A unique solution: PQSensor offers a unique, cost effective and convenient solution to the problem of wide bandwidth measurement in high voltage systems. Very high accuracy over a very wide bandwidth, from sub-synchronous to high frequencies, is obtained in a way not offered by any other means in power systems. The PQSensor current probes are installed in conventional capacitor voltage transformers, CVTs, in the earth connection points in the main terminal box, which in turn makes the installation very quick and convenient. The PQSensor signal-conditioning module is mounted on the CVT support structure.

Requirements

- Changes in nature and size of loads and utility practices, commercialization and de-regulation of the energy market and hence higher competition have made power quality assessment an important requirement in the modern management of electricity supply systems in the world.
- Nowadays connection of non-linear loads with large MW size directly to higher voltage systems is a normal practice. Such loads are large industrial complexes, traction loads and wind farms and growing number of high voltage dc (HVDC) systems. These are in addition to the penetration of harmonics and transients (such as voltage dips) from LV and MV to HV systems.
- The monitoring of wide bandwidth transients, such as ferroresonance oscillation, line and capacitor switching is essential to assess power system performance and response to undesirable events.
- The EN 50160, IEC 61000-4-30, IEEE 519, UK Standard G5/4 and other national standards all impose limits on the level of harmonics and other disturbances that can exist in a system. These standards are used as the basis in legal proceedings all over the world.

Consequence

- One aspect of power quality assessment is compliance with the international and domestic standards for harmonic pollution.
- 50/60 Hz to 2.5/3.0 kHz or 50th harmonic must be considered as harmonics affect system losses, user equipment functionality, system protection operation, communication systems and cause damage to plant equipments, etc.
- Accurate monitoring of non-system frequency phenomena, such as capacitor banks or line switchings, sudden voltage changes and low frequency effects such as Ferro-resonance are also essential in power system operation.

The Problem

- If utilities and users are to monitor power quality and other wideband transients in high voltage systems then they face a problem.
- CVTs are the main instrument transformers to interface instrumentation equipments such as meters and protection devices in 70 kV systems and higher.
- The main reason for using CVTs is the reduced cost and size compared to the conventional electromagnetic transformers.
- However, due to their construction CVTs do not have a suitable frequency characteristic and that they are tuned to give an accurate representation of the primary voltage at the fundamental frequency only.
- Accurate measurements that require a wider bandwidth are not possible if the secondary output of CVTs is used.
- Utilities are generally aware of CVT characteristic and do not use CVT output for wideband or power quality measurements.

A cost effective solution for wideband measurement in power systems
CONVENTIONAL SOLUTION

- Until now there has not been a convenient and cost effective method of performing wide bandwidth, including harmonic measurements in HV systems without the use of special, costly, voltage dividers.

- The cost of a three phase set resistive-capacitor divider (RCD) installation, which offers a wide bandwidth frequency response but with a very limited output power, includes capital cost, installation cost, extra substation space and the cost of system outage which is usually prohibitively long.

- Some utilities have used single-phase wound voltage transformers (WVT) to measure harmonics in the limited frequency range, despite the reported inaccuracy of these devices even in the lower frequency range.

- WVTs are not always available in all three phases because of the cost and possible interaction with system and line capacitance in the form of ferroresonance.

- The earlier assumption that the frequency response of WVTs is adequate is not now widely accepted. IEC 1000-4-7 states, “VTs for EHV seem not to be suited for harmonic measurements above 5th order. If special design measures are taken, the errors may be acceptable at least up to 1 kHz”. A CIGRE publication concludes “many types of magnetic voltage transformers have a considerable error of transformation ratio at higher frequencies”, and also states that an accuracy of 5% in the frequency range considered cannot be achieved using EHV WVTs.

- Therefore, much benefit can be gained if accurate wideband measurement can be conveniently made in all three phases by the use of CVTs.

A VERY COST EFFECTIVE SOLUTION

In European patent EP 1295133 and US patent US 6,919,717 a new technique has been described concerning harmonic measurement in HV systems. The patent offers PQSensors™ for the conventional CVTs. The technique involves minimal cost and time in retrofitting to installed CVTs or in modifications during the manufacture of new units without requiring any change in the manufacturing routines. The technique does not require any pre-measurement simulations, studies or tests and is independent of the CVT internal nonlinearities and burden. The technique simply exploits one of the Kirchoff’s fundamental circuit rules. PQSensor™ is added to the CVT installation. This small addition is a substitute for expensive Resistive-Capacitive Divider installations.

The magnitude of high order harmonic voltages are usually low in power systems. However, the acceptable limits imposed by regulators and utilities for such harmonics are also low. One amongst many advantages of PQSensor is its inherent ability to measure, very accurately, high order harmonics. The level of the harmonic voltage does not influence the PQSensor measurement accuracy. Its accuracy is constant over the whole range, which is in contrast to any other direct voltage measurements including the WVT and more costly RCD techniques.

PQSensor, a transducer for CVTs to enhance its power quality measurement capabilities

PQSensor™ current sensors, and signal conditioning module; No change is required in CVT design; quick to install and no extra substation space is needed. A perfect substitute for RCDs
- PQSensor™ current sensors are installed in CVT terminal box.
- PQSensor™ signal conditioning module is mounted on the CVT stand.

### COMPARISON TABLE

<table>
<thead>
<tr>
<th>Resistive Capacitive Dividers</th>
<th>Inductive (wound) Voltage Transformers</th>
<th>PQSensor for CVTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Wide bandwidth is offered.</td>
<td>1. Limited bandwidth than previously assumed (IEC &amp; CIGRE reports).</td>
<td>1. Very wide bandwidth, standard model offers flat response from 5 Hz to 5 kHz, −3dB at 12.8 kHz. Advance models offer wider frequency range for special applications with higher frequency requirements.</td>
</tr>
<tr>
<td>2. Expensive: costs as much as a CVT</td>
<td>2. Cost increases for higher voltage</td>
<td></td>
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<tr>
<td>3. Similar size as CVTs.</td>
<td>3. Bulkier than CVTs.</td>
<td></td>
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<tr>
<td>4. Regular calibration is required, especially when burden changes.</td>
<td>4. Long commissioning time, hence long busbar and/or line outage is required.</td>
<td></td>
</tr>
<tr>
<td>5. Special circuit matching is required</td>
<td>5. Long/expensive installation and civil work is required (similar to CVT).</td>
<td></td>
</tr>
<tr>
<td>6. Long/expensive installation and civil work is required (similar to CVT).</td>
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<td></td>
</tr>
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<td>7. Long commissioning time, hence long busbar and/or line outage is required.</td>
<td>7. Long/expensive installation and civil work is required (similar to CVT).</td>
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</tr>
<tr>
<td>8. Low output power, i.e. cannot supply meters, relays, etc. thus must be used in parallel with CVTs.</td>
<td>8. May cause ferroresonance in system, hence cannot be used everywhere, every time.</td>
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CVTs with PQSensor™; offer a complete solution for 50/60 Hz, harmonic and transient measurements in power systems