PHENIX TECHNOLOGIES

AC RESONANT TEST SYSTEMS

PHENIX Technologies is a leading manufacturer of high voltage test systems. We have been engineering and supplying systems throughout the world for over 20 years and are one of the original manufacturers of resonant test systems.

With a complete and modern facility including transformer production and high voltage testing, all major components are designed, built, and tested in-house. Engineering and production methods use the most advanced techniques and technologies.

Application

AC Resonant Test Systems are especially valuable in any application where the load is largely capacitive with low loss such as power cables, gas-insulated switch gear, generator windings, and dry testing of insulator strings. All PHENIX Resonant Test Systems are built for indoor, as well as fair weather outdoor operation. These units can also be designed to operate in adverse weather conditions.

In most cases, the complete test system can be trailer- or truck-mounted to provide mobility for field tests of installed power cables or generators. Being operated in a resonant mode results in the system operating at a unity power factor. Thus, these systems are ideal for on-site operation due to reduced power consumption needs when compared to conventional AC dielectric test systems.

Resonance Theory

Resonance is defined as the condition at which the net inductive reactance cancels the net capacitive reactance. The resonant circuit must have both capacitance and inductance. (In addition, resistance will always be present due either to the lack of ideal elements, or the control offered on the shape of the resonance curve.)

When resonance occurs, the energy absorbed at any instant by one reactive element is exactly equal to that released by another reactive element within the system. In other words, energy pulsates from one reactive element to the other. Therefore once the system has reached a state of resonance, it requires no further reactive power since it is self-sustaining. The total apparent power is then simply equal to the average power dissipated by the resistive elements.

The average power absorbed by the system will also be at a maximum at resonance. The commonly used measure of the quality in a resonant circuit is the quality factor, or Q. The power source of resonant circuits operating in the resonant mode (exciter and regulator) is used to supply the dissipated energy. Q is approximately equivalent to the ratio of the output kVA to the input kVA. Given kVA requirements of the load and the Q of the test sytem, the input power can be obtained by dividing the kVA by the Q.

Parallel or Series Resonant Mode

The proper mode of operation must be chosen according to the test objects and the measurements to be carried out.

The series resonant mode is well suited for sensitive partial discharge measurements. Harmonics from the supply are better suppressed than in parallel mode.

The parallel resonant mode provides a more stable output voltage with test specimens, such as large generator windings, or other specimens with corona losses.

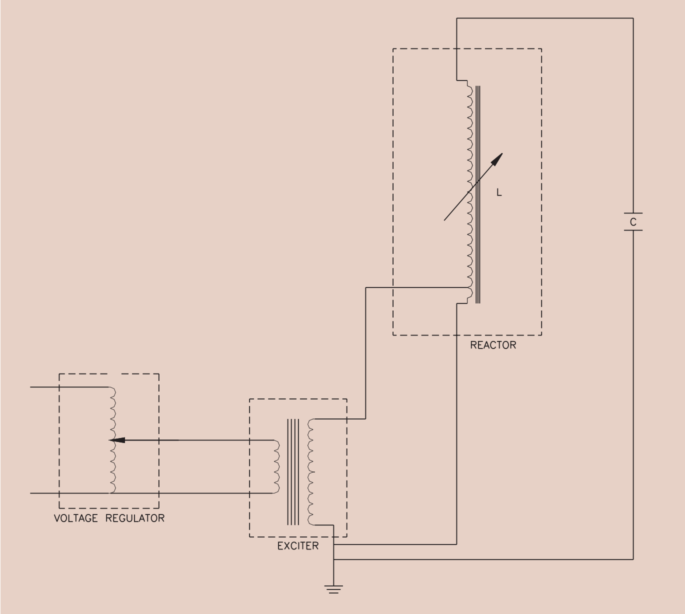
The test voltage rate of rise is stable in parallel mode, independent of the degree of tuning and the Q of the circuit. Furthermore, parallel mode allows the test set to be energized to full voltage without a load. This is useful for calibrating the instrumentation and checking for the partial discharge level of the test equipment.

