Asia-Pacific
Economic Cooperation

Asia-Pacific
Legal Metrology Forum

APEC/APLMF Training Courses in Legal Metrology (CTI-10/2005T)
Training Course on Electricity Meters
February 28 to March 3, 2006 in Ho Chi Minh City, Vietnam

Prepared and presented by:
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2006

Introduction to the

Training Course on Electricity Meters

Electricity Meters

This course is intended to allow participants with varying levels of technical and legislative expertise to enhance their understanding of electricity measurement from a legal metrology perspective

Electricity Meters

The purpose of this course is to provide participants with an awareness of issues that may require consideration in your home economies.

Electricity Meters

Metrology, is defined as the "Science of Measurement"

Legal Metrology is intended to ensure the appropriate quality and credibility of measurements, which can result in significant benefits to society.

Electricity Meters

The measurement of electricity is a complex process. Achieving accuracy and equity in the trade of electricity requires an effective system for achieving metrological control, and a consistent application of the measured quantities.

Electricity Meters

The process of ensuring accuracy and equity in the trade of electricity requires a common understanding of:

- electricity delivery configurations,
- the measurement principles,
- the quantities being measured,
- the purpose of the measurements, and
- how accuracy and equity are achieved

Electricity Meters

This course on Electricity Meters is comprised of the following modules:

1) Introduction to Electricity Metering
2) Electricity Metering Circuits
3) Single Phase & Polyphase Load Analysis
4) Measurement Concepts
5) Demand Measurement
6) Volt-Ampere Demand Measurement
7) Basic Induction Meter
8) Electronic Metering
9) Type Approval of Electricity Meters
10) Verification & Test Methods
11) Reverification Intervals
12) In-Service Compliance Programs
13) Measurement Standards & Test Equipment
14) Measurement Dispute Investigations

Electricity Meters

There are a number of ways
to measure electricity.
Measurement accuracy
will not necessarily result in equity
if the accurate measurements are used
in an inappropriate or inconsistent
manner.

Electricity Meters

This session is designed to focus on the
principles of electricity measurement
that are required to more effectively
achieve an acceptable level
of accuracy and equity
in the trade of electricity.

Electricity Meters

Questions?

Comments?

Next: Electricity Distribution Systems

Electricity Distribution Systems

Electricity Distribution Systems

The transmission and distribution of alternating current electricity typically ranges from 100 volts for residential consumers to 500,000 volts or greater for transmission lines.

The frequency is usually 50 or 60 hertz, or cycles per second, but other frequencies are sometimes used.

Electricity Distribution Systems

Electricity Measurement Points:

- Generation plants
- High voltage transmission lines
- Transmission interchange sites
- Distribution substations
- Industrial operations
- Commercial operations
- Apartment complexes
- Urban residential services
- Rural services

Electricity Distribution Systems

Distribution Systems may deliver electricity using the following service configurations:

- Single Phase 2-wire
- Single Phase 3-wire
- Polyphase 3-wire Network
- Polyphase 3-wire Delta
- Polyphase 4-wire Delta
- Polyphase 4-wire Wye

Electricity Distribution Systems

Single Phase 2-wire:

A common residential service in many parts of the world which provides a single voltage, usually 100 to 240 volts

Single Phase 3-wire:

A common residential service in North America which provides 2 voltages, 120 volts and 240 volts

Electricity Distribution Systems

Polyphase 3-wire Network:

Common in apartment buildings where it provides 120 volts and 208 volts.

Polyphase 3-wire Delta:

Generally used in industrial operations or for a single polyphase motor load such as water pumping station.

Electricity Distribution Systems

Polyphase 4-wire Delta:

Sometimes used in supplying electricity to sparsely populated rural areas.

It is an economical way of providing a combination of a single phase 3-wire service and a limited supply of polyphase power.

Electricity Distribution Systems

Polyphase 4-wire Wye:

Commonly used for industrial and commercial operations.

It is widely used for electricity distribution systems, where it is transformed to other suitable service configurations.

Electricity Distribution Systems

During this session the electricity metering for these various service types will be examined.

Electricity Distribution Systems

Questions?

Comments?

Next: Sine Wave and Phasor (Vector) Concepts

Sine Wave and Phasor (Vector) Concepts

Sine Wave and Phasor Concepts

Electrical power in alternating current systems can be visually represented in different ways, including the use of sine waves and phasors.

The type of circuit evaluation required will determine the method used.

Sine Wave and Phasor Concepts

Sine waves are useful for illustrating the quality of the alternating current and voltage wave forms, including the effects of harmonic distortion.

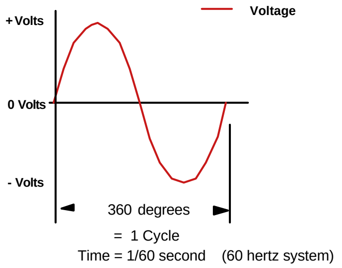
Phasors (vectors) are useful in determining how an electricity meter will respond in calculating electrical power and energy.

Sine Wave and Phasor Concepts

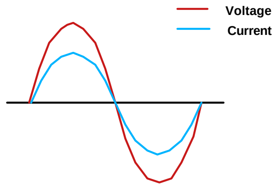
Much of this course will involve the visual representation of electricity within metering circuits.

This portion of the session is intended to ensure a common understanding of the methods used.

Sine Wave and Phasor Concepts

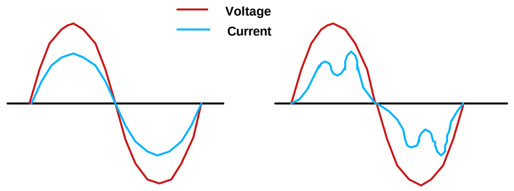


Sine Wave and Phasor Concepts



Voltage and Current "in phase"
shown as true (pure) sine waves

Sine Wave and Phasor Concepts

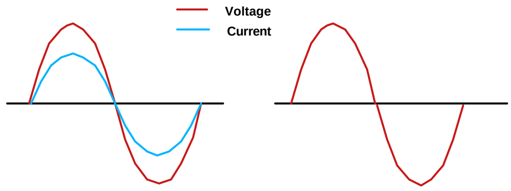


Current as a true sine wave   Current shown with distortion

The load may cause distortion in both the current and voltage wave forms.

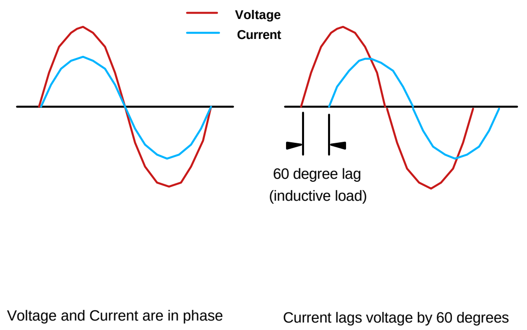
Distortion may cause excessive conductor heating, voltage drops, and line losses

Sine Wave and Phasor Concepts

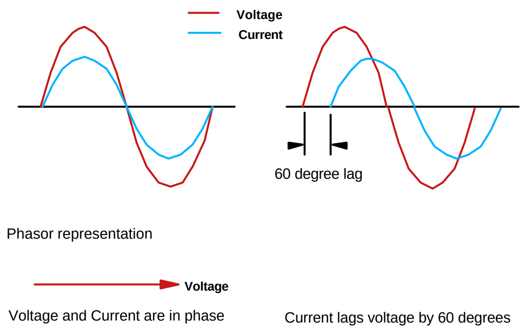


Voltage and Current are in phase

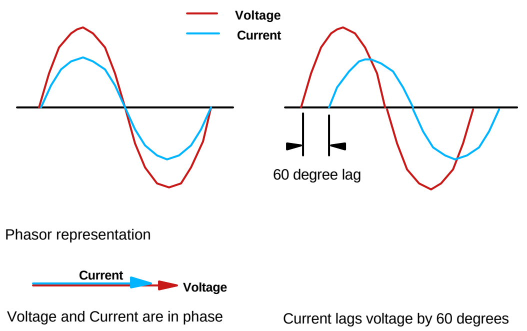
Sine Wave and Phasor Concepts



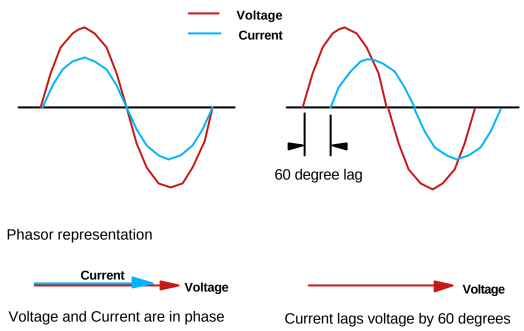
Sine Wave and Phasor Concepts



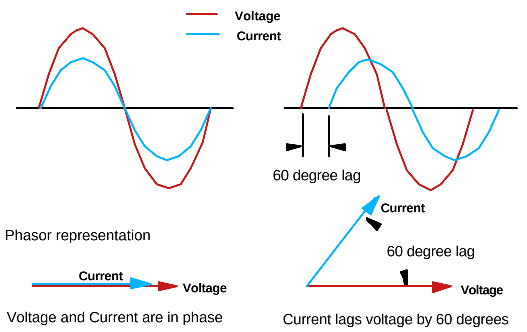
Sine Wave and Phasor Concepts



Sine Wave and Phasor Concepts



Sine Wave and Phasor Concepts



Phasors used in Power Calculations

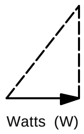
The relationship between the phasors can be used to determine:

- Phase angle - in degrees lead or lag
- Active power - in Watts (W)
- Reactive power - in Reactive Volt-Amperes (VARs)
- Apparent power - in Volt-Amperes (VA)
- Power factor - as a ratio or percent

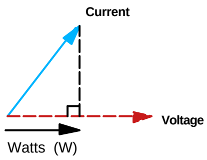
This can be demonstrated using the circuit from the previous example

Phasors used in Power Calculations

The relationship between the phasors can be used to calculate Watts:

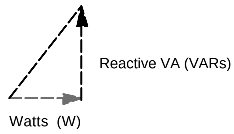


Active power (Watts) is comprised of the portion of the current which is in phase with the voltage (the "in phase component")

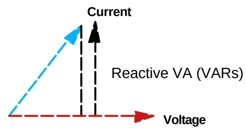


Phasors used in Power Calculations

The relationship between the phasors can be used to calculate Reactive Volt-amperes:

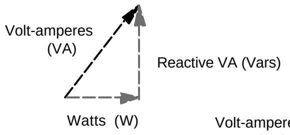


Reactive power (VARs) is comprised of the portion of the current which is 90 degrees out of phase with the voltage

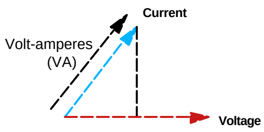


Phasors used in Power Calculations

The relationship between the phasors can be used to calculate Volt-amperes:

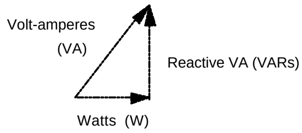


Apparent power (VA) is comprised of the total current, without regard to phase angle.

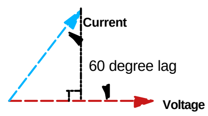


Phasors used in Power Calculations

The relationship between the phasors can be used to calculate values using the Power Triangle



The value of any quantity can be determined using:
1) any other two values, or
2) one other value and the phase angle



Power Meters

Watt (W) meter:
Measures active electrical power, normally displayed as kW.

Reactive Volt-Ampere (VAR) meter:
Measures reactive electrical power, normally displayed as kVAR.

Volt-Ampere (VA) meter
Measures apparent electrical power, normally displayed as kVA.

Energy Meters

Watt hour (Wh) meter:
Measures active electrical energy, integrating active power with respect to time, normally displayed as kWh.

VAR hour (VARh) meter:
Measures reactive electrical energy, integrating reactive power with respect to time, normally displayed as kVARh.

VA hour (VAh) meter
Measures apparent electrical energy, integrating apparent power with respect to time, normally displayed as kVAh.

Electrical Power and Energy

Power - the rate of energy output or transfer

Energy - capacity to do work
- integration of power over time

The methods for calculation of these values will be covered in more detail later in the course.

Sine Wave and Phasor Concepts

Questions?

Comments?

Electricity Metering Circuits

Prepared and presented by:
George A. Smith, Measurement Canada
Paul G. Rivers, Measurement Canada
2006

Electricity Metering Circuits

1 Phase Metering

Various methods are used to
supply and measure
1 Phase (Single Phase) electricity

Electricity Metering Circuits

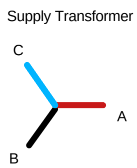
1 Phase Metering

1 Phase (single phase) supply methods:
1 Phase 2-Wire supply,
1 Phase 3-Wire supply,

1 Phase (single phase) metering methods:
1 Phase 1 Element meter
1 Phase 1.5 Element meter,
1 Phase 2 Element meter

Electricity Metering Circuits

1 Phase 2-Wire

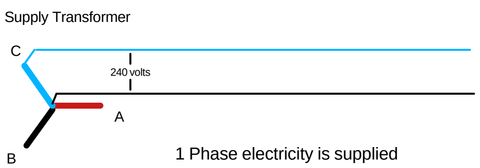


1 Phase 2-Wire services are typically supplied from a 3 Phase supply transformer.

The 3 Phase supply transformer is shown as a 3 Phase 4-wire Wye configuration, using a different color for each phase voltage.

Electricity Metering Circuits

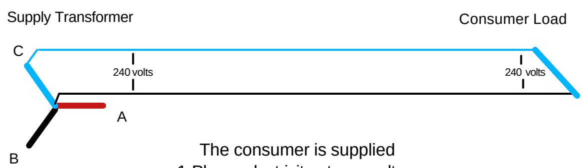
1 Phase 2-Wire



1 Phase electricity is supplied
by one of the 3 phases

Electricity Metering Circuits

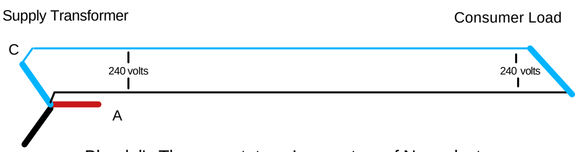
1 Phase 2-Wire



The consumer is supplied
1 Phase electricity at one voltage

Electricity Metering Circuits

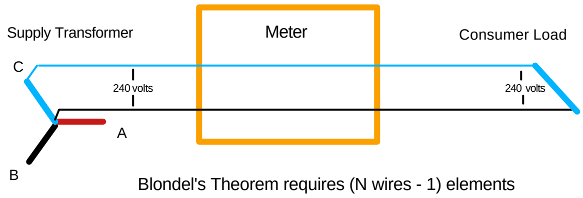
Blondel's Theorum



Blondel's Theorum states: In a system of N conductors, N-1 metering elements, properly connected, will measure the power or energy taken.
The connection must be such that all voltage coils have a common tie to the conductor in which there is no current coil.

Electricity Metering Circuits

1 Phase 2-Wire

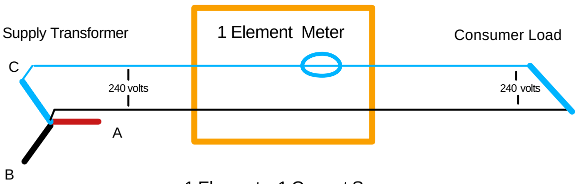


Blondel's Theorem requires (N wires - 1) elements

1 Element = 1 Current Sensor + 1 Voltage Sensor

Electricity Metering Circuits

1 Phase 2-Wire

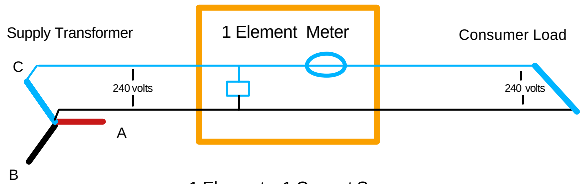


1 Element: 1 Current Sensor
1 Voltage Sensor

= Current Sensor

Electricity Metering Circuits

1 Phase 2-Wire

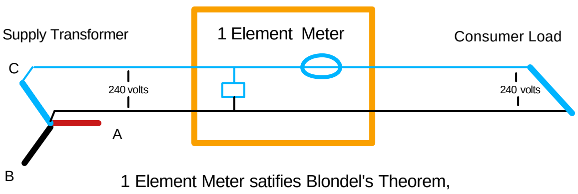


1 Element: 1 Current Sensor
1 Voltage Sensor

= Current Sensor = Voltage Sensor

Electricity Metering Circuits

1 Phase 2-Wire



1 Element Meter satifies Blondel's Theorem, and provides accurate measurement

= Current Sensor = Voltage Sensor

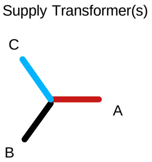
Electricity Metering Circuits

1 Phase 3-Wire

1 Phase 3-Wire services are the common method of supplying electricity to homes in North America

Electricity Metering Circuits

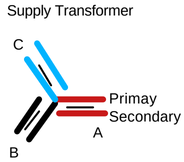
1 Phase 3-Wire



1 Phase 3-Wire services are typically supplied from a 3 Phase supply

Electricity Metering Circuits

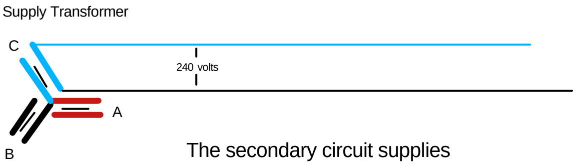
1 Phase 3-Wire



The transformer secondary circuits are isolated from the primary circuits

Electricity Metering Circuits

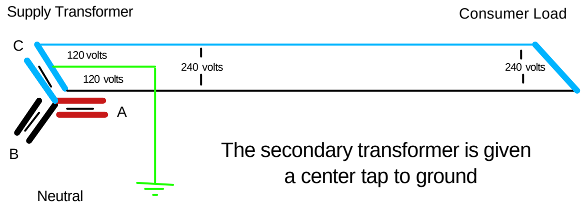
1 Phase 3-Wire



The secondary circuit supplies electricity to the consumer

Electricity Metering Circuits

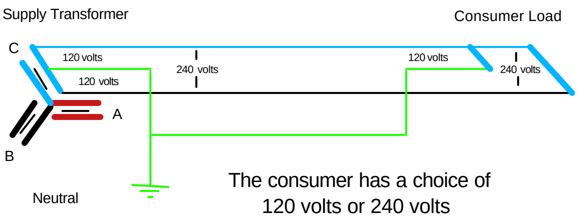
1 Phase 3-Wire



The secondary transformer is given a center tap to ground

Electricity Metering Circuits

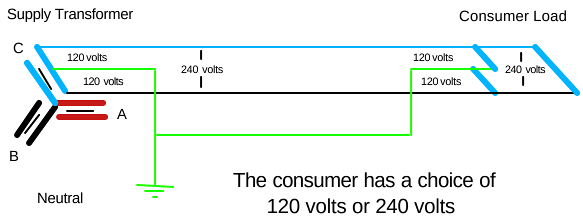
1 Phase 3-Wire



The consumer has a choice of 120 volts or 240 volts

Electricity Metering Circuits

1 Phase 3-Wire



The consumer has a choice of 120 volts or 240 volts

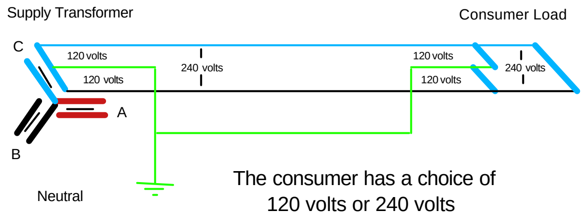
Electricity Metering Circuits

1 Phase 3-Wire

1 Phase 3-Wire service
using a Blondel Compliant
2 Element meter

Electricity Metering Circuits

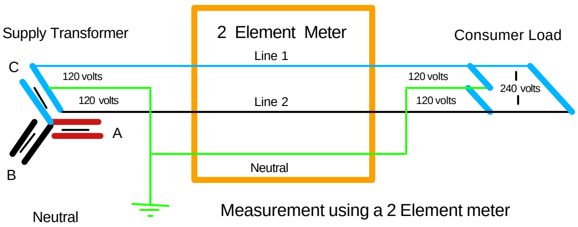
1 Phase 3-Wire



The consumer has a choice of
120 volts or 240 volts

Electricity Metering Circuits

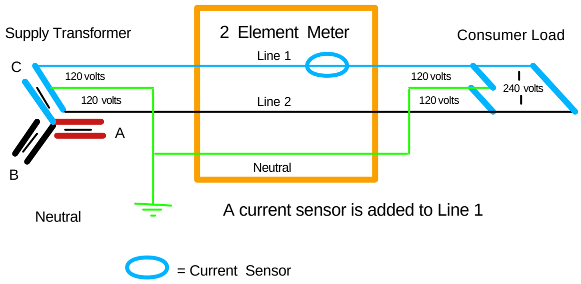
1 Phase 3-Wire



Measurement using a 2 Element meter

Electricity Metering Circuits

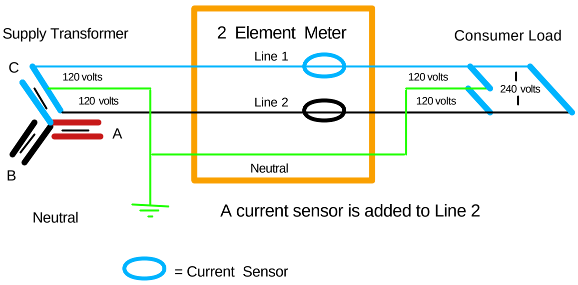
1 Phase 3-Wire



A current sensor is added to Line 1

Electricity Metering Circuits

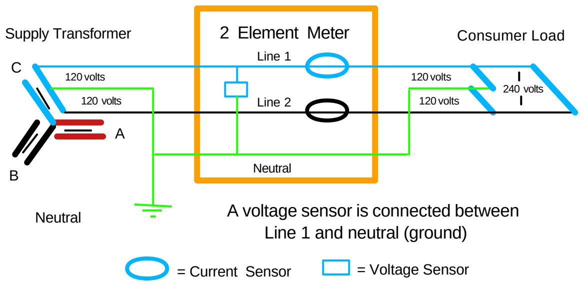
1 Phase 3-Wire



A current sensor is added to Line 2

Electricity Metering Circuits

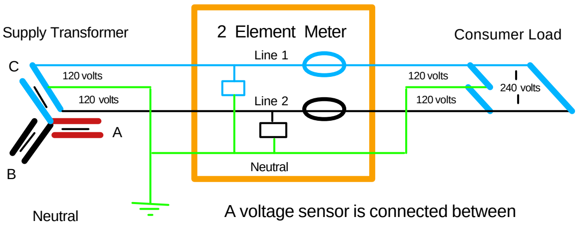
1 Phase 3-Wire



A voltage sensor is connected between
Line 1 and neutral (ground)

Electricity Metering Circuits

1 Phase 3-Wire

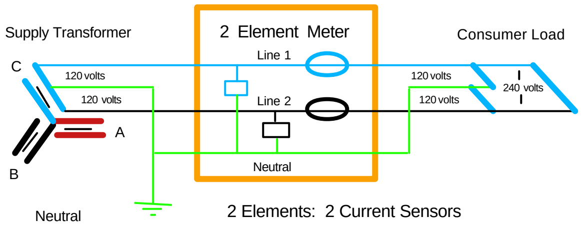


A voltage sensor is connected between Line 2 and neutral (ground)

= Current Sensor = Voltage Sensor

Electricity Metering Circuits

1 Phase 3-Wire

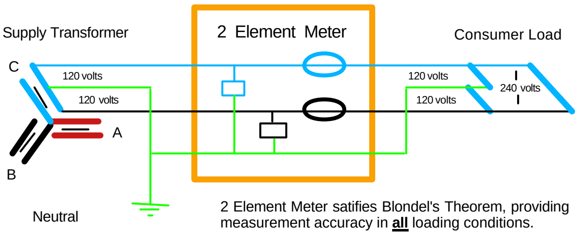


2 Elements: 2 Current Sensors
2 Voltage Sensors

= Current Sensor = Voltage Sensor

Electricity Metering Circuits

1 Phase 3-Wire



2 Element Meter satifies Blondel's Theorem, providing measurement accuracy in **all** loading conditions.

= Current Sensor = Voltage Sensor

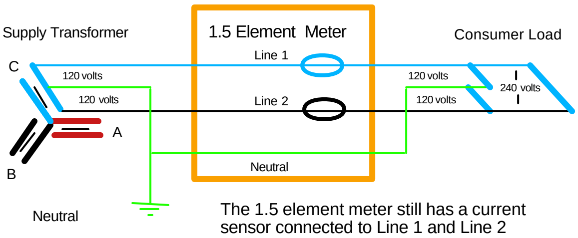
Electricity Metering Circuits

1 Phase 3-Wire

1 Phase 3-Wire service
using a Non Blondel Compliant
1.5 Element meter

Electricity Metering Circuits

1 Phase 3-Wire

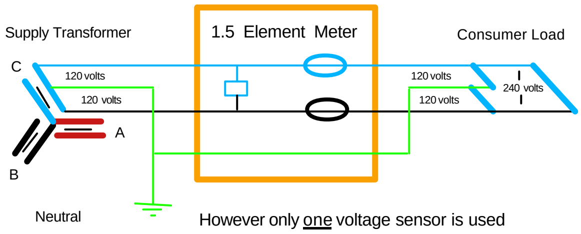


The 1.5 element meter still has a current sensor connected to Line 1 and Line 2

= Current Sensor

Electricity Metering Circuits

1 Phase 3-Wire

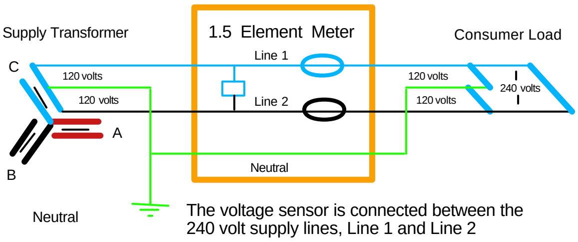


However only one voltage sensor is used

= Current Sensor = Voltage Sensor

Electricity Metering Circuits

1 Phase 3-Wire

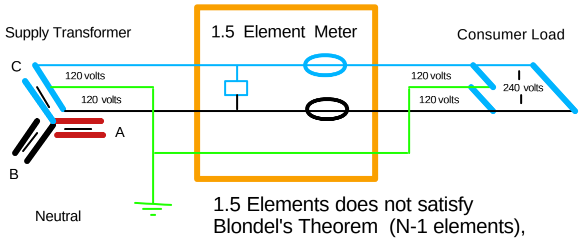


The voltage sensor is connected between the 240 volt supply lines, Line 1 and Line 2

= Current Sensor = Voltage Sensor

Electricity Metering Circuits

1 Phase 3-Wire

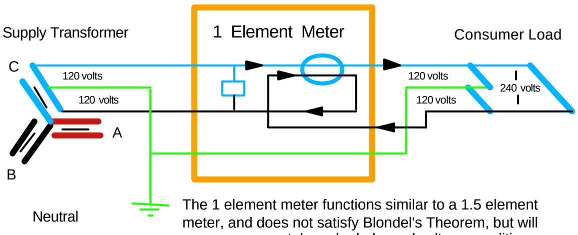


1.5 Elements does not satisfy Blondel's Theorem (N-1 elements), however it will measure accurately under <u>balanced voltage</u> conditions.

Electricity Metering Circuits

1 Phase 3-Wire

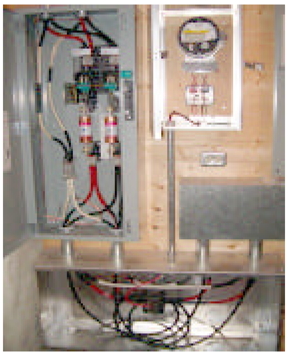
<u>Transformer Type Installation</u>



The 1 element meter functions similar to a 1.5 element meter, and does not satisfy Blondel's Theorem, but will measure accurately under <u>balanced voltage</u> conditions.

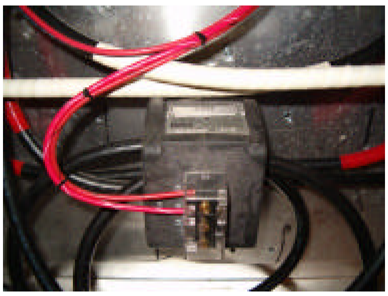
= Ring Style Current Transformer = Voltage Sensor

Electricity Metering Circuits

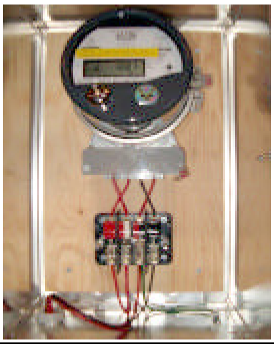


Electricity Metering Circuits

Electricity Metering Circuits



Electricity Metering Circuits



Electricity Metering Circuits

1 Phase Metering

Questions?

Comments?

Next: 3 Phase 4-Wire Open Delta

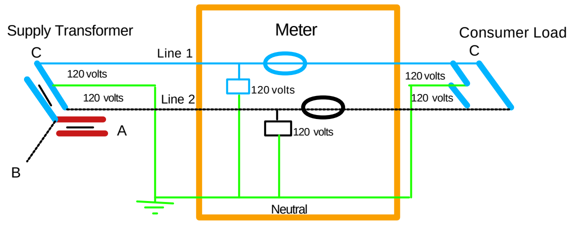
Electricity Metering Circuits

3 Phase 4-Wire Open Delta

The 3 Phase 4-Wire open delta service is an economical way of providing a combination of a single phase 3-wire service and a limited supply of polyphase power.

Electricity Metering Circuits

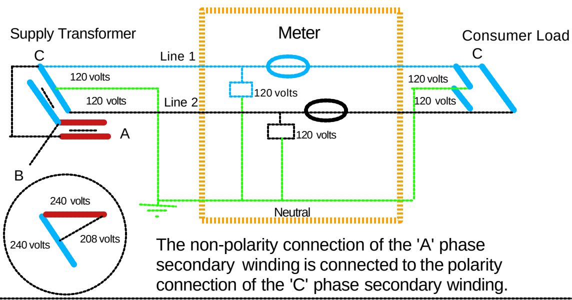
3 Phase 4-Wire Open Delta



The service configuration begins as a single phase 3-wire service.

Electricity Metering Circuits

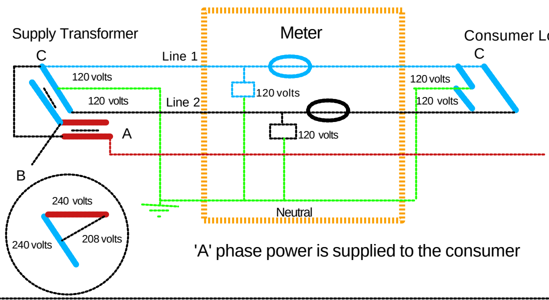
3 Phase 4-Wire Open Delta



The non-polarity connection of the 'A' phase secondary winding is connected to the polarity connection of the 'C' phase secondary winding.

