RITZ INSTRUMENT TRANSFORMERS, INC.

PQSensor™

POWER QUALITY SENSOR
For use with Capacitor Voltage Transformers

General Description

A power quality sensor is available to very accurately measure harmonics over a wide bandwidth from sub-synchronous to high frequencies. The PQSensor™ current probes are installed in capacitor voltage transformers (CVT's) at the ground connection points in the secondary terminal box. The PQSensor™ signal-conditioning unit can be mounted on the CVT support structure. There are two outputs; each is a 20 mA ac signal. With optional amplifier, a standard 115 V line voltage (63.5 V phase-neutral) wide bandwidth output is available. The PQSensor™ can be supplied with the current probes already installed on Ritz CVT's or purchased separately for retrofitting on existing CVT's.

Background

Power quality assessment will become an increasingly important requirement in the management of electric supply systems. This recognition has led to the refining of the standards governing the presence of harmonics. All standards require measurements up to the 40th and most, including IEEE 519 up to the 50th harmonic.

IEEE 519 requires that the individual harmonic level should not exceed 1% of the fundamental with the total harmonic distortion (THD) of 1.5% for voltage levels of 161kV and above. THD is the square root of the sum of the squares of the percentage of all measured harmonic voltages or

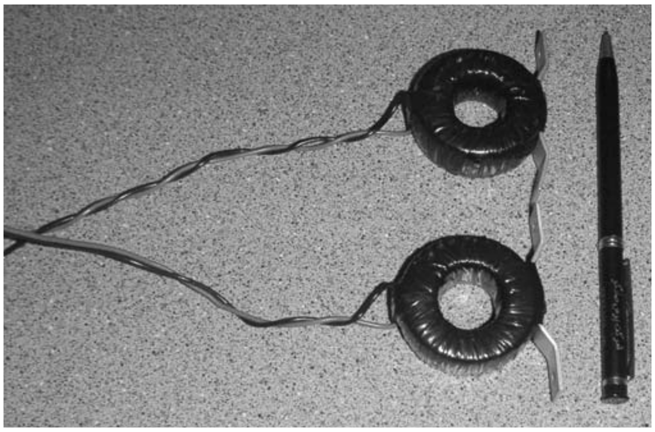
$$V_{THD} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots}}{V_1} \times 100\%.$$

The standard also asks for an accuracy of 5% of the limit for measurement.

Options for Measuring Harmonics

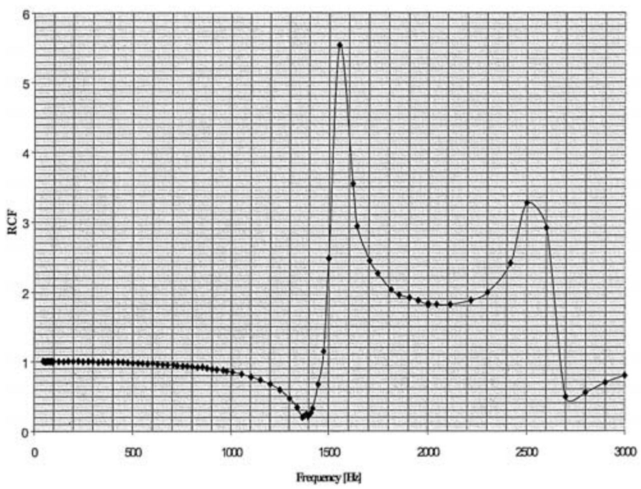
If utilities and users are to monitor power quality and other wideband transients in high voltage systems, then there is a need for a cost effective and accurate means to do so. Sophisticated power quality monitors are now available from various manufacturers. The challenge, however, is to provide inputs to these monitors which accurately reflect the phenomena occurring on the monitored system in a cost effective and safe way.

The best performance from a conventional device in terms of a wide bandwidth frequency response is offered by a resistive-capacitor divider (RCD). Normally considered an electric laboratory piece of equipment, it is very expensive, has a very limited output and would not normally be present in a substation environment.



PQ SENSOR™ SIGNAL CONDITIONING UNIT AND CURRENT SENSORS.

