UNIT - V

ENERGY AUDIT INSTRUMENTS

INSTRUMENTATION FOR ENERGY AUDIT

With the rising costs of energy and concerns about global warming, it is imperative that countries adopt the most efficient energy conservation measures and technologies. Energy conservation must evolve as a way of life in developing countries in the Asia-Pacific region given the limited availability of resources. If we are to share commercial energy equitably across all sections of society, it is necessary to conserve energy and use it efficiently. Industries can become globally competitive when their products are energy efficient and their production processes consume the least amount of energy.

For this purpose, energy audits and conservation studies must be conducted at regular intervals in all industries. One of the main bottlenecks in conducting these studies is the lack of technical information on various types of equipment and how energy performance should be measured. Energy audit is an official survey or study of the energy consumption and its objectives are to recommend steps for improving energy efficiencies, reducing the energy costs and wastage, improving quality etc.

The requirement for an energy audit such as identification and quantification of energy necessitates various measurements; these measurements require the use of instruments. The parameters generally monitored during the energy audit may include basic electrical parameters in AC and DC systems and parameters of importance other than electrical such as temperature & heat flow, radiation, air and gas flow, liquid flow etc. Measuring electrical parameters does not seem to be much of a problem except for total harmonic distortions and transients, or the occasional blowing of fuse because screw drivers and bus bars are a bad mix. However, other more common measuring tasks such as flows of gases and liquids, as well as stack gas composition are more challenging and riddled with problems, even if one uses expensive and sophisticated equipment.

Whilst much data and characteristics on equipment/systems can be obtained from the energy audit personnel, the information may not be adequate to provide a full picture of their operation. To obtain accurate operating conditions and operating performance of equipment/systems, the auditor should have the necessary measuring instruments to take readings of corresponding parameters such as temperature, pressure, flow, lighting lux level, running current, etc.

The requirement for an energy audit such as identification and quantification of energy necessitates measurements; these measurements require the use of instruments. These instruments must be portable, durable, easy to operate and relatively inexpensive.

The parameters generally monitored during energy audit may include the following:

Basic Electrical Parameters in AC and DC systems – Voltage (V), Current(I)

Power factor, Active power (kW), apparent power (demand) (kVA), Reactive power (kVA), Energy consumption (kWh), Frequency (Hz),etc.

Parameters of importance other than electrical such as temperature & heat flow, radiation, air and gas flow, liquid flow, revolutions per minute (RPM), air velocity, noise and vibration, dust concentration, Total Dissolved Solids (TDS), pH, moisture content, relative humidity, flue gas analysis – CO2, O2, CO, SOx, NOx, combustion efficiency etc.

The operating instructions for all instruments must be understood and staff should familiarize themselves with the instruments and their operation prior to actual audit use.

ELECTRICAL MEASURING INSTRUMENTS

These are instruments for measuring major electrical parameters such as kVA, kW, PF, Hertz, kVAr, Amps and Volts. In addition some of these instruments also measure harmonics.

These instruments are applied on-line i.e on running motors without any need to stop the motor. Instant measurements can be taken with hand-held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals. Some commonly used.

TYPICAL ELECTRICAL INSTRUMENTS

Voltmeter

An inexpensive voltmeter is useful for determining operating voltages on electrical equipment, and especially useful when the nameplate has worn off of a piece of equipment or is otherwise unreadable or missing. The most versatile instrument is a combined volt-ohm ammeter with a clamp-on feature for measuring currents in conductors that are easily accessible. This type of multimeter is convenient and relatively inexpensive.

Wattmeter/Power Factor Meter

A portable hand-held wattmeter and power factor meter is very handy for determining the power consumption and power factor of individual motors and other inductive devices. This meter typically has a clamp-on feature which allows an easy connection to the current-carrying conductor, and has probes for voltage connections.