Electricity Metering Circuits

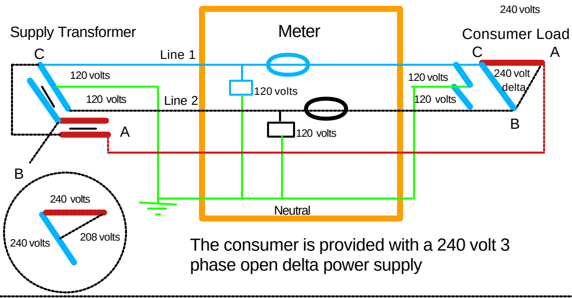
3 Phase 4-Wire Open Delta



'A' phase power is supplied to the consumer

Electricity Metering Circuits

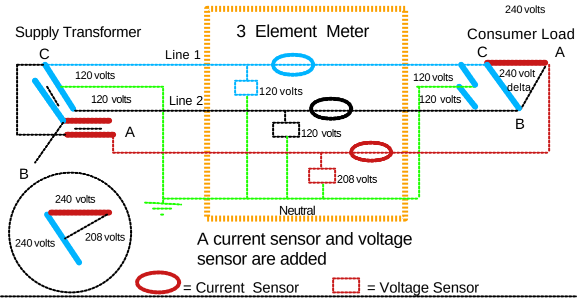
3 Phase 4-Wire Open Delta



The consumer is provided with a 240 volt 3 phase open delta power supply

Electricity Metering Circuits

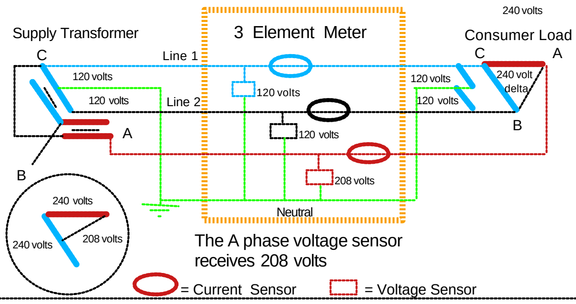
3 Phase 4-Wire Open Delta



A current sensor and voltage sensor are added

Electricity Metering Circuits

3 Phase 4-Wire Open Delta



The A phase voltage sensor receives 208 volts

Electricity Metering Circuits

3 Phase 4-Wire Open Delta

Questions?

Comments?

Next: Polyphase Supply & Metering Methods

Electricity Metering Circuits

Polyphase Metering

Various methods are used to supply and measure polyphase electricity

Electricity Metering Circuits

Polyphase supply methods
- 3 Phase 4-Wire Wye,
- 3 Phase 3-Wire Wye (grounded)
- 2 Phase 3-Wire Wye (network)

Polyphase metering methods:
- 2 Element meter,
- 2.5 Element meter,
- 3 Element meter

Electricity Metering Circuits

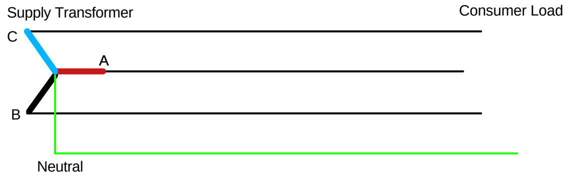
3 Phase 4-Wire Wye Service

3 Phase 4-Wire services
are a common method of
supplying polyphase electricity
to commercial and
industrial consumers

Electricity Metering Circuits

3 Phase 4-Wire Wye Service

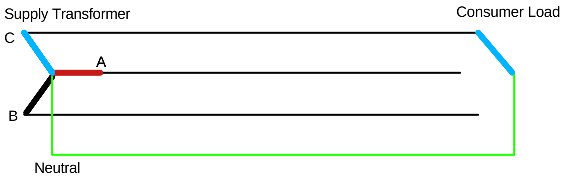
has a grounded neutral conductor



3 Phase 4-Wire Wye supply

Electricity Metering Circuits

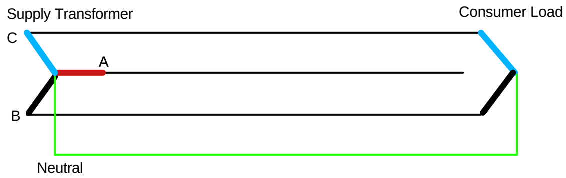
3 Phase 4-Wire Wye Service



A 1 phase load is applied

Electricity Metering Circuits

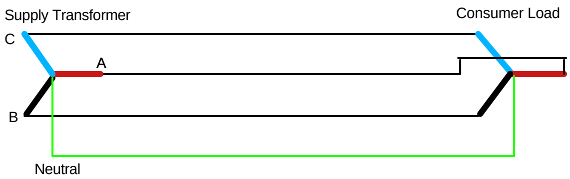
3 Phase 4-Wire Wye Service



A 2 phase load is applied

Electricity Metering Circuits

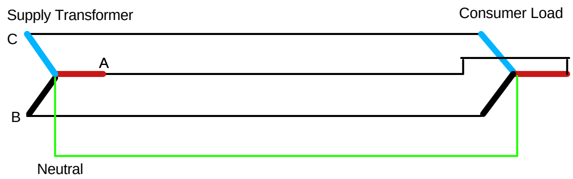
3 Phase 4-Wire Wye Service



A 3 phase load is applied

Electricity Metering Circuits

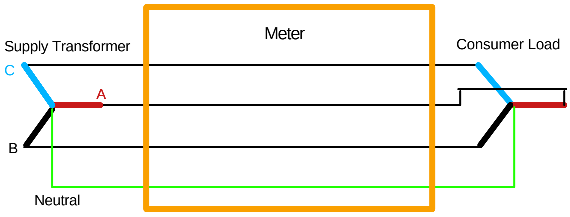
3 Phase 4-Wire Wye Service



Blondel's Theorem requires N-1 elements

Electricity Metering Circuits

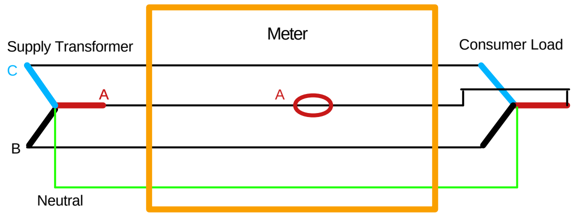
3 Phase 4-Wire Wye Service



A 3 element meter is recommended

Electricity Metering Circuits

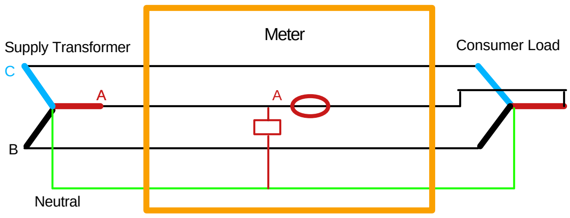
3 Phase 4-Wire Wye Service



= Current Sensor

Electricity Metering Circuits

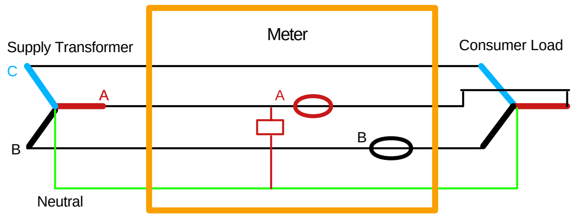
3 Phase 4-Wire Wye Service



= Current Sensor = Voltage Sensor

Electricity Metering Circuits

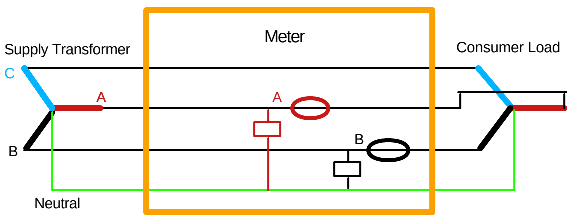
3 Phase 4-Wire Wye Service



= Current Sensor = Voltage Sensor

Electricity Metering Circuits

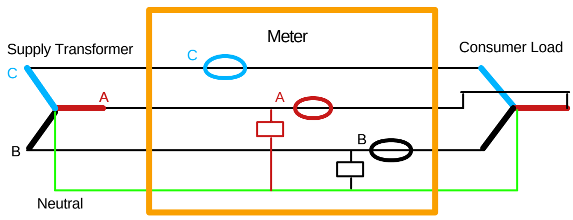
3 Phase 4-Wire Wye Service



= Current Sensor = Voltage Sensor

Electricity Metering Circuits

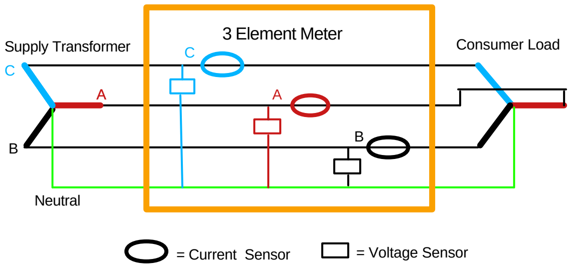
3 Phase 4-Wire Wye Service



= Current Sensor = Voltage Sensor

Electricity Metering Circuits

3 Phase 4-Wire Wye Service

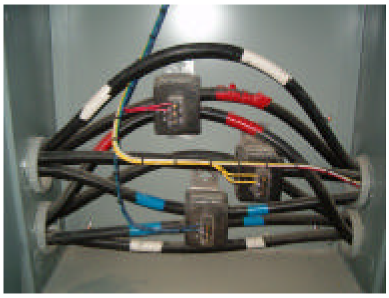


Colour coding of the supply wires to a transformer type meter will reduce the probability of wiring errors. In Canada, the color code is as follows:

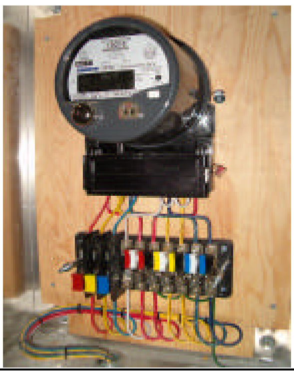
Red --------------------------- A phase voltage
Yellow ----------------------- B phase voltage
Blue -------------------------- C phase voltage
White ------------------------ Neutral
Green ------------------------ Ground
Red with White tracer - A phase current, polarity
Red with Black tracer - A phase current, return
Yellow with White tracer - B phase current, polarity
Yellow with Black tracer - B phase current, return
Blue with White tracer - C phase current, polarity
Blue with Black tracer - C phase current, return

Electricity Metering Circuits

3 Element Wye Meter Installation Current Tranformers



3 Element Meter Installation



Electricity Metering Circuits

3 Phase 4-Wire Wye Service

Questions?

Comments?

Next: 3 Phase 4-Wire Wye, 2.5 element meter

Electricity Metering Circuits

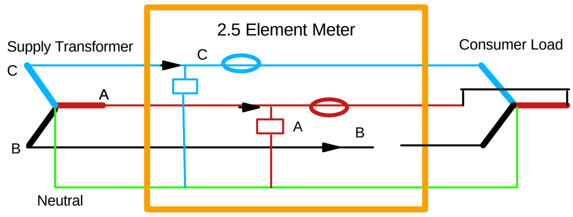
3 Phase Metering

3 Phase 4-Wire Wye service
is sometimes fitted with a
2.5 element meter

Electricity Metering Circuits

3 Phase 4-Wire Wye Service

2.5 element meter

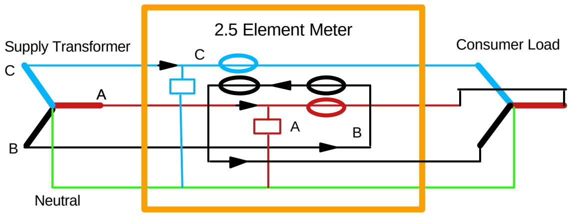


A phase and C phase are complete elements

Electricity Metering Circuits

3 Phase 4-Wire Wye Service

2.5 element meter

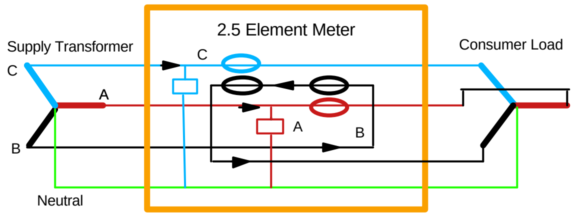


B phase voltage is not measured (1/2 element)
If the voltage is not balanced, errors will occur

Electricity Metering Circuits

3 Phase 4-Wire Wye Service

2.5 element meter



The 2.5 element meter is <u>not recommended</u>

Electricity Metering Circuits

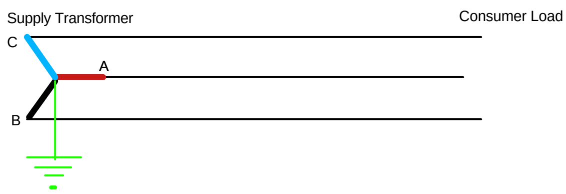
3 Phase 3-Wire Grounded Wye

3 Phase 3-Wire grounded Wye
may be used for high voltage
transmission lines

Electricity Metering Circuits

3 Phase 3-Wire Grounded Wye

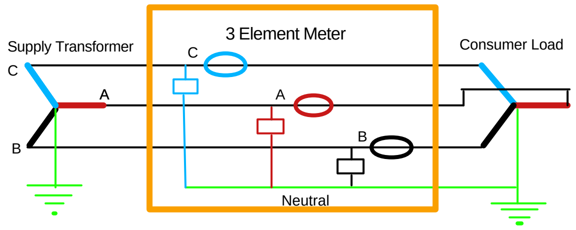
may be used for high voltage transmission lines



3 Phase 3-Wire Wye supply (grounded)

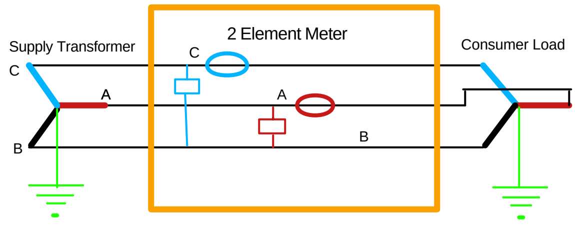
Electricity Metering Circuits

3 Phase 3-Wire Grounded Wye



Electricity Metering Circuits

3 Phase 3-Wire Grounded Wye



2 element metering is accurate if there is no ground current

Electricity Metering Circuits

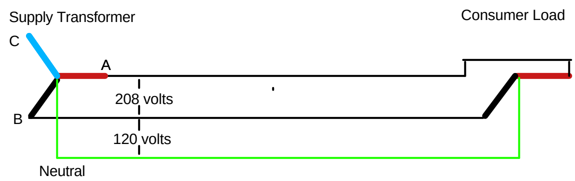
3 Phase 3-Wire Network Service

3 Phase 3-Wire Network services
are a common method of providing
both 120 and 208 volt electricity
to apartment complexes

Electricity Metering Circuits

3 Phase 3-Wire Network Service

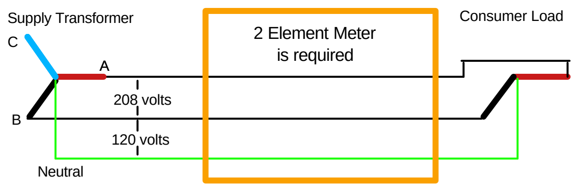
120 / 208 volt load



Electricity Metering Circuits

3 Phase 3-Wire Network Service

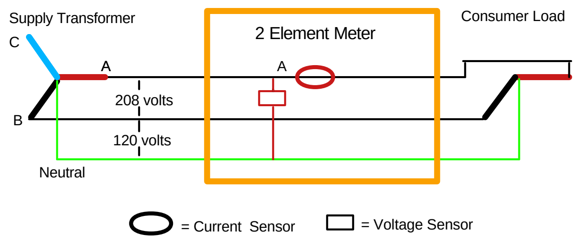
120 / 208 volt load



Electricity Metering Circuits

3 Phase 3-Wire Network Service

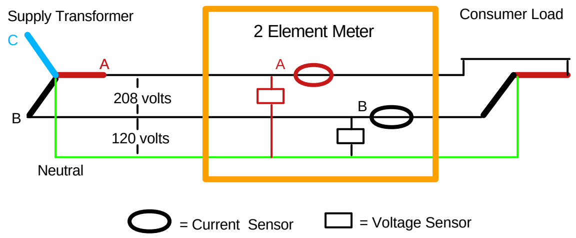
120 / 208 volt load



Electricity Metering Circuits

3 Phase 3-Wire Network Service

120 / 208 volt load



Electricity Metering Circuits

120/208v Network meters in an apartment complex

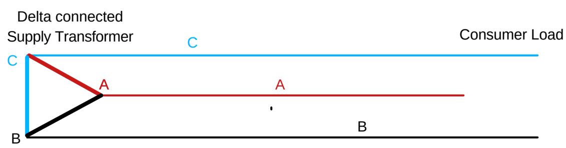
Electricity Metering Circuits

3 Phase 3-Wire Delta Service

3 Phase 3-Wire Delta services are a common method of providing 3 phase electricity to large motor loads such as pumping stations

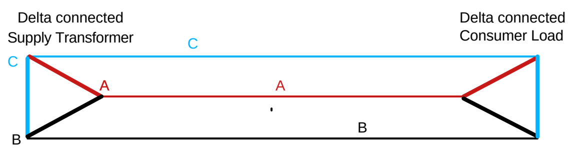
Electricity Metering Circuits

3 Phase 3-Wire Delta Service



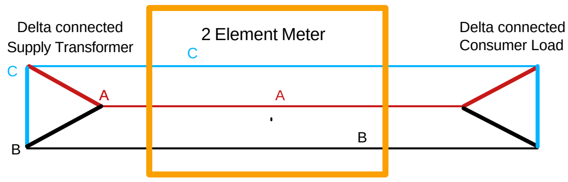
Electricity Metering Circuits

3 Phase 3-Wire Delta Service



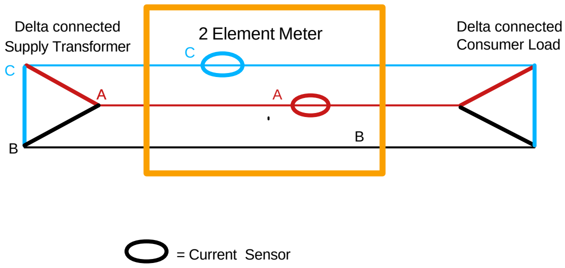
Electricity Metering Circuits

3 Phase 3-Wire Delta Service



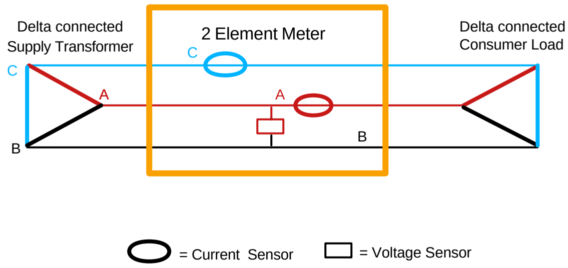
Electricity Metering Circuits

3 Phase 3-Wire Delta Service



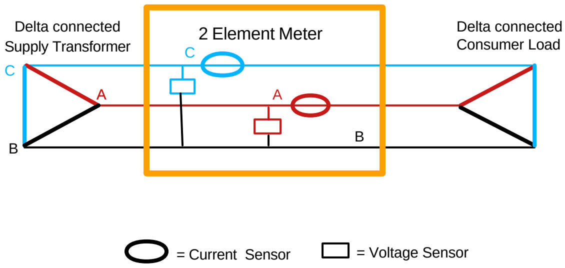
Electricity Metering Circuits

3 Phase 3-Wire Delta Service



Electricity Metering Circuits

3 Phase 3-Wire Delta Service



Electricity Metering Circuits

Questions?

Comments?

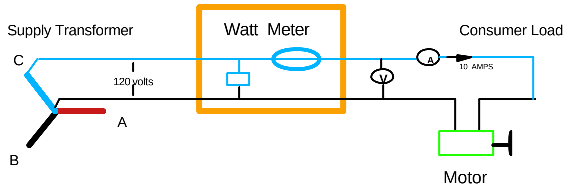
Single Phase and Polyphase Load Analysis

Prepared and presented by:
George A. Smith, Measurement Canada
Paul G. Rivers, Measurement Canada
2006

Single Phase Load Analysis

- Single Phase 2-Wire Load
- Single Phase 2-Wire Service
  1.0 Element Meter
- Single Phase 3-Wire Service
  2 Element Meter
  1.5 Element Meter

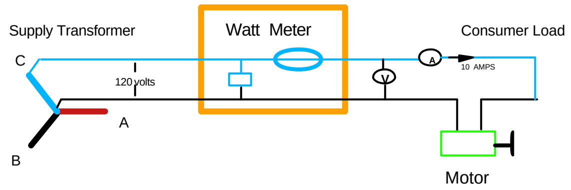
Single Phase 2-Wire Load



The above drawing shows a simple single phase motor circuit, which contains a wattmeter, an ammeter and a voltmeter.

The basic principles here apply equally to polyphase circuits.

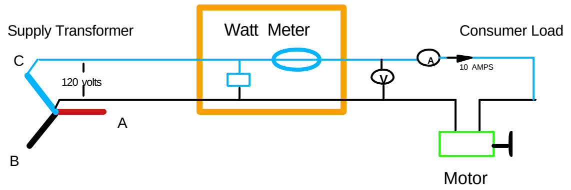
Single Phase 2-Wire Load



The motor contains many turns in the internal coil windings. The current is therefore inductive as well as resistive and will cause a magnetic field to be present.

As a result the current will lag the voltage. In this case, let's assume the lag to be 30 degrees.

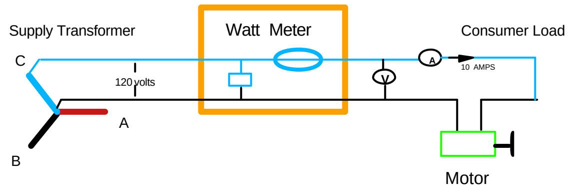
Single Phase 2-Wire Load



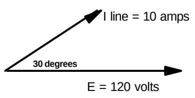
Apparent Power is equal to the voltage times the current and is expressed in volt-amperes (VA) or more commonly in KVA

This is the power which the utility delivers to the customer and is measured by the voltmeter and ammeter.

Single Phase 2-Wire Load

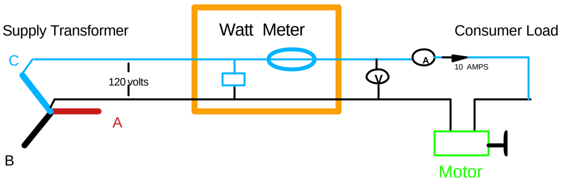


Apparent Power = E x I
= 120volts x 10amps
= 1200 VA



Note: E = volts
I = amperes

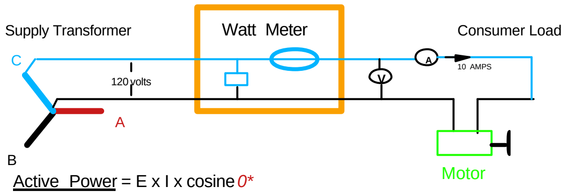
Single Phase 2-Wire Load



Active Power is equal to the voltage times the in phase component of the current and is expressed in watts (W) or more commonly in kW.

This is the power which is used to drive the shaft in the electric motor and is the power which is of value to the customer and measured by the wattmeter

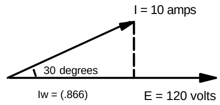
Single Phase 2-Wire Load



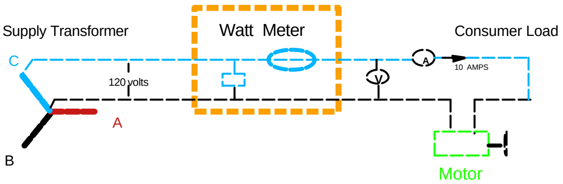
Active Power = E x I x cosine *0**
= 120volts x 10amps x cos 30 degrees
= 1200 VA x .866
= 1039.2 watts

The Phase angle or Power Factor affects the magnitude of Active Power Measurement

*0** = theta = phase angle of the current



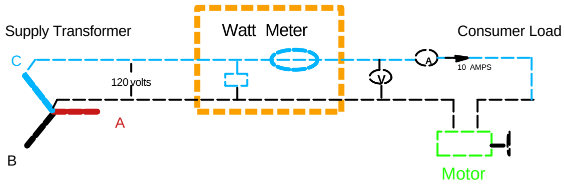
Single Phase 2-Wire Load



Reactive Power is equal to the voltage times the component of the line current which is displaced from the voltage by 90 degrees and is expressed in volt amp reactance (vars) or more commonly in KVARs.

This is the power which is required to create and maintain the magnetic field in the electric motor. Reactive Power represents the reactive losses created by the customers motor.

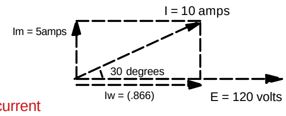
Single Phase 2-Wire Load



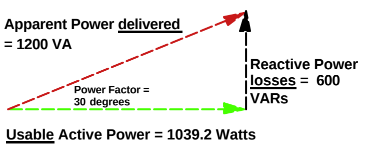
Reactive Power = E x I x sine *0**
= 120 volts x 10 amps x 0.5
= 600 VARs

The Phase angle or Power Factor also affects the magnitude of the Reactive Power

0 = Theta* = phase angle of the current



Single Phase 2-Wire Load



The power triangle for this circuit reveals the apparent power delivered, the active power used by the consumer, and the reactive power losses.

Single Phase 2-Wire Load

Questions?

Comments?

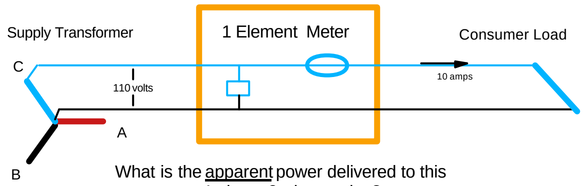
Next: Single Phase 2-Wire Service

Single Phase Load Analysis

Single Phase 2-Wire Service

1 Element Meter

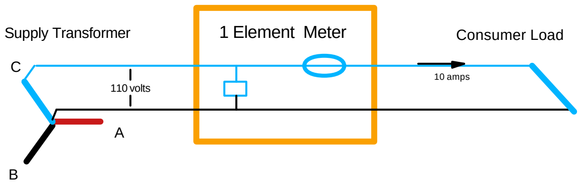
Single Phase 2-Wire Service



What is the apparent power delivered to this consumers 1 phase 2 wire service?

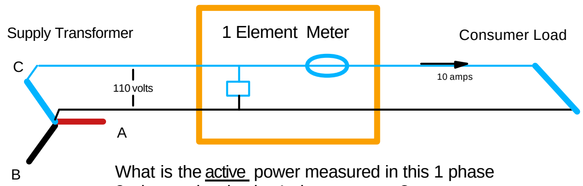
Service is 110 volts, Load is drawing 10amps, unity power factor

Single Phase 2-Wire Service



Apparent Power = E x I
Apparent Power = 110volts x 10amps
Apparent Power = 1100 va

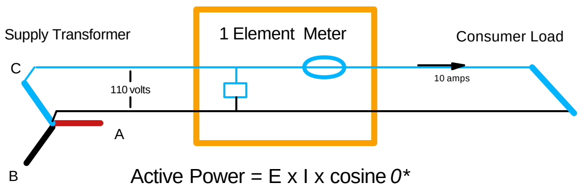
Single Phase 2-Wire Service



What is the active power measured in this 1 phase 2 wire service, by the 1 element meter?

Service is 110 volts, Load is drawing 10amps, unity power factor

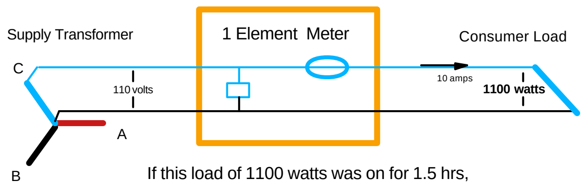
Single Phase 2-Wire Service



Active Power = E x I x cosine *0**
Active Power = 110 volts x 10 amps x 1.0
Active Power = 1100 watts

*0** = theta = phase angle of the current

Single Phase 2-Wire Service



If this load of 1100 watts was on for 1.5 hrs, the meter would register the following energy.

Energy = Active Power x Time
= 1100watts x 1.5hrs
= 1650 watthours

Single Phase 2-Wire Service

Questions?

Comments?

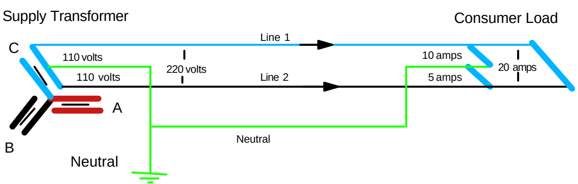
Next: Single Phase 3-Wire Service, 2 Element Meter

Single Phase Load Analysis

Single Phase 3-Wire Service

2 Element Meter

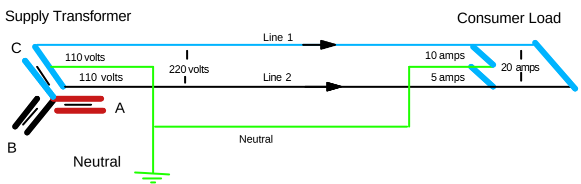
Single Phase 3-Wire Service, 2 Element Meter



How much active power is the consumers load drawing?

Note : Unity power factor

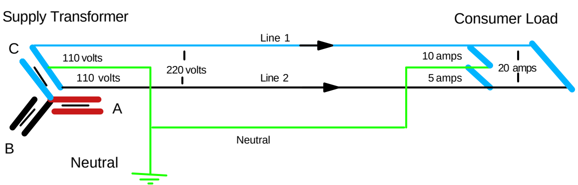
Single Phase 3-Wire Service, 2 Element Meter



Active Power = Load 1 + Load 2 + Load 3
= (E x I x cos0*) + (E x I x cos0*) + (E x I x cos0*)

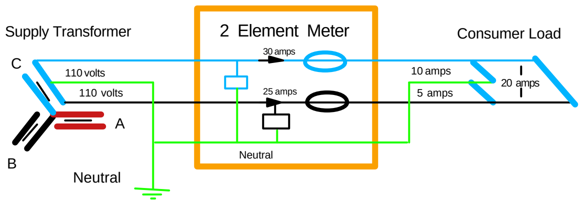
E = Voltage, I = Current, PF = 1.0, 0* = theta = phase angle of the current

Single Phase 3-Wire Service, 2 Element Meter



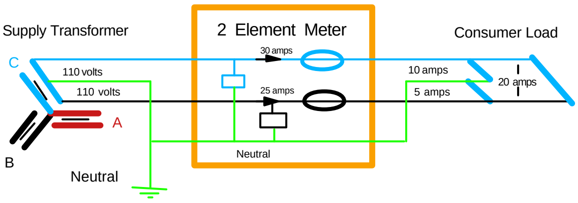
Active Power = (E x I x cos0*) + (E x I x cos0*) + (E x I x cos0*)
= (110v x 10a x 1.0) + (110v x 5a x 1.0) + (220v x 20a x 1.0)
= (1100 watts) + (550 watts) + (4400 watts)
= 6050 watts

Single Phase 3-Wire Service, 2 Element Meter



How much active power is the <u>2 element</u> meter measuring?