Most power quality monitors are currently receiving their inputs from wound or inductive type voltage transformers (VTs). The advantage with VTs is that they can also provide inputs into conventional revenue meters and relays and therefore may already be present if harmonic measurement is being considered as an add-on. What is not well understood is that wound VT's have a limited frequency range. Graph 1 shows the performance of a typical 230kV wound VT. It can be seen that the frequency response becomes unacceptable around 1kHz, well below the frequency limit established in the major standards. The upper limit increases for lower voltage class units but worsens for higher voltage class units.



TYPICAL RCF VERSUS FREQUENCY PERFORMANCE FOR A 230kV INDUCTIVE VOLTAGE TRANSFORMER

Capacitor voltage transformers have become the dominant technology for voltage measurement at transmission voltage levels because they provide reliable and accurate performance at reasonable cost. CVT's, because they are essentially tuned to the system frequency, are not in themselves capable of harmonic measurement. Because of the prevalence and reasonable cost of this technology, much effort has been expended to add the functionality of harmonic measurement.One seemingly simple solution is to add an additional tap point to the capacitor stack by creating a C_3 capacitor and thereby creating an auxiliary output that bypasses the electro-magnetic unit. While fine in theory and for the laboratory, it is troublesome for a substation environment both because of the absence of isolation between high voltage and instrumentation and the susceptibility of the low output signal to noise and unacceptable transient response in situations where monitoring voltage dips are of interest.

There is an alternate solution for employing CVT's for harmonic measurement, which eliminates the objections of the C_3.

A power quality sensor, to be used in conjunction with CVT's, has been developed and patented which overcomes the aforementioned objections. Ritz has worked very closely with the inventor to confirm the PQ Sensor's™ ability to accurately replicate the harmonic component up to the 50th harmonic and to be able to withstand the realities of a substation environment and still function properly. Ritz in partnership with the inventor and owner of the patent can offer the PQ Sensor™ already installed in a Ritz CVT or as a standalone product for retrofitting on existing CVT's.

Principle of Operation

The PQ Sensor™ exploits one of Kirchoff's fundamental circuit rules. Consider the typical CVT circuit shown in Figure 1. Current through C_1 is the total current in the CVT and a function of the applied voltage, the passive elements of the CVT and the secondary burden. The voltage at the terminal of the electro-magnetic unit (EMU), consisting of a tuning reactor, intermediate transformer and ferroresonence suppression circuit is equal to the voltage across C_2. At each instant of time or for any frequency the input voltage $\underline{V}in$ is equal to the sum of the voltages across C_1 (VC_1) and C_2 ($V\ C_2$).

Hence:

$$\underline{V}_{in}(j\omega) = \underline{V}_{c1}(j\omega) + \underline{V}_{c2}(j\omega) = \frac{1}{j\omega C_1}\underline{I}_{c1}(j\omega) + \frac{1}{j\omega C_2}\underline{I}_{c2}(j\omega)$$

**where underlined represents a complex value*

$\underline{I}_{C1}(j\omega)$, $\underline{I}_{C2}(j\omega)$ denotes currents in C_1 and C_2

Thus, if these two currents are measured, then by knowing the C_1 and C_2 values, the primary voltage can be calculated for each frequency.

In order to measure currents through C_1 and C_2, current sensors, Sensor 1 and Sensor 2 must be installed in C_2 and ground branches as shown in Figure 2. Note that both sensors are at ground potential and thus high-voltage winding insulation is not required.