Clamp On Ammeter

These are very useful instruments for measuring current in a wire without having to make any live electrical connections. The clamp is opened up and put around one insulated conductor, and the meter reads the current in that conductor. New clamp on ammeters can be purchased rather inexpensively that read true RMS values. This is important because of the level of harmonics in many of our facilities. An idea of the level of harmonics in a load can be estimated from using an old non-RMS ammeter, and then a true RMS ammeter to measure the current. If there is more than a five to ten percent difference between the two readings, there is a significant harmonic content to that load.

Lux meters

A lux meter is a device for measuring brightness. It specifically measures the intensity with which the brightness appears to the human eye. This is different than measurements of the actual light energy produced by or reflected from an object or light source.

The lux is a unit of measurement of brightness, or more accurately, luminance. It ultimately derives from the candela, the standard unit of measurement for the power of light. A candela is a fixed amount, roughly equivalent to the brightness of one candle.

While the candela is a unit of energy, it has an equivalent unit known as the lumen, which measures the same light in terms of its perception by the human eye. One lumen is equivalent to the light produced in one direction from a light source rated at one candela. The lux takes into account the surface area over which this light is spread, which affects how bright it appears. One lux equals one lumen of light spread across a surface one square meter.

A lux meter works by using a photo cell to capture light. The meter then converts this light to an electrical current. Measuring this current allows the device to calculate the lux value of the light it captured.

4. TEMPARATURE MEASURING INSTRUMENTS

Several temperature measuring devices are generally needed to measure temperatures in offices and other worker areas, and to measure the temperature of operating equipment. Knowing process temperatures allows the auditor to determine process equipment efficiencies, and also to identify waste heat sources for potential heat recovery programs. Inexpensive electronic thermometers with interchangeable probes are now available to measure temperatures in both these areas. Some common types include an immersion probe, a surface temperature probe, and a radiation shielded probe for measuring true air temperature.

Some typical temperature measuring instruments used for energy audit are:

Contact Thermometer

These are thermocouples which measures for example flue gas, hot air, hot water temperatures by insertion of probe into the stream. For surface temperature, a leaf type probe is used with the same instrument.

Infrared thermometer

An infrared thermometer is a thermometer which infers temperature from a portion of the thermal radiation sometimes called blackbody radiation emitted by the object being measured. They are sometimes called laser thermometers if a laser is used to help aim the thermometer, or non-contact thermometers to describe the device's ability to measure temperature from a distance. By knowing the amount of infrared energy emitted by the object and its emissivity, the object's temperature can often be determined. Infrared thermometers can be used to serve a wide variety of temperature monitoring functions. A few examples provided to this article include:

- Detecting clouds for remote telescope operation
- Checking mechanical equipment or electrical circuit breaker boxes or outlets for hot spots
- Checking heater or oven temperature, for calibration and control purposes
- Detecting hot spots / performing diagnostics in electrical circuit board manufacturing
- Checking for hot spots in fire fighting situations

- Monitoring materials in process of heating and cooling, for research and development or manufacturing quality control situations.

  There are many varieties of infrared temperature sensing devices available today, including configurations designed for flexible and portable handheld use, as well many designed for mounting in a fixed position to serve a dedicated purpose for long periods.

5. PRESSURE AND FLOW MEASURING INSTRUMENTS

Measuring air flow from heating, air conditioning or ventilating ducts, or from other sources of air flow is one of the energy auditor's tasks. Airflow measurement devices can be used to identify problems with air flows, such as whether the combustion air flow into a gas heater is correct. Some of the typical instruments measuring air and water pressure, flow rates etc include:

Pitot Tube and manometer

Air velocity in ducts can be measured using a pitot tube and inclined manometer for further calculation of flows.

Anemometers

Two types of anemometers are available for measuring airflow: vane and hot-wire. The volume of air moving through an orifice can be determined by estimating the free area of the opening (e.g., supply air register, exhaust hood face, etc.) and multiplying by the air speed. This result is approximate due to the difficulty in determining the average air speed and the free vent area. Regular calibrations are necessary to assure the accuracy of the instrument. The anemometer can also be used to optimize the face velocity of exhaust hoods by adjusting the door opening until the anemometer indicates the desired airspeed.