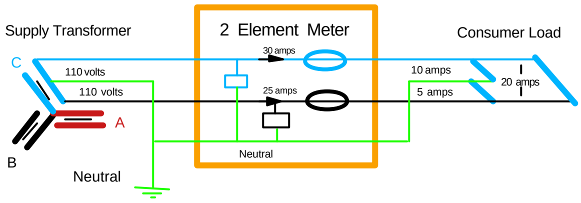
Single Phase 3-Wire Service, 2 Element Meter



Active Power (meter) = (Element 1) + (Element 2)

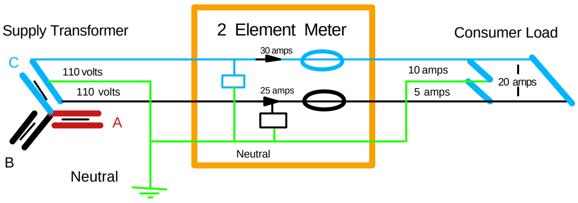
Element = One voltage sensor and one current sensor

Single Phase 3-Wire Service, 2 Element Meter



Active Power = (Element 1) + (Element 2)
= (E x I x cos*0*) + (E x I x cos*0*)
= (110v x 30a x 1.0) + (110v x 25a x 1.0)
= (3300watts) + (2750watts)
Active Power = 6050watts

Single Phase 3-Wire Service, 2 Element Meter



Active Power calculated for the load = 6050 watts
Active Power indicated by the meter = 6050 watts

Single Phase 3-Wire Service, 2 Element Meter

Questions?

Comments?

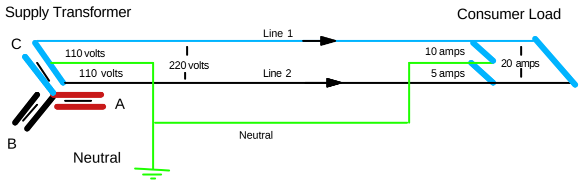
Next: Single Phase 3-Wire Service, 1.5 Element Meter

Single Phase Load Analysis

Single Phase 3-Wire Service

1.5 Element Meter

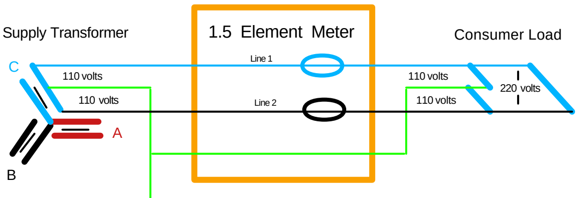
Single Phase 3-Wire Service, 1.5 Element Meter



Using the same load conditions as with the 2 element meter, let's see if a 1.5 element meter can also accurately measure this load?

Active Power (load) = 6050 watts

Single Phase 3-Wire Service, 1.5 Element Meter

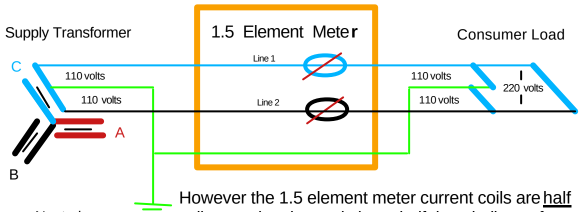


Neutral

The 1.5 element meter has a current coil connected to Line 1 and a current coil connected to Line 2,

= Current Sensor

Single Phase 3-Wire Service, 1.5 Element Meter

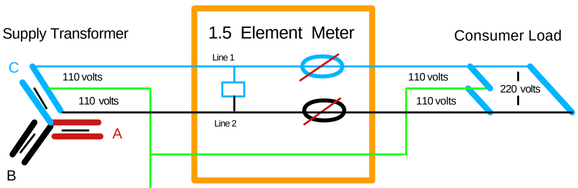


Neutral

However the 1.5 element meter current coils are <u>half</u> coils,meaning they only have half the windings of a full current coil.

= Full Current Coil = Half Current Coil

Single Phase 3-Wire Service, 1.5 Element Meter

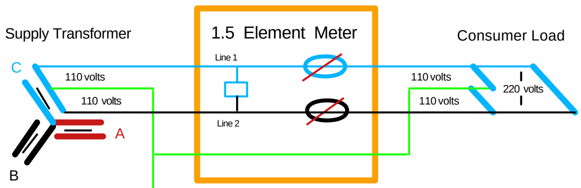


Neutral

Only <u>one</u> voltage sensor is required, connected between Line 1 and Line 2

= Half Current Sensor = Voltage Sensor

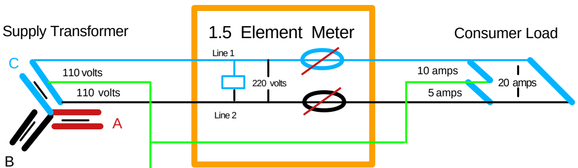
Single Phase 3-Wire Service, 1.5 Element Meter



Neutral

Using the same **6050 watt load** from the previous examples, what active power is measured by the 1.5 element meter?

Single Phase 3-Wire Service, 1.5 Element Meter



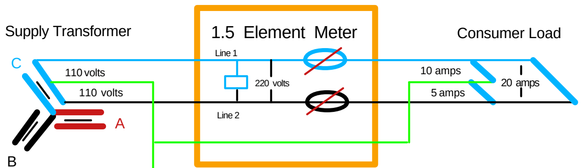
Neutral

Note : The 1.5 element meter shares one voltage coil for two elements

Active Power measured = (E x I_{L1} / 2 x cosθ*) + (E x I_{L2} / 2 x cosθ*)
= (220v x 30 / 2 x 1.0) + (220v x 25 / 2 x 1.0)
= (3300 watts) + (2750 watts)
= 6050 watts

Active Power calculated = 6050 watts

Single Phase 3-Wire Service, 1.5 Element Meter



Neutral

Active Power calculated for the load = 6050 watts
Active Power indicated by the meter = 6050 watts

Although the 1.5 Element meter does not satisfy Blondel's Theorem (N-1 elements), we have shown that the meter will measure accurately under <u>balanced voltage</u> conditions.

If voltages L1 - N and L2 - N are not balanced, errors will occur.

Single Phase 3-Wire Service, 1.5 Element Meter

Questions?

Comments?

Next: Polyphase Load Analysis

Polyphase Load Analysis

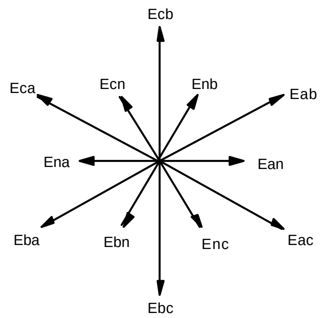
- Polyphase Phasors
- 3 Phase 4 Wire Wye Service
  - 3 Element Meter
  - 2.5 Element Meter
- 3 Phase 3-Wire Delta Service
  - 2 Element Meter

Polyphase Phasors

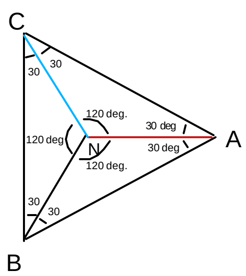
In order to describe how polyphase meters operate, it is necessary to have a common understanding of how phasors are used

Polyphase Phasors

Phasors are a visual representation of the various voltage and current values, and their relationship to each other during one cycle



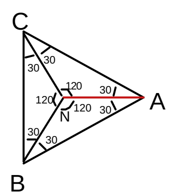
Polyphase Phasors



This diagram can be used to plot voltage phasors and establish their relationship to each other.

Polyphase Phasors

Voltage Ean is often used as the point of reference

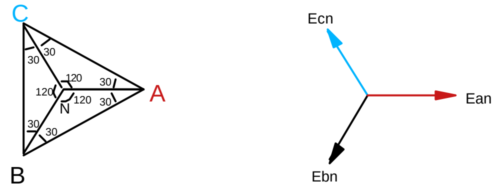


The phasor Ean shows the position of voltage A in relation to Neutral

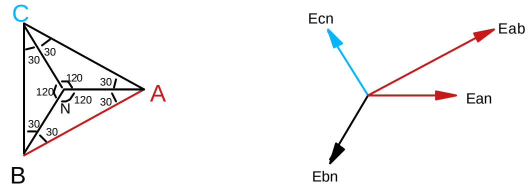
Polyphase Phasors

Other phasors are added to represent
the other line to neutral voltage values
in the polyphase circuit

Polyphase Phasors

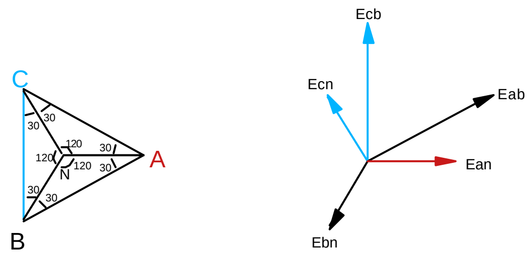


Polyphase Phasors



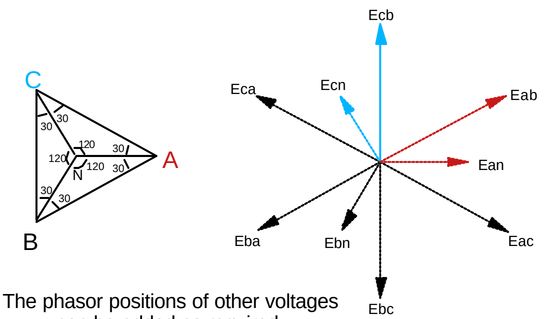
The phasor Eab shows the position
of voltage A in relation to voltage B

Polyphase Phasors



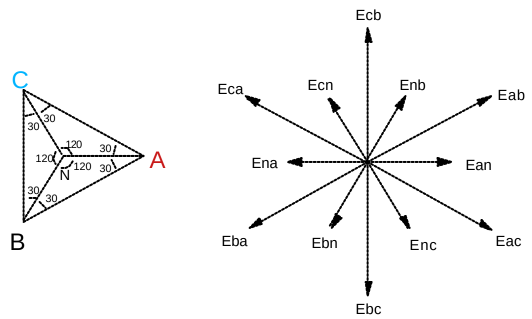
The phasor Ecb shows the position
of voltage C in relation to voltage B

Polyphase Phasors



The phasor positions of other voltages
can be added as required

Polyphase Phasors



Polyphase Phasors

Questions?

Comments?

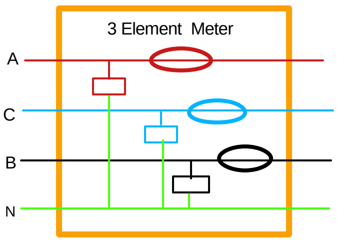
Next: 3 Phase 4-wire Wye Services, 3 Element Meter

Polyphase Load Analysis

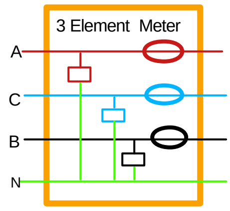
3 Phase 4-Wire Wye Service

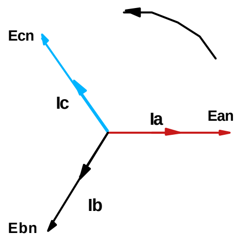
3 Element Meter

3 Phase 4-Wire Wye Service, 3 Element Meter



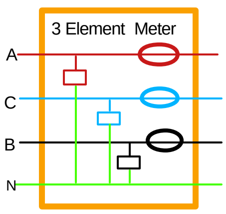
3 Phase 4-Wire Wye Service, 3 Element Meter

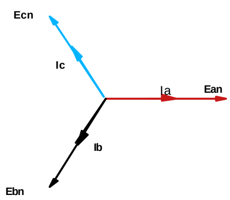




Phasor Representation
ABC Rotation

3 Phase 4-Wire Wye Service, 3 Element Meter





Power Formula :

Active Power = (Ean x Ia x cos0*) + (Ebn x Ib x cos0*) + (Ecn x Ic x cos0*)

cos0* = cosine of the current phase angle relative to unity power factor

3 Phase 4-Wire Wye Service, 3 Element Meter

Questions?

Comments?

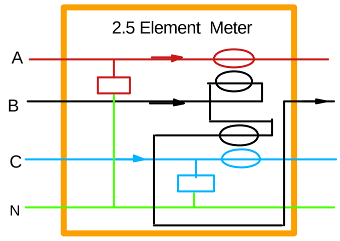
Next: 3 Phase 4-Wire Wye Service, 2.5 Element Meter

Polyphase Load Analysis

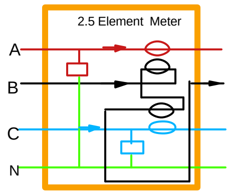
3 Phase 4-Wire Wye Service

2.5 Element Meter

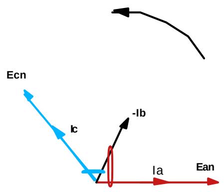
3 Phase 4-Wire Wye Service, 2.5 Element Meter



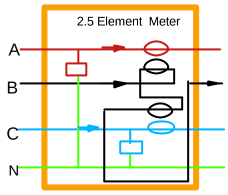
3 Phase 4-Wire Wye Service, 2.5 Element Meter

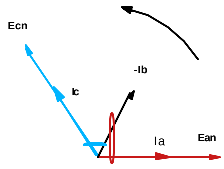


Phasor Representation
ABC Rotation



3 Phase 4-Wire Wye Service, 2.5 Element Meter





Active Power = (Ean x Ia x (cos0*)) + (Ean x -Ib x (cos60-0*))
+
(Ecn x Ic x (cos0*)) + (Ecn x -Ib x (cos60+0*))

0* = theta = phase angle of the current relative to unity power factor

3 Phase 4-Wire Wye Service, 2.5 Element Meter

Questions?

Comments?

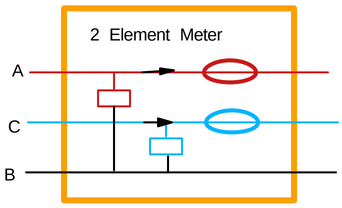
Next: 3 Phase 3-wire Delta Service

Polyphase Load Analysis

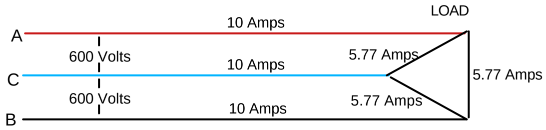
3 Phase 3-Wire Delta Service

2 Element Meter

3 Phase 3-Wire Delta Service



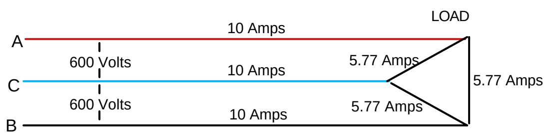
3 Phase 3-Wire Delta Service



Consider a 3 phase 3- wire delta load:

Phase voltage: 600v
Line current = 10 amperes, balanced load, unity power factor
Phase current = Line current / √3
Phase current = 5.7735 amperes

3 Phase 3-Wire Delta Service



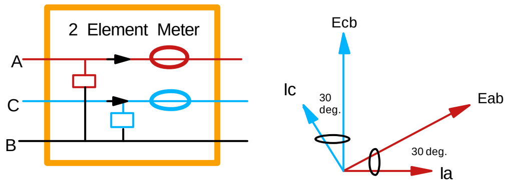
Calculate the Active Power:

Active Power = 3 x E phase x I phase cos*0**
Active Power = 3 x 600 x 5.7735 x 1.0 = **10392 watts**

or; Active Power = √3 x E line x I line cos*0**
Active Power = 1.732 x 600 x10 x 1.0 = **10392 watts**

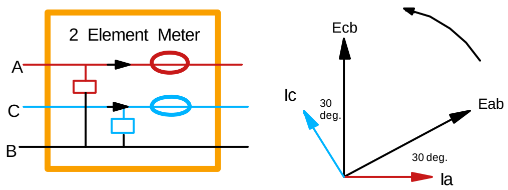
cos*0** = cosine of the current phase angle relative to unity power factor

3 Phase 3-Wire Delta Service



Ia is at unity power factor, but measures in relation to Eab
Ic is at unity power factor, but measures in relation to Ecb

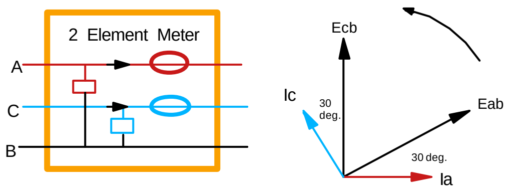
3 Phase 3-Wire Delta Service



Active Power = (Eab x Ia x cos(30+*0**))
+
(Ecb x Ic x cos(30-*0**))

*0** = theta = phase angle of the current relative to unity power factor

3 Phase 3-Wire Delta Service



Active Power = (Eab x Ia x cos(30+*0**)) + (Ecb x Ic x cos(30-*0**))
= (600v x 10a x cos(30+*0**)) + (600v x 10a x cos(30-*0**))
= (600 x 10 x 0.866) + (600 x 10 x 0.866)
= 5196 + 5196
= **10392 watts**
Active Power is correctly measured by the meter

3 Phase 3-Wire Delta Service

Questions?

Comments?

Measurement Concepts

4 Quadrant Measurement

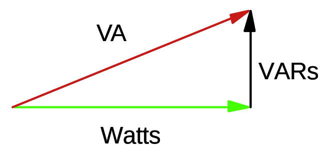
Watts hours, (Wh)

Reactive Volt-Ampere hours (VARh)

and Volt-Ampere hours (VAh)

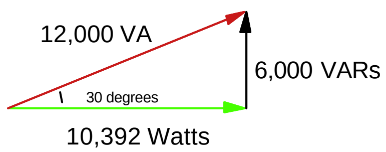
Prepared and presented by:
George A. Smith, Measurement Canada
Paul G. Rivers, Measurement Canada
2006

Measurement Concepts



The Power Triangle

Measurement Concepts



VA = Square root of (10,392 W squared + 6,000 VARs squared)

= 12,000 VA

4 Quadrant Measurement

Most metering points require measurement of electricity being delivered to a consumer.

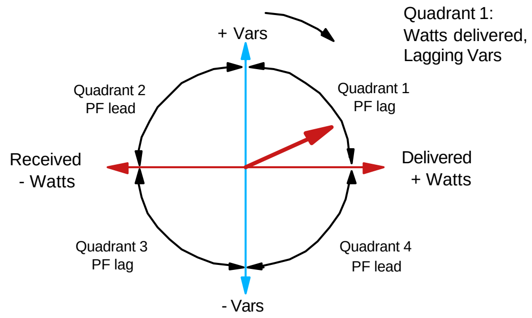
Electricity is often transferred between suppliers, and require that electricity be measured in two directions, with both lagging and leading power factor.

Where bi-directional measurement is required, 4 Quadrant metering is often used.

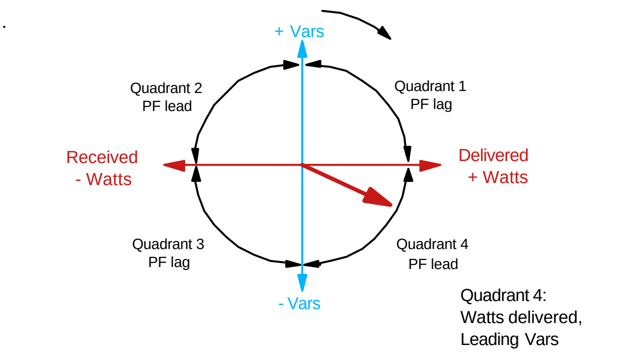
4 Quadrant Measurement

4 Quadrant measurement can be represented using a single phasor diagram that combines the measurement of electricity in all phases, in both directions, including all possible power factors.

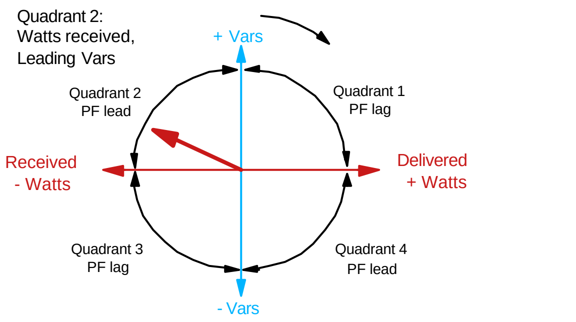
4 Quadrant Measurement



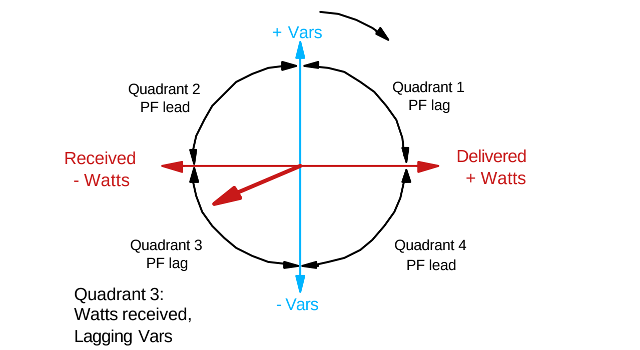
4 Quadrant Measurement



4 Quadrant Measurement



4 Quadrant Measurement



4 Quadrant Measurement

Questions?

Comments?

Next: Watthour Measurement

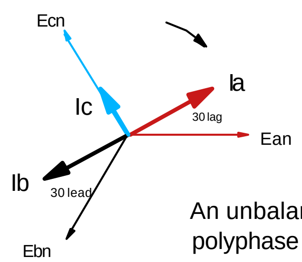
Watthour Measurement

Watthour measurement can be calculated by multiplying total Watts X time

Watthours = Watts X Time (in hours)

The following example shows
the calculation of Watts
in an unbalanced polyphase circuit.

Watt Measurement



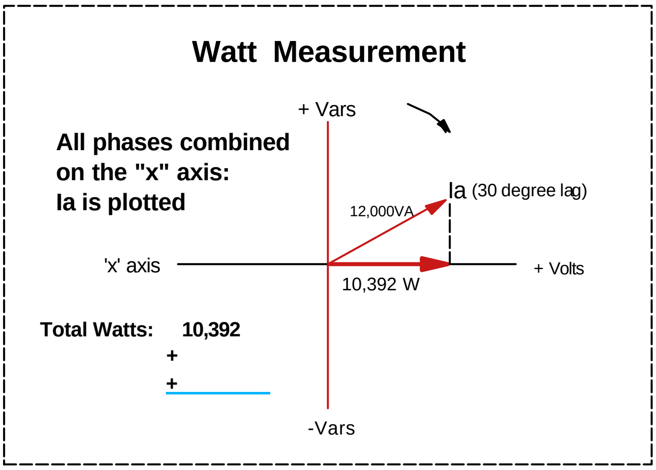
An unbalanced polyphase load:

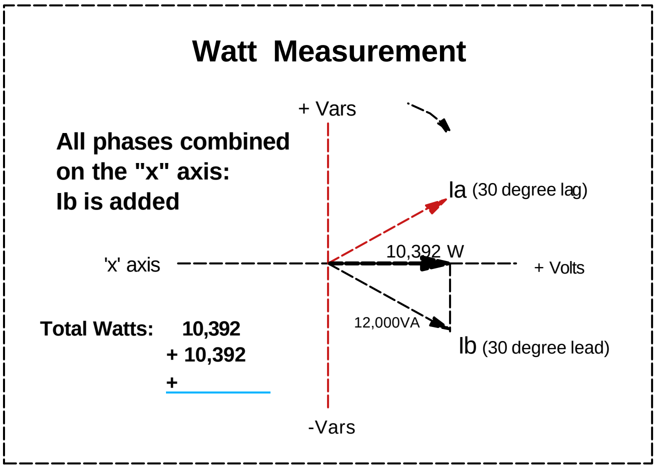
Ean = 120 V, Ia = 100 A, 30 degree lag
Ebn = 120 V, Ib = 100 A, 30 degree lead
Ecn = 120 V, Ic = 50 A, In phase

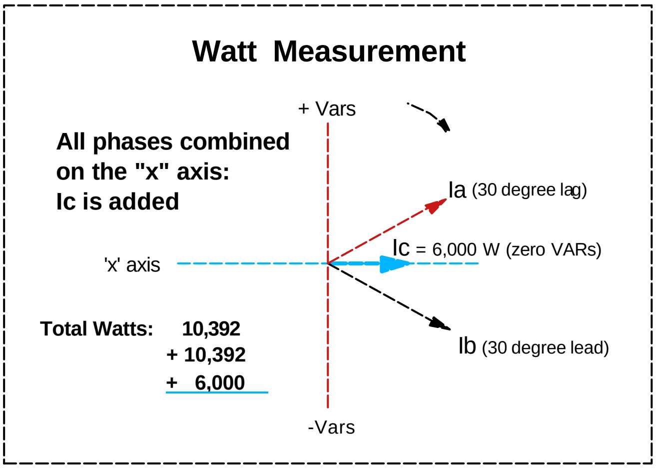
Watt Measurement

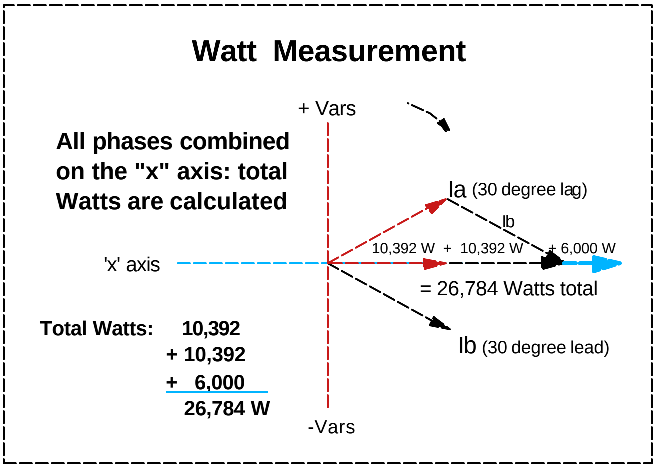
Watts are calculated using the portion of the current which is in phase with the associated voltage.

In a polyphase circuit the watts in the 3 phases can be represented on a phasor diagram using the same 'x' axis as reference.









Watthour Measurement

The meter can then use the total Watts to determine Watthours

Watthours = Watts X Time (in hours)

Watthour Measurement

Questions?

Comments?

Next: VAR hour Measurement

VARhour Measurement

Reactive Volt-Ampere hours (VARhours)
are calculated using the portion of the current
which is 90 degrees out of phase
with the associated voltage

In a polyphase circuit the VARs in each phase
can be represented on the 'y' axis,
where lagging power factor gives positive VARs
while leading power factor gives negative VARs

VAR Measurement

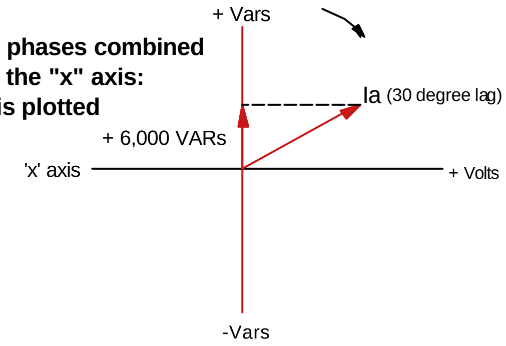
The total VARs within a polyphase system may
be added differently in different meters.

Adding VARs algebraically, as positive and negative
values, will result in the NET value for VARs.

Adding the absolute value of VARs, without
considering them as positive and negative
will result in the GROSS value for VARs.

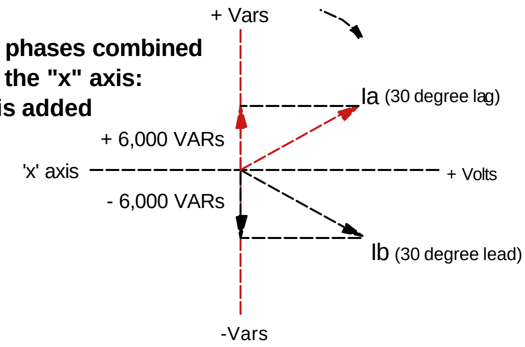
VAR Measurement

All phases combined
on the "x" axis:
Ia is plotted



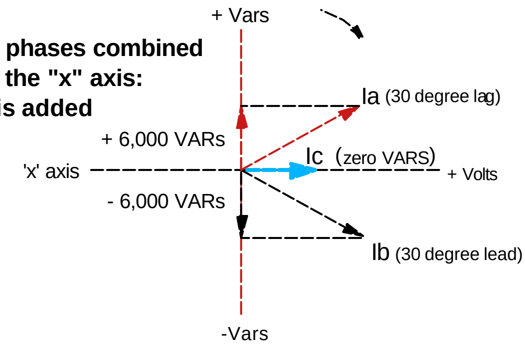
VAR Measurement

All phases combined
on the "x" axis:
Ib is added



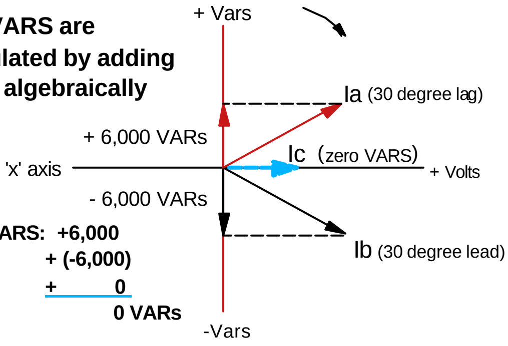
VAR Measurement

All phases combined
on the "x" axis:
Ic is added



VAR Measurement

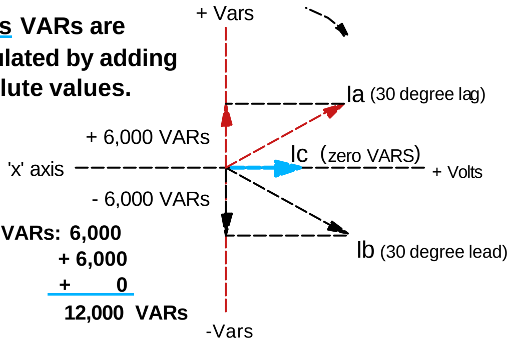
Net VARS are calculated by adding them algebraically



Net VARS: +6,000
+ (-6,000)
+ 0
0 VARs

VAR Measurement

Gross VARs are calculated by adding absolute values.



Gross VARs: 6,000
+ 6,000
+ 0
12,000 VARs

VARhour Measurement

VARhours = VARs X Time (in hours)

VARhours can be calculated using either net VARs or gross VARs

Since the two methods will result in different quantities, the calculation method (net or gross) should be clearly defined.

VARhour Measurement

Calculation of NET VARs treats a three phase service as a single entity.

