HIGH VOLT

AC Resonant Test Systems
Types WR and WRM

1.20/3

Applications, Advantages

Resonant Test Systems, types WR and WRM are applied for the generation of a continuously variable alternating (AC) voltage of a fixed frequency (mainly 50 or 60 Hz) for high-voltage (HV) routine, type and development testing of capacitive test objects. They can also be applied for HV on-site tests, but HIGHVOLT offers for that application the more economic solution of frequency-tuned resonant test systems (see Catalog Sheets 8.02, 8.03 and 8.04).

Capacitive test objects are cables, capacitors, gas-insulated switchgear (GIS), but also large rotating machines, instrument and power transformers (for applied voltage tests). Resonant test systems enable not only HVAC tests at 50/60 Hz, but also at higher frequency (e. g. at > 100 Hz for instrument transformers) and dynamic tests with fast voltage changes (e. g. for capacitors). Because of their precise sine-wave, resonant test systems are very well suited for the combination of HVAC withstand tests with partial discharge (PD) measurement. HIGHVOLT adapts the resonant test systems to the requirements of the relevant standards and the customers' demand.

The main advantage of resonant test systems is the low power demand, because only the losses in the test circuit must be replaced by the power supply. The quality factor Q which is the relation between the test power S and the loss power P ranges between Q = 10 and values up to 100, this means only 10 to 1 % of the test power must be supplied. A resonant test system is remarkably lighter, cheaper and more economic than an AC transformer test system and should be applied if the test objects are capacitive. In case of a disruptive discharge the test object is not destroyed, because the system goes out of resonance. HIGHVOLT resonant test systems are characterized by a very modern system configuration and have proven highest reliability.

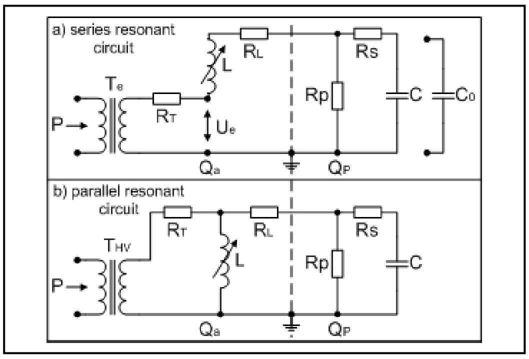

Fig. 1: Principle circuit diagrams (T_e-exciter transformer; R_T and R_L-loss resistors; L-variable inductance; T_{HV}-HV transformer; C-test object; R_P and R_S-loss resistors; C_O-basic load)

Fundamentals

The connection of an HV reactor (inductance L) to a capacitive test object (C) forms an oscillating circuit with the natural frequency

$$f = 1/2\pi \sqrt{LC}.$$

By a variable inductance this frequency can be tuned to that of the power supply (e. g. 50 Hz) which means resonance (Fig. 1). The capacitive test power S exceeds the feeding power P according to the quality factor Q. The quality factor Q of the whole circuit is the combination of that of the test system Q_A and that of the test object Q_P by

$$Q = Q_A \cdot Q_P / (Q_A + Q_P) \qquad (1)$$

For the more important **series resonant circuits** (Fig. 1a) resonance is connected with the increase of the voltage from the exciting voltage U_e to the test voltage U

$$U = Q \cdot U_e. \qquad (2)$$

Parallel resonant circuits can be understood as HV current compensation by a variable inductance in parallel to a HV test transformer (Fig. 1b). In that case the voltage is determined by the ratio of the HV transformer. Parallel resonance is only applied if capacitances or losses of the test object are not stable (e. g. at rotating machines) or if the tests include dynamic processes.

The inductance of the HV reactor can be varied only in a certain range (e. g. L_{max} = 20 L_{min}), for **series resonance circuits** the load capacitance can be varied in a corresponding limited load range (C_{max} = 20 C_{min}). The system must be equipped with a basic load capacitor $C_O \geq C_{min}$ which enables no-load operation, but reduces the test object capacitance to ($C_{max} - C_O$). Fig. 2 shows the load-voltage characteristic for a system with two taps at the reactor, each corresponding to a certain inductance and voltage. In the double logarithmic load-voltage characteristic (Fig. 2) both, powers S and currents I, are given by straight lines. When the system is e. g. be designed according to the constant current of I_1, the hatched area cannot be used because of too high current I_2. A clear definition of the necessary load-voltage requirement including duty cycle is the basis for an economic selection of a resonant circuit.

