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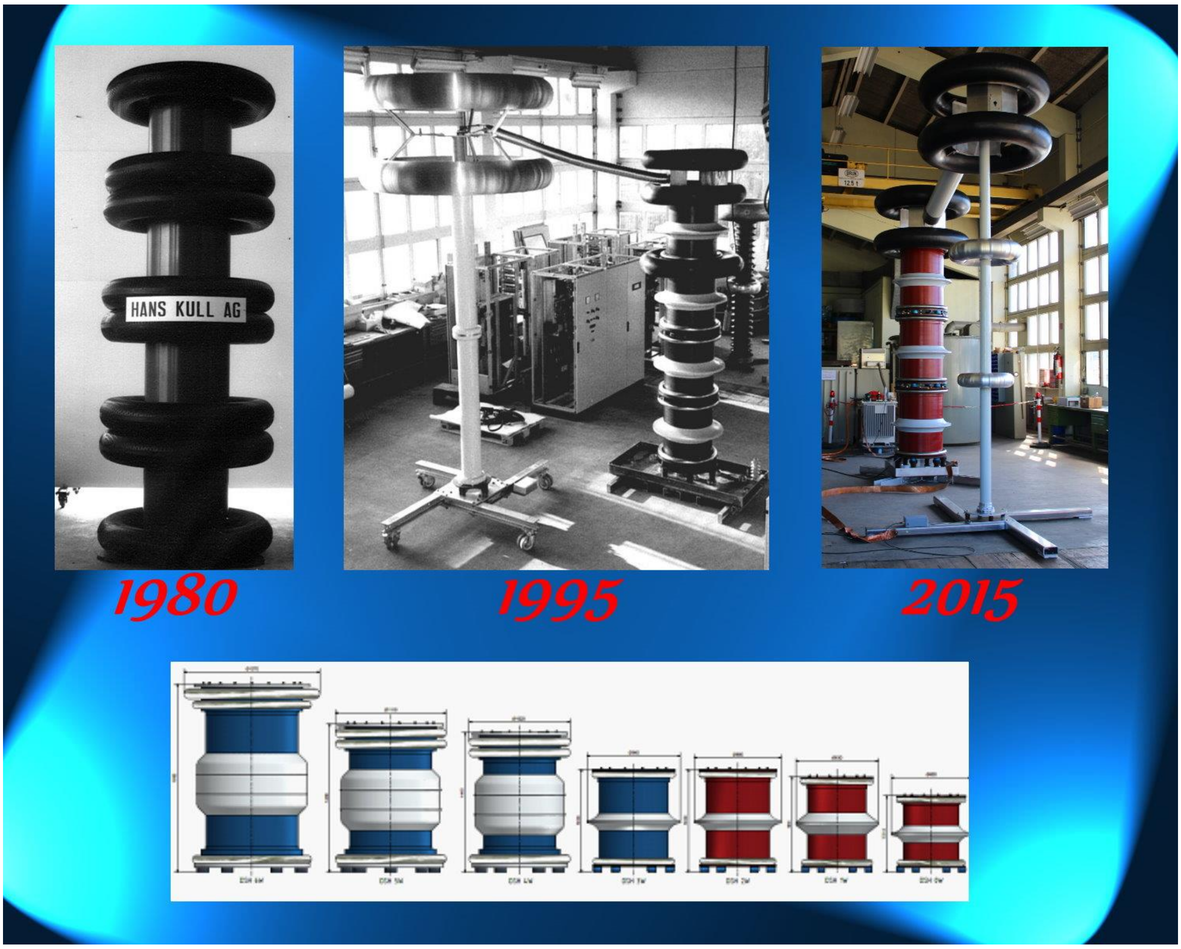
The Development of Modular Frequency Variable Series Resonant Test Systems



THE ADVANCED SOLUTION FOR
ON-SITE TESTING

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The Development of Modular Frequency Variable Series Resonant Test Systems

Motivation for the Development

GIS installations, power cable systems, power transformers and hydro generators are erected on site and even the single components were tested in the factory, there is always the risk of a transport or erection damage or of an assembly fault. On-site test shall eliminate such defects before the components are putted into service. Therefore there is a demand for test systems with following features:

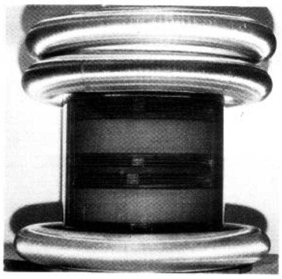
- suitable On-duties and testing power
- light weight and easy to transport by ship, truck and airplane
- high flexibility
- easy and reliable to operate
- suitable for all climatic zones and even off-shore

With conventional power frequency test sets, on-site tests can be performed, but they are heavy and difficult to transport, or provided not enough power for testing of components with high capacitance. Another solution was therefore required.

