MR KNOWLEDGE BASE

FURNACE APPLICATIONS IN THE UPPER PERFORMANCE SEGMENT

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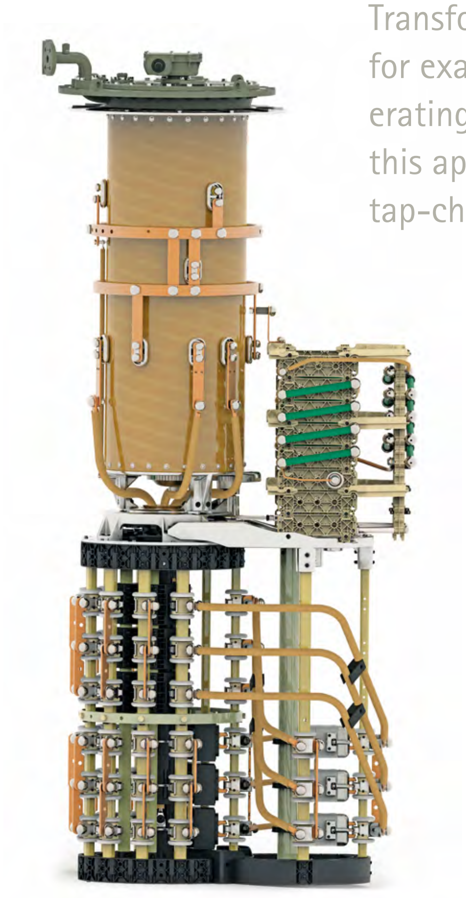
VACUTAP® VRL® – THE NEW DIMENSION FOR FURNACE APPLICATIONS.



Transformers and tap changers for process operation as seen, for example, in steel mills, are subjected to challenging operating conditions. In addition to special ambient conditions, this application is usually characterized by high numbers of tap-change operations in short time intervals.

The tap changers of the MR VACUTAP® series enable optimal furnace operation. The use of vacuum technology and the large maintenance intervals associated with it minimize downtime and maintenance work. This can optimize the operating costs compared to conventional oil-technology tap changers.

Vacuum-technology on-load tap-changers available to date were optimally suited for furnace applications with an electrical service life of 600,000 tap-change operations, but limited to a maximum load current of 1,300 A.
Along with the performance increase of the VACUTAP® VRL®, the maximum possible load current for furnace applications also increases.

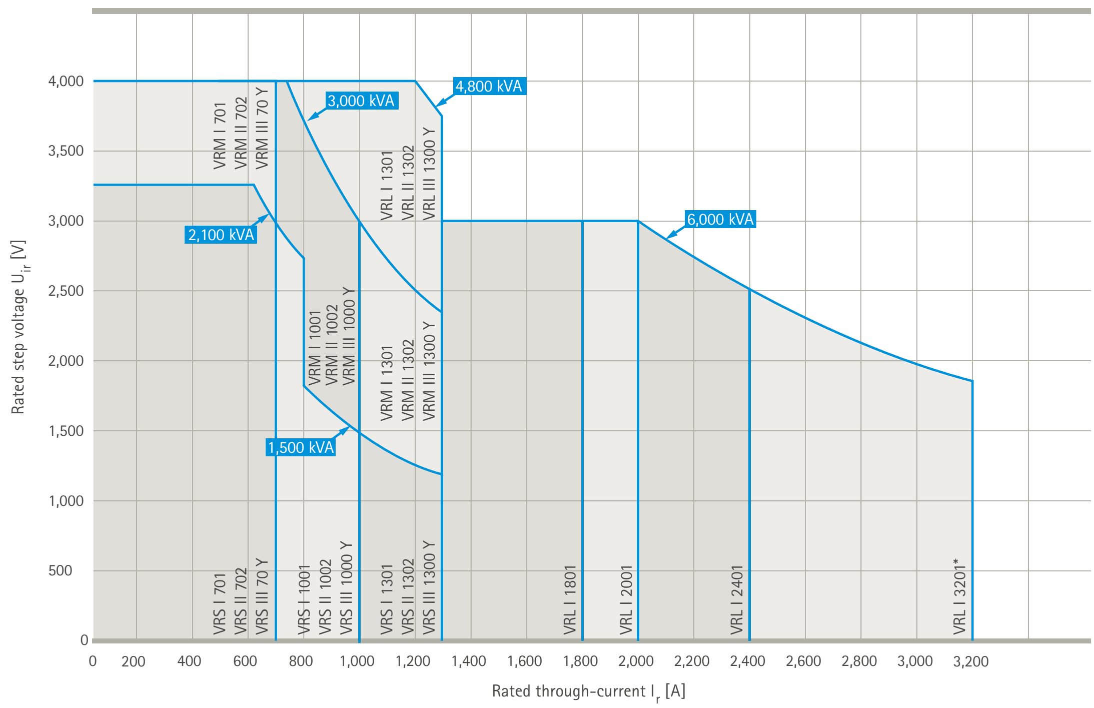


Figure 1: VR step capacity diagram
*On-load tap-changer types marked with an * are special applications and available only upon request.*

CHALLENGES IN REAL PROCESS OPERATION.

