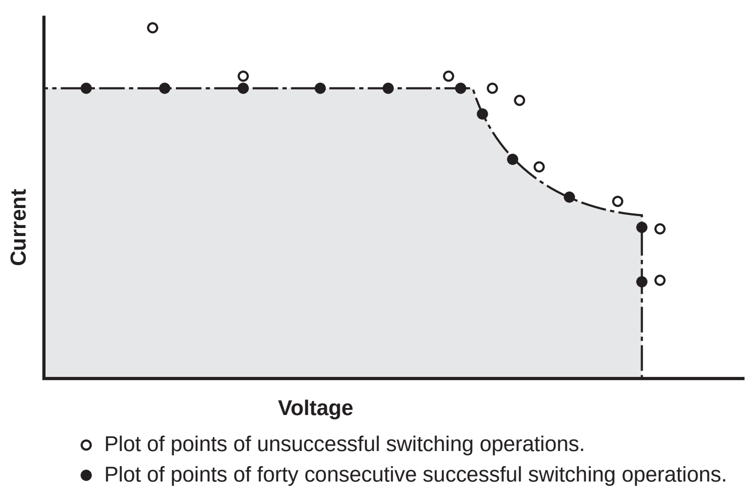



**Figure 17 - Typical interrupting characteristic for breaking capacity test.**

3. **Short Circuit Current Test**. The rms symmetrical short circuit current rating is required to be ten times the tapchanger maximum rated through current when rated current exceeds 400 Amperes. For test purposes, it is required that the initial peak current be 2.5 times the rms value of the short circuit test current. Three test applications each with the heating effect of a 2.0 second duration fault are required.

4. **Transition Impedance Test**. The transition impedance test relates to the allowed rise in temperature of the current limiting resistor in resistance type tapchangers. With the tapchanger mechanism operating without interruption and at normal speed for the full range of operation (commonly 32 steps) and at 1.5 times the tapchanger maximum rated through current, the temperature rise of all components must not exceed 350½C relative to the surrounding oil and must be such as to not damage any components.

   No equivalent test is specified for reactance type tapchangers.

5. **Sequence Test**. The LTC is to be operated over one complete cycle. The exact time sequence of operation of the tap selector, change-over selector, arcing switch or arcing tap switch, as appropriate, are recorded. The results of this test will be used later in a Routine test.

6. **Dielectric Tests**. Applied voltage test, Basic Lightning Impulse Insulation Test, Switching Impulse Test and, for some ratings, Partial Discharge testing is specified. Dielectric testing of the tapchanger includes live parts to ground, between phases, between first and last contacts of the dial switch and other clearances peculiar to the tapchanger.

The standard also requires the following three routine tests:

1. **Mechanical Test**. The fully assembled tap changer is operated through 20 complete mechanical cycles.

2. **Sequence Test**. The sequence of operation of the LTC will be recorded during the routine mechanical test. The results of the recording shall be substantially in agreement with those of the Design Sequence Test.

3. **Auxiliary Circuits Insulation Test**. The control wiring shall withstand a power frequency test of 1.5kV applied for 1 minute between all line terminals and the frame.

## TAPCHANGER CONTROL

In the power transformer industry, it is common that the transformer per se, the tapchanger and the tapchanger control will each have been designed and manufactured by a different supplier. In the case of the control, this has often meant that a given control could be adapted and used with many different LTC's.

Almost all LTC controls receive input signals scaled to 120Vac and 0.2 Amp for the load voltage and current. The analog circuitry of the traditional control would manipulate those sensed quantities with particular operator selected setpoints to determine the need for a raise (or lower) tapchange operation to hold the output voltage within the desired band. The circuit of Figure 18 describes this most fundamental scheme.