Calculation of GROSS VARs treats the three phases as three separate and independant entities.

Both methods can be performed accurately, but the method used can have a significant effect on the calculation of VARs and VA.

VARhour Measurement

The meter can then use the total VARs to determine VARhours

VARhours = VARs X Time (in hours)

VARhour Measurement

Questions?

Comments?

Next: Volt-Ampere hour Measurement

VAhour Measurement

Volt-Ampere hour (VAhour) measurement
is used to determine line losses,
transformer losses, and the
sizing of equipment required for
supplying electrical energy
to a consumer.

VA Measurement

The calculation of volt-amperes in a polyphase system is generally based upon one of two internationally recognized methods:

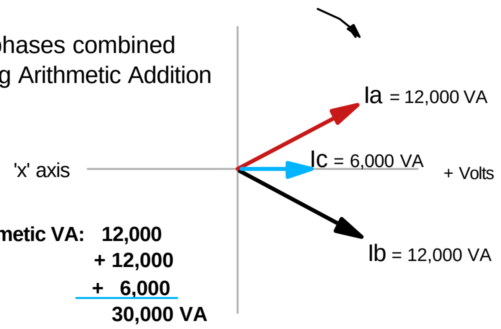
1) Phasor (Vector) Additon
or
2) Arithmetic Addition

VA Measurement

Arithmetic Addition of VA involves
the simple addition of the VA
in each of the phases.

VA Measurement

All phases combined
using Arithmetic Addition



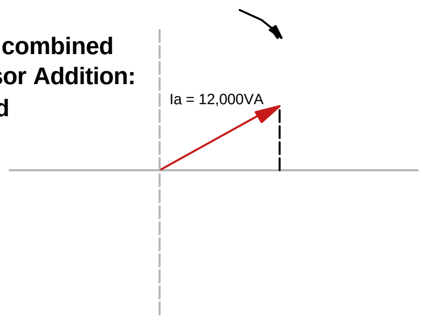
Arithmetic VA: 12,000
+ 12,000
+ 6,000
30,000 VA

VA Measurement

Phasor Addition involves the addition
of the phasor value of VA
in each of the phases.

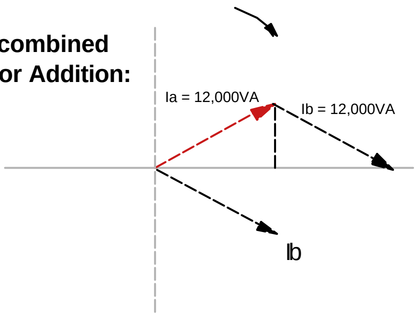
VA Measurement

All phases combined
using Phasor Addition:
Ia is plotted



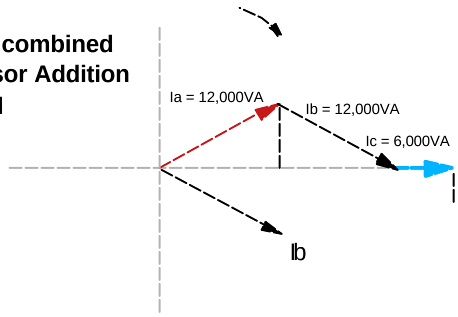
VA Measurement

All phases combined using Phasor Addition: Ib is added



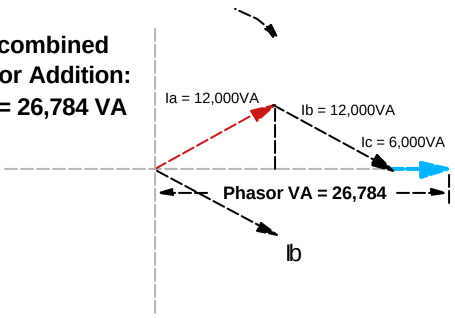
VA Measurement

All phases combined using Phasor Addition IC is added



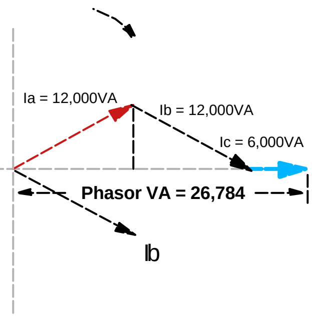
VA Measurement

All phases combined using Phasor Addition: Phasor VA = 26,784 VA



VA Measurement

All phases combined using Phasor Addition: Phasor VA = 26,784 VA



Net VARs = 0 VARs
Phasor VA = 26,784 VA
Gross VARs = 12,000 VARs
Arithmetic VA= 30,000 VA
Difference = +12%

VA hour Measurement

Calclation of Phasor VA treats a three phase service as a single entity.

Calculation of Arithemetic VA treats the three phases as three separate and independant entities.

The calculation method selected should be clearly defined and consistently used.

VA hours = VA X Time (in hours)

Energy Measurement

Questions?

Comments?

Electricity Metering

Demand Measurement

Prepared and presented by:
Paul G. Rivers, Measurement Canada
George A. Smith, Measurement Canada
2006

Demand Measurement

First introduced over 100 years ago, in 1892 by a gentleman by the name of Hopkinson.

Mr. Hopkinson recognized that there are two main components in the measurement of electricity.

Demand Measurement

First Component :

Energy in kilowatthours (kWh)

It was clear that the measured kWh in a system provided a good representation of the cost of the electricity supplied to the customer.

Demand Measurement

Second Component :

Power in kilowatts (kW)

Hopkinson determined that kW provided a good representation of the cost to the utility for supplying the electricity to the customer.

Demand Measurement

As a result, this was the first introduction to demand measurement and the very beginning of demand metering.

Demand Measurement

What is Demand?

Demand is often referred to as the maximum rate of energy transfer demanded by the consumer.

Demand Measurement

What is Demand?

Kilowatt demand is generally defined as the kilowatt load (power) averaged over a specified interval of time.

Demand Measurement

What is Demand?

Kw demand is determined from the energy (kwh's) consumed and the time (hours) it takes to consume the energy.

Demand Measurement

Basic Power formula

Energy = Power x Time

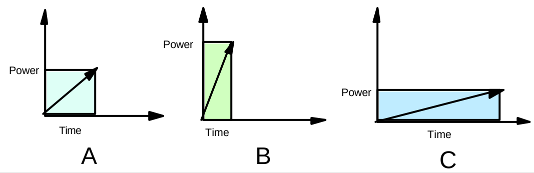
or

Power (Kw's) = Energy(Kwh's) / Time (hours)

Demand Measurement

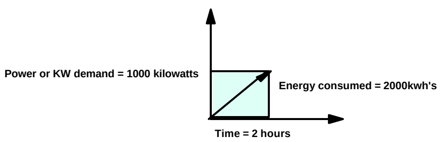
The rate or speed of energy transfer to the customers load will directly impact the measured kilowatts, otherwise known as the customers demand.

Power (kw) = Energy (kwh) / Time (hours)



Demand Measurement

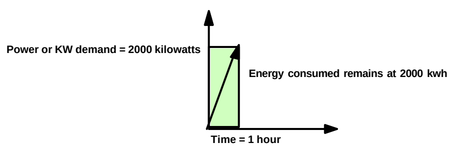
Consider Customer A's Load



Power (kw) = Energy (kwh) / Time (hours)

Demand Measurement

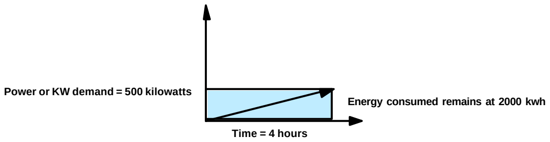
Consider Customer B's Load



Power (kw) = Energy (kwh) / Time (hours)

Demand Measurement

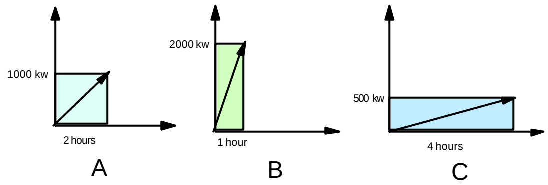
Consider Customer C's Load



Power (kw) = Energy (kwh) / Time (hours)

Demand Measurement

Review All Three Customers



Energy consumed in all three cases is the same = 2000 kwh's

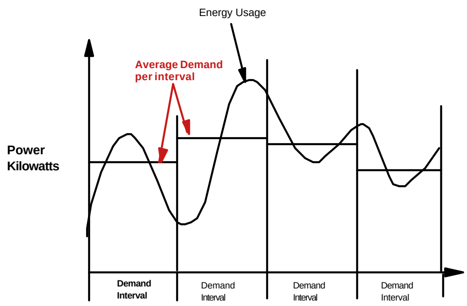
Demand Measurement

Time / Demand Interval

The demand interval is the length of time over which demand is measured.

The demand interval is usually 5, 10, 15, 30 or 60 minutes.

Demand Measurement



Demand Measurement

Maximum Demand?

The maximum measured demand for any customer is the greatest of all the demands measured within a given time interval, which has occured during the billing period.

A billing period may be one month.

Demand Measurement

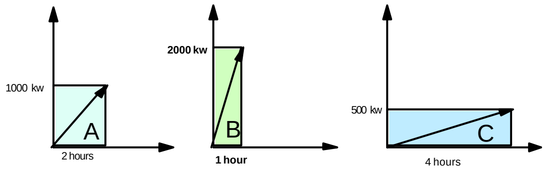
Why is Demand Measured?

The size and capacity of transformer banks, sub-stations, transmission lines, switch gear, etc is determined by the maximum demand imposed on these devices by the customer.

Demand Measurement

As a result, the utility must install larger, more costly equipment in order to supply the same amount of energy in a shorter time period for customer B.

The measured maximum demand of 2000 kw's is a result of this high rate of transfer and can be used to charge the customer for the up front cost to meet his/her needs.



Demand Measurement

Demand Measurement (Considerations)

When establishing the appropriate length of the demand interval, (5, 10, 15, 30 or 60 minutes) one must take into consideration the type of load being measured.

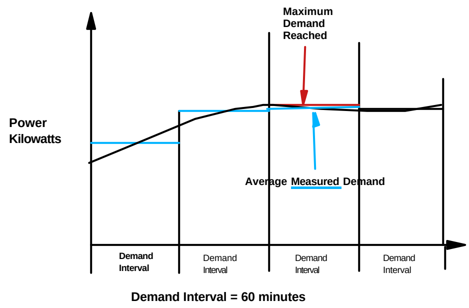
Steady loading versus fluctuating loading

Demand Measurement (Considerations)

For example measuring the demand over a longer time interval, such as 60 minutes will work well when the loading is fairly steady.

The average measured demand and the maximum demand within a demand interval will be very close if not the same.

Demand Measurement

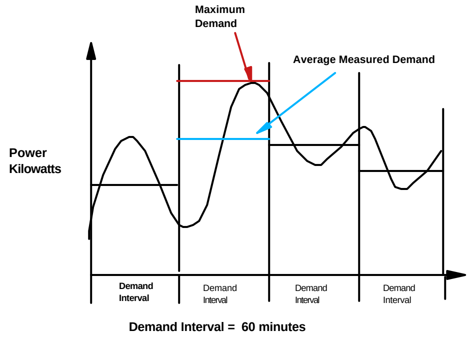


Demand Measurement (Considerations)

However, measuring a fluctuating load with the same time interval (60 minutes) may not provide a measured demand value which is representative of the customers maximum or peak usage during the billing period.

Unless a shorter time interval is used , there can be a significant difference between the average demand measured and the maximum demand required by the customer.

Demand Measurement

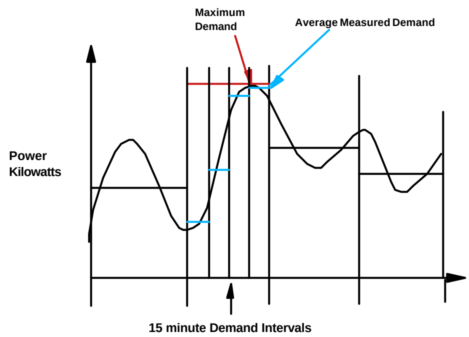


Demand Measurement
(Considerations)

By shortening the demand interval length from 60 minutes to 15 minutes, the average measured demand for each 15 minute interval becomes a better representation of the energy consumed within the shortened time period.

The highest measured demand, becomes the maximum or peak demand value in which the customer is billed upon.

Demand Measurement



Demand Measurement

Questions?

Comments?

Next: Methods of Determining Maximum Demand

Demand Measurement

Principle Methods of Determining Maximum Demand

Demand Measurement

Principle Methods

1) Average Demand Method
   - Integrating Demand
2) Exponential Demand Method
   - Thermal Demand
   - Thermal Emulation
   - Lagged Demand

Demand Measurement

Average Demand Method?

Average demand or integrating demand is based upon the average power measured during a minimum time interval of 15 minutes.

Demand Measurement

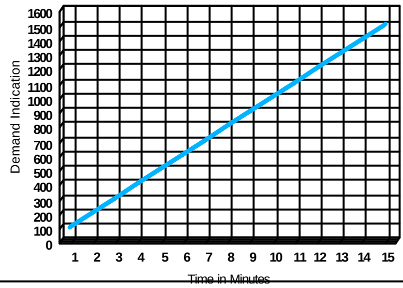
Average Demand Method?

The response characteristic of an average or integrating demand meter is linear.

It will register 50 % of the load in half the demand interval and 100% of the load by the end of the demand interval.

Average / Integrating Demand Method

15 Minute Interval - Load = 1500 watts
Average Demand Measured is 1500 watts (100% of the load) in 15 minutes



Demand Measurement

Exponential or Lag Demand Method?

Exponential demand or Lag demand is based upon the rate of conductor temperature rise, measured over a minimum time interval of 45 minutes.

Demand Measurement

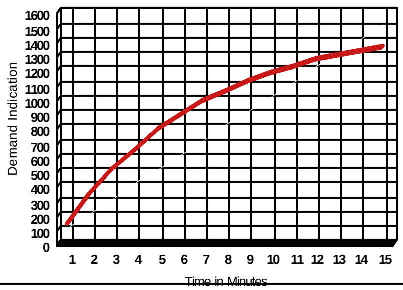
Exponential or Lag Demand Method?

The exponential or lag demand meter has a exponential response characteristic.

In this case, it will register 90% of the load within a third of the interval, 99% in two thirds the interval and 99.9% by the end of the demand interval.

Exponential / Lag Demand Method

45 Minute Interval - Load = 1500 watts
Exponential Demand Measured in 15 minutes (1/3 of the demand interval) = 1360 watts = 90% of the load



Demand Measurement

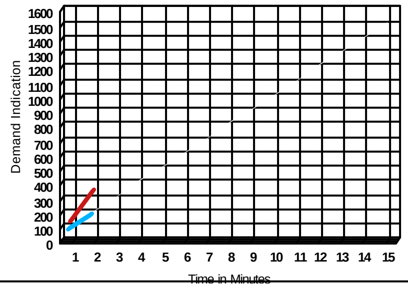
Demand Method Comparison

Average verses Exponential

The values in the following graphs provide the response of the two demand methods in relation to steady state load conditions, and must be taken in context with the base load conditions.

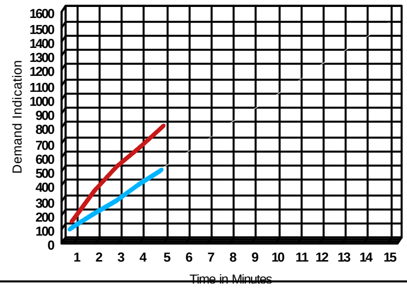
Demand Method Comparison

2 Minute Duration
Exponential Method = 345
Average Method = 200



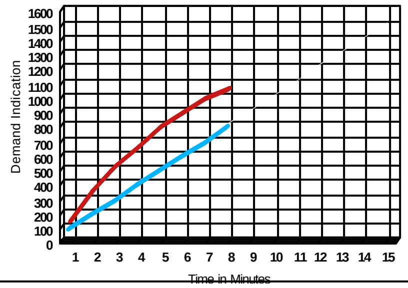
Demand Method Comparison

5 Minute Duration
Exponential Method = 790
Average Method = 500



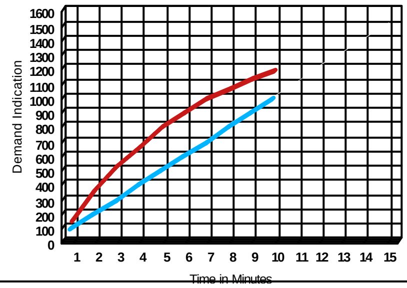
Demand Method Comparison

8 Minute Duration
Exponential Method = 1050
Average Method = 800



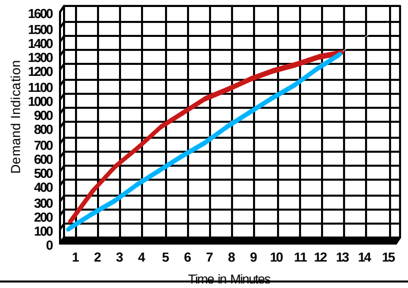
Demand Method Comparison

10 Minute Duration
Exponential Method = 1180
Average Method = 1000



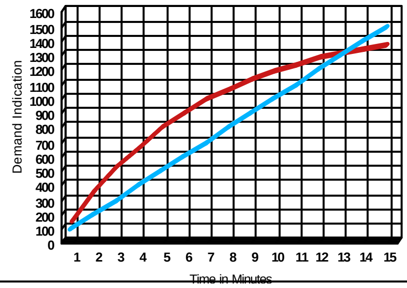
Demand Method Comparison

13 Minute Duration
Exponential Method = 1300
Average Method = 1300



Demand Method Comparison

15 Minute Duration
Exponential Method = 1360
Average Method = 1500



Demand Measurement

Demand Meter Response Characteristics (Considerations)

Similiar to the length of the demand interval, the response characteristics of a demand meter (linear vs exponential) can also impact on the measurements end result, depending on the type of loading imposed on the system, by the customer.

Demand Measurement

Overall Considerations

Consideration should be given to the standardization of both the demand interval length and the response type of the demand meter used within one's respective economy to ensure all customers are billed equitably.

Demand Measurement

Questions?

Comments?

Volt-Ampere Demand

Measurement

Prepared and presented by:
George A. Smith, Measurement Canada
Paul G. Rivers, Measurement Canada
2006

Volt-Ampere Demand

The cost of supplying electrical energy to a consumer increases as the power factor decreases.

The cost increase is due to 2 factors:
1) increased capital costs, and
2) increased line losses

Volt-Ampere Demand

Volt- Ampere demand measurement is a common method for electricity suppliers to recover these increased costs.

Volt-Ampere Demand

The method of integrating energy consumption over time (e.g. 15 minutes) to establish Volt-Ampere demand, is similar to the method used to calculate Watt demand.

However, there is only one generally accepted definition of total Watts in a polyphase circuit, but there are more than one definition of total Volt-Amperes.

Volt-Ampere Demand

The addition of volt-amperes in a polyphase system is generally based upon one of two internationally recognized methods:

1) Phasor (Vector) Additon
or
2) Arithmetic Addition

Volt-Ampere Demand

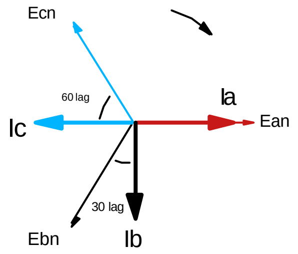
'Phasor Addition' and 'Arithmetic Addition' methods use the same units of measure (VA) but can yield significantly different values for the same load conditions.

This can lead to measurement inequity, consumer complaints, and a reduced confidence in measurement.

Volt-Ampere Demand Calculation Comparison

The following example provides a comparison of the calculated VA values in a three phase circuit, where the individual currents are lagging the voltage by different phase angles.

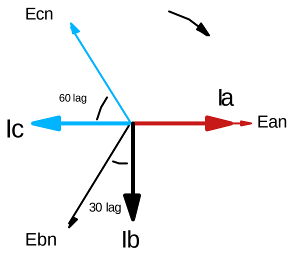
VA Demand Calculations



Ia is in phase with Ean
Ib lags Ebn by 30 degrees
Ic lags Ecn by 60 degrees

VA Demand Calculations

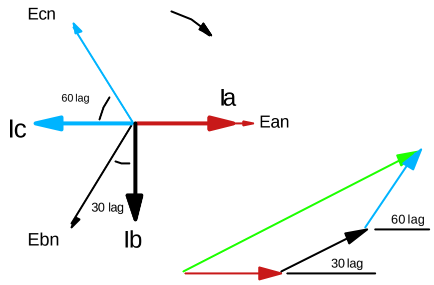
E_{L-N} = 120 Volts
Ia = 100 Amps
Ib = 100 Amps
Ic = 100 Amps



Ia is in phase with Ean	12,000 VA,	12,000 W,	0 VARs
Ib lags Ebn by 30 degrees	12,000 VA,	10,392 W,	+6,000 VARs
Ic lags Ecn by 60 degrees	12,000 VA,	6,000 W,	+10,392 VARs
Arithmetic VA =	36,000 VA,	28,392 W,	+16,392 VARs

VA Demand Calculations

E_{L-N} = 120 Volts
Ia = 100 Amps
Ib = 100 Amps
Ic = 100 Amps

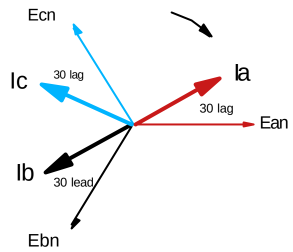


Total Watts = 28,392 Watts
Total Vars = +16,392 Vars
Vectorial VA = 32,784 VA $= \sqrt{(28,392 \text{ sqd} + 16,392 \text{ sqd})}$ VA
Arithmetic VA = 36,000 VA = 12,000 + 12,000 + 12,000 VA
% Difference = +9.8%

Volt-Ampere Demand Calculation Comparison

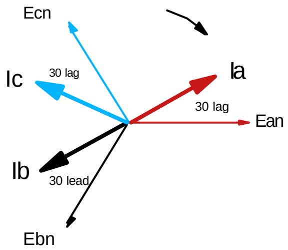
The next example provides a comparison of the calculated VA values in a three phase circuit where two of the currents are lagging, and one current is leading the voltage.

VA Demand Calculations



VA Demand Calculations

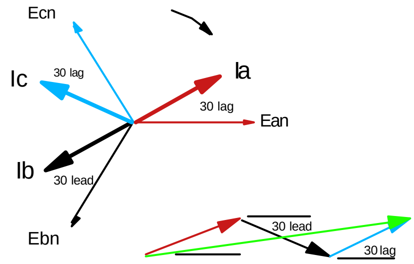
E_{L-N} = 120 Volts
Ia = 100 Amps
Ib = 100 Amps
Ic = 100 Amps



Total Watts = 31177 Watts
Gross Vars = 18000 Vars
Net Vars = +6000 Vars

VA Demand Calculations

E_{L-N} = 120 Volts
Ia = 100 Amps
Ib = 100 Amps
Ic = 100 Amps



Total Watts = 31177 Watts
Gross Vars = 18000 Vars
Net Vars = +6000 Vars

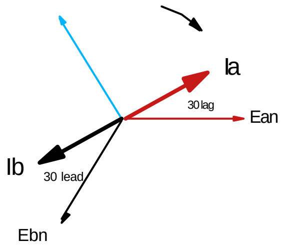
Vectorial VA = 31749 VA
Arithmetic VA = 36000 VA
% Difference = +13.4%

Volt-Ampere Demand Calculation Comparison

This last example provides a comparison of the calculated VA values in a 120/208 volt network service with a purely resistive (1.0 PF) 208 volt load.

Ia and Ib represent the same current, with Ib serving as the return for Ia.

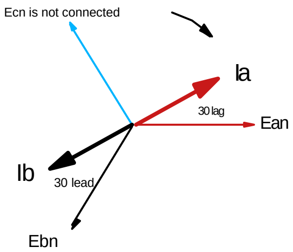
VA Demand Calculations



Example of a purely resistive (1.0 PF) 208 volt load connected between Ean and Ebn. (zero VARs)
Ia & Ib represent the same current,
with Ib serving as the return for Ia.

VA Demand Calculations

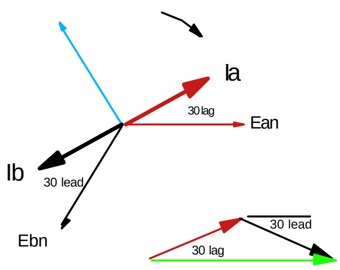
E_{L-N} = 120 Volts
Ia = 100 Amps
Ib = 100 Amps
Ic = n/a



Total Watts = 20785 Watts
Gross Vars = 12000 Vars
Net Vars = 0 Vars

VA Demand Calculations

E_{L-N} = 120 Volts
Ia = 100 Amps
Ib = 100 Amps
Ic = n/a



Total Watts = 20785 Watts
Gross Vars = 12000 Vars
Net Vars = 0 Vars

Vectorial VA = 20785 VA
Arithmetic VA = 24000 VA
% Difference = +15.5%

VA Demand Calculation Comparison

Phasor addition of VA treats a three phase service as a single entity.

Arithmetic addition of VA treats the three phases as three separate and independant entities.

VA Demand Calculation Comparison

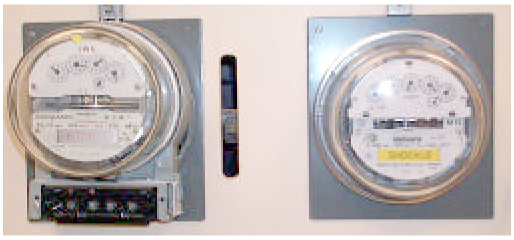
In order for VA demand measurement to be equitable within a geographical area, the method of VA addition must be consistent.

Volt-Ampere Demand Measurement

Questions?

Comments?

Basic Induction Meter



Prepared and presented by:
Paul G. Rivers, Measurement Canada
George A. Smith, Measurement Canada
2006

Basic Induction Meter

Three Main Components are ;

a) Motor Section

b) Braking Section

c) Gear Train Section

Basic Induction Meter

The watthour meter works on the Induction Principle and is essentially an induction motor driving an eddy current dampening unit.

The stator consists of an electromagnet and the rotor is an aluminum disc mounted on a shaft.

A permanent magnet or braking system is used to keep the disc at a manageable speed.

A train of gears and dials come off the disc shaft and register the energy consumed

Basic Induction Meter

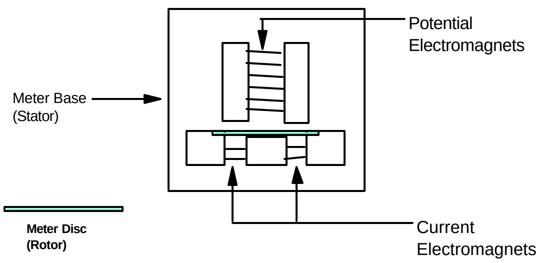
Motor Section :

As an induction type motor, the potential and current coils can be considered the stator part of the motor, and the disc can be considered the rotor part of the motor.

The stator will provide the torque upon which the rotor (disc) will move or rotate.

Basic Induction Meter

The stator section of the motor consists of a potential electromagnet and a current electromagnet



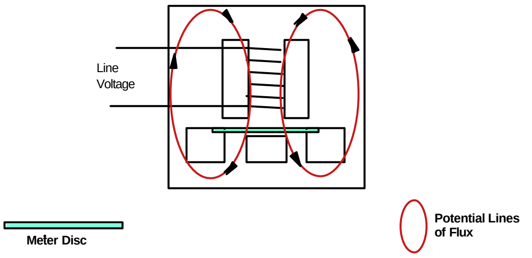
Basic Induction Meter

Motor Section :

- magnetic fluxes of the potential and current electromagnets.
- interact with the aluminum disc
- providing the necessary torque needed to move the disc
- and register the energy

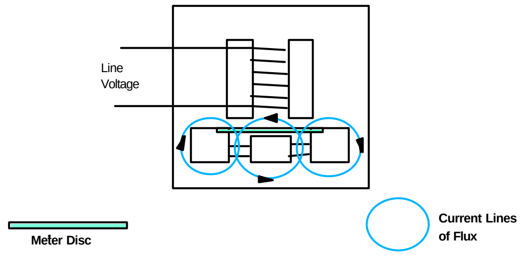
Basic Induction Meter

Potential Coil Flux Interaction



Basic Induction Meter

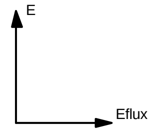
Current Coil Flux Interaction



Basic Induction Meter

Potential Coil Flux :

The flux produced by the potential coil **lags** the voltage by 90 degrees due to the coils high inductance characteristics. (many turns of fine wire)



Basic Induction Meter

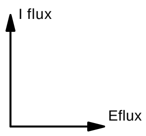
Current Coil Flux :

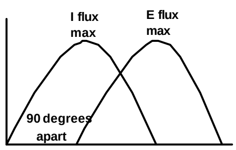
The flux produced by the current coil is **in phase** with the current due to the coils highly resistive characteristics.

(few turns of course wire)

Basic Induction Meter

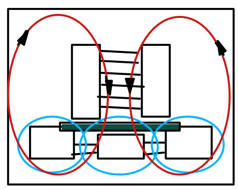
The **two fluxes are 90 degrees apart.** Even uniform torque is therefore applied to the disc at any given time in the current and voltage cycles.





Basic Induction Meter

1ST Quarter

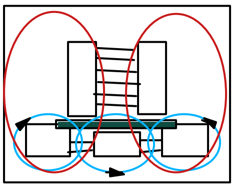


Every quarter of a cycle, the maximum rate of change (slope) of either the voltage or current signwave will produce the maximum amount of eddy currents within the disc, producing maximum torque on the disc.

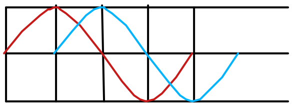
Here in the 1st quarter, the voltage flux is at it's maximum rate of change.

Basic Induction Meter

2nd Quarter



In the 2nd quarter, current flux is now at it's maximum rate of change in the cycle



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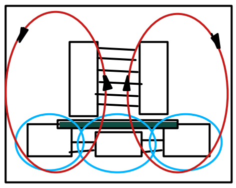
Basic Induction Meter

3rd Quarter

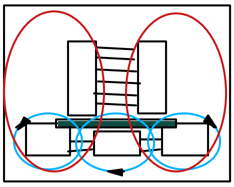


Every half cycle the flow of the fluxes through the disc change direction due to the alternating signwave of the voltage and current.

- 3rd quarter, the voltage is at it's maximum rate of change.
- flux flowing opposite direct through the disc.

Basic Induction Meter

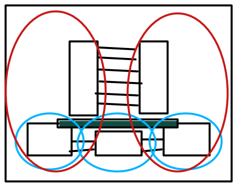
4th Quarter



- 4th quarter the current flux is at it's maximum rate of change
- flux flowing in opposite direction from 2nd quarter.

.