The significant increase in the permitted load current of MR vacuum tap changers is, however, accompanied by new aspects to be taken into account: The higher the switched current in the vacuum interrupter, the stronger the erosion of the contacts in the vacuum interrupter.

During the performance increase tests of the VACUTAP® VRL®, investigations at MR revealed that, as the load current increases, the electrical service life of the on-load tap-changer comes to the fore while mechanical aspects more likely fade into the background.

In the performance range with rated currents from 1,800 to 3,200 A, the load on the vacuum tubes is disproportionately high and thus results in limitations of the electrical service life.

By analyzing real operating data for transformers in process operation, it becomes apparent that the transformer, and consequently also the tap changer, usually operate in partial-load operation and that there are also operating situations in which there are tap-change operations for the tap changer without load or circulating current, known as load-free switching.

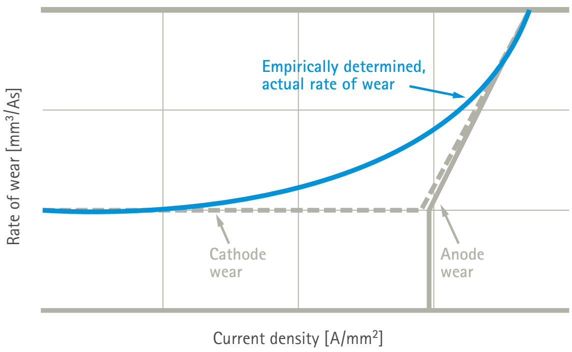


Figure 2: Contact wear as a function of the current density for CuCr contacts (diagram based on Slade "The Vacuum Interrupter: Theory, Design, and Application" 2008)