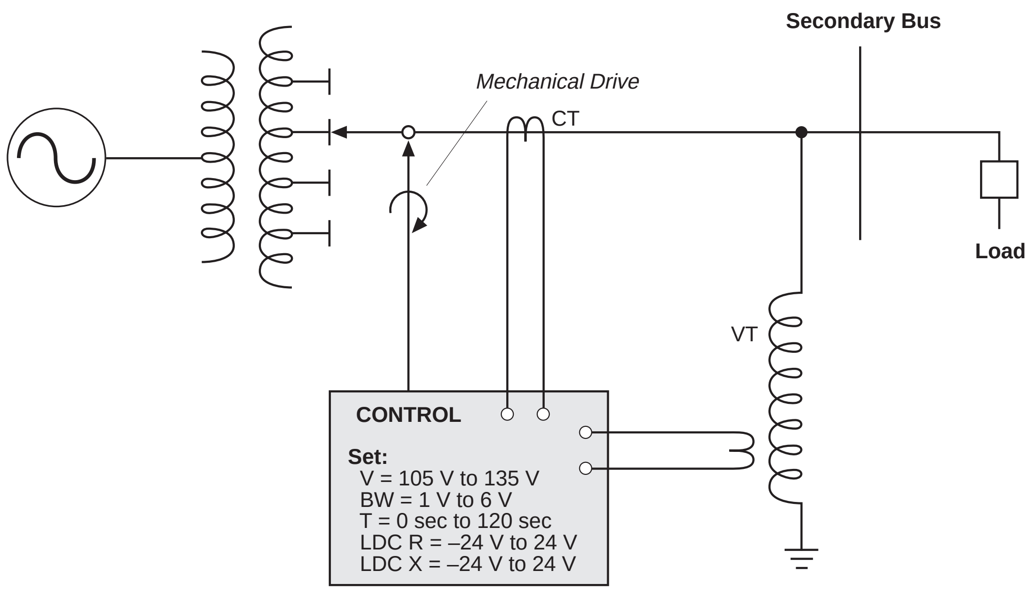



**Figure 18 - LTC Control Circuit Required to Satisfy Basic Criteria**

In recent years, the trend to control designs based on digital technology has greatly expanded the function of the control to where, in some cases, the control is a principal point of data collection and control for the SCADA system. A digital control may be programmed to provide and receive numerous parameters and functions of interest to the user, such as:

- Reverse power flow detection and altered operation based on such detection.
- System voltage, current, power factor and related quantities for display.
- Retention in non-volitile memory of particular parameters of interest perhaps with date/time stamping coincident with those events.
- Demand metering.
- Special control algorithms which are active only during particular (pre-defined) system disturbance conditions.
- The means to alarm an operator when the control recognizes its own failure.
- The means to communicate to the user the system parameters of interest using a serial communications line.
- The means to receive, from a command center, the serial message commanding a change of control settings.

Feedback from the tapchanger to the control opens many more possible features. The total capability of such a system is still evolving.

## CONCLUSIONS

The science of tapchanging underload is so well established in the industry that it is very easy to overlook the principles involved and dismiss it as a matter of little concern. In fact tapchangers are very sophisticated and precise mechanical switches. Various suppliers have refined the operation of these switches to meet their particular needs. The user needs to recognize the instrinsic differences among the resistance type flag cycle, resistance type pennant cycle, and reactance type in order to fairly evaluate the competitive merits of each.

The present lack of standardized performance criteria for load tapchangers will soon be resolved. When approved, a new IEEE Standard, C57.131, “Standard Requirements for Load Tap Changers,” will consolidate performance criteria for resistance and reactance style units.

A study of the LTC control has usually been treated as a topic isolated from the switch, but the emerging prevalence of system communications and the possibility of LTC status being known by the control will make it necessary, in the future, to consider the two parts as an entity.

# APPENDIX A
# DEFINITIONS RELATING TO LOAD TAPCHANGERS

It is important that common terminology be used when speaking of the operation of differing tap changers. The following definitions are extracted from IEEE PC57.131, Draft 6, "Standard Requirements for Load Tap Changers."

*Definitions Common to Resistance and Reactance Type LTC:*

**Load-Tap-Changer (LTC)**. A selector switch device, which may include current interrupting contactors, used to change transformer taps with the transformer energized and carrying full load.

**Tap Selector**. A device designed to carry, but not to make or break, current, used in conjunction with an arcing switch to select tap connections.

**Arcing Switch**. A switching device used in conjunction with a tap selector to carry, make, and break current in circuits which have already been selected.

**Arcing Tap Switch**. A switching device capable of carrying current and also breaking and making current while selecting a tap position. It, thereby, combines the duties of an arching switch and a tap selector.

**Change-Over Selector**. A device designed to carry, but not to make or break, current, used in conjunction with a tap selector or arcing tap switch to enable its contacts, and the connected taps, to be used more than once when moving from one extreme position to the other.

**Coarse Change-Over Selector**. A change-over selector which connects the tap winding to a coarse winding, a main winding, or to portions of the main winding.

**Reversing Change-Over Selector**. A change-over selector which connects one or the other end of the tap winding to the main winding.

*Definitions Pertinent to Resistance Type LTC:*

**Main Contacts**. A set of through-current carrying contacts which has no transition impedance between the transformer winding and the contacts and does not switch any current.

**Main Switching Contacts**. A set of contacts which has no transition impedance between the transformer winding and the contacts and makes and breaks current.

**Transition Contacts**. A set of contacts which is connected in series with a transition impedance and makes and breaks current.

*Definitions Pertinent to Reactance Type LTC:*

**Bypass Contacts**. A set of through-current carrying contacts which commutate the current to the transfer contacts without any arc.

**Transfer Contacts**. A set of contacts which makes and breaks current.

# Missouri Valley Electric Association

## Substation Design and Apparatus Committee

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## A Review of Concepts and Standards

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