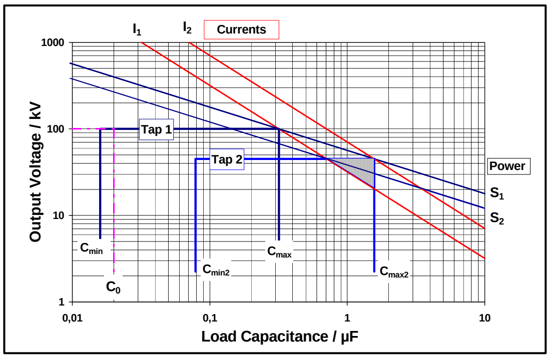

Fig. 2: Load-voltage characteristic of a series resonant system with a reactor of two taps

The HV reactor of variable inductance (Fig. 3: no. 5; Fig. 4 and 5) is completed by numerous components to a comfortable resonant test system (Fig. 3). The system is supplied with the feeding power P from the power network via a switching cubicle (Fig. 3: no. 1), a voltage regulator (no. 2, for lower and medium power a regulator transformer (Data Sheet 1.26), for high power a Thoma regulator (Data Sheet 1.27)) and an exciter transformer (no. 4). The exciter transformer is equipped with several taps for an optimum adaptation of the output voltage of the regulating transformer to the characteristic of the test object and the requested test voltage level. In case of tank-type reactors (Fig. 4) the exciter transformer (Data Sheet 1.29) is built into the tank of the HV reactor. Different taps can be switched by a tap-changer (optionally motor-driven). In case of modular reactors (Fig. 5) the exciter transformer is a separate unit (Data Sheet 1.28). For the reduction of high-frequency noise signals which may disturb sensitive PD measurement a low-voltage filter (no. 3) can be attached to the tank of the HV tank-type reactor or to the enclosure of a Faraday cage.

The **HV reactor** (no. 5) varies its inductance by a gap of adjustable distance of the magnetic core arranged inside the winding. The moveable part of the core is driven by a frequency-controlled motor via a suitable gear.

The test object (no. 9) is connected via a HV filter (no. 6, 7, 8). The filter consisting of a blocking impedance no. 7 (Data Sheet 1.35) and HV capacitors (no. 6 and no. 8) has several functions: It reduces the conductor-connected HF noise for PD measurement, protects the HV reactor in case of a breakdown, the two capacitors (no. 6 and 8) act as a basic load which guarantees resonance if no test object is connected, capacitor no. 6 is a divider for voltage measurement (Data Sheet 5.20) and capacitor (no. 8) (Data Sheet 1.31) is the coupling capacitor for PD measurement. If the test object is a cable, it should be connected via a suitable cable end termination (see Data Sheet 7.90 respectively 7.71). For very precise voltage or tan delta measurement a compressed-gas standard capacitor (no. 10, see Data Sheet 5.31) can be added.

For control and measurement three HIGHVOLT control and measuring systems are available (see Data Sheet 1.52; types BC 5 R, CMS 22 R and CMS 23 R).

The **basic control, type BC 5 R** is based on one universal operator device, type BG5 (no. 11, Data Sheet 1.54), with a SIMATIC software package for controlling the programmable logic controllers (PLC, type SIMATIC) via an optic PROFIBUS connection (no. 18). The PLC's are mainly arranged in the switching cubicle (no. 1) as well as the peak voltmeter (no. 13, see Data Sheet 5.56). The BC 5 R control enables manual and simple-automatic operation of the test system including automatic tuning to resonance (also during a test), preselection of voltage cycles, automatic switch-off in case of breakdown, digital measurement of actual test voltage and test system parameters. Partial discharge (PD) (no. 14) and tan delta (no. 15) measurements are separated from the control.

The **computer control, type CMS 22 R** uses an industrial personal computer (IPC; no. 12) instead of the operator device. It is connected to the PLC's via ETHERNET. The software package WGMS 22 R (see Data Sheet 1.55) enables both, manual and automatic testing including PD and tan delta recording, evaluation and presentation. In that case the operator device (no. 11) is reduced to the very simple plug-in type BG6 to control power on/off and emergency-off.

The **advanced computer control, type CMS 23 R**, is the combination of BC 5 R and CMS 22 R controls. The operator device, type BG 5 (no. 11), is considered as the redundancy to the IPC (no. 12). This computer control enables the printing of test records and can be connected via the remote diagnostics and access module (no. 16, see Data Sheet 1.56) to the local area network (LAN) of the user as well as via INTERNET to the HIGHVOLT Service Center for technical support, software updates and trouble shooting.