Principle of Operation in Parallel Resonant Mode

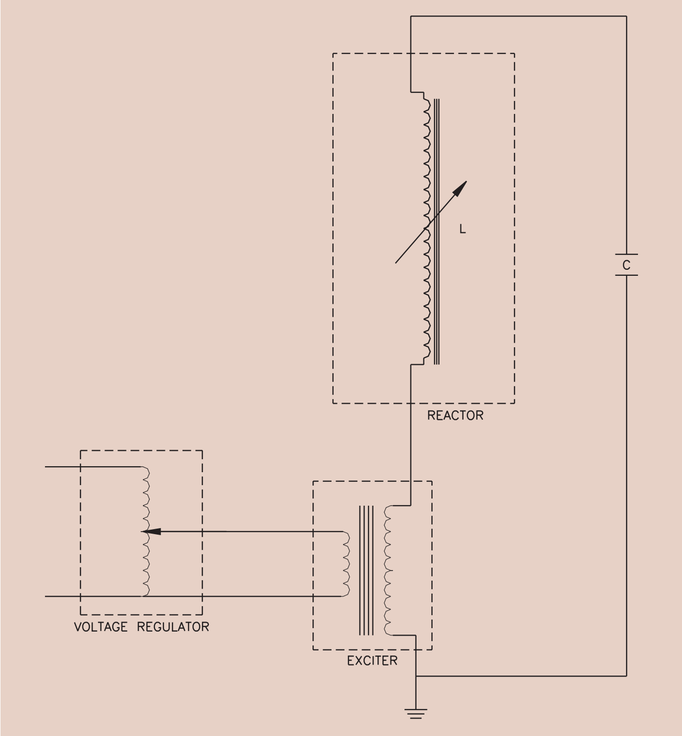
Pictured right is a simplified diagram of a parallel resonant test system. The difference between series and parallel mode can be seen in the connection from the exciter transformer to the high voltage reactor.

The start of the high voltage winding is grounded instead of being connected to the high voltage output of the exciter transformer, as in the series resonant mode. The output of the exciter transformer is connected to a tap provided on the high voltage reactor. Notice that the high voltage reactor is in the configuration of an auto-transformer. Furthermore, in this configuration the high voltage reactor is electronically in "parallel" with the load capacitance.

In the event of a breakdown of the test sample, the output current of the test set is limited by the short-circuit impedance of the regulator, exciter transformer, and the "auto-transformer." In most cases it can be said that the short-circuit current of a parallel resonant system is below the nominal current.



Principle of Operation in Series Resonant Mode



Above is a simplified diagram of a series resonant test system. A voltage regulator of an auto-transformer type (Toroidal, CTVT or Thoma) is connected to the supply voltage. The regulator provides a variable voltage to the exciter transformer.

The exciter transformer is fed by the output of the voltage regulator. This transformer steps the voltage up to a usable value by the high voltage portion of the circuit.

The high voltage reactor L and the load capacitance C represent the high voltage portion of the circuit.

The inductance of the high voltage reactor can be varied by changing the air gap of the iron core.

The load capacitance C consists of the capacitance of the load. The coupling capacitance for PD measurement, stray capacitance and, in the case of tank-type (T), sets the high voltage bushing.

When testing, the high voltage reactor is adjusted so that the impedance of L corresponds to the impedance of C at the frequency of the supply voltage. Thus the circuit is tuned to series resonance at 50 or 60 Hz.

The Q of the basic resonant circuit or with a low loss test specimen (e.g. OF cable, XLPE cable, SF switchgear, bushing, etc.) is typically 50 to 80. The high voltage reactor is designed for a minimum Q of 40. The system Q is designed around the anticipated load. For example if the set is operated in conjunction with water terminations, the system will operate at a Q as low as 20. If the system is used for testing samples with large resistive losses, such as generator windings, the system will provide full power with a Q as low as 10.

