MicroTAPP allows up to 16 transformers in up to 8 groups with different impedances, tap changers and high voltage inputs to operate in parallel simply and efficiently.

MicroTAPP is a complete voltage control system, including voltage control, voltage monitoring, tap position indication, tap changer monitoring, remote communication.

2V164 is a simpler transformer voltage control relay including line drop compensation, voltage monitoring, tap position indication, remote communication.

1M122 is a parallel control scheme for control of up to 4 transformers using the master-follower method.

Other available voltage control accessories:
- 2V200 tap position transducer
- 4D200 tap position display module
- 4M900 tap position selector switch
- 2V165 parallel control relay
- 1X200 local/remote operator control panel
- 2V67 under/over voltage monitoring relay
VOLTAGE REGULATION

METHODS

Automatic voltage control methods for the operation of parallel transformers have advanced with the use of numeric relays.

The simplest form of Automatic Voltage Control (AVC) can be used where a single transformer supplies a single load, refer Figure 1. If the load is some distance from the transformer, there will be a voltage drop in the line. The AVC relay makes an estimate of the voltage at the load using a model of the line and applies Line Drop Compensation (LDC) based on the conditions seen at the transformer:

\[ V_{\text{eff}} = V_{VT} - I_{CT}(R_{\text{line}} + jX_{\text{line}}) \]  
\[ V_{\text{dev}} = V_{\text{eff}} - V_{\text{target}} \]

where \( V_{\text{eff}} \) is the effective voltage at the single load, \( V_{VT} \) and \( I_{CT} \) are the measured voltage and current respectively, \( R_{\text{line}} + jX_{\text{line}} \) is the model for the impedance of the line, \( V_{\text{dev}} \) is the voltage deviation from target, and, \( V_{\text{target}} \) is the target voltage.

The above represents the ideal situation: in reality there are usually a number of loads on a transformer distributed at different distances (electrically) from the transformer, so the model of the line will always be a compromise. It can be shown an optimum voltage control will establish a constant voltage point at the electrical mid-point of the network, thus achieving a minimum overall variation between the no-load and full-load conditions.

Figure 1: Transformer connected to single load

PARALLEL TRANSFORMERS

It is normal practice for power utilities to parallel transformers to obtain a higher security of supply. In Figure 2, which shows an example with two transformers, the load on each transformer (discounting any circulating current) is half of the total load, so the model will produce half the required voltage boost. If the effective terminal voltages of the paralleled transformers are not identical, a circulating current will flow around them. This will be highly reactive since the transformers are highly inductive.

Figure 2: Parallel transformers connected to single load

If two paralleled transformers operate the simple AVC scheme described above, eventually one transformer will be on the highest tap and the other on the lowest tap. The busbar voltage will be an average of their terminal voltages and a high amount of circulating current will flow between them.

This will cause an unnecessary power loss within the transformers and the network, reducing their useful capacity and efficiency, and can result in the loss of one transformer due to overload, and a consequent severe overvoltage.

VOLTAGE CONTROL SCHEMES

The main aims of any voltage control scheme must therefore be to:

• Maintain the correct voltage at the customer, taking into account line voltage drops.
• Minimize reactive circulating current around paralleled transformers, and across networks.

MASTER-FOLLOWER SCHEME

In this scheme, one AVC relay in each paralleled group of transformers is nominated as the master; all other AVC relays in the group are set as followers, or slaves. When the master issues a tap instruction to its tap-changer, the followers all issue identical instructions to their tap-changers. All the transformers are kept in step. While this is the simplest and most traditional method used, it does put constraints on the power system design such that:

• Transformers must be identical.
• Transformers must have the same number of taps and tap steps.
• Transformers must always be on the same tap position.
• Transformers must have the same impedance.
• Transformers must be fed from the same primary source.

TRUE CIRCULATING CURRENT SCHEME

With numerical techniques and relay peer-to-peer communication, the various components that make up the measured current \( I_{CT} \) can be completely isolated, giving improved performance. Figure 3 shows the current seen by two AVC relays \( I_{CT1} \) and \( I_{CT2} \) with respect to their phase voltages \( V_{VT} \) (when the transformer LV circuit breakers are closed the measured voltages will be identical). The load currents, \( I_{\text{load1}} \) and \( I_{\text{load2}} \) have the same power factor. Transformer 1 is on a higher tap position than transformer 2, hence a circulating current will flow represented by \( I_{\text{circ1}} \) and \( I_{\text{circ2}} \) in the diagram. If the measured currents, \( I_{CT1} \) and \( I_{CT2} \) are summed, the network power factor can be found. The true load on each transformer and its contribution to circulating current can be established; therefore, compensation is always correct resulting in the complete elimination of droop in the AVC response.

Figure 3: True Circulating Current Scheme

MODIFIED NEGATIVE-REACTANCE SCHEME (TAPP)

A modification of the circulating current principle is used to allow operation of transformers in any configuration, in parallel at a site, or across a network. A network power factor setting \( p_{\text{sys}} \) is used to calculate the magnitude of circulating current as the vector difference between \( I_{CT1} \) and \( I_{CT2} \) and the transformer target load line at the target power factor.

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Figure 4 shows the situation where Transformer 1 is exporting reactive current, either to an adjacent transformer or into the network. The relay will operate to bring the voltage to the correct level in such a way as to reduce the magnitude of the reactive current. If, as for the previous example, two transformers are in parallel at the same site the circulating current will flow into Transformer 2 which will also act to correct the voltage while at the same time reduce the circulating current to a minimum.