Water flow meter

This non-contact flow measuring device using Doppler effect / Ultra sonic principle. There is a transmitter and receiver which are positioned on opposite sides of the pipe. The meter directly gives the flow. Water and other fluid flows can be easily measured with this meter.

Flow meters are used in fluid systems (liquid and gas) to indicate the rate of flow of the fluid. They can also control the rate of flow if they are equipped with a flow control valve.

6. MISCELLANEOUS INSTRUMENTS

Combustion Analyzer

Combustion analyzers are portable devices capable of estimating the combustion efficiency of furnaces, boilers, or other fossil fuel burning machines. Two types are available: digital analyzers and manual combustion analysis kits. Digital combustion analysis equipment performs the measurements and reads out in percent combustion efficiency. These instruments are fairly complex and expensive.

The manual combustion analysis kits typically require multiple measurements including exhaust stack: temperature, oxygen content, and carbon dioxide content. The efficiency of the combustion process can

be calculated after determining these parameters. The manual process is lengthy and is frequently subject to human error.

Fyrite Gas Analyzers

They are fast, accurate and easy to use instruments for measuring and analyzing carbon dioxide or oxygen. Fyrite absorbing fluid is selective in the chemical absorption of carbon dioxide or oxygen, respectively. Therefore, the Fyrite's accuracy, which is well within the range required for industrial and professional applications, does not depend upon complicated sequential test procedures. In addition, Fyrite readings are unaffected by the presence of most background gases in the sample.

Tachometers

In any audit exercise speed measurements are critical as they may change with frequency, belt slip and loading. A simple tachometer is a contact type instrument which can be used where direct access is possible. More sophisticated and safer ones are non contact instruments such as stroboscopes.

Mechanical stroboscopic instruments are instruments with mechanical shutters (choppers) in the form of disks or hollow cylinders with slits through which the object is observed. By measuring the disk's speed of rotation at which the object viewed through the shutter appears stationary, the frequency of the periodic motion of the object can be determined. Such instruments are called stroboscopic tachometers. The principal advantage of the stroboscopic tachometer is that it permits the angular speeds of rotation of objects to be measured without contact between the instrument and the object. Consequently, speeds can be measured for objects that are visible but not easily accessible. This advantage also permits measurement of the speeds of low-power objects without the speed being affected by the use of the instrument.

Leak Detectors

Compressed air is one of the most costly utilities in a facility today. A simple program of leak inspection and repair can go a long way towards reducing excessive energy costs.

Ultrasonic instruments are available which can be used to detect leaks of compressed air and other gases which are normally not possible to detect with human abilities. Ultrasonic Leak Detector is a hand held, high quality compressed air leak detection system that has all the features necessary for flexible use in finding costly air leaks. Ultrasonic Leak Detector is a complete kit, the high quality flexible sensor is mounted on the end of a flexible steel pipe so the ultrasonic sound sensor can access hard to reach areas. The unit converts the ultrasonic noise of a leak into a sound humans can here (hissing sound) with some beeping sound or LED display.

Fuel Efficiency Monitor

This measures oxygen and temperature of the flue gas. Calorific values of common fuels are fed into the microprocessor which calculates the combustion efficiency.

Metering and Monitoring System

Energy

Drivers

> Monitor energy consumption by different areas, different systems enables the owner to identify opportunities to save energy.

> Observe energy flow in, energy flow out and where its been used.

Level of detail

> Identify billing discrepancies

> Allocate costs/tenant billing

> Reduce peak demand, power factor penalties

> Find opportunities, verify savings

> Green standards compliance

> Reduce rates with energy suppliers

Power Monitoring

Drivers

> Maximising the efficiency and reliability of the electrical infrastructure

> Measuring the quality and quantity of power flowing through a given part of the electrical system.