In case of a flashover during testing on the high voltage side, the resonant circuit is detuned and the test voltage collapses immediately. The short circuit current is limited by the impedance of the high voltage reactor. This means that the short circuit current of a series resonant system with a Q of 40 is 2.5% of the load current to which it is tuned.

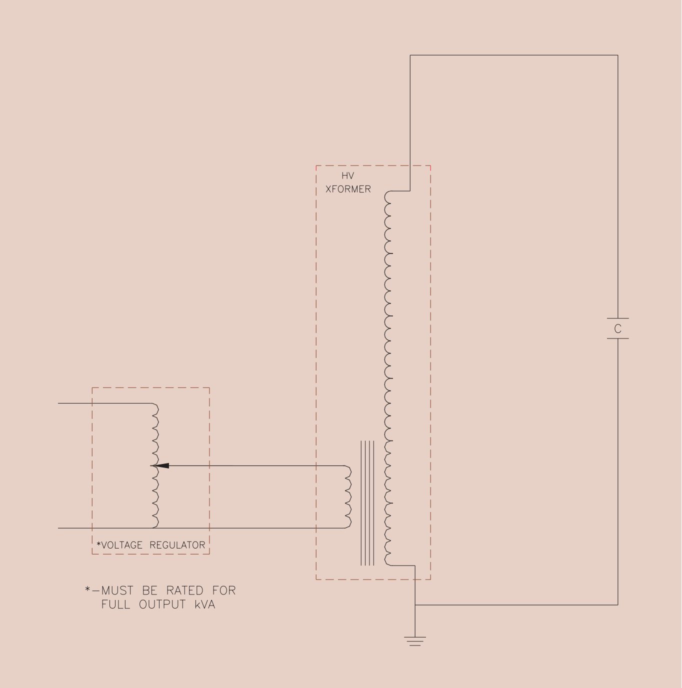
Conventional Dielectric Sets Versus Resonant Mode

Both resonant and conventional AC test systems have their fields of operation.

For all applications where the test specimen represents, in addition to capacitance, a relatively high ohmic content, a conventional test set (possibly with reactive compensation) is recommended.

This is also valid for tests on specimens with an unstable ohmic component, such as pollution tests, wet tests, or tests on objects with heavy corona. For these types of tests, a high voltage source with a relatively low short-circuit impedence is required to maintain a stable voltage on the test specimens. (A series resonant test system has an inherently high short-circuit impedence.)

When testing specimens representing a highly loss-free capacitive load, the series resonant test system has some outstanding advantages.



Above is an electrical representation of a conventional AC Dielectric Test System. The differences in a AC Resonant Test System and a conventional AC Dielectric Test System can be seen by viewing the electrical representation of both the Series and Parallel type Resonant Test System on the previous page (#3).

In the event of a breakdown, the fault current is very small as the resonance circuit is detuned. This reduces the damage to the fault location.

When testing SF6 switchgear, multiple breakdowns resulting in high transients do not occur. Therefore, no special protection against transients, such as a crowbar system on the primary side, is needed for series resonant test systems.

No separate compensating reactors are needed. This results in a lower overall weight.

As the capacitive load is always fully compensated, power requirements of the supply are smaller. The power breaker, the voltage regulator and the power filters have low power ratings.

The series resonant circuit suppresses harmonics and interference from the supply to a high degree. This facilitates partial discharge measurements.

Tank Type Versus Cascade Type Resonant Systems

Tank Type Systems:

- Can be run in parallel or series resonant mode.
- Utilize the capacitive tap of the high voltage bushing for output voltage measurement.
- Can be raised to full rated output voltage by operating the system in parallel resonant mode.
- Can be provided with several output voltage taps extending the tuning range of the system.
- Can be provided with rated output voltage levels of up to 400 kilovolts.
- Can be provided with angled or vertical output bushings.