The control and measuring system can be delivered in a rack or a desk (see Data Sheet 7.31).

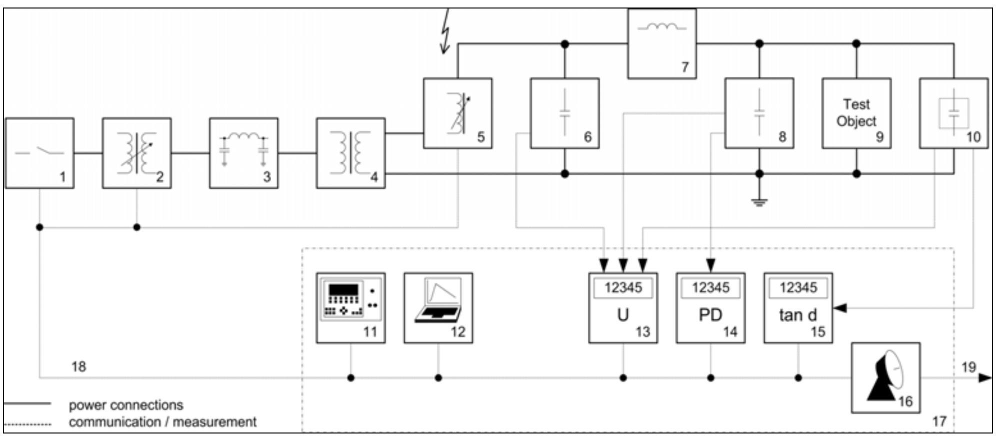

Fig. 3: Principle circuit diagram of resonant test systems, types WR/WRM, with computer control and measuring system, type CMS 23 R

Systems Type WR with Metal Tank Reactors

Test systems with tunable metal tank reactors are available for rated voltages between 50 and 350 kV with test power between 300 and 10000 kVA. A typical duty cycle for metal tank reactors is 1 h ON / 1 h OFF eight times per day. They are mainly applied in series resonant circuits for testing medium and high-voltage cables (see Data Sheet 1.23). For testing capacitors and rotating machines special reactors, provided for series and parallel resonant circuits, are supplied (see Data Sheet 1.24). In combination with shielded test rooms ("Faraday cages") for sensitive PD measurement, the metal tank enables the cost-saving arrangement of the reactor outside the test room with only the bushing inside.

The tank type reactors (Fig. 4) are equipped with a so called "plunger" core with one moving limb in its centre surrounded by four return limbs with the related yokes. The moving limb can be positioned by a motor drive and a special spindle arranged on the core itself. This design of high mechanical stability guarantees both, a stable gap (that means a stable inductance and consequently a stable voltage) and low acoustic noise. The exciter transformer is incorporated in the tank.

For an increase of the test capacity a second HV reactor can be operated in parallel. Both reactors are synchronized with one control system (virtual electric shaft) in this case.

Fig. 4: Tunable metal tank reactor

Systems Type WRM with Modular Reactors

Tunable reactor modules for series resonant circuits are available between 250 and 400 kV and test power between 1000 and 14000 kVA per unit. Typical duty cycles are 1 h ON / 1 h OFF six times per day or 1 h ON / 2 h OFF three times per day for larger types. The smaller types (1000 and 1600 kVA per module) are mainly applied for testing of GIS, power and instrument transformers (see Data Sheet 1.21). The larger types (up to 14000 kVA per module, see Data Sheet 1.22) are designed for testing EHV cables. Additional cooling equipment may increase the duty cycles.
The modular type reactors are designed with two HV coils on a horizontally arranged magnetic core consisting of two parts with exactly adjustable gaps in between (Fig. 5). One of the U-shaped core parts can be moved by a gear and an external drive via insulating rods. The core as well as the outer steel tube is connected to the middle potential between the two HV coils. The external electrodes of the modules and reactor cascades are adapted to the requirements of their own air insulation as well as to those of their environment.
In order to increase the rated voltage and/or the available testing power, the reactor modules can be cascaded by installation on top of each other. In case of limited room height, a further option is the collocated installation with a combined control by pure electrical control (virtual electric shaft).
A special mechanical design of the modules for mobile on-site test systems is also available.

Fig. 5: Cascade of three tunable reactor modules

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