Level of detail

> Increase facility uptime

> Verify reliable power equipment operation

> Improve response to power related issues

> Ensure PQ/energy contract compliance

> Network protection and control

Selection of meters

> The cost of the meter determines its limitations.

> Metering devices are constrained by hardware, firmware and software functionality.

> Complex meters provide greater accuracy, and more information

Where to measure and why?

> The most important location to measure power quality is at the main switchboard(s)

> Although every building is different, their loads can be divided into three common categories.

> Incoming power meters are designed to monitor connections points with external utility sources or local powers sources (renewable, generators)

> Critical loads power meters for critical loads or specialty equipment.

> Feeders metering to monitor power distribution that serve non-critical loads

Types of meters and their core features

Power meters (Incoming)

Energy data (active, reactive, apparent)

Electrical parameters (V, I, PF, F)

Power Quality (THD, Individual Harmonics up to 511th)

512 Samples per cycle or greater

Waveform capture, Detection of sags and swells and transients

On board logging and alarming with device time stamp

Gateway functionality

0.2% accurate

Disturbance Direction Detection

PQ standards comparison

IEC61000-4-30 Class A

Power meters (Feeder)

Energy data (active, reactive, apparent)

Electrical parameters (V, I, PF, F)

Basic Power Quality (THD, Individual harmonics up to 31st)

On board logging and alarming with device time stamp

64 Samples per cycle

0.5% accurate

Power meters (Critical Loads)

Energy data (active, reactive, apparent)

Electrical parameters (V, I, PF, F)

Power Quality (THD, Individual Harmonics up to 127st)

256 Samples per cycle or greater

Waveform capture, Detection of sags and swells and transients

On board logging and alarming with device time stamp

Gateway functionality

0.2% accurate

Disturbance Direction Detection

Disturbance Direction Detection

> Disturbance direction detection helps determine the location of a power system disturbance.

> Meter analyses the disturbance information to determine the direction of the disturbance relative to the meter.

> Analysis includes a confidence level indicating the level of certainty that the disturbance is in the determined direction.

> Disturbance direction detection is enabled on meter by default.

> The results of the disturbance direction detection algorithm appear in the meter's event log.

Incoming metering – application

Application

Energy usage monitoring

Monitor total energy usage of the building

Load monitoring

Monitor power demand to avoid penalties and help to select the best utility contract

Reliable data

On board logging allows the meter to store data even if comms is lost

Basic Power Quality monitoring

Monitor total power factor to avoid penalties

Monitor THD (Total Harmonic Distortion) to make sure electrical equipment is working within specification and

enable preventive maintenance to extend life

Advanced Power Quality event monitoring

Monitor power quality events (sags, swells, power outages, transients) and use the information to determine the

source of the event. User can use this info to ask utility for compensation in case of equipment damage

Utility bill verification

Revenue grade accuracy allows one to verify utility bills and detect billing issue.

Alarm configuration

Capturing time stamped events in a non-volatile memory

Additional Inputs

Bring other measurements such as water, gas consumed or temperature or pressure

Standards

EN50160 reporting to check incoming power supply quality

IEC61000-4-30 Class A compliant to measure harmonics to comply with G5/4-1

Incoming meter recommended features

> **High accurate** (0.2 class) equal or greater than utility meter

> **High sampling rate** (512 or higher samples per cycle) for accuracy, individual harmonics and to capture high resolution waveforms of high speed PQ events (20μS)

> **Short-term disturbances** Transients, interruption, sag and swell

> **Long-term disturbances** under voltage, over voltage, harmonics, unbalance, voltage fluctuations, power frequency variations, power factor, flicker

> **Disturbance direction detection** helps determine the location of a power system disturbance

> **On board logging with device time stamp** for reliable and accurate capture of historical trend data and Power Quality waveforms in non-volatile memory in case of loss of communications to device

> **On board alarming with device time stamp** for reliable and accurate capture of events including short-term and long-term Power Quality disturbances for diagnostics and root cause analysis purposes

