High Voltage Testing using Series Resonance with Variable Frequency

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1. Abstract

For AC high voltage testing different kinds of equipment are known and available /1/. This paper describes the AC testing using the series resonance principle. The tuning of the resonant circuit with its changing test capacitances however is not achieved by varying the inductance /2/, but varying the frequency /3/. The described high voltage sources are available in a voltage range up to 800 kV, a current range up to 200 A and a frequency range from 30 Hz to 200 Hz.

The advantage of variable frequency test systems compared to other AC test systems, such as transformers and resonant test systems with variable inductance, is their optimum testing power / weight ratio. This ratio results in reduced weight, dimensions, cost and price. Therefore this kind of AC test equipment is especially suited for on site testing of capacitive test objects like gas insulated busbars, cables and GIS substations.

2. Function principle

The basic function principle as described in /2/ is shown in Fig. 1.
In case of on site testing, for example after laying tests of high voltage cables, a power supply of some 100 kVA is required. Usually a power supply in this power range is not available at a substation. Therefore the test equipment has to be designed to be fed by a Diesel-generator set. A pulse width modulated frequency converter is used to adjust frequency and output voltage of the test system. Special care has to be taken to assure the stability of the output frequency and voltage. The output signal of the frequency converter (FU) is shown in Fig. 2.

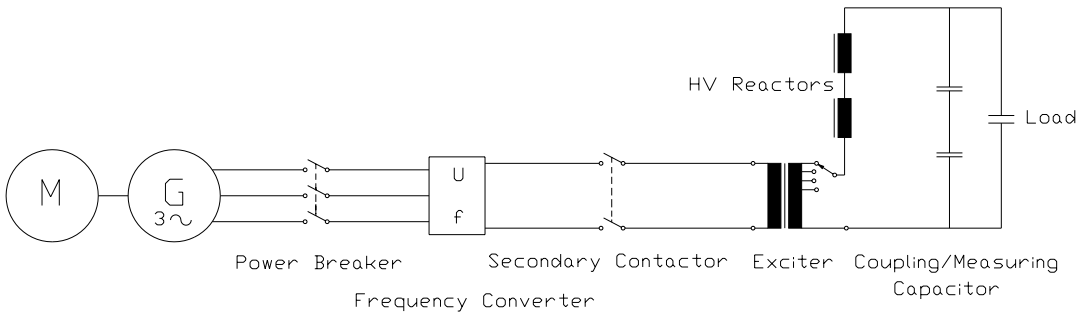


Fig.

1: The main components of a series resonant test system with variable frequency are a Diesel generator for power supply independent on mains supply if necessary (e.g. for on site use). The frequency converter for frequency and voltage adjustment, the filter set-up to enable PD measurement at PD levels down to less than 10 pC (not shown in the diagram), the exciter transformer for the excitation of the resonance circuit and the high voltage reactor for the high voltage generation.

Fig. 2:

Typical output voltage of the frequency converter. The strongly non sinusoidal wave shape of the pulse width modulated frequency converter can be used for the excitation of the resonant circuit. However special care has to be taken to achieve PD levels in the range of less than 10 pC.

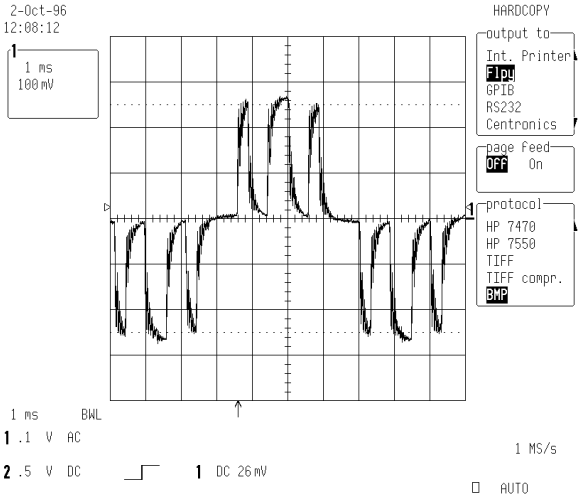
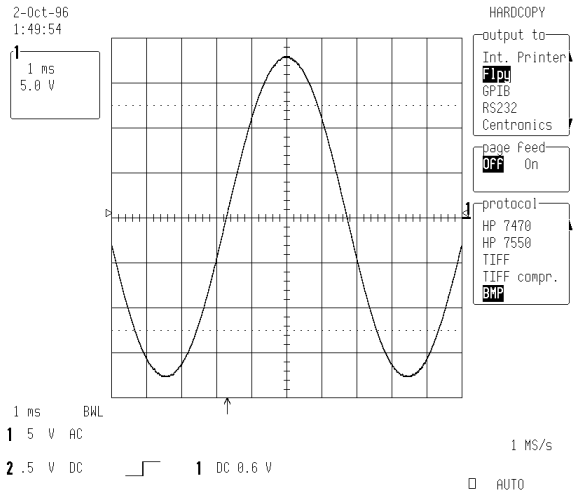


Fig. 3:

Output voltage signal of the resonant test system. This is again a sine wave voltage with an amount of harmonics much less than 1 % (acc. to IEC 60 less than 5 % is required). This phenomenon results from using the series resonance principle. However (invisible in this scaling) this signal is still containing an amount of harmonics, which prevents PD measurement. To achieve PD levels of less than 10 pC, a special filter set-up is required to reduce the harmonics.