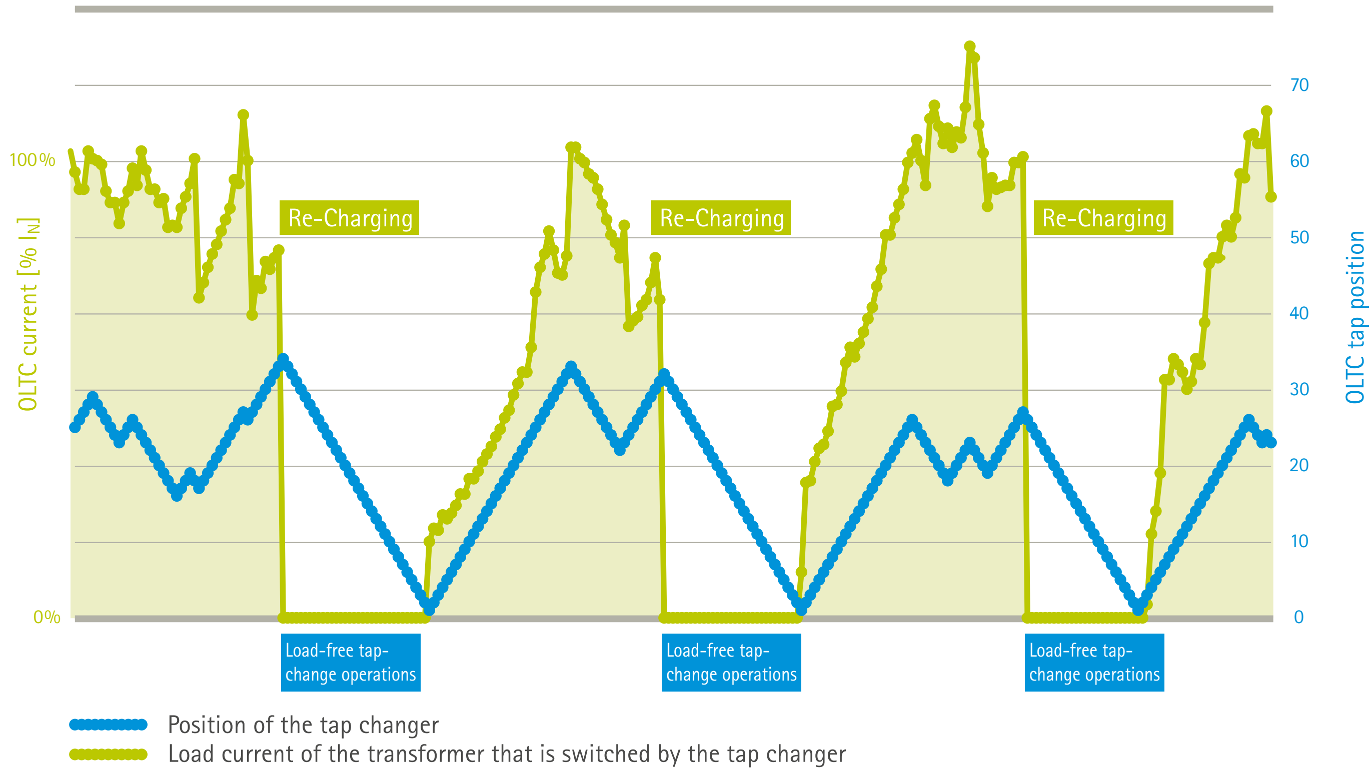


Figure 3: Example diagram of load profile and OLTC tap position in real process operation

In the performance range available to date with a rated current up to 1,300 A, it was not necessary to take into account the above-mentioned operating conditions (load-free switching and partial load) in regard to the electrical service life. To enable economically optimum usage of tap changers in the performance range above 1,300 A, however, taking load-free and partial-load switching into account is strongly advised. Partial load here refers to operation that uses < 100% of the nominal current. The difference between full and partial load is so relevant because, as shown above, erosion of the contacts in the vacuum interrupter – and thus the electrical service life in the performance range under consideration – depend significantly on the current actually switched.

The evaluation of large amounts of operating data from process operation shows a very broad range of possible load profiles. Select load profiles are shown in Figure 4. The number of load-free and partial-load tap-change operations varies greatly and depends individually on the philosophy of the operator and/or the requirements of the process. An added complication here is that, while the transformer and tap changer are being designed, the future load profile is unknown or the OEM is not provided with this information by the future operator.

INDIVIDUAL LOAD PROFILES AND THEIR EFFECTS ON SERVICE LIFE AND MAINTENANCE.

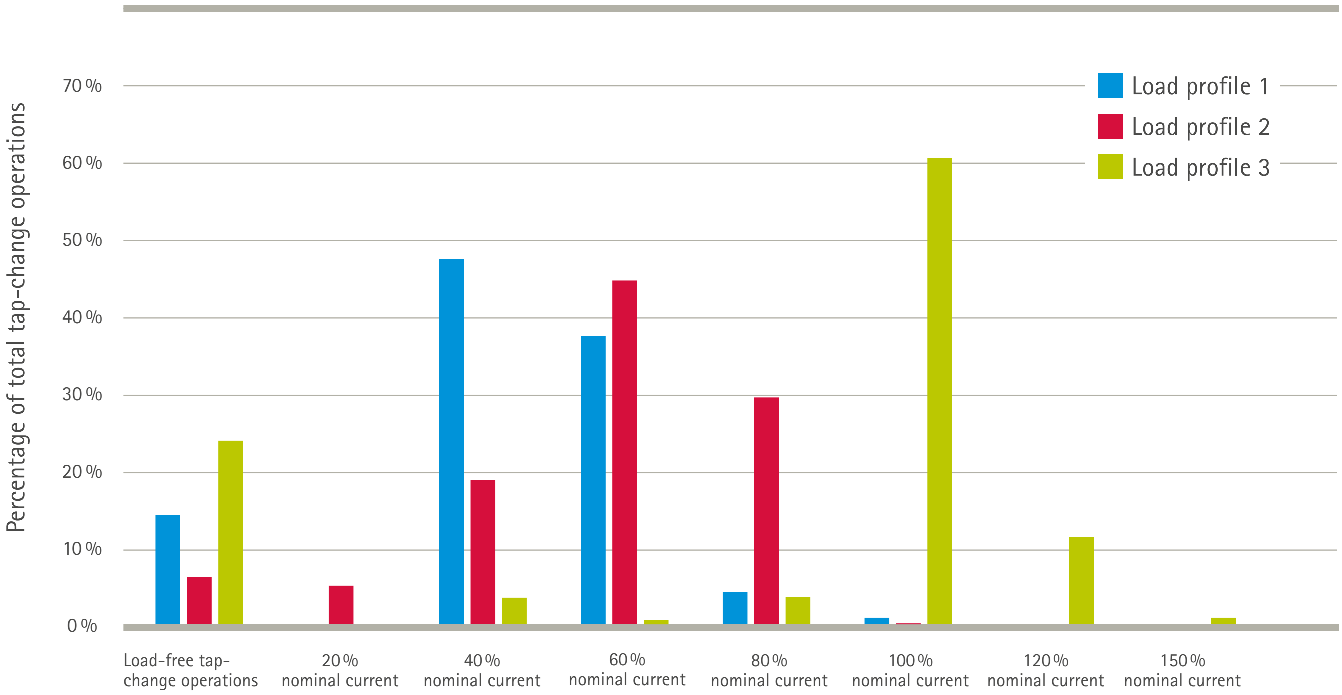


Figure 4: Real load profiles of tap changers in process operation

In **Load profile 1**, you can see that approx. 85% of the tap-change operations occur at 40–60% of the nominal current and no tap-change operations occur above the nominal current.