Cascade Type Systems:

- Can be run only in series resonant mode.
- Require a stand-alone voltage divider for output voltage measurement.
- Require a preload capacitance (normally the voltage measurement divider) to achieve full rated voltage.
- Are available in a single tuning range (if only one module is provided). For models with multiple cascaded modules, external high voltage bus bars can be purchased which effectively extend the tuning range of the system.
- Can be provided with rated output voltage levels of up to 2,000 kilovolts.

General Description of All PHENIX RTS Controls

PHENIX Technologies' controls provide all metering and instrumentation necessary for proper adjustment and accurate measurement.

A programmable logic controller (PLC) is at the heart of our state-of-the-art control system. This component replaces many relays and other electronic components previously required for control functions.

With fewer components that can fail or malfunction, system reliability is increased considerably.

Maintenance, trouble-shooting and service are all made easier by the PLC. In addition, operating procedures can be modified through software rather than making hardware changes. Capabilities may be modified or extended out in the field with much greater ease.

Features of All RTS Controls

- Keyswitch for control power combined with emergency off pushbutton switch
- Control "power on" light
- Security circuit with indicating light for use with test cage interlock system
- Zero-start interlock, which requires operator to raise voltage from zero level
- High voltage on/off pushbuttons with indicating lights
- Motorized control of output voltage from near zero to full voltage with raise/lower pushbuttons and indicating lights
- Pushbuttons for changing reactance when tuning to resonance in manual mode
- Electronic arc detector overload circuit with pilot light and reset pushbutton
- High voltage ready indicating light which illuminates when high voltage may be turned on
- Automatic return of motorized regulator to zero position when high voltage is shut off or when a failure occurs
- Reactor over temperature protection
- Provision for external warning device (maximum 250 VA)
- Motorized tap changer (Conventional model only)

Standard Metering

Output Voltmeter
- Digital
- Peak-reading calibrated to RMS
- Value accuracy +/- 1%

Output Currentmeter
- Digital
- RMS-reading
- Operator may select to read exciter or specimen current Accuracy +/-1%

Exciter Voltmeter
- Analog accuracy +/-2%

Resonance meter
- Analog
- Zero-center null meter

Inductance Meter
- Analog
- Indicates gap position

Deluxe Controls

With the Deluxe Controls, a control desk is provided with a writing shelf. A storage compartment is built into the base on the control desk. The height of the control console ensures a good view of the test area. Space for additional measuring instruments such as a Phenix P.D. Detector is provided. Other configurations for control consoles are available. (reference brochure #90102 Control Centers)

Double-wide control console with writing desk. Shown with optional port recorder.

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Deluxe RTS Control Features

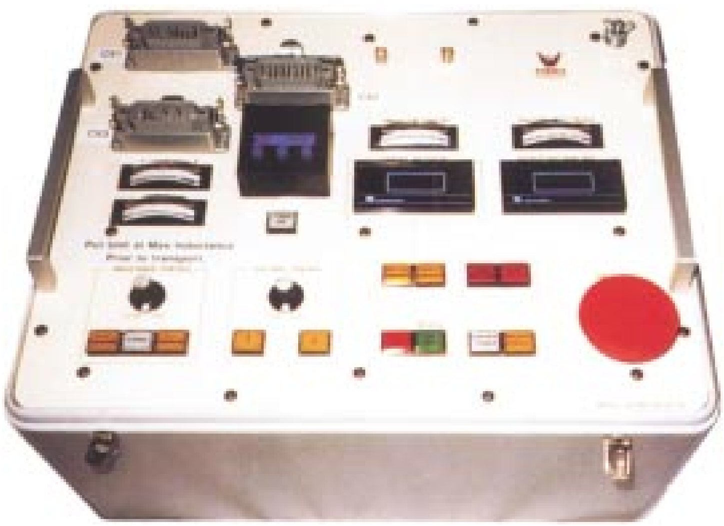
Test set-up and operation have been greatly simplified by the implementation of menu-driven screens on the operator interface which intuitively step the user through the set-up procedure. A significant portion of the metering section once performed by panel instrumentation has been turned over to the operator interface and is displayed on its LCD dot matrix display. As an added benefit, many of the once "optional features" have been incorporated as standard functions, such as:

- Automatic tuning
- Automatic voltage regulation
- Overvoltage
- Peak memory voltage retains the highest level reached during a test
- Digital dwell timer
- 0-1 volt output proportional to test voltage

Deluxe controls are housed in a 19" rack mount case which is mounted on a pedestal desk with a writing table. They are ideal for test lab environments yet sturdy enough to stand up to the rigors of field testing.