Conventional Test System 300kV

The Idea of Frequency Variable Testing

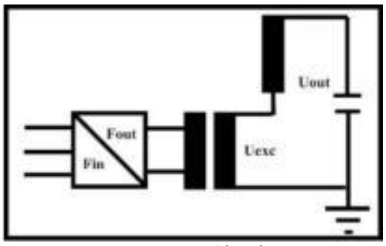
The idea of using frequency tuned resonant circuits for on-site testing was born in the 1970ties at the Federal Institute of Technology in Zürich. A first prototype of a frequency variable resonant test set was built and presented to the professionals in 1979. (1)
Hans Kull AG (nowadays ***agea-kull ag***) was involved just from the beginning in this development and manufactured the first prototype of a bar core reactor 180kV, 6.4A (today: DSH0 type)
Even the systems were interned to test GIS systems (2), the application of this new principle for cable, transformer and generator on site testing followed soon. (3,4)



Prototype Reactor 1979

The Principal of Frequency Variable Testing

The test sets work according the series resonant principle. The load capacitance and the high voltage reactors create together an electrical resonant circuit, which is excited by a frequency variable power source and an exciting transformer. Series resonant circuits are voltage resonant circuits. This means that a relative low exciting voltage is amplified by the resonant circuit to a much higher output voltage. The highest voltage increase is achieved when operating the test circuit at its natural frequency, because this is the only frequency which is amplified by the circuit. This case is called resonance and now the ex-citing source has only to provide the ohmic losses, because the capacitive load current is completely compensated by the high voltage reactors. Size and power of the voltage source can be therefore small compared to the testing power.



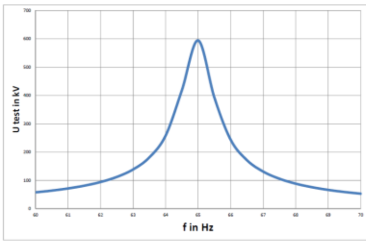
Resonant Circuit

The resonance frequency is determined by $f_0 = 1/(2\pi * \sqrt{(LC)})$
whereby

f_0 =	Resonance frequency
L=	Inductance of the reactor arrangement
C=	Load capacitance

The maximum possible voltage increase is given by the quality-factor Q of the test circuit: Uout/Uex = Q = Sout/Ploss
whereby

Uout=	Output voltage of the test set during testing
Uex=	Exciting transformer voltage during testing
Sout=	Apparent testing power
Ploss=	Losses in the test circuit during testing
Q=	Quality factor of the test circuit



Resonance curve
Test voltage vs. Frequency

Introduction of the New Testing Principle and First Test Sets

After the presentation of the new testing method by ETH, FKH and Hans Kull AG at the ISH conference in 1979 in Milan, first multi-module systems for GIS testing were built. Different voltage sources as Diesel-generators or motor-generator-sets were investigated to excite the systems (4), but in the long term the static converter turned out to be the most effective and easiest to operate solution, even they generate high pd-impulses and require measures to eliminate them.

With respect to a wide range of applications, the early systems were designed as a kit solution for flexible use with the possibility to test GIS/GIL, transformers and cable systems with the same test set. (5)

DSH0 Reactor

In order to increase the nominal voltage, the reactors were later equipped with a silicone-jacket. The result was a 220kV, 6.4A, 50H reactor which is now our DSH0W type. The main application of this reactor is GIS testing with increased frequency, but it can be used for cable and transformer testing as well.

The DSH0 reactors are now for more than 35 years in service and proved in this time their suitability for on-site applications and their long lifetime as well. Different voltage levels and inductances together with accessories like transport housings and castor platforms established a wide range of applications for this reactor size. They cannot only be used in frequency variable test sets, but also as parallel-compensation reactors in power frequency test sets for laboratory or on-site applications.
The steady increasing capacity and power consumptions of the test objects demanded however in the long term view more powerful solutions.

400kV Test Set with MG-Set

Diversification

Based on the experience with the DSH0 reactors, in the middle of the 1990'ties more powerful GIS test sets with increased on-duty and wider frequency range were designed and the generator-based power sources definitely substituted by static converters.
A suitable selection of the inductance enables testing with increased frequency and allows testing of complete GIS arrangements including cable connections and installed instrument transformers.

GIS Test Set 540kV

With the new millennium on-site testing of laid power cables became more and more an important application of frequency variable resonant test sets and required solutions with higher power than ever before. ***agea-kull*** kept the advantages of modular systems, but increased the size of the reactors in order to enable longer on duties at reduced operation frequencies down to 20Hz with a corresponding increasing of the load range. (6) Container solutions allow an easy transportation of the complete test set all over the world and the still comparatively low weight allows the erection of the reactors even at difficult on-site situations (off-shore, caverns, tunnels, urban substations, mountain areas, etc.)

Cable Test Set 280/540kV

Prospects

The development of modular frequency variable resonant test sets is still not at the end. Reactors with more power and operating frequencies below 20Hz will further extend the load range and/or reduce the required number of reactors.

On the other hand, small and light weight reactors make the series resonance principle very interesting for on-site testing of medium voltage equipment.

Medium Voltage Test Unit

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