HIGH VOLT

AC Resonant Test Systems for On-Site Testing of GIS and HV Components

8.04/2

Situation and Application

Whereas HV type and routine tests in factory test fields shall confirm the reliable design and the correct manufacturing of the HV insulation, **HV on-site tests**, which may include partial discharge (PD) measurement, are applied as a part of the commissioning of the equipment, after an on-site repair or for diagnostic purposes.

The general principle of the HV test technique that the applied test voltage shall simulate an operational stress must be applied on site also. This means the preferred on-site test voltage shape is an AC voltage. But the AC on-site test system should be as lightweight, compact and robust as possible. Also its feeding power demand must be kept to a minimum.

HIGHVOLT AC Resonant Test Systems of variable frequentcy, type WRV ...G and WRV ...M fulfil all these requirements in the best possible way. They are used for on-site testing of

- gas-insulated substations (GIS) and gas-insulated transmission lines (GIL)
- instrument transformers and power transformers
- short cables (for long cables see HIGHVOLT Leaflets No. 8.02 and 8.03) and
- circuit breakers and disconnectors

of HV, EHV and UHV classes (for medium-voltage test equipment see HIGHVOLT Leaflet No. 8.03).

The main application is GIS on-site testing, and the relevant IEC Publication 60517 accepts a wide range of frequencies between 10 and 300 Hz. The testing with frequentcies > 80 Hz enables tests including the voltage transformers and avoids further assembling works at the GIS on site.

HIGHVOLT supplies on-site test systems, type WRV ... G with completely metal-enclosed, SF_6-insulated HV reactors up to 740 kV. They can be directly flanged to the GIS under test for a completely shielded HV test circuit of high PD sensitivity, lowest space demand and without additional safety requirement (See the photograph on the front page, by courtesy of Siemens.).

The systems, type WRV ... M, with modular reactors (see Fig. 2) are prepared for multi-purpose applications in a voltage range from 50 kV to 800 kV. Their inductance can be well adapted to the test object capacitance by the series and parallel connection of the reactor modules.

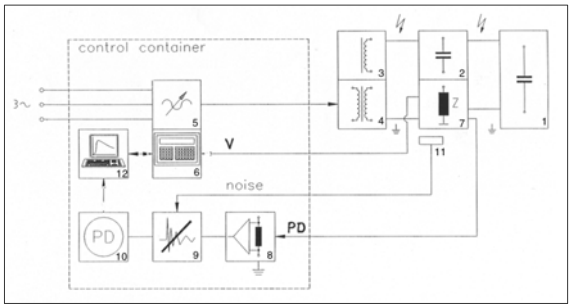

Fig. 1: WRV test circuit with PD measuring system (explanation of the numbers in the text)

Fundamentals

A capacitive test object (Fig. 1, no. 1, capacitance C) and a HV reactor of fixed inductance L (no. 3) form a HV oscillating circuit of the natural frequency

$$f = 1 / (2 \pi \sqrt{CL}).$$

By exciting this HV circuit with an AC voltage of its natural frequency, which is supplied by a frequency converter (no. 5) via the exciter transformer (no. 4), the system is tuned into resonance and delivers a high test voltage V_T and a high reactive test power P_T. The relation between these parameters and the exciter voltage V_E respectively the feeding power P_F is characterised by the quality factor

$$Q = P_T / P_F \approx V_T / V_F.$$

This quality factor is about twice the quality factor of resonant test systems with tuneable inductance and fixed frequency. This means for identical test conditions the power demand of a frequency-tuned resonant test system is about half of that of an inductance-tuned one.

The maximum capacitive load causes the lowest test frequency and the maximum test current

$$I_T = 2 \pi f_{min} \cdot C_{max} \cdot V_T.$$

The selection of the frequency range (f_{min}, f_{max}) determines the obtainable load range (C_{min}, C_{max}) according to

$$C_{min} / C_{max} = (f_{min} / f_{max})^2.$$

For WRV test systems described in this leaflet f_{min} = 50 Hz and f_{max} = 250 ... 300 Hz is selected, which gives a wide load range of C_{max}, / C_{min} = 25 ... 36. Usually the capacitance of the voltage divider / coupling capacitor (Fig. 1, no. 2, 7) can be selected in such a way that the system operates without test object at f_{max} = 250 ... 300 Hz. The relation between load and frequency is given in the load characteristics (Fig. 3, 5, see below).