By contrast, **Load profile 2** shows a shift in the numbers of tap-change operations at higher nominal currents: 75% of the tap-change operations occur in the range of 60–80% of the nominal current.

In relation to the load for the vacuum interrupter, **Load profile 3** certainly represents the most challenging scenario: The vast majority of tap-change operations occur in the range > 100% of the nominal current.

In all 3 scenarios, the share of load-free tap-change operations is at 5–25%.

If the electrical load for the tap changer is not recorded and evaluated, then to ensure safe operation over the service life it is necessary to assume that worst-case conditions are present.

This can result in the need to plan and carry out maintenance measures unnecessarily early, which leads to unnecessarily high OPEX.
The identification of various, typical load profiles and the definition of the corresponding boundary conditions for operation of the on-load tap-changer (maintenance intervals, service life, etc.) is an approach to give operators the option of assessing their own operating situation and using the components correctly. This approach requires exact knowledge of the current process operation. If changes are made during operation (e.g. because the process control is changed or optimized), then previously defined boundary conditions and maintenance intervals are obsolete and a new evaluation is necessary.

MONITORING OF PROCESS OPERATION – THE SAFE AND EFFICIENT SOLUTION.

A far more exact and more convenient solution involves metrological monitoring of the actual operating states and evaluation of the load and the loss-of-life of the tap changer based on the current operating conditions.

Data such as load current, step voltage, switching direction of the tap changer, insulating fluid temperatures and other parameters can be different for nearly every tap-change operation. For this purpose, it is expedient to record these parameters metrologically.

The characteristic data of the tap changer in general and in the special application are also incorporated into the evaluation. Thus, for example, the selection of the transition resistance, the wiring of the vacuum tubes and their contact material and tube geometry are also to be taken into account in the service-life calculation. There is also particular emphasis on the special adjustment and exact measurement of each individual device, which are transferred as input parameters to the monitoring system during initialization and during each OLTC replacement.

Based on the measured data as well as the characteristic parameters of the tap changer, each switching operation is evaluated individually in real time and the resulting loss-of-life is calculated. Then a learning algorithm provides a forecast of when, from the current perspective, the electrical service life end or maintenance interval will be reached. This forecast of the maintenance interval provides the operator with the flexibility to integrate the maintenance of the tap changer optimally into the maintenance schedule of the overall system and thus to achieve economically optimal operation.

A patent-pending monitoring system with this kind of design is capable, with adequate advance timing, of giving specific indications about required maintenance measures and the remaining electrical service life of the tap changer. For load profiles 1 and 2 shown in Figure 4, the electrical service life would increase by up to 100% due to the monitoring system. Even a transformer with the exceedingly demanding load profile 3 (high percentage of tap-change operations at nominal load and overload) could be operated up to 50% longer by using a corresponding monitoring system.

When such a system is used, the tap changer's maximum possible electrical service life and longest possible maintenance interval can be utilized.

By means of precise maintenance, the monitoring system for tap changers in process operation offers operators a sustainable and economic solution over the entire service life.

THE FOLLOWING SHOWS A SIMPLIFIED REPRESENTATION OF THE MONITORING PARAMETERS AND FUNCTIONS OF THE MONITORING SYSTEM:

PARAMETERIZATION

- Transition resistance
- Contact material of the vacuum interrupter
- Geometry and functional limits of the vacuum interrupter
- Step voltage
- Measurement and adjustment results of the respective individual device

MEASUREMENT

- Recording the load current
- Recording temperatures
- Recording the switching direction
- Recording the switching frequency
- Recording the state of excitation of the transformer

CALCULATION

- Evaluation of the individual tap-change operation taking into account the parameters and measured values above
- Application of the executed tap-change operation to the electrical service life
- Application of the tap-change operation to the mechanical maintenance interval
- Self-teaching algorithm to forecast the time when the electrical service life or maintenance interval will be reached

MAINTENANCE AND SERVICE LIFE

- Maintenance intervals and electrical service life are anticipated, individually calculated and forecast based on the operating behavior
- Maintenance can always be carried out at the maximally economic time
- With knowledge about the actual load on the tap changer, maintenance tasks that are not technically required can be avoided, which results in savings on materials, packaging, and costs for transport and work

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THE POWER BEHIND POWER.