> **Inputs** to bring in additional energy measurements (WAGES) from other devices or to monitor status of breakers and other equipment

> **Outputs** to share energy pulses with external sources or alarm status

> **High speed time stamping** to determine sequence of events

Critical loads – application

Application

Reliable data

On board logging allows the meter to store data even if comms is lost

Basic Power Quality monitoring

Monitor total power factor to avoid penalties

Monitor THD (Total Harmonic Distortion) to make sure electrical equipment is working within specification and enable preventive maintenance to extend life

Advanced Power Quality event monitoring

Monitor power quality events (sags, swells, transients) and use the information to determine the source of the event.

Alarm configuration

Capturing time stamped events in a non-volatile memory

Additional Inputs

Bring other measurements such as water, gas consumed or temperature or pressure

Critical load meter recommended features

> **High accurate** (0.2 class meter).

> **High sampling rate** (256 or higher samples per cycle) for accuracy, individual harmonics and to capture high resolution waveforms of high speed PQ events.

> **Short-term disturbances** Transients, sag and swell.

> **Long-term disturbances** under voltage, over voltage, harmonics, unbalance, voltage fluctuations, power frequency variations, power factor.

> **Disturbance direction detection** helps determine the location of a power system disturbance.

> **On board logging with device time stamp** for reliable and accurate capture of historical trend data and Power Quality waveforms in non-volatile memory in case of loss of communications to device.

> **On board alarming with device time stamp** for reliable and accurate capture of events including short-term and long-term Power Quality disturbances for diagnostics and root cause analysis purposes.

> **Inputs** to bring in additional energy measurements (WAGES) from other devices or to monitor status of breakers and other equipment.

> **Outputs** to share energy pulses with external sources or alarm status Confidential Property of Schneider Electric 29Feeder meter – application.

Feeder meter – Application

Energy usage monitoring

Monitor energy usage by group of area or group of loads.

Help to plan and audit energy saving activities.

Load monitoring

Monitor power demand to better manager electrical infrastructure (circuit breakers, transformers, etc.)

Help to plan and audit energy saving activities.

Avoid downtime and perform preventive maintenance to critical loads.

Reliable data

On board logging allows the meter to store data even if comms is lost.

Basic Power Quality monitoring

Monitor total power factor to identify source of anomalies and enable preventive maintenance.

Monitor THD (Total Harmonic Distortion) to make sure electrical equipment is working within specification and enable preventive maintenance to extend life.

Feeder meter recommended features

> **Good accuracy** (0.5 class meter).

> **Long-term disturbances** (under voltage, over voltage, harmonics, unbalance, power factor).

> **Onboard logging with device timestamp** for reliable and accurate capture of historical trend data in non-volatile memory in case of loss of communications to device.

> **Onboard alarming with device timestamp** for reliable and accurate capture of events including most long-term Power Quality disturbances for increasing power quality awareness and diagnostic purposes.

> **Inputs** to bring in additional energy measurements (WAGES) from other devices or to monitor status of breakers and other equipment.

> **Outputs** to share alarms status or energy pulses with external sources.

Software

> To unlock the potential behind a good power quality monitoring system is an extensive link between hardware and software.

> Hardware meters collect stores data and capture events

> Power Monitoring Software allows the user to carry out visualisation and root cause analysis.

> Features of power quality software.

> Tracking of real time power conditions.

> Analysis and isolate the source of power quality issues.

> Verify compliance with power quality standards.

> Visualisation of power quality alarms and events.

Common Power Management Applications

> Most applications involving energy or power meters are not possible without software. Software plays a

key role in common power management applications by providing the following.

> Data acquisition from multiple sources for a system wide data set.

>Long-term storage of historical metering data in a database.

> Business logic for virtual metering, aggregation and hierarchy definition.

> Ability to share power management data with other systems.

> Rich set of visualization and reporting tools.

> Many systems (BMS, EMS, SCADA) may offer energy monitoring functions do not have power monitoring capabilities.