Basic Induction Meter



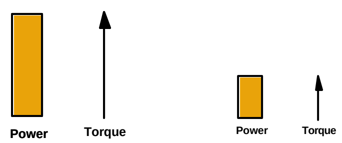
- driving torque on the disc is a result of eddy currents within the disc.

- due to the interaction between the disc and magnetic lines of fluxes.

Basic Induction Meter

Applied Torque :

The torque applied to the meter disc is proportional to the power (voltage and current) flowing through electromagnets.



Basic Induction Meter

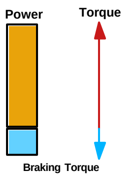
Braking Section

Since the meter register does not produce enough load to prevent the meter from running at an excessive speed, permanent magnets are used to provide a braking or retarding force on the disc.

Basic Induction Meter

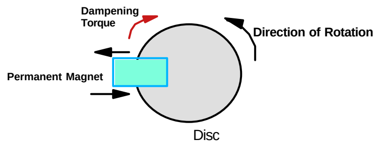
Braking Section

In order for the driving torque to remain proportional to the power, the counter torque or braking effect must also be proportional to the load.



Basic Induction Meter

Braking Section



The magnetic fields interact with the permanent magnet flux to produce a dampening torque of opposite thrust.

Moving the magnet inward or outward, will increase or decrease the braking force, slowing or speeding up the disc.

Basic Induction Meter

Disc Constant (Kh)

The disc constant (Kh) represents the watthours of energy required to rotate the disc one complete revolution.

The watthour meter constant (disc constant) depends upon the fundamental design of the meter.

Basic Induction Meter

Disc Constant (Kh)

Therefore;

$$Kh = \frac{\text{Power x Time}}{\text{Speed}} = \frac{\text{Watt hours}}{\text{Revolutions}}$$

Basic Induction Meter

Gear Trains (Registers)

The function of the gear train is to count and totalize the number of disc revolutions in terms of energy units (kilowatthours)

Formula:

$$\text{Revolutions} = \frac{\text{Energy}}{\text{Kh}}$$

Basic Induction Meter

Gear Trains (Registers)

How many revolutions of the disc must the register record to measure 1000 watthours if the meter Kh is 7.2?

$$\text{Revolutions} = \frac{\text{Energy}}{\text{Kh}} = \frac{\text{1000 watthours}}{\text{7.2 wh/rev}}$$

= 138.889 revolutions of the disc

Basic Induction Meter

Gear Trains (Registers)

In the gear train section of the meter, there are three ratio's to consider

Shaft Ratio

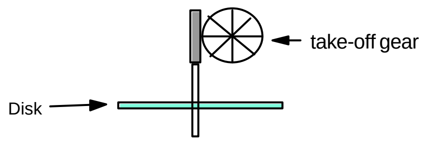
Register Ratio

Gear Ratio

Basic Induction Meter

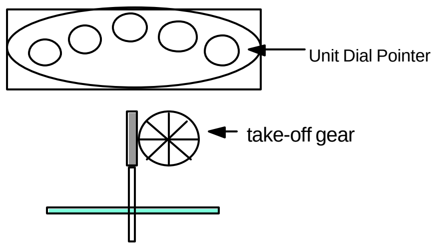
Gear Trains (Registers)

Shaft Ratio = <u>number of disc revolutions</u>
one revolution of take-off gear



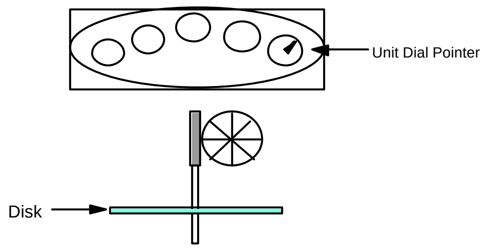
Basic Induction Meter

Register Ratio = <u>number of revolutions of take-off gear</u>
one revolution of unit dial pointer



Basic Induction Meter

Gear Ratio = <u>number of disc revolutions</u>
one revolution of unit dial pointer



Basic Induction Meter

Adjustments and Compensation

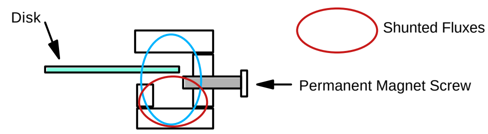
Induction watthour meters must have the capability to make adjustments to the meter in order that the speed of the disc correctly measures the energy consumed.

Basic Induction Meter

Adjustments and Compensation

Full Load Adjustment :

This is a course adjustment by way of magnetic shunting. Permanent magnets are used to divert some of the permanent magnet flux away from the disc.

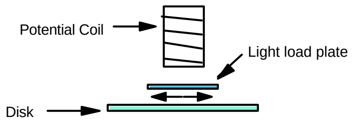


Basic Induction Meter

Adjustments and Compensation

Light Load Adjustment :

This is a fine adjustment by applying a small but constant additional torque to the disc. The potential coil flux is used to produce this additional torque, using a movable plate.

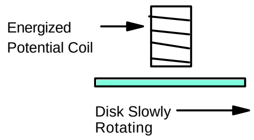


Basic Induction Meter

Adjustments and Compensation

Anti Creep Adjustment :

Creep is a slow continuous rotation of the disc when the potential coil is energized, but no current is flowing.

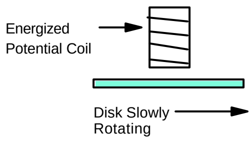


Basic Induction Meter

Adjustments and Compensation

Anti Creep Adjustment :

Creep can be a result of mechanical or magnetic dissymmetry, stray magnetic fields or excessive line voltage.

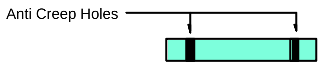


Basic Induction Meter

Adjustments and Compensation

Anti Creep Adjustment :

To prevent creep, the disk is designed with fixed anti-creep compensation, two holes or slots are inserted through the disc and are diametrically opposed to one another.

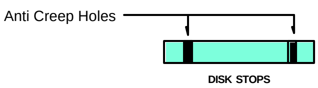


Basic Induction Meter

Adjustments and Compensation

Anti Creep Adjustment :

As the potential lines of flux make contact with the holes, the resulting distortions of the eddy currents produce a small locking torque, stopping the disc.

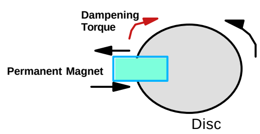


Basic Induction Meter

Adjustments and Compensation

Temperature Compensation :

Any change in temperature can effect the strength of the braking magnets or change any resistance found in the meter.

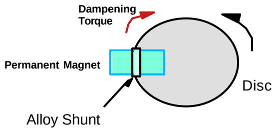


Basic Induction Meter

Adjustments and Compensation

Temperature Compensation :

To compensate for temperature effects, the permanent magnet has a temperature sensitive alloy shunt, whose permeability varies inversely with the temperature.



Basic Induction Meter

Adjustments and Compensation

An induction type meter must also be designed with current and voltage overload compensations.

These compensations are addressed by the use of magnetic shunts which divert some of the fluxes away from the disc, produced by excessively high voltages and currents.

Basic Induction Meter

Questions?

Comments?

Electronic Metering

Prepared and presented by:
Paul G. Rivers, Measurement Canada
George A. Smith, Measurement Canada
2006

Electronic Metering

Since the late 1970's several electronic technologies have been developed.

The intent was to both replicate and improve on the Principle of Induction Metering.

Electronic Metering

The first step in the process of improving on the Electro-mechanical Induction Meter was to develop a Hybrid Meter before the advent of a fully Electronic Meter.

This was known as the transition stage

Electronic Metering

Hybrid Meters :

A hybrid meter is a device that uses two types of technologies;

Mechanical and Electronic

Electronic Metering

Hybrid Meters :

A hybrid meter is a device that uses two types of technologies; Mechanical and Electronic

The mechanical component usually consists of an induction meter and the disc. The electronic component consists of a microprocessor based register

Electronic Metering

Solid State Meters :

A solid state meter is a device that uses only one type of technology;

Electronic

Electronic Metering

Solid State Meters :

A solid state meter is a device that uses only one type of technology; Electronic

The device is completely microprocessor based with no induction meter disc.

Electronic Metering

Measurement Capabilities:

A single electronic meter is capable of measuring a multitude of billing functions such as ;

Watts / Watthours
VA / VAhours — Amp squared hours
Var / Varhours — Volt squared hours
Transformer / line loss compensation

Electronic Metering

Measurement Capabilities:

The demand section of the meter can be programmed to measure ;

- Averaging or Block Interval
- Sliding Average or Sliding Block Interval
- Exponential (or thermal emulation)

Electronic Metering

Measurement Capabilities:

In addition, the demand intervals or sub-intervals can be programmed to different values such as;

60 minute interval, 15 minute sub-interval

15 minute interval, 5 minute sub-interval

Electronic Metering

Measurement Capabilities:

The VA function can be programmed to measure ;

- Arithmetic VA, or,
- Phasor (Vector) VA

Electronic Metering

Features and Functionality :

Electronic meters have many different features and functionalities which can be utilized for;

various billing applications
load monitoring purposes
communication and programming efficiencies

Electronic Metering

Features and Functionality :

Mass Memory Recorder
Pulse Outputs (KYZ)
Load Profiling
Time of Use
Interval Data or Time Stamping

Electronic Metering

Additional Features and Functionalities :

- Communication Ports (optical / modems)
- Automatic Meter Readers
- Pre-payment metering
- Loss Compensation
- Bi-directional
- 4 quadrant metering

Electronic Metering

Modes of Operation:

Electronic meters typically have three modes of operation:

- Normal (Main) Mode
- Alternate Mode
- Test Mode

Electronic Metering

Normal Mode :

This is the default mode and is the mode in which the meter operates while in service.

Typically this mode is used to display main billing quantities, such as KWH, maximum KW, maximum KVA.

Electronic Metering

Alternate Mode :

Used to display quantities that are not needed on a regular basis, such as power factor, volts, amps, etc.

Typically accessed via a magnetic read switch.

Meter automatically returns to normal mode

Electronic Metering

Test Mode :

Purpose of this mode is to provide a convenient means of testing a meters accuracy. Allows testing of the registers without altering billing data.

In test mode operation the demand interval is reduced to 3 minutes in order to facilitate accelerated testing.

Electronic Metering

An electricity meter, whether fully electro-mechanical a hybrid or fully electronic can always be divided into four elemental components.

Electronic Metering

An electricity meter, electromechanical or electronic can be divided into four elemental components;

SENSORS
MULTIPLIERS
NUMERICAL CONVERSION
REGISTERS

Electronic Metering

SENSORS

Provide interface between incoming voltage and current and the metering circuit.

Electronic Metering

MULTIPLIERS

Perform the heart of the metering function by providing the product of the voltage and current.

Electronic Metering

NUMERICAL CONVERSION

Process of transforming the output of the multiplier stage into a form which can be processed by the register

Electronic Metering

REGISTERS

The devices that store and display the metering quantities.

Electronic Metering

Of course an electronic meter is a little more complicated, also has components such as;

Electronic Metering

Of course an electronic meter is a little more complicated, also has components such as;

-Multiplexers
-Anologe to Digital Converters
-Microprocessors
-Displays / Registers
-Communication and Input/Output Ports
-LED's and Clocks

Electronic Metering

Methods of Measurement :

Four basic forms of electronic metering measurement have been introduced to the industry;

- Mark-Space Amplitude or Time Division Multiplicaton
- Transconductance
- Digital Sampling
- Hall Effect

Electronic Metering

Time Division Multiplication :

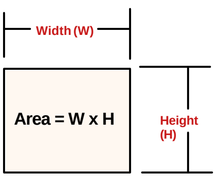
TDM is a well established form of electronic metering

Based on analogue multiplication of instantaneous voltage and current waveforms to derive power, which is output as a series of pulses.

Electronic Metering

Time Division Multiplication :

Physical Parameter	Electrical Parameter
Width	Voltage (E)
Height	Current (I)
Area	Power (ExI)



Electronic Metering

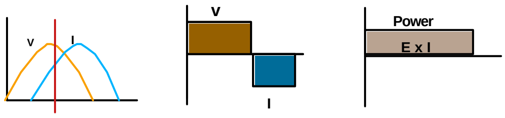
Time Division Multiplication :

A signal is formed with amplitude proportional to instantaneous current, and duration proportional to instantaneous volts.

Average value of the waveform is equal to instantaneous power

Electronic Metering

Time Division Multiplication :



Electronic Metering

Time Division Multiplication :

-good cost to accuracy ratio
-excellent linearity and reliability
-performance under distortion is limited
-direct measurement limited to watts / vars
-calibration is necessary

Electronic Metering

Hall Effect :

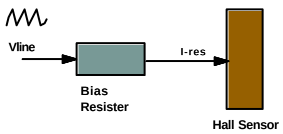
The Hall effect is based on well known principles

If a current conducting material is subject to a magnetic field, a voltage proportional to the product of the current and the magnetic field strength will develop across the material

Electronic Metering

Hall Effect :

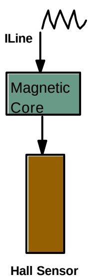
A resistor is placed in series with the line voltage to create a current that is applied to the Hall Cell



Electronic Metering

Hall Effect :

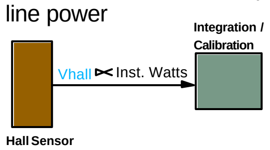
The line current is used to create a magnetic field that flows through the Hall Cell at right angles.



Electronic Metering

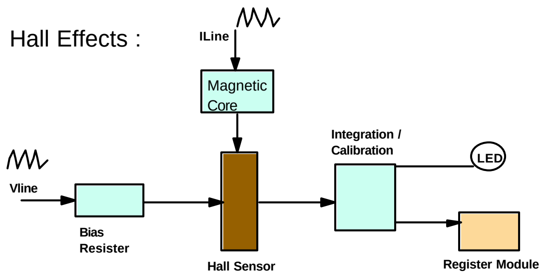
Hall Effect :

The developed Hall Voltage will be a product of the line voltage and line currents, therefore proportional to instantaneous line power



Electronic Metering

Hall Effects :



Electronic Metering

Hall Effect :

-very cost effective technology
-can measure watts / vars, but not va
-linearity less than TDM technology
-excellent response for harmonic content
-susceptable to large temperature changes

Electronic Metering

Transconductance :

Transconductance is another form of metering that incorporates both TDM and Hall Effect technology by;

- conducting analogue multiplication of the line voltage and current to produce a voltage signal proportional to line power via the use of transistors.

Electronic Metering

Transconductance :

The secondary current from the meters transformers is converted to a voltage and applied across the bases of the two transistors.

The line voltage is applied between the collectors and the emitters of the transistors.

Electronic Metering

Transconductance :

A potential difference between the two collector legs is created.

This voltage is the product of the line voltage and line currents and therefore proportional to the line power.

Electronic Metering

Transconductance :

-excellent cost to accuracy ratio
-requires four quadrant amplifier for superior performance under varying power factors and harmonic distortion.

Electronic Metering

Digital Sampling :

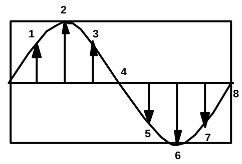
Digital sampling is the only technology that does not use an analogue values of voltage and current.

In this process, the analogue values of voltage and current are converted to digital data, prior to any multiplication taking place.

Electronic Metering

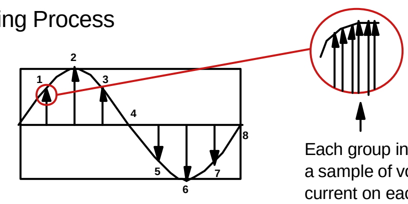
Sampling Process

In the following example, 8 samples are taken per cycle.



Electronic Metering

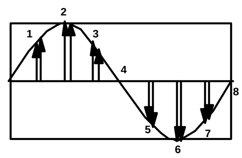
Sampling Process



Each group includes
a sample of voltage and
current on each of the
three phases

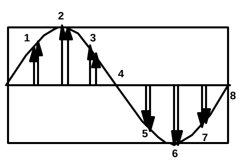
Electronic Metering

Two consecutive cycles have samples that are 34 microseconds apart, this is called sample migration and ensures that each group of samples is not taken at an identical point during the cycling of the signal.



Electronic Metering

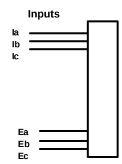
After 60 cycles the microcontroller has a complete picture of the waveform. Sample rate is 8 times 60 cycles = 480 plus 1 because of the migration.
(401 samples for 50 hz frequency)



Electronic Metering

Theory of Operation:

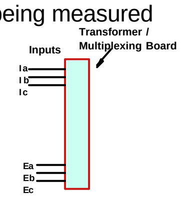
- Transformers sense the input signals from the voltage and current



Electronic Metering

Theory of Operation:

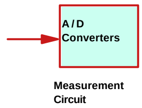
- A multiplexer polls sequentially the different quantities being measured



Electronic Metering

Theory of Operation:

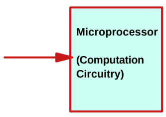
- These quantities are fed to the measurement circuit, sampled and converted to digital signals representing voltage and current.



Electronic Metering

Theory of Operation:

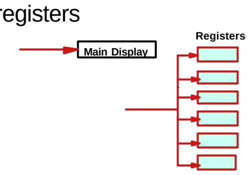
- These pulses are then processed by the microprocessor of the computation circuit to obtain the calculated quantities



Electronic Metering

Theory of Operation:

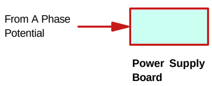
- The calculated quantities can now be displayed on the main display or stored in the meters internal registers



Electronic Metering

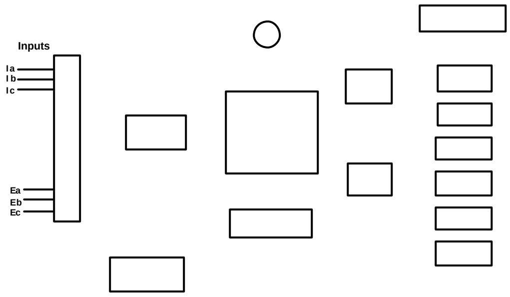
Theory of Operation:

- The power to energize the electronic portion is taken from A phase potential circuit



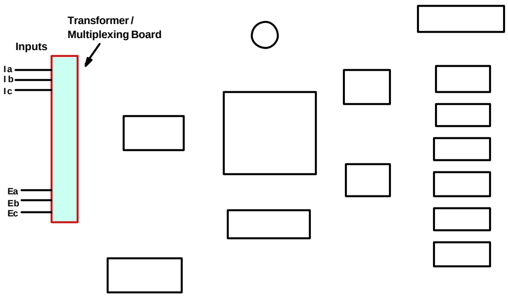
Electronic Metering

Typical Electronic Meter Block Diagram



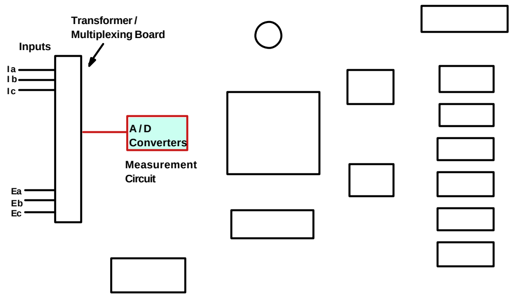
Electronic Metering

Typical Electronic Meter Block Diagram



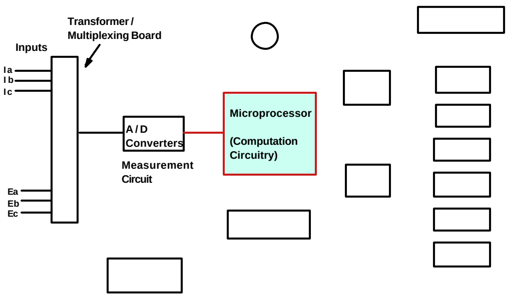
Electronic Metering

Typical Electronic Meter Block Diagram



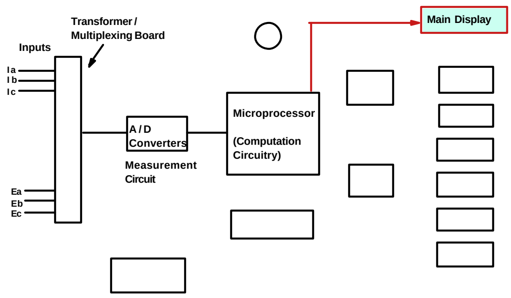
Electronic Metering

Typical Electronic Meter Block Diagram



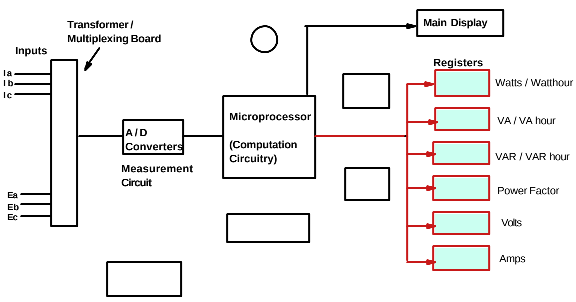
Electronic Metering

Typical Electronic Meter Block Diagram



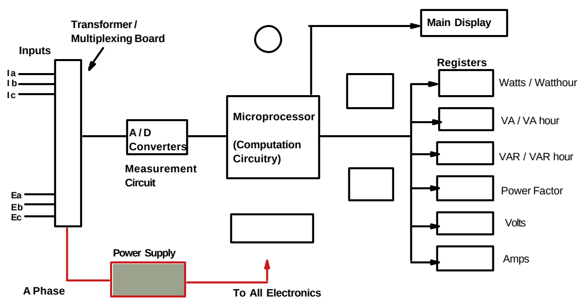
Electronic Metering

Typical Electronic Meter Block Diagram



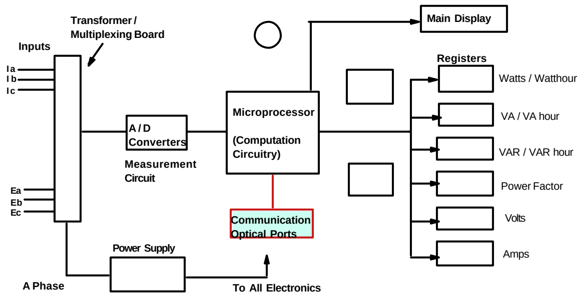
Electronic Metering

Typical Electronic Meter Block Diagram



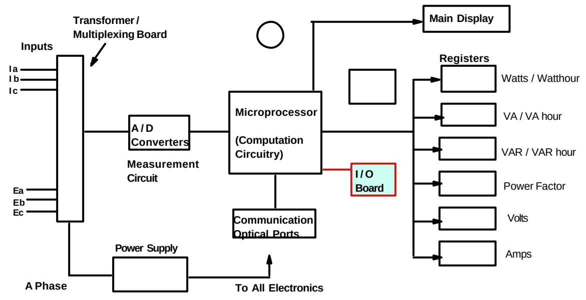
Electronic Metering

Typical Electronic Meter Block Diagram



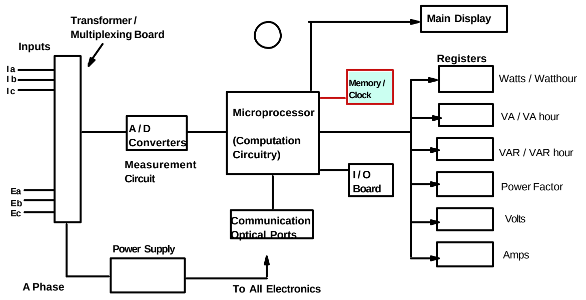
Electronic Metering

Typical Electronic Meter Block Diagram



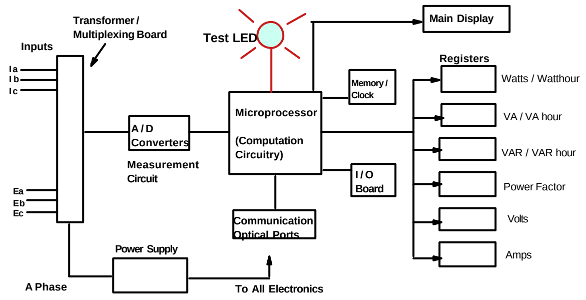
Electronic Metering

Typical Electronic Meter Block Diagram



Electronic Metering

Typical Electronic Meter Block Diagram



Electronic Metering

Digital Sampling Meters:

Most inaccuracies can be fully compensated algorithmically eliminating the need for any physical calibration of the meter.

Not very cost effective technology for single phase residential compared to TDM, Hall Effect or Transconductance technologies

Electronic Metering

Advantages :

- ability to handle complex billing rates
- increased accuracy
- ability to measure various quantities, one device
- ability to collect meter data remotely
- ability to program meter remotely
- have time saving features
- ability to measure all four quadrants

Electronic Metering

Disadvantages :

- more sophisticated testing apparatus required
- more accurate reference standards are required
- more advanced training is required

Electronic Metering

Questions?

Comments?

TYPE APPROVAL

OF

ELECTRICITY METERS

Prepared and presented by:
George A. Smith, Measurement Canada
Paul G. Rivers, Measurement Canada
2006

TYPE APPROVAL

Purpose of Type Approval:

- to determine if a meter type is suitable for trade measurement, and,

- to reduce the amount of testing required during meter verification

This avoids complete testing of each device, and reduces the cost of achieving measurement accuracy.

TYPE APPROVAL

Type Approval Testing:

The legal metrology legislation of a nation will establish:
- the requirement for type approval prior to use in trade measurement;
- the metrological requirements;
- the technical requirements;
- the performance requirements;
- the qualifications of the organization(s) responsible for the testing

TYPE APPROVAL

Suitability for use:

The meter must accurately measure and record electricity consumption, and indicate the quantities in appropriate units

It must be durable, reliable, withstand expected operating conditions, and provide sustained accuracy

TYPE APPROVAL

Quality requirements:

A meter type must be of consistent quality. The submitted example must represent the subsequent (future) production.

Meters should be manufactured under a Quality Management System.

TYPE APPROVAL

Meter Type:

Same uniform construction
Same manufacturer
Similar metrology properties
Use the same parts & modules
Specified range(s) of operation
Specified configuration(s)

Software flexibility makes a "meter type" more difficult to define.

TYPE APPROVAL

Documentation:

The documentation submitted must provide evidence that the meter type complies with the specified requirements

TYPE APPROVAL

Accuracy requirements:

Electricity meters are presently tested using National, Regional, or IEC Standards (International Electrotechnical Commission)

TYPE APPROVAL

International Standards and Recommendations:

An international standard which is accepted in most parts of the world, should reduce testing costs for manufacturers, nations and consumers.

TYPE APPROVAL

International Standards:

OIML Recommendation IR-46 for Electrical Energy Meters has been withdrawn and is being revised to address changing technology

(Technical Committee TC12)

TYPE APPROVAL

Rated operating conditions:

The meter operating conditions should be clearly defined

- Configuration
- Voltage range
- Current range
- Frequency range
- Phase angle range (e.g.from 0.5 inductive to 1 to 0.8 capacitive)

TYPE APPROVAL

Accuracy in relation to current range:

Meter accuracy can vary considerably over the range from zero current to maximum current.

Terminolgy defines the different current values used in type approval testing

TYPE APPROVAL

Starting current (I_{st}):

The lowest current required for the meter to register energy

Energy registration below this value may be the result of electrical "noise" rather than actual electrical energy

TYPE APPROVAL

No-load registration:

No energy registration should occur within the current range from zero to the starting current (I_{st})

(Can be tested at a percentage of starting current at unity power factor.)

TYPE APPROVAL

Transitional current (I_{tr}):

- the transition point between the range of highest accuracy, and the lower current range.

- there is reduced measurement accuracy below the transitional current value

TYPE APPROVAL

Low current (I_{low}):

The current range between starting current and transitional current

Large metering errors can occur if the load is lower than the transitional current for a large part of the time. (starved meters)

TYPE APPROVAL

Meter Accuracy Class:

Greater accuracy usually means greater cost

Accuracy requirements vary with the application
Meters may be rated by accuracy class

OIML defines accuracy class A, B, C & D

TYPE APPROVAL

Meter Accuracy Class:

Quantity	Maximum permissible errors (%) for meters of class			
	A	B (1)	C	D
Current I from I_{tr} to I_{max} and power factor variation from 0.8 cap to 0.5 ind,	2.0%	1.0%	0.5%	(2) 0.2%
Current I between I_{tr} and I_{low}(3), at unity power factor	2.5%	1.5%	1.0%	0.4%

(1) This class is the lowest accuracy class recommended for large consumers, e.g. above 5000 kWh/year, or other value chosen by the National Authority.
(2) For this class the requirement is from power factor 0.5 ind. To 1.0 to 0.5 cap.
(3) The relation I_{ow} / I_{tr} shall be 0.4 for class A and B and 0.2 for class C and D. The meter shall be able to carry Imax continuously without larger error than base maximum permissible error.

TYPE APPROVAL

Suitability for use in trade measurement:

The meter must accurately indicate the quantities in appropriate units

The legal units of measure, and the calculation methods used, may be determined by the government authority

The approval process evaluates the correct application of these legal requirements

TYPE APPROVAL

Technical requirements

Resistance to Severe Operating Conditions:

Meters require the ability to withstand expected electrical disturbances

These may be transient disturbances or semi steady-state disturbances

TYPE APPROVAL

Transient disturbances:
Electrostatic discharge
Transient bursts on I/O ports

Short-time overcurrent during a short-circuit when the load is protected with the proper fuses

TYPE APPROVAL

Temperature dependence:

The meter must operate accurately within specified requirements over the range between the upper and lower temperature limits

TYPE APPROVAL

Load Asymmetry:
The accuracy with current in only one element,

Load Imbalance:
The accuracy when load is varied from fully balanced current conditions to where the current in one of the meter's elements is zero.

TYPE APPROVAL

Voltage variation:
Meter operation from 0.9 to 1.1 rated voltage

Frequency variation:
Meter accuracy when the frequency is varied from 0.98 to 1.02 of the rated frequency

TYPE APPROVAL

Harmonics Effects:

Meter should maintain accuracy with:
- voltage harmonic distortion up to 5%
- current harmonic distortion up to 40%
  (up to 20th or 50th harmonics)
- DC and even harmonics in the AC current
- when the current is half-wave rectified.

TYPE APPROVAL

Harmonics in the AC circuit:
The distortion of the voltage
or current sine wave

Harmonic:
One of the frequencies used to describe
the distortion in the sine wave

TYPE APPROVAL

Distortion factor (d):
The ratio of the r.m.s. value of the harmonic content
to the r.m.s. value of the sinusoidal quantity

Expressed in % THD, (% total harmonic distortion)

TYPE APPROVAL

Security:
Security is required to provide sustained
confidence in measurement results

Mechanical Security:
Prevents access to accuracy adjustments
Maintains mechanical integrity
Access should require breaking the seal(s)

TYPE APPROVAL

Software security:

Software security should require
either breaking a seal, or leaving
permanent evidence of the change.

TYPE APPROVAL

Questions?

Comments?