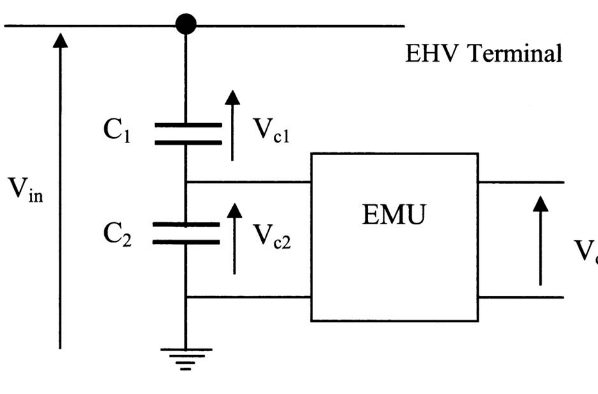


FIGURE 1 TYPICAL CVT CIRCUIT

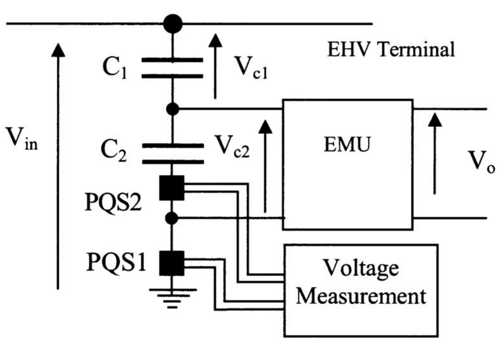


FIGURE 2 INSTALLATION OF CURRENT SENSORS

Technical Specification

1.1 Absolute gain error: 0.5% at operating frequency, measured at either outputs into 75Ω terminations. The adjustments will compensate for variations in the CT's, CVT's, and circuit components.

1.2 Gain stability over operating temperature range, at operating frequency, (measured at "Diff Output" with 75 ohm termination) 0.3% of full-scale output.

1.3 Gain stability over operating temperature range, at operating frequency, (measured at the integral output with 75 ohm termination): 0.4% of full-scale output. This does not include any effects of the CVT.

1.4 Frequency response of 5 Hz up to 20 kHz.

1.5 Frequency response measured of "Diff Output": -0.17 dB max at 5kHz with respect to gain at operating frequency.

1.6 Frequency response of "Output": -0.25 dB max. It will not have DC response.

1.7 The phase error is less than 1.5 degrees at 3 kHz and less than 3 degrees at 5 kHz. Improved phase response is offered on request for special applications.

1.8 Maximum burden of 150 Ω pure resistive. This corresponds to a maximum voltage at the measurement device (e.g. power quality monitor) of 3 V rms at a current of 20mA. The burden may be selected to be any value up to the maximum to suite the measurement device (the monitor). All figures related to accuracy and error mentioned in this document would also apply for burdens up the maximum values.

1.9 Output current levels: Differential current output of 20 mA rms, driving 75Ω through 300 meters of cable. Cable capacitance is typically 100pF/m.

As a general rule in the design of power quality monitoring devices, excessive capacitive or inductive burdens should be avoided since they affect the device's overall frequency response.

1.10 Operating temperature range: -10 to +55 °C.

1.11 Power supply input voltage 48Vdc ±10% or 85-260 V dc/ac ±10%. The unit can be supplied from the CVT nominal output of 69 V ac. Power consumption 200 mW.

1.12 Size:

1.12.1 Signal conditioning module: 10.2X6.3X3.6 inches (260x160x92 mm).

1.12.2 Current transformers: outer and inside diameters of 2 inches (50 mm) and .8 inches (20 mm), a depth of .8 inches (20mm).

1.12.3 Outdoor specification conform to IP65.

PQSensor™ OUTPUTS

The PQSensor™ provides 20 mA rms ac current. It has two outputs; each is a 20 mA rms ac signal. An optional amplifier may be mounted close to the meter to provide a standard 115 V wide bandwidth output.

2.1 A very important feature of this technique, in addition to its immunity to the effect of CVT burden, is its inherent ability to measure low-level harmonic voltages. Magnitudes of high-order harmonic voltages are usually low in power systems. The level of the harmonic voltage does not affect the PQSensor™ measurement accuracy as the main measurement is carried out in a path whose reactance reduces as frequency increases, thus creating a healthy condition for accurate signal measurement. Field experience has confirmed that the measured currents in the CVT's capacitors look more distorted than the CVT terminal voltage, implying that the harmonic current magnitudes in the CVTs capacitor branch are magnified which in turn makes the measurement of low-level harmonic voltages more accurate than any other direct voltage measurement including the wound VT and more costly resistive or capacitive divider (RCD) methods.