Portable Controls

Portable controls are housed in fiberglass case which can be easily stored and transported. Portable units are economical, yet have all of the control and metering functions necessary to perform a complete test.



The portable control unit, shown above, weighs only 65 pounds (29.5 kg). Dimensions are 21" wide, 16" deep and 13" high (533mm x 406mm x 330mm).

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General Description of PHENIX Units

The regulating transformer is the first power section of the Resonant Test System. This is used to regulate the supply voltage from near-zero up to the magnitude of the supply voltage (220 V, 380 V, 480 V, etc.) and, ultimately, the high voltage output. This function is performed by a variable auto-transformer. PHENIX Technologies utilizes one of three designs, dependent on the power requirements of the system. For smaller power requirements the classic toroidal design is an excellent choice.

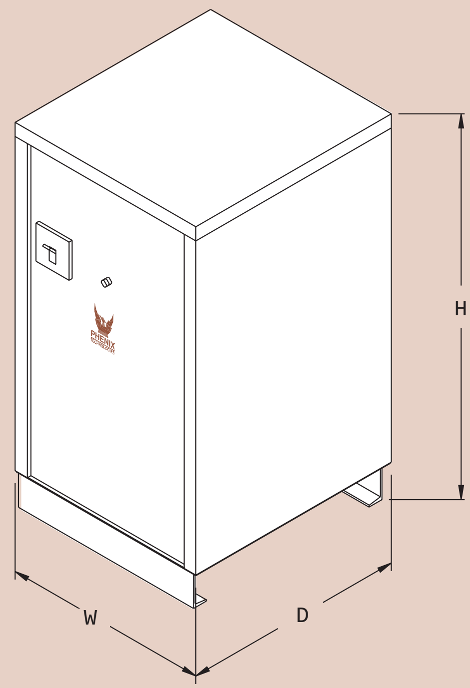
For higher power requirements of up to 2 MVA, we use our own PHENIX column-type variable transformer (CTVT) designed and manufactured by PHENIX for this purpose. The PHENIX CTVT utilizes carbon rollers for current collection to eliminate the problems associated with slide contacts. The PHENIX CTVT is designed with a low voltage difference (less than 0.7 volts) between adjacent turns to provide very high resolution on the output. The unique screw and drive system eliminates problems caused by chain-based drives.

For extremely large kVA inputs and/or input voltages of 1000 VAC or greater, we also use our own Thoma-type regulator which provides a step-less output, constant impedance which is ideal for this application.

Additionally, line filters are installed between the regulator and the input to the exciter. Their purpose is to reduce the noise from the incoming power supply. Their attenuation is rated 40 dB at 2 kHz, increasing to 100 dB at 14 kHz and remaining at 100 dB above 14kHz.

Typical PHENIX Regulating Transformers

The weights and dimensions shown on this page are offered as representations. The actual sizes and weights may vary due to selected options or special restrictions imposed by the purchaser. Please refer to the formal quotation for actual values as described by the technical drawing to the right.



Power	Length	Width	Height	Weight	Length	Width	Height	Weight
kVA	mm	mm	mm	kg	Inches	Inches	Inches	Pounds
7.5	599	610	737	91	22	24	29	200
10	599	610	737	100	22	24	29	220
20	599	610	737	100	22	24	29	220
40	599	610	1041	191	22	24	41	420
60	599	610	1321	285	22	24	52	828
75	813	813	1676	445	32	32	66	980
125	1067	813	1219	568	42	32	48	1250
200	1067	813	1219	589	42	32	48	1295
300	1067	813	1524	614	42	32	60	1350