After passing a special filter set-up, to reduce the harmonics of frequency converter and to enable PD measurement the power is connected to the exciter transformer. From hereon the system operates as a conventional series resonant test system. Due to the physical behaviour of the series resonant circuit a sinusoidal output voltage is achieved as shown in Fig. 3.

3. PD Measurement

Normally test equipment is designed to operate at background noise PD levels of less than 2 pC. In case of operating frequency converters close to test equipment, problems of an increase of the background noise level arise. In case of using a frequency converter for the power supply of the test equipment a background noise level of less than 2 pC seemed impossible. Therefore in the past the solutions were: performing no PD measurement or using the window technique on the PD detector. However using the window technique in this case leads to a signal reduction of that amount, that the PD measurement becomes doubtful, or at least not completely comparable.

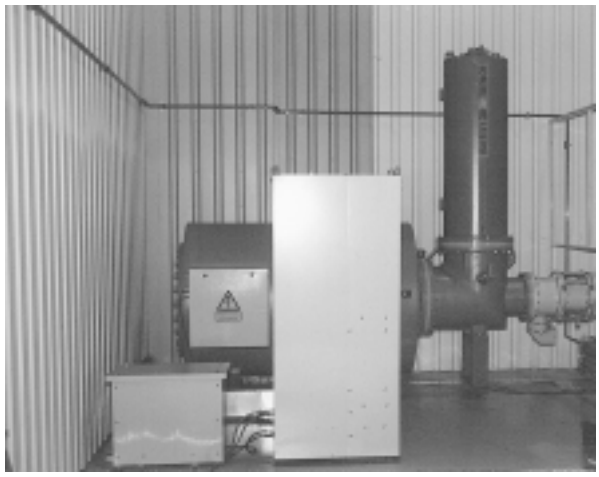
Therefore for this equipment a special filter set-up, together with a coreless, disc winding reactor design were used to achieve a harmonic attenuation of more than 100 dB.

4. General usage

This kind of series resonant test system can be used in different areas of high voltage testing of test objects with capacitive behaviour. For example routine testing of switchgear units, high voltage cables, instrument transformers and others. The difference to conventional test equipment is the deviation of the testing frequency from the power frequency at a certain test capacitance. For some test objects a test frequency, differing from the power frequency is allowed by IEC. For others (after laying tests of high voltage cables) there are no standards at all. So testing at variable frequency in a range from 30 Hz up to 200 Hz, or at least up to 70 Hz is reasonable.
The following examples show the typical usage of the variable frequency test equipment:
Fig. 4 shows a SF6 insulated series resonant test system, which is used for routine testing on gas insulated switchgear units.

Fig. 4

Series resonant test system for routine testing of gas insulated switchgear units. Rated voltage 400 kV, PD level ‹ 2 pC, max. output current 0.8 A, frequency range 45 to 65 Hz. In this case the high voltage reactor is a gas insulated and coreless one, consisting of disk windings to enable further reduction of the harmonics for the PD measurement. No window technique is used for the PD measurement. The picture shows the complete test system without control unit.



Another usage is for the after laying test of high voltage power cables. Fig. 5 shows the set-up for a mobile test equipment. The total equipment, except the second reactor and the Diesel generator is placed on a 40 t trailer.

Fig. 5:

Resonant test system with variable frequency. Rated data: Maximum output voltage 440 kV, maximum output current 133 A, Frequency range: 30..300 Hz, Duty cycle: 1 h ON, 2 h OFF, 6 times in 48 h. The complete system (without the Diesel and the series/parallel reactor) is mounted on a trailer to enable roll on / roll off testing. The ratings of the equipment shown on the Fig. are 220 kV, 66 A.

5. Outlook

In the future an increase of variable frequency test equipment is expected, as this kind of equipment is more economical than all others. For some special cases, the after laying test of high voltage cables, it is the first time to have a mobile test equipment for such ratings available.

The deviation of the power frequency will be a point of future discussion. However at the very moment no research data on the behaviour of the test objects are available in the frequency range from 30 to 70 Hz. Hopefully the existence of the test equipment will also enable some research work on this subject, to open an area of more economic test equipment.

6. References

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