One output of the PQSensor™ is proportional to the derivative of the voltage and is called the "Diff Output", which is proportional to the currents in the CVT's capacitors, and *is only available in, and is unique to,* the PQSensor™ technology. This output gives a much better signal for harmonic measurement in particular if the harmonic analyser or power quality meter has a low-resolution analogue to digital converter. Once harmonics are calculated for the voltage derivative, a simple compensation is used to convert the derivative into actual voltage inside the monitor. This process may be implemented in the monitor or carried out externally in a spreadsheet. As far as the measurement device is concerned, the "Diff Output" offers a much better signal particularly for very low-level harmonics.

2.2 The second output is proportional to the actual voltage and is called "Output". The process of converting the voltage derivative to the actual voltage is carried out inside the PQSensor™. No further action, other than the normal power quality measurement, is required in the monitor. The output signal is the true picture of, and has the same shape as the input voltage.

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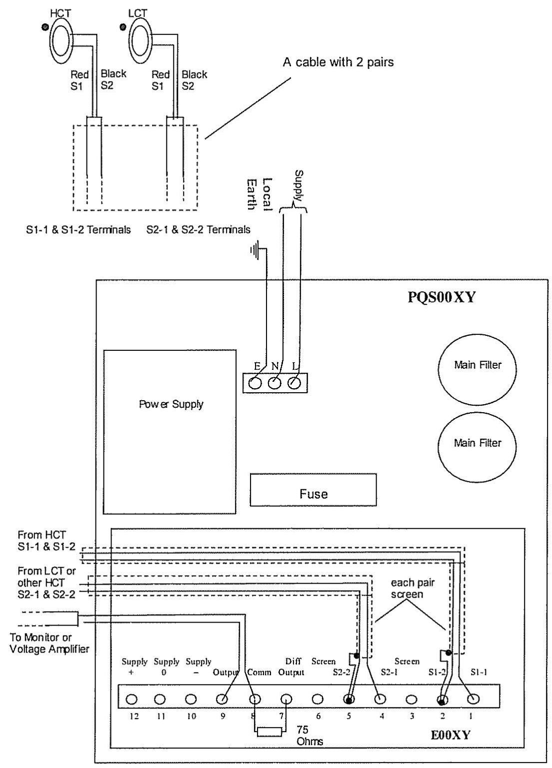

FIG. 3 - SIGNAL CONDITIONING LAYOUT AND TERMINAL DIAGRAM

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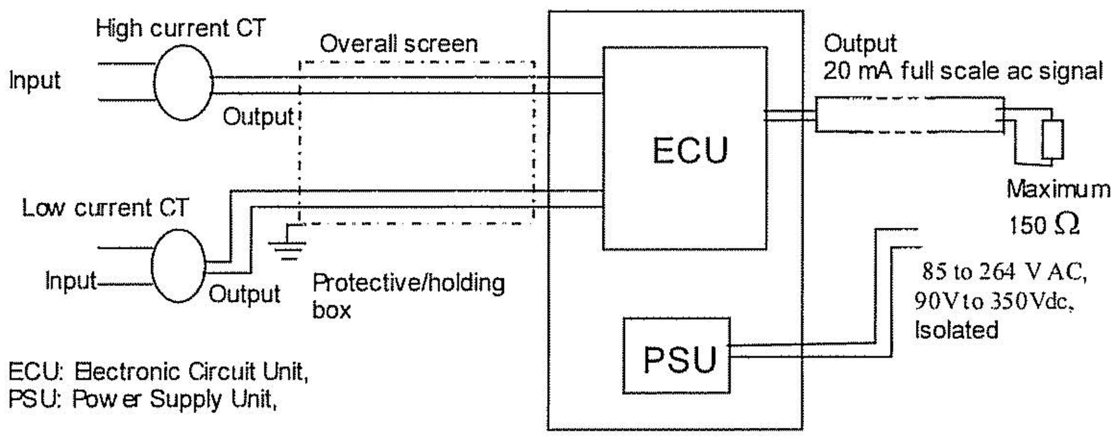

FIG. 4 - CT AND SIGNAL CONDITIONING WIRING DIAGRAM

RITZ INSTRUMENT TRANSFORMERS, INC.
One Ritz Avenue • Waynesboro, GA 30830
(706) 554-8800 • FAX (706) 554-8808
www.ritzusa.com

Sales Representative

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