Electricity Meter Verification and Test Methods

Prepared and presented by:
George A. Smith, Measurement Canada
Paul G. Rivers, Measurement Canada
2006

Meter Verification Process

Verification is intended to confirm that a meter conforms to an approved pattern,
and
complies with the applicable technical requirements and performance criteria.

Meter Verification Process

The meter verification process may use one of the following methods:

1) screening (all meters tested);
2) acceptance sampling;
3) compliance sampling.

Meter Verification Process

Technical requirements should include:

- required Type Approval markings
- applicable measurement unit identifiers
- electronic display functionality
- circuit association is correct (voltage & current coils)
- detent operation of registers
- data retention requirements (power outage)
- battery condition
- meter is free of material deficiencies

Meter Verification Process

Nameplate marking should include:

- manufacturer
- model, type
- element configuration
- measurement functions
- type of demand, demand interval
- meter multiplier(s), test constants
- pulse output constants
- voltage rating, current rating
- frequency rating
- register ratio (electromechanical meters)
- firmware version

Meter Verification Process

The meter verification process should confirm the performance of each approved measurement function that may be used for establishing a charge in the trade of electricity.

Type approval documents may require additional verification tests for certain meter types.

Meter Verification Process

Verification of accuracy is based upon test results at a few specified points.

However, the intent is that all measurement functions will be accurate within specified tolerances throughout their range.

Meter Verification Process

The meter verification process may require either single phase testing of all meter types
or
three phase testing of polyphase meter types.

Measuring apparatus or standards used for meter verification should be calibrated and certified.

The error determined for a meter at any test point should be recorded to the nearest 0.1%.

Meter Verification Process

Certificate of Inspection:

The results of a meter inspection should be recorded, as evidence of the meter's compliance with specified requirements in the event of an audit or measurement complaint.

The record should include a description of the meter, all approved and verified measurement functions, and the associated test errors.

Meter Verification Process

Meter Test Conditions:

- meters should be fully assembled;
- within ± 3 degrees of level (electromechanical meters);
- normal operating mode approved for verification;
- within ±2.0% of test current, voltage, and test load;
- power factor within ±2.0 degrees;
- transformer type meters - use representative current range
- Errors shall be determined to a resolution of 0.1%

Some test specifications may require:

- voltage circuits connected in parallel
- current circuits connected in series

Meter Verification Process

METROLOGICAL REQUIREMENTS

Verify the following:

- accuracy at all energy test points
- accuracy at all demand test points
- bi-directional operation in each direction
- transformer / line loss compensation
- programmable metrological values are correct
- multi-rate register operation
- meter multipliers
- pulse initiator constants

Meter Verification Process

Error Calculations:

The meter error is generally calculated using the following equation:

$$\%Error = (R / T - 1) \times 100$$

R = the quantity registered (indicated) by the meter under test

T = the true value of the quantity indicated by the reference meter.

Meter Verification Process

Voltage Squared Hour Meters:

Voltage squared hour function shall be evaluated at 95% and 105% of the nominal nameplate voltage.

Ampere Squared Hour Meters:

Ampere squared hour function shall be evaluated at 2.5%Imax and 25%Imax.

Meter Verification Process

Prepayment meters:

- Verify the programmed parameters.
- Perform tests which confirm correct operation of the programmed parameters.

Meter Verification Process

Zero load test

- An electromechanical meter should not complete one revolution of its disc.
- An electronic meter should not register energy at a current less than the starting current.

Comparative registration (dial) test

- Electromechanical meters - zero error relative to the disc, tested to a resolution of 3.0%.
- Electronic meters - ±1.0%

Meter Verification Process

Electromechanical meters have a long history of being relatively consistent in construction and operating characteristics.

The test points required for the verification of this meter type are quite well established, as are indicated in the following test tables.

Meter Verification Process

Energy Tests: Single Phase, 1 Element and 1½ Element Meters

Test Configuration	Current	Power Factor	Tolerance
Series Test	25% Imax	1.0	±1.0%
Series Test	25% Imax	0.5	±1.0%
Series Test	2.5% Imax	1.0	±1.0%

Meter Verification Process

Energy Tests: Polyphase 2 Element and 3 Element meters

Test Configuration	Current	Power Factor	Power Factor	Power Factor	Tolerance
		W•h, VA•h	var•h (1)	Q•h (1)	
Series Test	25% Imax	1.0	0.5	0.5	±1.0%
Series Test	2.5% Imax	1.0	0.5	0.5	±1.0%
Each Element	25% Imax	1.0	0.5	0.5	±1.0%
Each Element	25% Imax	0.5	0.866	1.0	±1.0%

Var hour and Q hour meters that operate on the crossed phase principle shall be tested as watt hour meters.

Meter Verification Process

Energy Tests: Polyphase 2½ Element Wye Meters

Test Configuration	Current	Power Factor	Power Factor	Power Factor	Tolerance
		W•h, VA•h	var•h	Q•h	
Series Test	25% Imax	1.0	0.5	0.5	±1.0%
Series Test	2.5% Imax	1.0	0.5	0.5	±1.0%
Each element	50% Imax	1.0	0.5	0.5	±1.0%
Each element	50% Imax	0.5	0.866	1.0	±1.0%
Split coil element	50% Imax	1.0	0.5	0.5	±1.0%

Var hour and Q hour meters that operate on the crossed phase principle shall be tested as watt hour meters.

The split coil element test is not required on reverification.

Meter Verification Process

Energy Tests: Polyphase 2½ Element Delta meters

Test Configuration	Current	Power Factor	Power Factor	Power Factor	Tolerance
		W•h, VA•h	var•h	Q•h	
Series Test	25% Imax	1.0	0.5	0.5	±1.0%
Series Test	2.5% Imax	1.0	0.5	0.5	±1.0%
Each Element	25% Imax	1.0	0.5	0.5	±1.0%
Each Element	25% Imax	0.5	0.866	1.0	±1.0%
Each Element	2.5% Imax	1.0	0.5	0.5	±1.0%

The tests for each element of 2½ element 4-wire Delta meters shall be applied to:
(a) the 2-wire element;
(b) the 3-wire element in series.

The series test for 3 element 4-wire Delta meters shall be conducted at the rated voltage of the lower rated potential coil.

The individual element tests shall be conducted at the rated voltage of the respective potential coil.

Meter Verification Process

Demand meter verification requirements:

- demand Type (block/rolling block or exponential)
- demand Interval (15 minute, 5 minute update etc)
- three full demand response periods
- demand reset operation
- normal mode demand interval

Meter Verification Process

Electromechanical Demand Meters:

- zero load must register within 1/32 inch of true zero
- take readings only after the driving pointer has disengaged
- block interval must be within ±1.0% of the set interval.

Grease dampened demand pointers:
- tested for hysteresis (grease memory)
- tested for pull-back after the test load is removed

Meter Verification Process

Demand Tests: Electromechanical 1 and 1½ Element Thermal Demand Meters

Test Configuration	Test Point	Power Factor	Tolerance
Series	66.6% F.S.	1.0	±1.5% F.S.
VA only: Series	66.6% F.S.	0.5	±1.5% F.S.
Any one element	20% F.S.	1.0	±1.5% F.S.

Meter Verification Process

Demand Tests: Electromechanical 2, 2½ and 3 Element Thermal Demand Meters

Test Configuration	Test Point	Power Factor	Tolerance
Series test	66.6% F.S.	1.0	±1.5% F.S.
VA only: Series test	66.6% F.S.	0.5	
2 el: Any one element	20 % F.S.	1.0	±1.5% F.S.
3 el: Any two elements	20 % F.S.	1.0	±1.5% F.S.
2½ el: Each single element (delta meters)	20 % F.S.	1.0	±1.5% F.S.
2½ el: Each single element (wye meters)	16.6 % F.S.	1.0	±1.5% F.S.

Meter Verification Process

Electronic meter types often vary in measurement capabilities and operational characteristics.

The verification requirements for these meters are not yet firmly established.

As electronic metering technology matures, and meter types become more uniform in operational charcteristics, it may be possible to refine and standardize the test points for electronic meter verification.

Meter Verification Process

Electronic Energy Meters:

It is generally agreed that, due to their operating charcteristics, electronic meters may be verified using a reduced set of test points, as indicated in the following test tables.

Meter Verification Process

Energy Tests: Electronic Single Phase, 1 and 1 ½ Element Meters

Test Configuration	Current	Power Factor	Power Factor	Power Factor	Power Factor	Tolerance
		W•h	VA•h	Var•h	Q•h	
Series Test	25% Imax	1.0		0.5	0.5	±1.0%
Series Test	25% Imax	0.5	0.5	0.866		±1.0%
Series Test	2.5% Imax	1.0				±1.0%

Meter Verification Process

Energy Tests: Electronic Polyphase 2, 2 ½ delta and 3 Element Energy Meters

Test Configuration	Current	Power Factor	Power Factor	Power Factor	Power Factor	Tolerance
		W•h	VA•h	Var•h	Q•h	
Series	25% Imax	1.0		0.5	0.5	±1.0%
Series	25% Imax	0.5	0.5	0.866		
Each Element	25% Imax	0.5				
Series	2.5% Imax	1.0				

The series test for 2 ½ and 3 element 4-wire Delta meters shall be conducted at the nameplate rated voltage.
The individual element tests shall be conducted at the rated voltage of the respective potential coil.

Meter Verification Process

Energy Tests: Electronic Polyphase 2 ½ Element Wye Energy Meters

Test Configuration	Current	Power Factor	Power Factor	Power Factor	Power Factor	Tolerance
		W•h	VA•h	Var•h	Q•h	
Series Test	25% Imax	1.0		0.5	0.5	±1.0%
Series Test	25% Imax	0.5	0.5	0.866		±1.0%
Each element	25% Imax	0.5				±1.0%
Split coil element	25% Imax	0.5				±1.0%
Series Test	2.5% Imax	1.0				±1.0%

Meter Verification Process

Electronic Demand Functions:

Each demand calculation type, such as:

- exponential,
- block interval,
- sliding block interval,

should be verified by conducting one test at 25% Imax 0.5 Pf, for each demand type.

Meter Verification Process

Demand Tests: Electronic 1 and 1½ Element Demand Meters

Test Configuration	Current	Power Factor	Power Factor	Power Factor	Tolerance
		W	VA	Var	±1.0%
Series Test	25% Imax	0.5	0.5	0.866	±1.0%
Any one element	25% Imax	1.0	1.0	0.5	±1.0%

Meter Verification Process

Demand Tests: Electronic 2, 2½ and 3 Element Demand Meters

Test Configuration	Current	Power Factor	Power Factor	Power Factor	Tolerance
		W	VA	Var	
Series Test	25% Imax	0.5	0.5	0.866	±1.0%

Meter Verification Process

Meters with Multiple or Auto-ranging Voltages:

Electronic meters which are capable of operating at multiple voltages should be verified at additional nominal service voltage ranges using a previously verified current and power factor test point (i.e. energy or demand).

Gain Switching Circuits:

Meters which are equipped with gain switching circuits should be tested at one test point in each gain switching range.

Meter Verification Process

Combination electromechanical / electronic meters:

Meters which have electronic metering elements and electromechanical metering elements which are independent of each other shall be verified as two independent meters.

The electronic portion of such devices shall be verified in accordance with the electronic requirements, and the electromechanical portion of such devices shall be verified in accordance with electromechanical requirements.

Meter Verification Process

Hybrid electromechanical-electronic meters:

This meter type has the disc of the electromechanical induction meter monitored electronically to provide metering functions.

Each approved function which is provided electronically, should be verified using the performance requirements for electromechanical meters.

Meter Verification Process

Questions?

Comments?

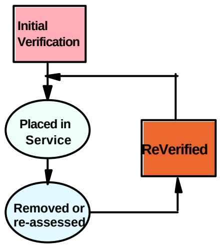
Reverification Intervals

Prepared and presented by:
Paul G. Rivers, Measurement Canada
George A. Smith, Measurement Canada
2006

Reverification Intervals

Reverification Process

The reverification process refers to the periodic retesting of a measurement device.



Reverification Intervals

Reverification Process

Purpose of the Reverification Process;

To ensure there is a continuing and sustained confidence level in the performance of a measurement device, over a period of time.

Reverification Intervals

Reverification Process

Benefits to Society;

- helps maintain high level of confidence in the overall measurement system.
- helps identify poor performers and or potential component failures in devices.
- ensures long term performance of devices

Reverification Intervals

(Seal Periods)

Reverification Intervals or Seal Periods are pre-determined periods of time in which a meter <u>type</u>, <u>design</u> or <u>functionality</u> is allowed to remain in service, before requiring some type of re-accessment of it's continuing performance.

Reverification Intervals

Typically, a reverification interval would be;

- long enough to obtain the maximum benefits of a device, while in service.

Reverification Intervals

Typically, a reverification interval would be;

- long enough to obtain the maximum benefits of a device, while in service.

- short enough to ensure any re-accessment of a devices performance is completed prior to any component or system failures. (life expectancy)

Reverification Intervals

Establishing Intervals or Seal Periods ;

- Reviewing Historical Data,

Reverification Intervals

Establishing Intervals or Seal Periods ;

- Reviewing Historical Data,
- Reviewing Past Practices,

Reverification Intervals

Establishing Intervals or Seal Periods ;

- Reviewing Historical Data,
- Reviewing Past Practices,
- Reliability analysis,

Reverification Intervals

Establishing Intervals or Seal Periods ;

- Reviewing Historical Data,
- Reviewing Past Practices,
- Reliability analysis,
- Approval of Type evaluation.

Reverification Intervals

Considerations :

- manufactures performance data

Reverification Intervals

Considerations :

- manufactures performance data
- quality of materials and processes used

Reverification Intervals

Considerations :

- manufactures performance data
- quality of materials and processes used
- mechanical verses electronic components

Reverification Intervals

Considerations :

- manufactures performance data
- quality of materials and processes used
- mechanical verses electronic components
- device functionality

Reverification Intervals

Considerations :

- manufactures performance data
- quality of materials and processes used
- mechanical verses electronic components
- device functionality
    - simple verses complex
    - single verses polyphase

Reverification Intervals

Reverification Intervals (Examples)

	Electro-mechanical			Hybrid		Electronic	
	Single Phase Energy	Poly Phase Energy	Single / Polyphase Demand	Single / Polyphase Energy	Single/ Polyphase Demand	Single/ Polyphase Energy/Demand TDM/Hall Effect Technology	Single/ Polyphase Energy/Demand Digital Technology
Possible Seal Periods (years)	12	8	6	8	6	10	12

Reverification Intervals

The reverification interval can be influenced by the level of confidence which is desired or considered acceptable to society in general, as provided by the legal metrology legislation of a nation.

At the end of the reverification interval, the meters are required to be removed from service.

Reverification Intervals

Methods of Reverification

The meters require reverification prior to return to service. The reverification process may include:

1) Screening (inspection of all meters), or

2) Sample inspection

Reverification Intervals

Methods of Reverification

Sampling:

Depending on the level of confidence desired, sampling is a cost effective alternative to 100 % inspection.

A sample of the reserviced meters is taken, and the overall performance is accessed, using a sampling plan such as ISO 2859.

Reverification Intervals

The reverification interval is influenced by the expected reliability of the device.

The reliability of a meter is reduced after being in servce.

The reverification interval for a reverified meter may be reduced as a result of the reduction in expected reliability.

Reverification Intervals

Questions?

Comments?

In-Service Compliance Programs

Prepared and presented by:
George A. Smith, Measurement Canada
Paul G. Rivers, Measurement Canada
2006

In-Service Compliance Programs

The use of meter reverification intervals is intended to ensure that the meters removed from service before reliability deteriorates, or accuracy drifts beyond specified accuracy requirements.

In-Service Compliance Programs

While this prevents meters of inferior accuracy from remaining in service, it also requires the removal of meter types with superior accuracy retention.

In-Service Compliance Programs

The purpose of the in-service compliance program is to establish the appropriate reverification interval, based upon the performance of a group of homogeneous meters.

In-Service Compliance Programs

COMPLIANCE SAMPLE PROCESS

The process begins with meters that were first verified using the accepted method, and placed into service.

The in-service meters are then listed in homogeneous compliance sample groups, or lots.

In-Service Compliance Programs

Homogeneous lot criteria is contained in ISO 2859-1:1999*, section 6.6.

The criteria requires that "each lot shall, as far as practicable, consist of items of a single type, grade, class, size and composition, manufactured under the same uniform conditions at essentially the same time."

* Sampling procedures for Inspection by Attributes

In-Service Compliance Programs

Electricity meter homogeneous criteria may include:

- manufacturer,
- model,
- number of elements
- voltage,
- current range
- metering functions
- year of manufacture
- year of reservicing
- recervicing organization

In-Service Compliance Programs

When the lot of meters approaches the end of the reverification interval, a random sample is selected from the lot, removed from service, and tested.

An analysis is performed on the test results to determine the degree of compliance with performance criteria.

In-Service Compliance Programs

Meter lots which demonstrate a lower level of compliance are required to be removed from service at the end of the original reverification interval.

Meter lots which demonstrate a high level of compliance are granted an extension beyond the original reverification interval.

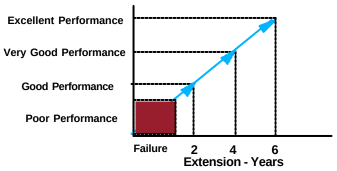
In-Service Compliance Programs

The higher the level of accuracy, the longer the extension applied to the reverification interval.

The interval could be extended from 1/6 to to a maximum of 2/3 of the original reverification interval.

In-Service Compliance Programs

The performance based approach to re-evaluation of the reverification interval



The results of the assessment determine the length of extension to the reverificationinteval.

In-Service Compliance Programs

Meter lots that receive extensions are elegible for compliance sampling as they approach the end of the extended reverification interval.

In-Service Compliance Programs

This process has been used in Canada for the past thirty years.

It has demonstrated that some meter models will receive short, or no extension to their reverification intervals, while other meter models have remained in service after receiving numerous consecutive extensions to the reverification interval.

In-Service Compliance Programs

Questions?

Comments?

Electricity Metering

Measurement Standards
and
Test Equipment

Measurement Standards and Test Equipment

Some considerations when selecting the appropriate measurement standards and test equipment include the following:

- accuracy requirements of the meter under test;
- accuracy requirements of the test equipment
- the accuracy of all standards used to calibrate the test equipment

Measurement Standards and Test Equipment

Other considerations include;

- Sensitivity
- Resolution
- Stability
- Reproducibility

Measurement Standards and Test Equipment

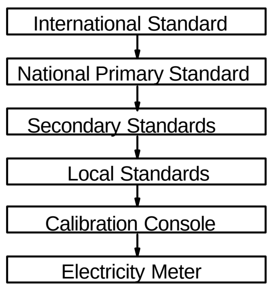
In addition, accurate electricity meter verification requires measurement standards and test equipment which are traceable to national and international standards.

Traceability of Standards:

Traceability is defined by the International Standards Organization (ISO) as:

"the property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties."

Measurement Standards and Test Apparatus
Hierarchy of Standards and Traceability



Measurement Standards
and Test Equipment

Multi-Function Measurement Standards

These standards are available with various levels of accuracy, and are capable of measuring a wide variety of electrical quantities.

Multi-function Measurement Standards

Single Phase Transfer Standard
1 voltage sensor
3 current sensors

Multi-function Measurement Standards

3 Phase Transfer Standard

Multi-function Measurement Standards

Measurement Functions include;
- Volts, Amps, Power factor
- Watts / Watthour
- VA / VAhour
- VARs / VARhour
- Q / Qhour
- Volt squared hour
- Amp squared hour
- Harmonic distortion

Multi-function Measurement Standards

Typical Ratings ;
Up to 600 volt input - autoranging
Up to 150 amp input- autoranging

Capabilities ;
- Pulse Outputs - Programable
- Pulse Inputs - Programable
- Communication Interfaces and more

Multi-function Measurement Standards

Certification of Standards:

Any electricity transfer standard used for electricity meter verification requires a valid calibration certificate.

Electricity transfer standards used to certify calibration consoles are one level higher on the traceability chain, and require a higher level of accuracy.

Measurement Standards

Calibration Consoles

Calibration consoles are complex devices, with many sources of error, and are subject to various conditions of use.

Calibration Consoles

Calibration consoles are subject to a variety of operational characteristics:

- wide variations of current loading
- several test voltages
- different meter types
- different meter configuations
- various meter burdens
- various numbers of meters under test
- extended loading at high currents

Calibration Consoles

The accuracy of a calibration console is reflected on every meter that it is used to verify.

It should be tested extensively to reduce potential sources of error, reduce measurement uncertainty, calibrated to established specifications and certified.

Calibration Consoles

Safety considerations:

- master shut-down switch
- indication that it is energized
- electrical isolation of current and voltage circuits from the primary power source
- effective grounding of exposed panels, or ground fault protection
- circuit protection

Calibration Consoles

Meter Mounting Arrangements:

When testing electromechanical meters, the console should support the meters within 3 degrees of level.

Calibration Consoles

Electrical Requirements:

Creep Switch - zero load test
Capable of Maximum Test Voltages and Currents

Operating Mode:

- Single Phase Testing
- Individual Element test capability
- Test with test Links closed

Calibration Consoles

Indicating Instruments:

Voltage (volts)
Current (amps)
Phase angle meter
Power:
- Watt meter
- Volt-ampere meter
- VAR meter

Calibration Consoles

Accuracy and Repeatability of Calibration Consoles

- capable of setting all currents, voltages, phase angles, and loads within the tolerances

Calibration Consoles

Calibration Console Reference Meters

- Energy Reference Meters
- Demand Reference Meters
- Control Circuits for Energy Meters
- Control Circuits for Demand Meters

Calibration Consoles

Metrological Requirements:
- should meet all accuracy requirements without including Manual Correction Factors.

Error Calculations:
- Console errors are calculated in %Error
- Recorded to 0.01%

Minimum Duration of Accuracy Tests:
- 0.01% resolution (10,000 pulses)

Calibration Consoles

Total Harmonic Distortion (THD);
- voltage and current are tested
- thermal demand <3% THD,
- all other test conditions <5% THD

Load Regulation:
- <0.25% variation in 1 hour
- electronic meters ±0.2% over each minute,
- all others ±0.3% over each minute.

Calibration Consoles

Test Positions and Test Loads

Current Switching Effects:
- switching back to a set load within +/- 0.2%

Sensitivity to Number of Meters under Test:
- vary number of test positions in operation from 1 position to all positions.

Calibration Consoles

Burden Effects:
- high burden vs low burden test deviation <0.1%
- perform tests using the burden producing the highest error.

Variations from Position to Position:
- errors < 0.1% allows testing in one position only when determining console errors.
- 0.1 to 0.2% requires testing in all positions for determining individual position errors.

Calibration Consoles

Sources of Errors

Intervening current transformer errors:
Intervening voltage transformer errors:

1:1 isolation transformers:
- for testing single phase 3-wire meters
- each position,
- each test point

Calibration Consoles

Interchanging certified console reference meters is permitted.

Pulse Counters and Generators are verified

Rangeability of console error calculation is verified to ensure that meters with large errors are correctly calculated

Statistical Calculations are verified

Calibration Consoles

USE REQUIREMENTS

Certified calibration consoles require periodic accuracy checks to ensure accuracy deviations do not exceed specified tolerances.

Daily or weekly accuracy checks, with a tolerance of ± 0.20% are recommended,

Calibration Consoles

During use, accuracy deviations may occur for many reasons including:

- equipment degradation
- inadequate maintenance
- inadequate accuracy checks
- inappropriate accuracy checks
- inadequate test procedures
- inadequate training

Calibration Consoles

Quality Management System Audits are recommended to evaluate the process, and ensure the following:

- the appropriate test equipment is used
- the test equipment is used appropriately
- use requirements are performed
- additional processes required to fulfill use requirements are performed
- the complete process achieves the intent of meter verification

Calibration Consoles

Calibration consoles and measurement standards are clearly an inherent part of any traceable measurement system and require a high level of calibration accuracy, with corresponding documented results.

Measurement Standards and Test Equipment

Questions?

Comments?

Measurement Dispute Investigations

Prepared and presented by:
George A. Smith, Measurement Canada
Paul G. Rivers, Measurement Canada
2006

Measurement Dispute Investigations

An effective meter approval and verification process should increase measurement accuracy, and reduce the number of measurement complaints.

Measurement Dispute Investigations

However, there will be times where the accuracy and equity in the trade measurement of electricity comes into question.

When this occurs, a dispute resolution process should be in place, and supported by the appropriate legislation.

Measurement Dispute Investigations

When a purchaser or seller is dissatisfied with:

- the condition or registration of a meter, or
- the application of the measured quantities in the billing process,

a process for requesting a measurement dispute investigation should be available to the person(s) making the complaint.

Measurement Dispute Investigations

Legislation can assist the dispute resolution process if it is an offence to supply less electricity* than the seller:

(1) professes to supply, or

(2) should supply, based upon the total price charged, and the stated price per unit of measurement used to determine the total price.

* subject to accepted limits of error

Measurement Dispute Investigations

The investigation should include one or more of the following steps:

(1) Seek information from the buyer, seller or any person who could be expected to have knowledge relevant to the matter;

(2) Examine any records that may be relevant to the matter; and

(3) Test the meter for accuracy.

Measurement Dispute Investigations

The testing of the meter should be scheduled so that the buyer and seller can witness the meter test if they choose.

Measurement Dispute Investigations

Billing Corrections

If a meter is found to register with an error exceeding specified tolerances, the error duration will need to be established.

Measurement Dispute Investigations

The duration of error may be easily determined where:

(a) the meter was incorrectly connected, or

(b) an incorrect multiplier has been used, or

(b) there has been an incorrect use of equipment effecting meter registration.

Measurement Dispute Investigations

The measurement error resulting from these types of conditions can be reasonably determined to have existed from the date of installation of the meter, or for the period that the multiplier or incorrect equipment was in use.

Measurement Dispute Investigations

Where the duration of the error is determined from past readings of a meter or other information, the buyer or seller can be made liable for the amount of the charge for electricity based on the full error, and for the full duration of time the error existed.

Measurement Dispute Investigations

Where the duration of the error is not clearly evident, the legislation should specify a time duration, beginning at a period of time before the date of the complaint or request for an investigation.

Measurement Dispute Investigations

When a dispute investigation results in the need for a correction to the quantity used for billing, the calculation methods used to calculate the error and correction should be verified for accuracy.

The various terms for error calculation, and the applicable formulas, must be used correctly if the revised billing corrections are to be accurate.

Measurement Dispute Investigations

EXPRESSIONS OF MEASUREMENT ACCURACY:

ACCURACY: The closeness of agreement between the registered value and the true value.

ERROR: The deviation between the registered value and the true value.

Absolute Error = Registered value - True value

CORRECTION: The amount required to correct the registered value.

Correction = True Value - Registered value

Expressions of Measurement Accuracy

	EXPRESSION	FORMULA	APPLICATION
			e.g. meter registers ½ of true value
1	Absolute Error =	R - T	= - 50 units * (see below)
2	%True Error =	(R - T) / T x 100	= - 50%
	or =	(R / T - 1) x 100	= - 50%
3	% Field Note Error =	(R - T) / R x 100	= - 100%
4	% Fiducial Error =	(R - T) / F x 100	= - 25%
5	% Proof =	R / T x 100	= 200%
6	Registration Factor =	R / T	= 0.5
7	% Registration =	R / T x 100	= 50%
8	Correction =	T - R	= + 50 units * (see below)
9	Correction Factor =	T / R	= 2.0
10	% Correction =	(T - R) / R x 100	= + 100%

* T = True value determined using certified traceable standards e.g. 100 units (T)
R = Registered value as indicated by the device under test e.g. 50 units (R)
F = Fiducial (Full Scale) range of the device. e.g. 200 units (F)

Measurement Dispute Investigations

Overall Registration Factor and Overall Correction Factor

When the error of one device is passed on to the error of the next device, such as where an incorrect transformer is connected to a meter with an unacceptable error, the Overall Correction Factor can be calculated as follows:

1) Calculate the Registration Factor (RF) for each component. (i.e. RF_1, RF_2, RF_3, etc.)

2) Calculate the Overall Registration Factor (RFo)

$$RFo = RF_1 \times RF_2 \times RF_3, \text{ etc.}$$

3) The Overall Correction Factor (CFo) can then be calculated;

$$CFo = 1 / RFo$$

Measurement Dispute Investigations

The legislation should be supported by a documented Measurement Dispute Investigation Process

and

and an official Appeal Process in the event that either of the parties are not satisfied with the findings.

Measurement Dispute Investigations

Questions?

Comments?

APEC/APLMF Seminars and Training Courses in Legal Metrology; (CTI-10/2005T)
Training Course on Electricity Meters
February 28 - March3, 2006
in Ho Chi Minh City, Vietnam

Asia-Pacific Economic Cooperation

Asia–Pacific Legal Metrology Forum

Overview of the Electricity Meters in Japan

Takao Oki
Masatoshi Tetsuka
Japan Electric Meters Inspection Corporation

JEMIC

Contents

Types of Legislation (1)

The measuring instruments used for tariff purposes (specified measuring instruments) are regulated by the following law and regulation

1. **Measurement Law**
2. Cabinet Order on Enforcement of Measurement Law
3. Regulation for Verification and Inspection of Specified Measuring Instruments
4. Regulation on Inspection of Verification Standard

Types of Legislation (2)

Measurement Law

1. The **Measurement Law obligates** us to do **accurate measurement** to secure proper administration of measurement as stipulated by its objectives.
2. The Measurement Law, enforced in November 1st,1993, forms the backbone of the measurement regime.

Types of Legislation (3)

Cabinet Order on Enforcement of Measurement Law

1. **Administration of proper Measurement**

   Ministry of Economy Trade and Industry(METI), Local Government, JEMIC

2. **Classification of specified measuring instruments**

3. **Duration of verification for specified measuring instruments:**

   Water meter : 8 years
   Gas meter : 10 years

Types of Legislation (4)

Regulation for Verification and Inspection of Specified Measuring Instruments

1. **Application for type approval and verification**

   Any person who intends to take the type approval or verification as to specified measuring instruments shall submit an application form to the METI, a governor of prefecture or JEMIC in accordance with the classification prescribed by Cabinet Order.