- AC on-site testing by resonant test systems of variable frequency, type WRV, simulates operational stress conditions.
- The weight, the size and the power demand of test systems type WRV are minimum.
- Systems with modular reactors, type WRV ... M, are designed for multi-purpose application and can be easily adapted to different test voltages, test powers and test object capacitances.
- Systems with SF_6-insulated reactors, type WRV ... G, are designed for direct connection to GIS under test, provide low-noise conditions for sensitive PD measurement and can be modified for multi-purpose application by a SF_6-to-air bushing.
- Systems of type WRV can be delivered including PD measuring systems modified for on-site application, control and transportation containers and all other necessary accessories.
- HIGHVOLT on-site test equipment type WRV ... M and WRV ... G has proven its reliability at a multitude of customers all over the world.

Principle Design

Systems Type WRV…M with Modular Reactors

The heart of the system is a frequency converter (Fig. 1, no. 5) used to convert the three-phase mains voltage into a pulse-width adjusted square-wave voltage. The three phases of the line voltage are rectified by a six-pulse rectifier and feed a capacitor bank, which is followed by an inverter bridge.

The square-wave output voltage is generated by operating the inverter bridge at the desired output frequency. The rms value of the output voltage is infinitely adjusted by pulse-width control. A micro-controller generates the necessary control signals for the frequency and the pulse width. It tunes the system automatically into resonance. While the micro-controller takes charge of direct control and monitoring of the inverter, the whole test procedure is controlled by a PLC via an operator panel (Fig. 1, no. 6) which can be linked to an external computer (PC, Fig. 1, no. 12) for data recording, automatic test procedures and test record printing (Leaflet 1.51).

Frequency converter and control are arranged in one desk (control and feeding unit, type RSE 70 (Leaflet 8.31), see photograph on the front page) one cubicle (RSE 150, Leaflet 8.32).

The second component is the exciter transformer (Fig. 1, no. 4) which adapts the output of the power and feeding unit (no. 5, 6) to the HV circuit (no. 3). The voltage measurement is realised by a voltage divider (no. 2), which can be a separate component (for systems of the type WRV ... M) or integrated into the adapter element between SF_6-insulated reactors and GIS under test (for systems of the type WRV ... G).

The system can be equipped with a PD measuring system (no. 10), coupled to the measuring impedance (no. 7) via some special components for noise reduction (no. 8, 9, 11). The inverter causes very short switching impulses which do not disturb the PD pattern or can be suppressed (of some 10 µs). Sensitive PD measurement, also according to the UHF method, can be performed.

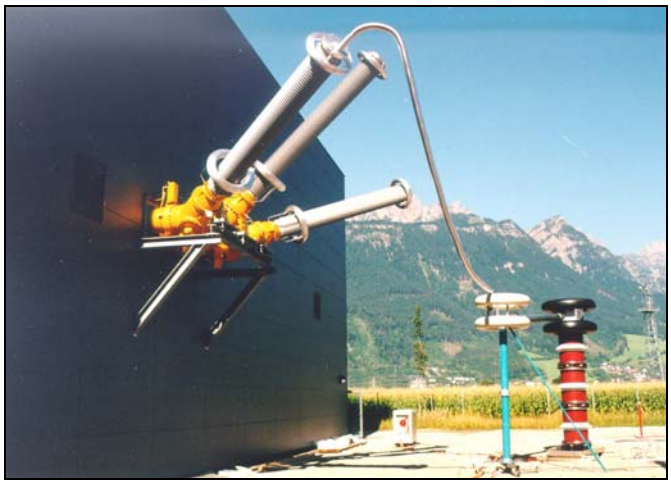

Fig. 2: Modular reactors of a system WRV 3/680 M during a GIS test.

Modular reactors of different design are available: The type from DEM ranges 80 kV/2A up to 230 kV/4.2 A (20 min) (Leaflet 8.11). There is the more powerful type DEI for up to 3 h per day, available from 160 kV/10 A to 400 kV/7,5 A (Leaflet 8.15).

The series and parallel connections of reactors, type DEM delivers e. g. the set of load curves given in Fig. 3, which enable the testing within a limited frequency range. When for instance 123 kV GIS including voltage transformers shall be tested and the basic load (divider) is C_{min} = 1 nF, all curves are applicable and the frequency range 100 to 200 Hz is covered for test objects with C_T = 0 ... 35 nF. But for testing 400 kV apparatus only the curve (3 s) is applicable which means, for f = 50 ... 200 Hz a GIS up to 16 nF can be tested. Also type DEI reactors can be connected in series or in parallel.