TRANSFORMER SWITCHING

If an operator had to switch out a transformer manually, with minimal voltage change, he would first put that transformer onto the tap position where it will cause minimal effect when switched out. i.e.: transformer current at unity power factor. This way there is little voltage drop across the transformer, so switching it out will cause little change to busbar voltage. Of course, it is necessary to tap the other transformer to keep the voltage at the correct level. During this time, there will be circulating current flowing, but this is acceptable for a limited period until the transformer is switched out. Implementation of this procedure without manual intervention is now possible as described below.

TRANSFORMER SWITCH-OUT

When one transformer of a group is switched out of service a voltage drop will occur as additional load is ‘picked up’ by the remaining transformers, particularly if the transformers are heavily loaded and have a high impedance. The effect can be eliminated if the individual transformer tap changers are operated to offset the voltage drop prior to switch-out, e.g. raising the tap position of the transformer that will remain in and lowering the tap position of the transformer that is to be switched out. On receipt of a signal (switch out command), MicroTAPP relays (allocated to a group) can be configured to communicate and operate each tap changer in such a way that minimal change in voltage will occur when the transformer is switched out. When the optimum tap positions are achieved a completion signal is returned. When the load current is removed from the transformer to be switched out, the remaining relays return to normal tap change control. If the load current is not removed, after a period of time the relays reset to normal operation. The switch-out command can be initiated either by a SCADA signal, from a PC via a communications network or from a hard wired local control switch.

LOCAL & REMOTE SUPERVISORY CONTROL

The MicroTAPP has integral control switches that can be operated locally or from a remote control center.

Local/Remote
A switch is provided to allow for the selection of control to be at the relay or from a remote location, normally a control center.

Auto/Manual
When the local/remote switch is set to ‘Local’ this switch allows the relay to be set changer. Control from a remote site is inhibited.

Raise/Lower
When the auto/manual switch is set to ‘Manual’ this switch allows the tap changer to be operated either to increase the tap position or reduce the tap position.

WAVEFORM QUALITY

With the MicroTAPP it is possible to record various measurements of waveform quality. Simple measurements that can provide indication of how the network is performing can be assessed through the use of 24-hour records of voltage, current, load, power factor, tap position, circulating current, frequency and NPS/PPS voltage. Additionally form factor and crest factor provide an indication of the presence of harmonics in the voltage waveform.
PSEUDO-VTTM
If a network configuration makes it necessary to change the controlled voltage point a voltage and current transformer would be required on the other side of the power transformer together with a complex switching arrangement for the tap-changer control system. The advanced functionality of the MicroTAPP uses algorithms that enable the terminal voltage of the non-measured side of the power transformer to be calculated and effective control to be carried out without a requirement for any additional inputs.

INDEPENDENT SINGLE TRANSFORMERS
At a single transformer site a MicroTAPP relay is arranged as shown in Figure 9. Connections are made to the VT for voltage measurement and to the CT for LDC and control of circulating current when the transformer is operated in parallel with other transformers at remote sites.

PARALLEL OPERATION AT SAME SITE
When transformers are operated in parallel at a site use of the peer-to-peer communication (MPPC) between each voltage control relay enables accurate LDC at all times. Figure 10, shows the general MPPC arrangement for a multiple transformer site. If a MicroTAPP relay is de-energised, communication between relays connected to the twisted pair cable is not affected.

PARALLEL OPERATION IN MULTIPLE GROUPS AT SAME SITE
In more complex sites transformers may operate in groups with the busbar split, making two effective load groupings. Regardless of the transformer grouping the MPPC should always be connected to each relay. Where operational requirements necessitate changes to the busbar configuration and LDC is used, consideration must be given to the MicroTAPP relay settings.

Take an example of four transformers normally operating in two groups, i.e. 2 on each busbar, refer Figure 11. The site can be operated as a single busbar with four transformers in parallel or as a two busbar site with each busbar supplied from two transformers. The actual level of LDC for each of the two busbar groups will be proportional to the load on each of the respective busbars and these levels will be maintained (by virtue of the MPPC) at the correct level even if one transformer is taken out of service in either of the groups.

PARALLEL NETWORKS
The MicroTAPP system uses a modified negative reactance design for the detection of circulating current. When selected for TAPP operation (modified negative reactance circulating current mode), the relay operates to minimise circulating current between transformers at the same site and also when transformers are operated in parallel across networks. For optimum performance the normal network power factor must be entered as a setting on relay.

Consider the network of Figure 12. Transformers 1 and 2 are at the same site and so have strong coupling; transformer 3 is some distance away and so the coupling will be weaker. Any mismatch in transformer open-circuit terminal voltages between transformers 1 and 2 will result in a high circulating current, while a difference between transformers 1 and 3 will result in a much lower circulating current because of the network impedance.

The true circulating current method fully eliminates circulating currents between transformers 1 and 2 and allows them to provide correct LDC under any power factor. A weaker compensation is also applied by measuring the difference between the transformer current and the power factor set point, Ires. Although the system power factor might fluctuate, the set point applied should be the average power factor. This prevents transformers 1 and 2 drifting from transformer 3, any tapping action will naturally keep them together. If there is circulating current flowing between the two sites it will be small so the LDC should not exhibit droop.

For further information please contact Relay Monitoring Systems.
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