2. **Requirements for type approval and verification**

   Technical Standards for Structure (Markings, Performance)

3. **Requirements for specified measuring instruments in-service**

   Performance, Maximum permissible errors in service

Specified Measuring Instruments

Classification of specified measuring instruments

Taxi meter	Weighing instrument
Thermometer	Hide planimeter
Volume meter	Current meter
Density hydrometer	Pressure gauge
Flow meter	Calorimeter
Maximum demand meter	**Watt-hour meter**
Var-hour meter	Vibration level meter
Illuminometer	Noise level meter
Instruments for measuring concentration	Relative density hydrometer

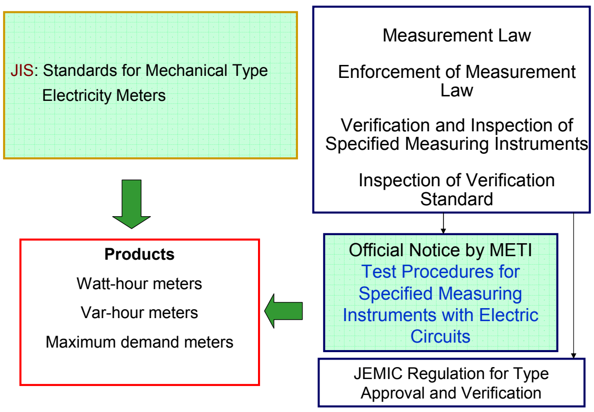
Types of Legislation (5)

Regulation on inspection of Verification Standards

JEMIC has been requested to perform the inspection of verification standard by the specified standard

1. Application for inspection
2. Requirements for verification standards
3. Construction
4. Method of inspection

Documentary Standards for Electricity Meters



Organization for Type Approval and Verification Services

The Japan Electric Meters Inspection Corporation **(JEMIC) provide type approval and verification for the electricity meters** used for tariff or certification purposes.

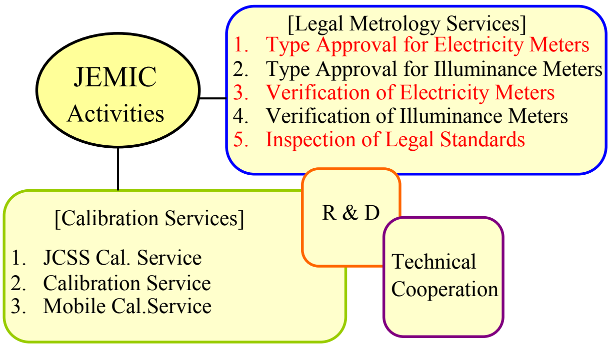
What is JEMIC ? (1)

1. In Japan the verification act of the electricity meter started at ETL (now AIST NMIJ) in 1912.
2. Then, the demand of verification increased with development of industry, and the more efficient and low cost system for verification is desired.
3. In such a reason, **JEMIC was launched** as a semi- government organization in 1964 **based on the JEMIC's law.**

What is JEMIC ? (2)

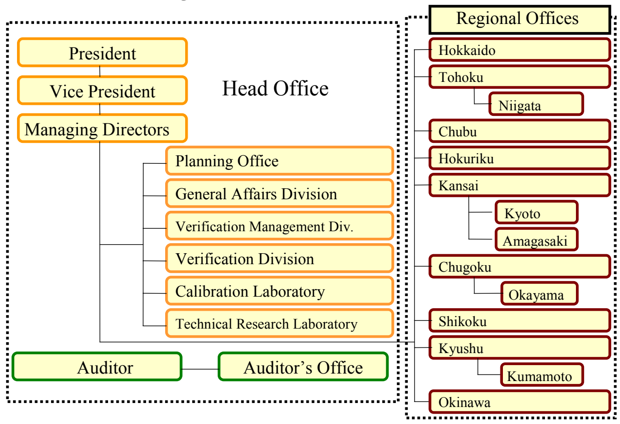
4. Simultaneously, JEMIC took over the verification activity which was being undertaken in ETL, the Japan Electric Association, and Tokyo metropolitan government.
5. Since then JEMIC has carried out the verification of electricity meters for 40 years.

What does JEMIC do?

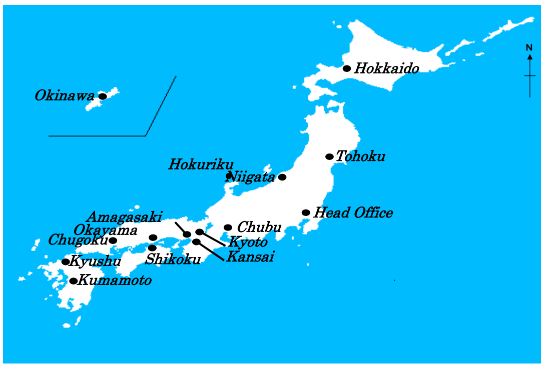


JCSS: The calibrations using the primary standards of the accredited calibration laboratories are carried out for the general industries

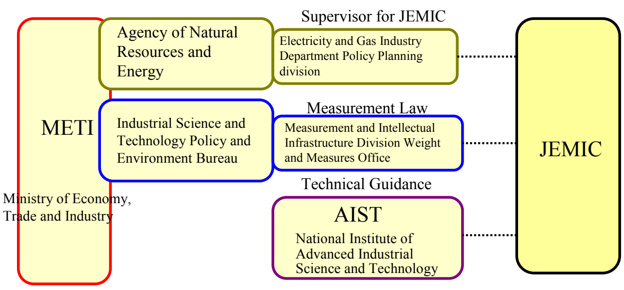
Organization Structure



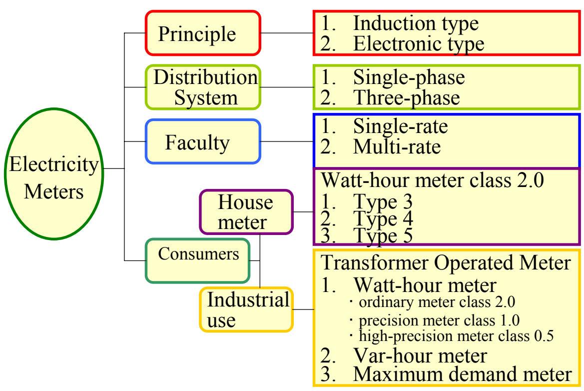
Location of Lab.s



Relationship Between JEMIC and METI



Classifications of the Electricity Meters in Japan



Purpose of Type Approval

1. It is practically impossible to conduct all electrical performance tests for every mass-produced electricity meters due to the huge cost and time involved.

2. Therefore, these tests are conducted on samples of newly developed electricity meters and those passing the test are given a type approval number.

Summary of Legislation

1. **Legal basis**

   The measuring instruments used for tariff purposes (specified measuring instruments) are regulated by the relevant regulations based on the Measurement Law of Japan.

2. **National regulatory organization**

   Ministry of Economy Trade and Industry(METI)

3. **Type approval and Verification body for Electricity meters**

   Japan Electric Meters Inspection Corporation (JEMIC)

JEMIC

APEC/APLMF Seminars and Training Courses
in Legal Metrology; (CTI-10/2005T)
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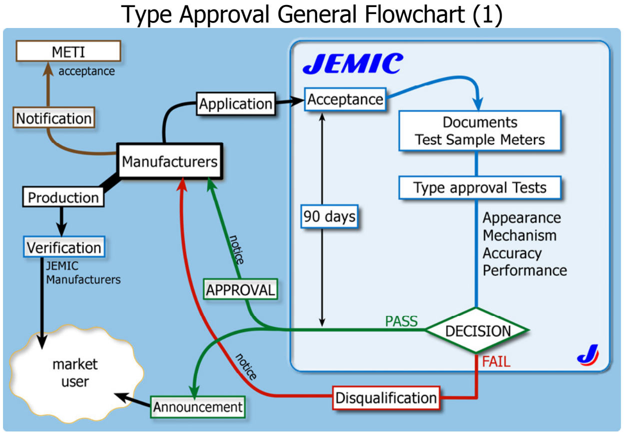
Type Approval

Type Approval General Flowchart (1)



Type Approval General Flowchart (2)

Commission Charges (Cabinet Order)

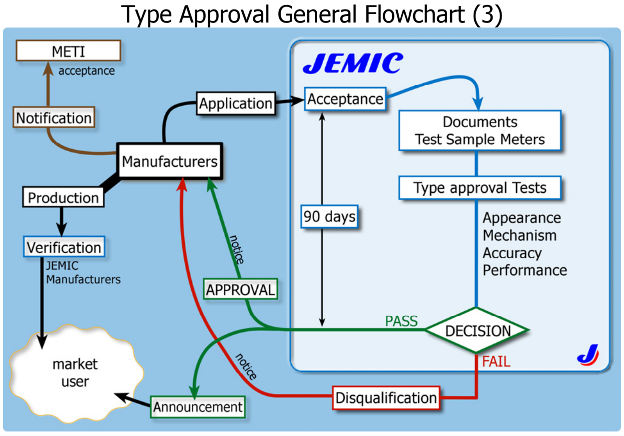
New Type

Direct connected meters : 126,800 yen ($1050)
Others : 185,400 yen ($1550)

Modification-Type

Direct connected meters : 38,300 yen ($320)
Others : 64,900 yen ($540)

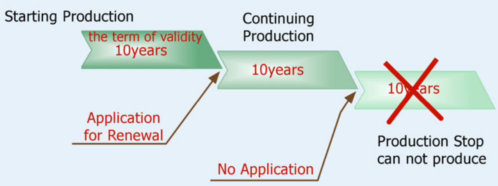
Type Approval General Flowchart (3)



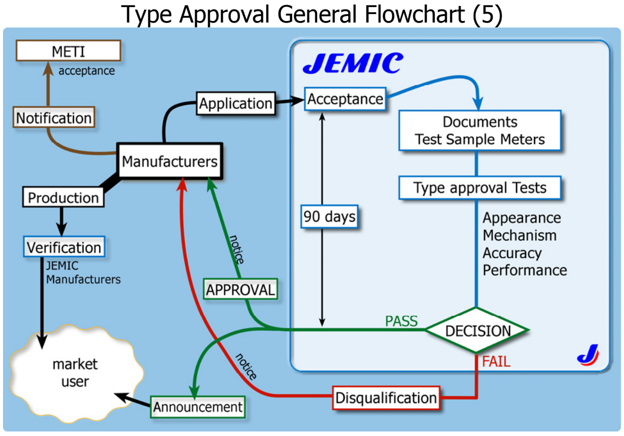
Type Approval General Flowchart (4)

Application for Renewal

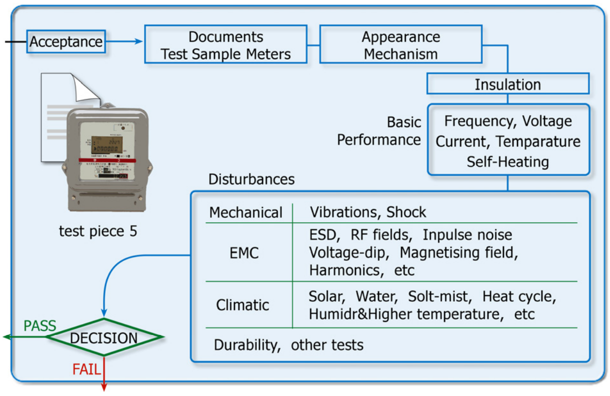
Commission Charges (Cabinet Order)
1,950 yen ($16) every 10years



Type Approval General Flowchart (5)



Type Approval General Flowchart (6)



Outline of Type Test (1) - Appearance,Mechanism


Description:
- type name
- name of manufacturer
- year of product
- classification
- rated value - phase-wire, frequency, voltage, current, meter constant

Structure:
- register
- sealing devices
- test pulse output device(Static)
- test index mark(Mechanical)

Outline of Type Test (2) - Insulation

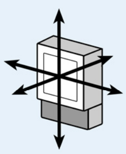
- Insulation Resistance Test DC 500V, 5MΩ
- A.C. Voltage Test 2kV, 1min
- Impulse Voltage Test 6kV


Outline of Type Test (3) - Basic Performance

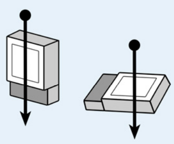
- Frequency	105% & 95% of Imax
- Voltage	110% & 90% of Imax
- Current	Imin to Imax
- Temperature	-10 to +50 deg C
- Self-Heating	Imax,2 hours
- Starting , No-load	

Outline of Type Test (4) - Disturbances(1)

Mechanical: Vibrations 16.7Hz, 4mm
Shock 500m/s^2



direction of Vibrations

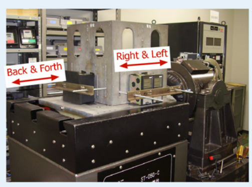


direction of shock

Outline of Type Test (5) - Disturbances(2)

shock test

vibration test



Outline of Type Test (6) - Disturbances(3)

SHOCK TEST

Outline of Type Test (7) - Disturbances(4)

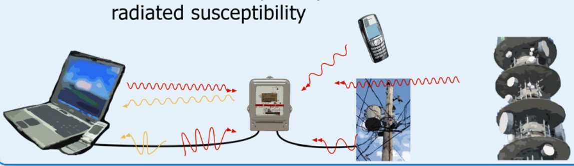
EMC:

	IEC61000series
- ESD	4-2
- RF fields	4-3 , (4-6)
- Impulse noise	(4-4)
- Voltage-dip	(4-11)
- Magnetising field	(4-8)
- Harmonics	(4-12 , 4-13)

Outline of Type Test (8) - Disturbances(5)

EMC : Electromagnetic Compatibility

- EMI(electromagnetic interference):Emission
  conducted emission
  radiated emission
- EMS(electromagnetic susceptibility):Immunity
  conducted susceptibility
  radiated susceptibility



Outline of Type Test (9) - Disturbances(6)

Climatic:

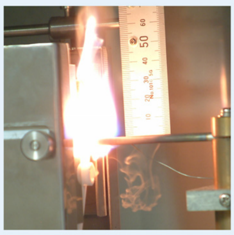
- Solar radiation
- Water
- Salt-mist
- Humid & Higher temperature
- Heat cycle

Outline of Type Test (10) - Disturbances(7)

Durability	Imax, 1000h	
Other tests	- over-current	Imax*30
	- tilt	3 degrees
	- glow-wire	960 deg C
	- spring hammer	0.2 N

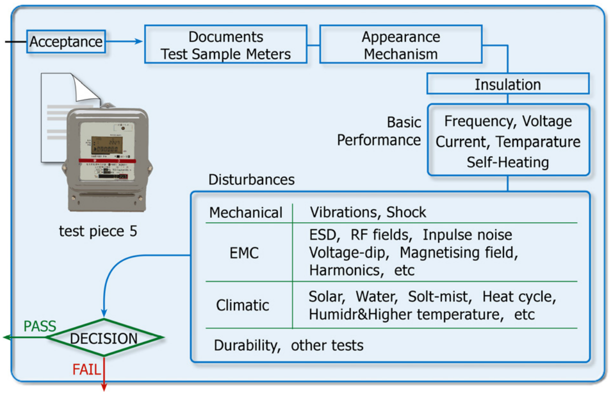
Outline of Type Test (11) - Disturbances(8)

glow-wire test

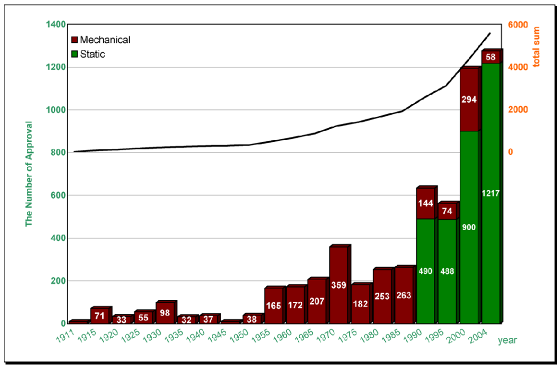


spring hammer test

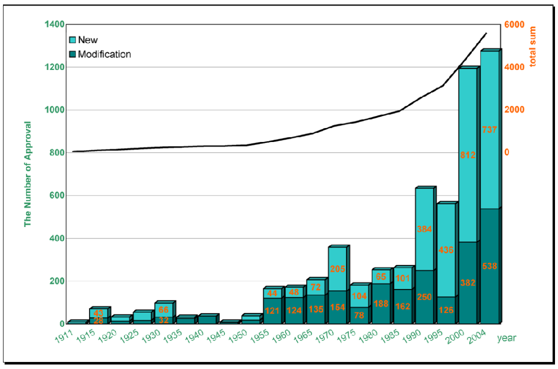
Outline of Type Test (12)



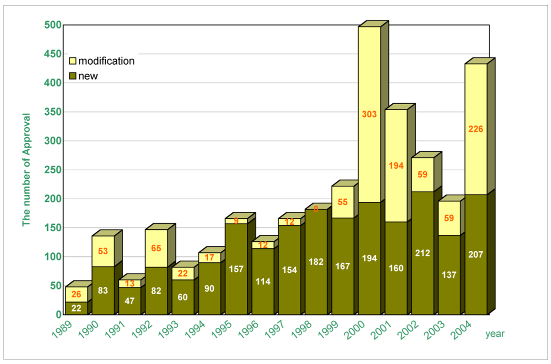
Statistics (1) - The Number of Approval : Mechanical & Static



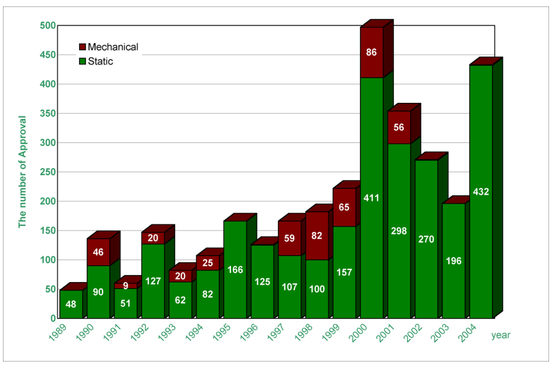
Statistics (2) - The Number of Approval : New & Modification



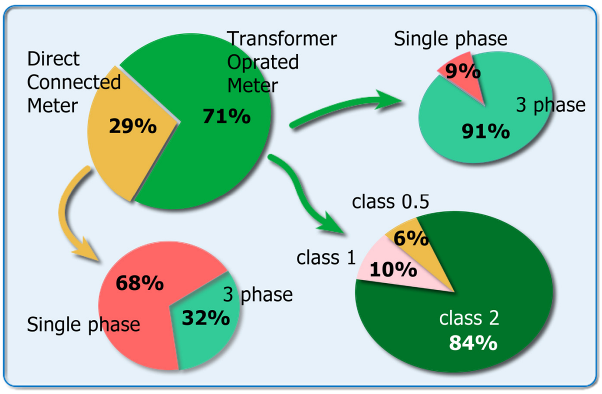
Statistics (3) - The Number of Approval : New & Modification



Statistics (4) - The Number of Approval : Mechanical & Static



Statistics (5) - The Number of Approval : Meter Categories



Conclusion

- Type Test
  New type, Modification-type
- Application
  Documents, Test piece (5)
- Test Items
  - accuracy (basic characteristic)
  - influence performance
    - Mechanical
    - EMC
    - Climatic

Verification (1)

Verification body (JEMIC)

1. Under the **ministerial ordinance**, JEMIC carries out verification tests on each meter submitted for verification.

2. The tests specified in the ordinance are the **same** for both **new and repaired meters.**

JEMIC

Verification (2)

Verification body (designated manufacturer)

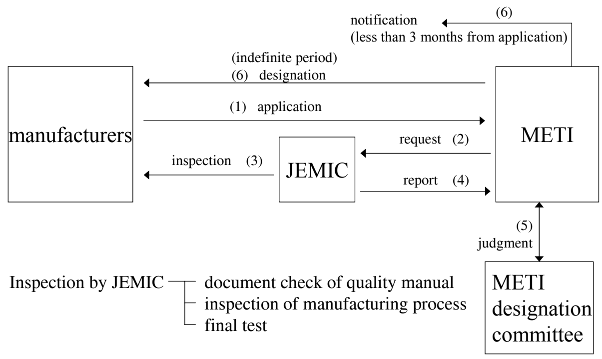
1. In 1992, the new Measurement Law came into force in JAPAN.
2. The Major change is the introduction of self-verification system for electricity meters by the designated manufacturers of meters which has the same effect as the national verification.
3. The self-verification of electricity meters was introduced on October 31, 1998 after the grace period of six years.

Verification (3)

Designation Procedure for Manufacturers in Japan

1. Before manufacturers can certify meters they have to meet certain conditions imposed by the ministerial ordinance of the Measurement Law.
2. One of conditions imposed by the ordinance requires manufacturers to have a Quality Assurance System that meets closely the requirement of ISO9001.
3. Manufacturers have to nominate a representative who takes responsibility for the quality assurance of production and certification of meters.

Designation Procedure for Manufacturers in Japan



Verification (4)

Tests for type approved meters

Meters tested for verification shall comply with the following requirements:

1. Insulation requirement
2. Starting current requirement
3. No-load requirement
4. Error test

Verification(5)

Test Conditions

1. Temperature: 23ºC+/- 5 ℃.
   (23 ºC +/- 2 ºC for high precision watt-hour meters)
2. Voltage: rated voltage +/- 0.3%
3. Frequency: rated frequency +/- 0.5%
4. Voltage and Current waveforms: Distortion Factor
   - Mechanical Type <3%
   - Static Type <2%

(<1% for high precision watt-hour meters)

Verification (6)

Verification Mark and Sealing (1)

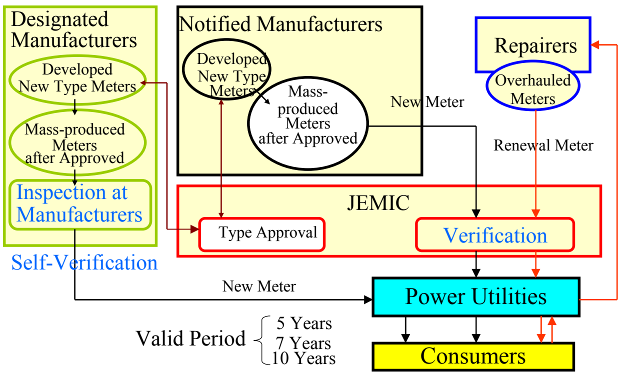
1. The verification mark shall be affixed to the meters which have passed the verification.

2. JEMIC has devised new sealing system, consisting of an ABS plastic cap loaded with a stainless steel spring.

3. The system permits a simple sealing process.

Verification Mark and Sealing (2)

Legal Electricity Meters Verification Scheme in Japan



Verification System for Electricity Meters in Japan (1)

1. In Japan, **all the electricity meters** used for electric dealings are **examined**.

2. The number of the examination items performed in order to test the performance of the electricity meter **exceeds 30 items**.

3. In the daily examination, a **huge amount of time and expense** are required to examine all of these examination items.

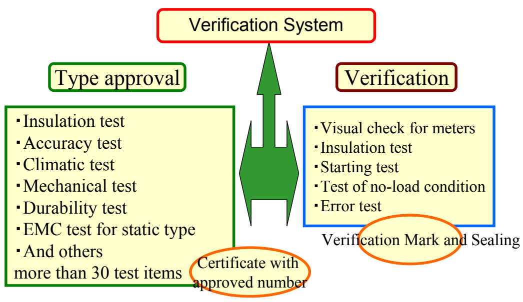
Verification System for Electricity Meters in Japan (2)

4. The examination system is **divided into the type approval and the daily examination** in order to carry out the verification system **more efficiently** and **economically**. That is, the **sampled meter** is submitted to JEMIC. The examination of **all items** is performed about these meters.

5. The sampled meter which passed all examinations receives **type recognition**.

6. As for the meter of the same type as the meter which received type recognition, many of examination items are **omitted**.

Verification System for Electricity Meters in Japan (3)

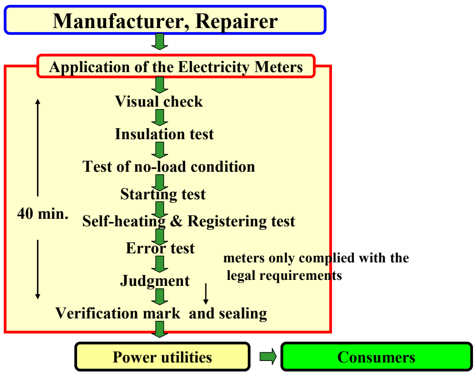


Time Limit to Perform Verification

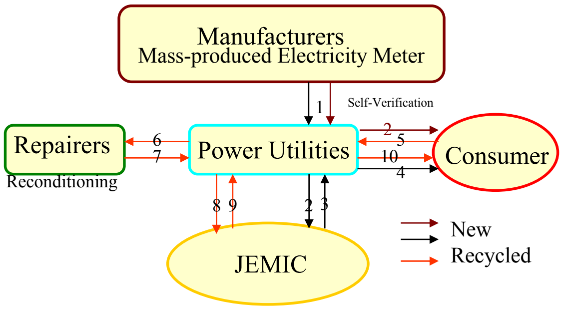
Periods prescribed by the Regulation are as follows:

1. Type approved direct-connected meter (Domestic meter): 20 days
2. Type approved transformer operated meter: 20 days
3. Type approved transformer operated meter and instrument transformer: 30 days
4. Inspection of instrument transformer carried out at consumer's premises: 50 days

The daily Verification process



Life Cycle of Electricity Meter



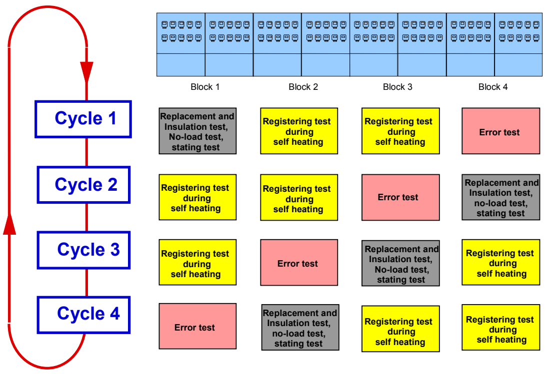
View of the Automatic Testing System for Electricity Meters

The automatic watt-hour meter testing system consists of 4 meter benches, a power source unit and P.C.

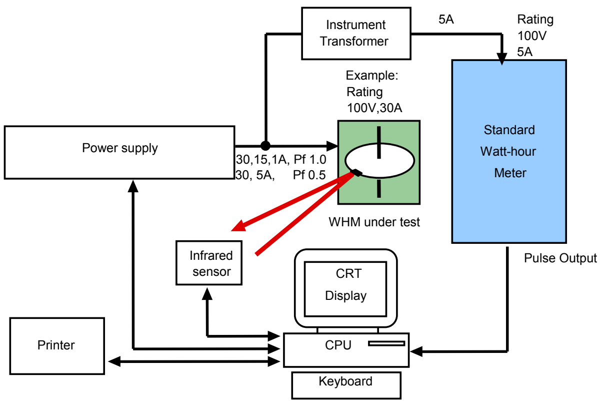
A group of 20 watt-hour meters undergoes the registering test after the no load test and starting current test.

The result of error tests are printed out.

Cyclic Operation of the Automatic Testing Equipment



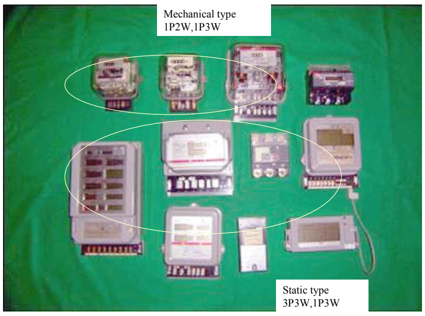
A Test Method



An Automatic Watt-hour Meter Testing System

The revolutions of the rotating disc of the meters being tested are detected by an infrared sensor and are compared with the out put pulse of the standard watt-hour meter.

Different types of electricity meters



Inspection of Instrument Transformers (1)

Instrument Transformers used with electricity meters shall comply with the legal requirements for inspection.

Inspection of Instrument Transformers (2)

Instrument transformers are classified into three:

1. A current transformer (CT) that transfers current of a large-current to small current (usually 5A) in Japan.
2. A voltage transformer (VT) which steps down high voltage to low voltage (usually 110V) in Japan.
3. Transformer (VCT) which contains both a current transformer and a voltage transformer and is mainly used for measuring electric power.

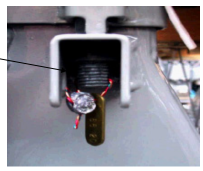
Combined errors of Instrument Transformers and Transformer Operated Meters

1. The combined errors shall comply with the maximum permissible errors for inspection.
2. Combined error = error of transformer operated meter +error of instrument transformer

Matching number

If the combined errors comply with the legal requirements for inspection, the matching number shall be attached to the meters and instrument transformers to ensure that combination of them is not changed in-service.