The system with external air insulation consists of

- the control and feeding unit, type RSE 70 (see front cover and Leaflet 8.31.) or RSE 150 (Leaflet 8.32).
- the dry-type exciter transformer with taps for typical output voltages of 5 ... 15 kV (leaflet 8.21).
- the HV reactor consisting of modules of type DSH, (Fig. 2, Leaflet 8.11) or of type DEI (Leaflet 8.15).
- the voltage divider can be used as the capacitive basic load (see Fig. 2).

As an additional option the system can be completed by a PD measuring system.

The larger systems based on DEI reactors can be supplied on a trailer (Fig. 5) or within a standard container for transportation to the site (see leaflets 8.61/8.62).

The type designation of an AC Resonant Test System with variable frequency with modular reactors is given by

WRV a / b M: a - rated current; b - rated voltage

Example: WRV 3/ 50 M, means a system for 450 kV rated voltage and a current of 3 A consisting of two modules. In the case of parallel connection of both modules it can be used for 230 kV / 6 A.

For inquiries of systems type WRV ... M, please, use the HIGHVOLT Questionnaire 8.101/1.

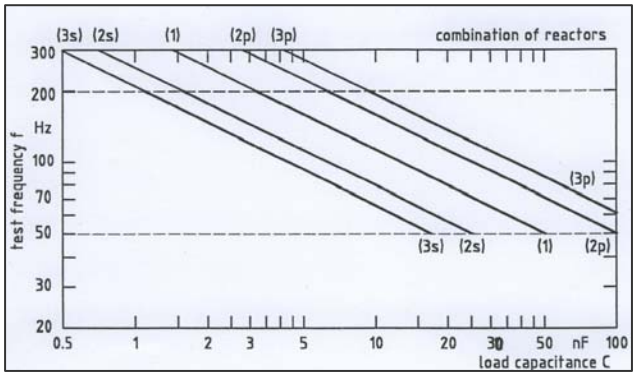

Fig.3: Frequency –load characteristics for the combinations of three modular reactors /t ype DEM

Systems Typ WRV…G
With SF_6-insulated reactors

The system is characterised by metal-enclosed, SF_6-insulated HV components. It consists of

- the control and feeding unit RSE 70 (see above, Leaflet 8.31),
- the oil-insulated exciter transformer with taps for output voltages of 10 ... 20 kV (Leaflet 8.24),
- the SF_6-insulated reactor (photograph on the front cover), by courtesy of Siemens) (Leaflet 8.13),
- a voltage sensor in an adapter element between reactor and GIS, alternatively
- a metal-enclosed, SF_6-insulated coupling capacitor for PD measurement (IEC 60270) and voltage measurement, including a blocking impedance, a calibration unit and a T-adapter for the connection to the reactor and to the GIS.

The reactors of type DEG have a core-less coil with a SF_6-impregnated foil insulation and integrated temperature sensor for over-temperature release. The HV termination is connected to a coaxial system, closed by a disc-type spacer and provided for direct connection to a single-phase SF_6 busbar. Adapters enable the connection to different types of GIS. The rated voltages of type DEG reactors are between 400 and 740 kV, the available current for 15 min is typically 1.5 A. Higher voltages can be reached by series connection, higher currents or longer duty cycles by parallel connection of reactors. Fig. 5 shows a load-frequency characteristic. For more details see the Leaflet no. 8.13.

The SF_6-Insulated reactors are characterised by minimum weight and space. Compared with SF_6-insulated test transformers of identical rated voltage, they deliver a several times higher current for a longer duty cycle. Furthermore their specific weight (kg/kVA) is about ten times lower.

DEG-reactors directly flanged to a GIS enable test conditions on site comparable with well shielded HV laboratories. Therefore systems of type WRV ... G are an optimum voltage source for PD measurement in the field.

The DEG-reactors can also be equipped with SF_6-to-air bushings and used for on-site testing of air-insulated components. An on-site test of a 400 kV outdoor voltage transformer is shown in Fig. 4.

The type designation of an AC Resonant Test System with a SF_6-insulated reactor is given by

WRV a / b G: a - rated current; b - rated voltage
Example: WRV 1.5 / 680 G means a system for 680 kV / 1.5 A.

For inquiries of systems type WRV ... M and G, use the HIGHVOLT Questionnaire 8.101, please.

You find relevant information about components for AC resonant Test Systems, type WRV, in the following HIGHVOLT Leaflets: No. 8.11 to 8.14, no. 8.15 to 8.18, no. 5.56, no. 1.51, LDIC Leaflets

Fig. 4: SF_6-insulated reactor with bushing to air

Fig. 5: Trailer with a modular test system: type WRV 3.8/600 M based on DEI reactors.

For further information please contact:

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