6600V 20A



Inspection of Instrument Transformers

Standard High Voltage Transformer

Maximum Permissible Errors for Verification

1. Domestic meters (Direct-connected watt-hour meters)

	Maximum Permissible errors	Power factor	Test current
Type 2	2.0%	1	5%In, 50%In, 100%In
	2.5%	0.5 inductive	20%In, 100%In
Type 3	2.0%	1	3.3%In, 50%In, 100%In
	2.5%	0.5 inductive	20%In, 100%In
Type 4	2.0%	1	2.5%In, 50%In, 100%In
	2.5%	0.5 inductive	20%In, 100%In
Type 5	2.0%	1	2%In, 50%In, 100%In
	2.5%	0.5 inductive	20%In, 100%In

2. Transformer operated meters

	Maximum Permissible errors	Power factor	Test current
Ordinary watt-hour meters	2.0% (2.0%)	1	5%In, 50%In, 100%In
	2.5% (2.5%)	0.5 inductive	20%In, 100%In
Precision watt-hour meters	1.0% (1.2%)	1	20%In, 50%In, 100%In
	1.5% (1.8%)		5%In
	1.0% (1.3%)	0.5 inductive	20%In, 50%In, 100%In
	1.5% (2.0%)		5%In
High precision watt-hour meters	0.5% (0.6%)	1	20%In, 50%In, 100%In
	0.8% (1.0%)		5%In
	0.5% (0.7%)	0.5 inductive	20%In, 50%In, 100%In
	0.8% (1.1%)		5%In
Var-hour meters	2.5% (2.5%)	0	100%In
		0.866 inductive	20%In, 50%In, 100%In
Maximum demand meters	3.0% (3.0%)	1	10%In, 50%In, 100%In
		0.5 inductive	100%In

Note (1) In: Rated current
(2) ( ): Maximum Permissible errors for a meter error + an instrument transformer error

3. Maximum Permissible Errors for Meters in-service and Duration of Verification

After a meter is installed on a customers premises for charging purposes, an error of the meter is required to remain within the maximum permissible errors for the entire duration of verification

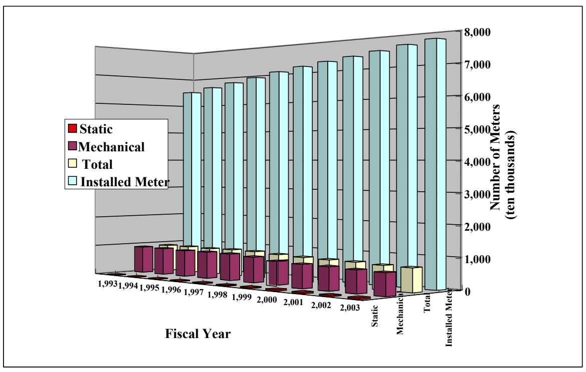
Electricity meters	Maximum permissible errors in-service	Verification period (in years)
Domestic Watt-hour meter 100%In to 20%In, pf 1 Rated current: 30, 120, 200 , 250A Rated current: 20, 60 A	+/-3.0%	10 7 (20, 60A)
Precision watt-hour meter 100%In to 10%In, pf 1 5%In, pf 1 Rated current: 5 A	+/-1.7% +/-2.5%	5(mechanical Type) 7(static Type)
High precision watt-hour meter 100%In to 10%In, pf 1 5%In, pf 1 Rated current: 5 A	+/-0.9% +/-1.4%	5(mechanical Type) 7(static Type)
Var-hour meter 50%In, pf 0.866 Rated current: 5 A	+/-4.0%	5(mechanical Type) 7(static Type)
Maximum demand meter 50%In, pf 1 Rated current: 5 A	+/-4.0%	5(mechanical Type) 7(static Type)

Number of Electricity Meters in-service (at 2004/4)

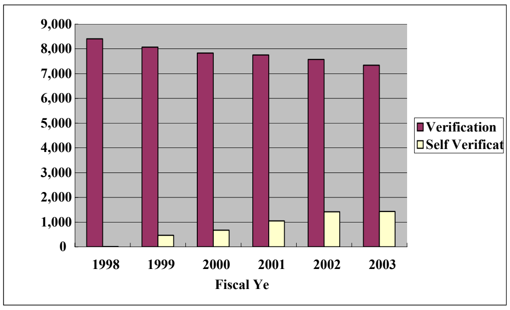
1. Direct-connected meter
   Domestic meter: 75,737,134pcs

2. Transformer operated meter
   Industrial use meter: 3,794,558pcs

Number of Electricity meters in service and Number of Meters Verified



Number of Meters Verified by JEMIC or Designated Manufactures



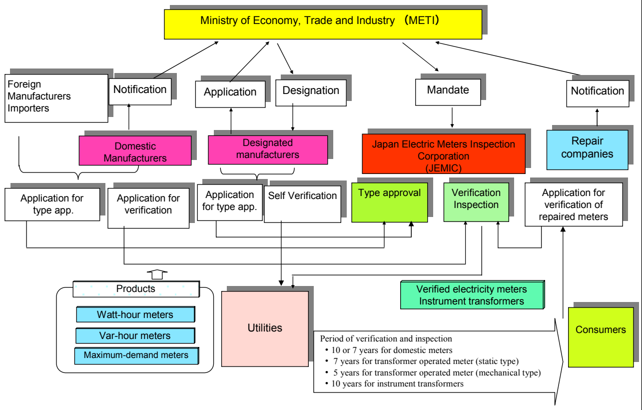
Verification Fees (Cabinet Order)

1. Type approved direct-connected meter:
   Initial verification of 1p3w 30A meter: 446 yen
   Subsequent verification of 1p3w 30A meter: 480 yen

2. Type approved transformer operated meter:
   Initial verification of 3p3w ordinary watt-hour meter: 2,464 yen
   Subsequent verification of 3p3w ordinary watt-hour meter: 2,650 yen

3. Instrument transformer:
   Voltage transformer 3p3w 6.6kV : 4,600 yen
   Current transformer 3p3w 50A : 3,300 yen

Scheme of Legal Metrology for Electricity Meters



Summery of Verification

1. Initial verification is performed by JEMIC or designated manufactures.
   (10 manufactures at February 2006)
2. Subsequent verification is performed by JEMIC.
3. Meters tested for verification shall comply with the maximum permissible error and technical requirements.

JEMIC

Verification Standards

1. **Inspection of Verification Standards**

2. **Traceability system of power and energy standards (Verification Standards)**

3. **Introduction of National Standard for power and energy**
   (A Digital System for Calibrating Active/Reactive Power and Energy Meters)

JEMIC

Inspection of Verification Standards (1)

1. The use of standard of specific accuracy is essential to ensure and maintain the reliability of verification.
2. The measurement law demands that not only verification organizations for electricity meters but also business which manufacturers and repairers such meters be equipped with verification standards(legal standards).
3. The legal standards such as standard watt-hour meters are inspected by JEMIC.

Standard Watt-Hour Meters

1. Rotary standard watt-hour meter
   (first generation1957~)
2. Stationary standard watt-hour meter
   (second generation1968~)
3. Static standard watt-hour meter
   (third generation1980~)

   Self calibration wide band
   watt-hour meter
   (fourth generation1999~)

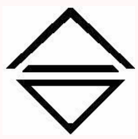
Inspection of Verification Standards (2)

1. The JEMIC carries out calibration of power and energy standrad for industry and inspection of tariff and certification electricity meters.
2. Power and Energy measurement system which is designated as Primary Measurement Standard was developed by JEMIC.
3. The JEMIC maintains such Primary Measurement Standard as power and energy standrad.

Inspection Mark of Verification Standards

1. Term of Validity; 1Year
2. Instruments Error;
   - High Precision Standards 0.2%
   - Precision Standards 0.5%

A measuring instrument which has passed the inspection of verification standards shall be affixed with an inspection mark of verification standards.



Traceability system of power and energy standards (Verification Standards) (1)

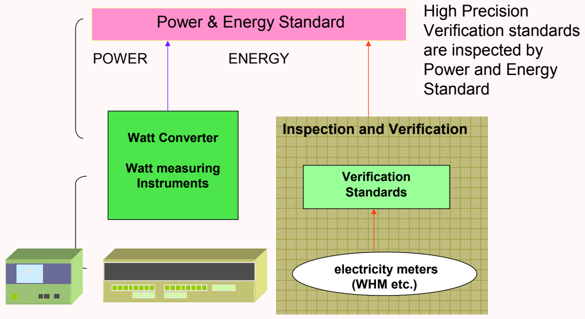
1. JEMIC establishes power and energy standards and supplies these standards to industries.
2. The scope and uncertainty of calibration service by JEMIC as an accredited calibration laboratory are shown as next page.
3. Power and Energy measurement system which is designated as Primary Measurement Standard was developed by JEMIC.

Calibration scope and uncertainty by using Primary Standard

	Scope of the Calibration Service		Best Uncertainty (k= 2)
Power	Watt Converter	<110V, <50A, 45 - 65Hz	50ppm
	Power Measuring Instrument	<110V, <50A, 45 - 65Hz	48ppm
Energy	Watt-hour Meter	<110V, <50A, 45 - 65Hz	50ppm

Best Uncertainty : 100V, 5A, 50Hz,60Hz, 1Phse 2-Wire

Traceability system of power and energy standards (Verification Standards) (2)



A View of Electric Energy Measurement

Introduction of National Standard for power and energy

A DIGITAL SYSTEM FOR CALIBRATING ACTIVE/REACTIVE POWER AND ENERGY METERS

Voltage : 100V
Current : 5A
Frequency : 50, 60Hz

Simple approaches for power/energy measurement with digital technique.

System Overview

Basic Principle

Active power (*P*) and reactive power (*Q*) can be calculated from voltage (*U*), current (*I*) and phase angle (*ø*) .

$P = UI\cos ø$

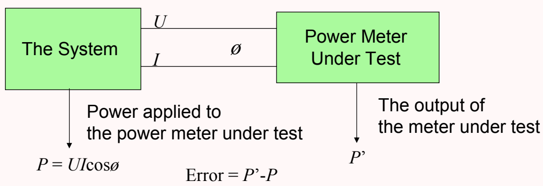
$Q = UI\sin ø$

The power calibration system

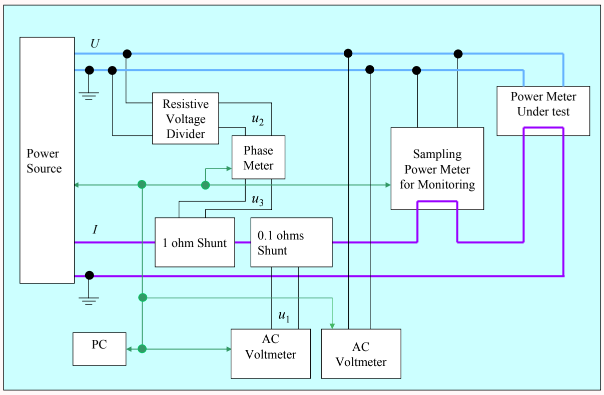
generates *U* and *I* with phase angle *ø*,

measures *U*, *I* and *ø* individually,

calculates *P* and *Q* from the measurement results of *U*, *I* and *ø* according to the "basic principle".



Block Diagram of the System



JEMIC

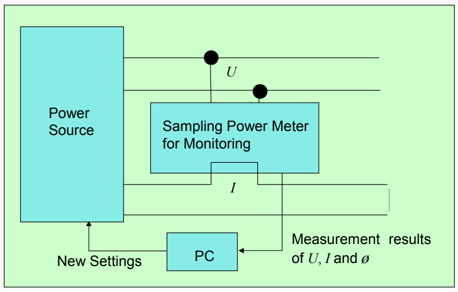
A view of Primary Standard for power and energy

The sampling power meter

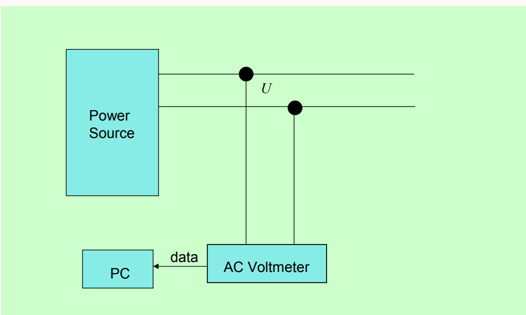
Multifunction
- RMS value of voltage and current
- Active / reactive power
- Phase angle
- Frequency

The sampling power meter is used for monitoring *U*, *I* and *ø*.

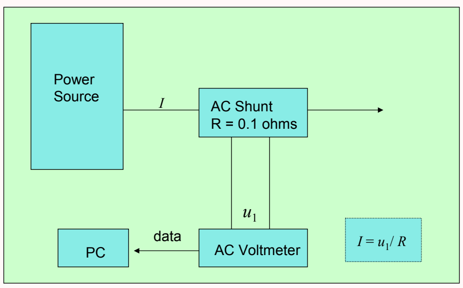
Monitoring the power source with the sampling power meter



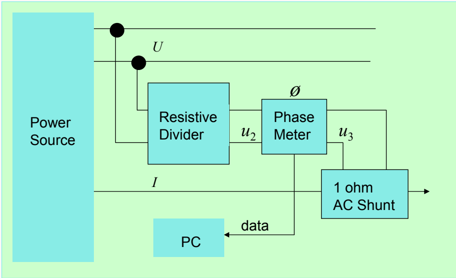
Voltage measurement



Current measurement



Phase angle measurement



Active power (*P*) and reactive power (*Q*)

Active power (*P*) and reactive power (Q) can be calculated from the measurement results of *U*, *I* and *ø*.

Active power

$$P = UI\cos ø = Uu_1\cos ø / R$$

Reactive power

$$Q = UI\sin ø = Uu_1\sin ø / R$$

Performance (1)
Uncertainty of power measurement

Power factor 1

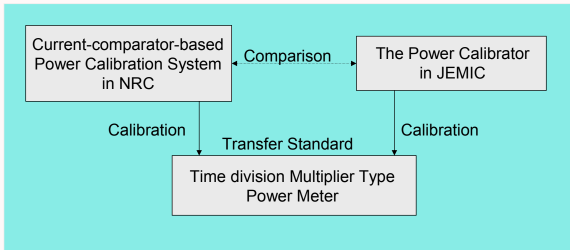
• Uncertainty of voltage measurement	14 μV/V
• Uncertainty of current measurement	14 μA/A
• Total	20 μW/VA

Power factor 0

• Uncertainty of phase measurement	11 μrad
• Total	11 μW/VA

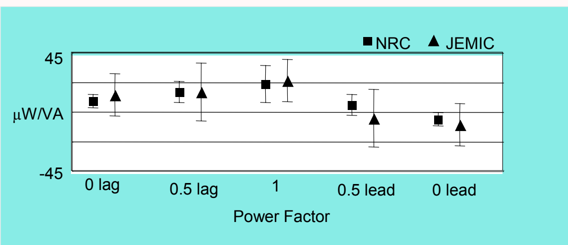
Performance (2)

Comparison between JEMIC's and NRC's system



Performance (3)
Comparison between JEMIC's and NRC's system

The error of the transfer standard measured with JEMIC's and NRC's system at 120V, 5A, 60Hz



Features of Power and Energy System

1. Theoretically simple
2. Simple design
3. Easy to operate
4. Sufficiently practical for calibrating precision power/energy meters

Summery of Verification Standards

1. The verification equipment must be traceable to national standards and be inspected by JEMIC.
2. **Traceable to the primary standards on energy measurements are essential to maintain a fair trade.**
3. A fair trade is to contribute for consume confidence.

Thank you for your Attention

JEMIC

APEC/APLMF Seminars and Training Courses
in Legal Metrology; (CTI-10/2005T)
Training Course on Electricity Meters
February 28 - March 3, 2006, Ho Chi Minh City, Vietnam

Asia-Pacific Economic Cooperation

Asia-Pacific Legal Metrology Forum

Overview of International Standards relate to Electricity Meters

- Report of International Meeting in South Africa -
- International Standards of IEC TC13 -

Meeting in South Africa (1)

Date	18th October 2005
Site	Cape Town South Africa
	Sheraton Hotel
Attendance	18 countries, 52 delegates

Australia,Austria,China,Denmark,Finland,
France,Germany,Hungary,India,Indonesia,
Italy,Saudi Arabia,Slovenia,South Africa,
Spain,United of Kingdom,United State,Japan

Meeting in South Africa (2)

- 1990 Beijing (with IEC 54, General Meeting)
- 1993 Sydney (with IEC 57, General Meeting)
- 1995 Durban (with IEC 58, General Meeting)
- 1998 Helsinki
- 2001 Winterthur
- 2005 Cape Town (with IEC 69, General Meeting)

- 2007,8? France(with IEC General Meeting) ?, China ?

Meeting in South Africa (3)

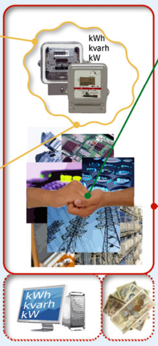
- Chairman's Report
  Globalization, Deregulation, Legal Requirements,etc
- WG's Report
  WG11, 13, 14, 15
- Liaison Report
  OIML
  TC56, 66, 8, SB1
  STS, DLMA UA
- others
  MID
  IEC Central Office Report

Working Group of TC13

WG11
Electricity metering equipment

accuracy, performance,
nameplate,display,etc
for type testing
& acceptance testing

WG13
dependability



WG14
communication

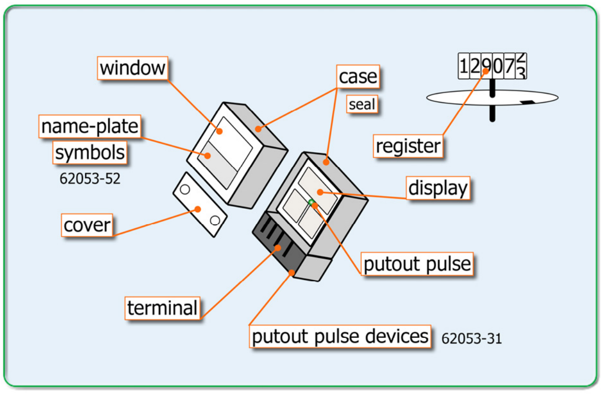
data modeling
& data exchange

WG15
payment systems
(prepayment)
metering systems
for electricity payment

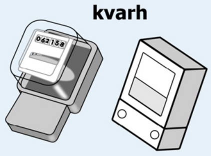
WG11 Documents (1)

	General		Particular		
Type test	IEC 62052-11 Metering equipment		IEC 62053-31 Pulse output devices	IEC 62053-52 Symbols	IEC 62053-61 Power consumption & voltage requirements
Type test		Static	IEC 62053-21 active energy classes 1 & 2	IEC 62053-22 active energy classes 0,2S & 0,5S	
Type test		Static	IEC 62053-23 reactive energy classes 2 & 3	IEC 62053-24 reactive energy classes 0.5 & 1	
Type test		Mechanical	IEC 62053-11 active energy classes 0,5, 1 & 2	IEC 60145 Var-hour	IEC 60211 Maximum demand indicators Class 1.0
Type test	IEC 62052-21 Tariff & load control equipment		IEC 62054-11 ripple control receivers	IEC 62054-21 time switches	
Acceptance test	IEC 62058-11 acceptance inspection methods		IEC 62058-21 Electromechanical active energy classes 0,5, 1 & 2	IEC 62058-31 Static active energy classes 0,5, 1 & 2	

WG11 Documents (2) - IEC62052-11,62053s



WG11 Documents (3) - IEC62053s



kWh
kvarh

Accuracy class
2, 1, 0.5, 0.2

Requirements

Mechanical
Electrical
Accuracy
test condition

→

Tests

Current
Voltage
Frequency
Temperature
Starting
No-load
etc

WG13 Documents (1)

IEC/TR 62059-11
General concepts

IEC/TR 62059-21
Collection of meter dependability data from the field

IEC 62059-31
Accelerated reliability testing — CD(13/1347)

IEC 62059-41
Reliability prediction — FDIS(13/1348)

IEC 62059-51 TR
Software aspects of reliability — Future work

WG14 Documents (1)

IEC 62056-21
Direct local data exchange

IEC/TR 62051-1
Glossary of terms data exchange using DLMS/COSEM

IEC 62056-31
Use of local area networks on twisted pair with carrier signaling

IEC 62056-32 TS
Using local area with baseband signaling

IEC/TS 62056-41
Data exchange using wide area networks: Public switched telephone network (PSTN) with LINK+ protocol

IEC 62056-42
Physical layer services and procedures for connection-oriented asynchronous data exchange

IEC 62056-46
Data link layer using HDLC protocol

EC 62056-47
COSEM transport layers for IPv4 networks

IEC/TS 62056-51
Application layer protocols

IEC/TS 62056-52
Communication protocols management distribution line message specification (DLMS) server

IEC 62056-53
COSEM application layer

IEC 62056-61
Object identification system (OBIS)

EC 62056-62
Interface classes

WG14 Documents (2)

Model Standards

IEC/TR 62051-1
Glossary of terms data exchange using DLMS/COSEM

IEC 62056-61
Object identification system (OBIS)

IEC/TS 62056-52
DLMS server

EC 62056-62
COSEM Interface classes

Media-specific protocol Standards (ISO,Internet)

IEC/TS 62056-51
Application layer protocols

IEC 62056-53
COSEM application layer

IEC 62056-21
Direct local data exchange

IEC 62056-31
Use of local area networks on twisted pair with carrier signaling

IEC/TS 62056-41
PSTN LINK+ protocol

IEC 62056-46
Data link layer using HDLC protocol

EC 62056-47
COSEM transport layers for IPv4 networks

IEC 62056-42
Physical layer services

IEC 62056-32 TS
Using local area with baseband signaling

WG15 Documents (1)

IEC/TR 62055-21
Framework for standardization

IEC 62055-31
Particular requirements - Static payment meters for active energy (classes 1 and 2)

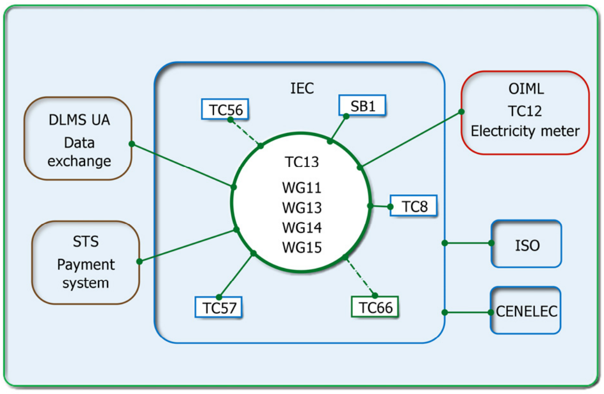
IEC/PAS 62055-41
Standard Transfer Specification(STS)

IEC 62055-41
STS - Application layer protocol for one-way systems — CDV(13/1367)

IEC 62055-51
STS - Physical layer protocol for one-way numeric and magnetic card token carriers — CDV(13/1368)

IEC 62055-52
STS -Virtual Token Carrier for Direct Local Connection (includes two-way transfers) — Future work

Mapping of Liaison(relationships) (1)



Mapping of Liaison(relationships) (2)

OIML:International Organization of Legal Metrology
IEC TC8:System aspects of electrical energy supply
IEC TC56(informal):Dependability
IEC TC57:Power system control and associated and communications
IEC TC66(informal):Safety of measuring, control and laboratory equipment
DLMS UA:DLMS User Association
STS:STS association
ISO:International Standardization Organization
CENELEC:European Committee for Electrotechnical Standardization

Conclusion

On-going & Future work

WG11
- Acceptance test IEC 62058-11, -21, -31
- varh meters 1 & 0.5 IEC 62053-24
- Safety aspects ←

WG13
- IEC 62059-31, -41
- Software aspects of reliability ← IEC 62059-51

WG14
- IEC 62056-32, -47
- Revision of IEC 62056-31 ←

WG15
- IEC 62055-41, -51
- IEC 62055-52 ←

APEC/APLMF Seminars and Training Courses
in Legal Metrology; (CTI-10/2005T)
Training Course on Electricity Meters
February 28 - March 3, 2006, Ho Chi Minh City, Vietnam

Asia-Pacific Economic Cooperation

Asia-Pacific Legal Metrology Forum

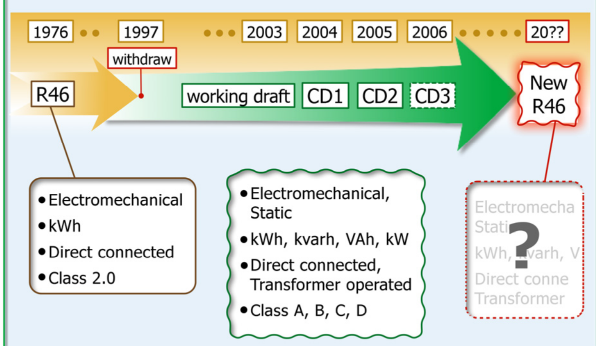
Current Situation of the Revision of OIML Recommendation

- Draft of R46 Electricity Meters -

Introduction

- OIML TC12
  "Instruments for measuring electrical quantities"
- R46 (1976)
  "Active Electrical Energy Meters for Direct Connection(Class 2)"
- Draft Revision Committee Draft CD2(2005)
  "Electricity Meters"

Progress



Outline of Contents(1)

Previous Edition (1976) <- index -> Draft (2005)

Previous	Draft
Terminology	Scope
Scope	Bibliography
Unit	Terminology
Technical requirements	Metrological Requirements
Pattern approval	Type approval
Initial verification	Test program
Examination for conformity with approved pattern	Test procedures for type approval
Statutory markings	Examination for conformity with type approval
	Initial Verification and subsequent-verification
20 pages	**over 40 pages**

Outline of Contents(2)

Previous Edition(1976) <- index -> Draft (2005)

Previous	Draft
Terminology	Scope
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Unit	Terminology
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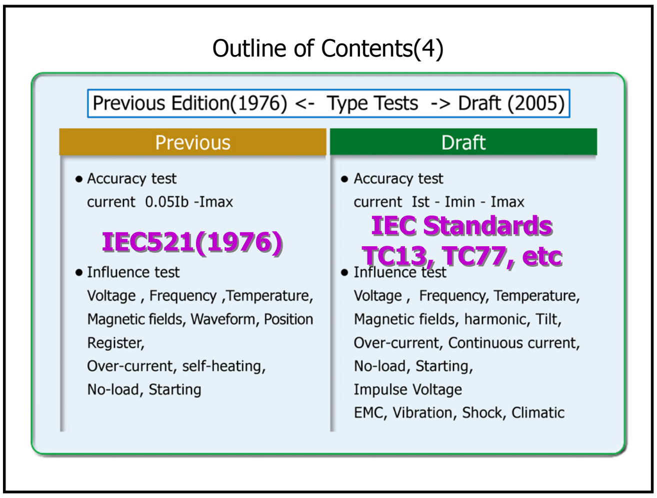
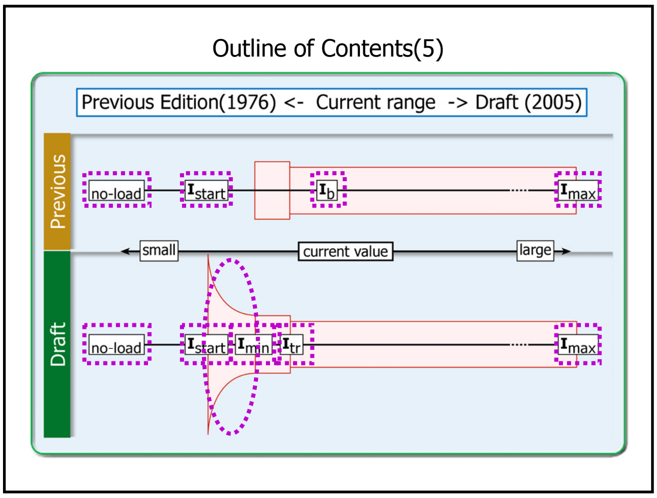
	Initial Verification and subsequent-verification

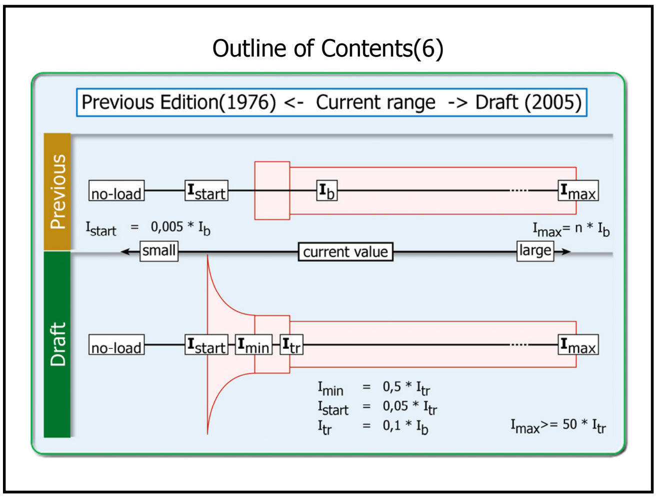
Outline of Contents(3)

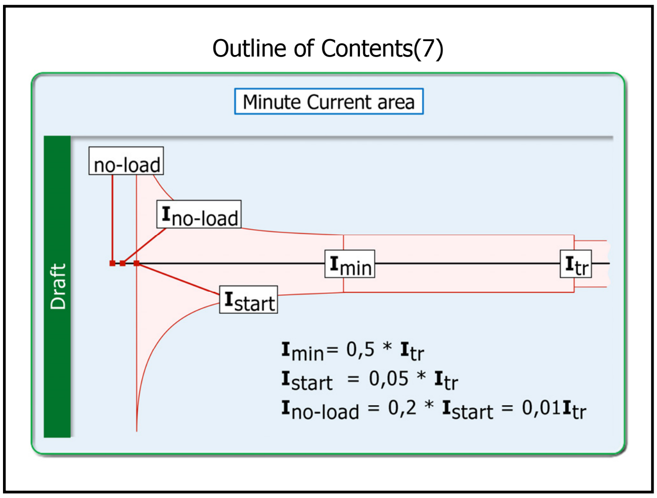
Previous Edition(1976) <- Type Tests -> Draft (2005)

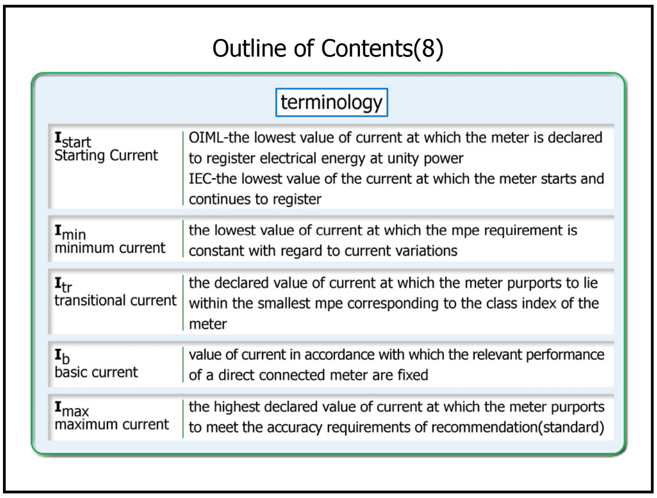
Previous	Draft
Accuracy test current 0.05Ib -Imax	Accuracy test current Ist - Imin - Imax
15 test items	**over 30 test items**
Influence test Voltage , Frequency ,Temperature, Magnetic fields, Waveform, Position Register, Over-current, self-heating, No-load, Starting	Influence test Voltage , Frequency, Temperature, Magnetic fields, harmonic, Tilt, Over-current, Continuous current, No-load, Starting, Impulse Voltage EMC, Vibration, Shock, Climatic



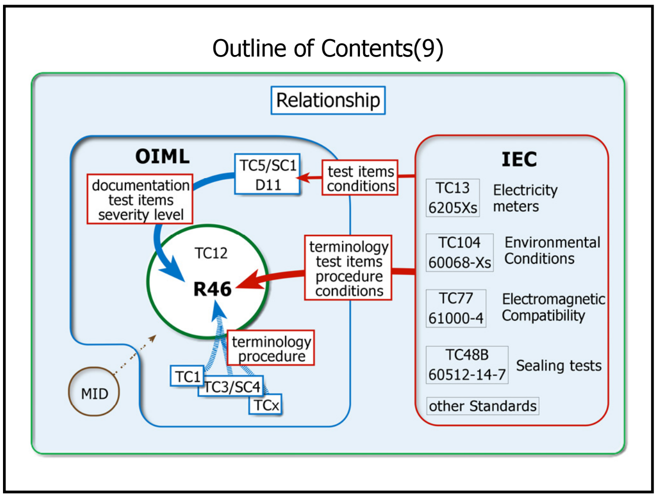








I_{start} Starting Current	OIML-the lowest value of current at which the meter is declared to register electrical energy at unity power IEC-the lowest value of the current at which the meter starts and continues to register
I_{min} minimum current	the lowest value of current at which the mpe requirement is constant with regard to current variations
I_{tr} transitional current	the declared value of current at which the meter purports to lie within the smallest mpe corresponding to the class index of the meter
I_b basic current	value of current in accordance with which the relevant performance of a direct connected meter are fixed
I_{max} maximum current	the highest declared value of current at which the meter purports to meet the accuracy requirements of recommendation(standard)



Conclusion

- OIML TC12
  "Instruments for measuring electrical quantities"

- Draft Revision Committee Draft CD3(2006)
  "Electricity Meters"

▶ Electric & Mechanical Meters
- ▷ classification - A, B, C, D
- ▷ test items - accuracy,EMC, climatic, harmonics, etc
  more than 30 tests

? var-hour, VA-hour, etc