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.
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.

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.

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.

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) Vol-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

Questions?

Comments?

Next: 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.

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.

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

Questions?
Comments?

Next: 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 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.

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.

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

The load may cause distortion in both the current and voltage wave forms. Distortion may cause excessive conductor heating, voltage drops, and line losses.

Voltage and Current are in phase
Voltage and Current are in phase
Current lags voltage by 60 degrees

Voltage and Current are in phase
Current lags voltage by 60 degrees

Voltage and Current are in phase
Current lags voltage by 60 degrees

Voltage and Current are in phase
Current lags voltage by 60 degrees

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
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").

Watts (W) | Current
---|---
---|---
Voltage

Watts (W)

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.

Reactive VA (VARs)

Volt-amperes (VA) is comprised of the total current, without regard to phase angle.

Volt-amperes (VA)

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

Watts (W) | Reactive VA (VARs)
---|---
---|---
Current

Watts (W)

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

1 Phase Metering

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

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

Supply Transformer

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.

Supply Transformer

1 Phase 2-Wire

1 Phase electricity is supplied by one of the 3 phases.

Supply Transformer

The consumer is supplied 1 Phase electricity at one voltage.
Blondel's Theorem 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.

Blondel's Theorem requires $(N \text{ wires} - 1)$ elements.

1 Element $= 1$ Current Sensor + 1 Voltage Sensor

1 Phase 2-Wire

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

1 Phase 3-Wire services are the common method of supplying electricity to homes in North America.
1 Phase 3-Wire services are typically supplied from a 3 Phase supply.

The transformer secondary circuits are isolated from the primary circuits.

The secondary circuit supplies electricity to the consumer.

The secondary transformer is given a center tap to ground.

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

Supply Transformer

Consumer Load

A

B

C

Neutral

120 volts

240 volts

Measurement using a 2 Element meter

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

= Current Sensor

= Voltage Sensor

The consumer has a choice of 120 volts or 240 volts
A voltage sensor is connected between Line 2 and neutral (ground).

2 Elements: 2 Current Sensors
2 Voltage Sensors

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

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

However only one voltage sensor is used.
The voltage sensor is connected between the 240 volt supply lines, Line 1 and Line 2.

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

The 1 element meter functions similar to a 1.5 element meter, and does not satisfy Blondel's Theorem, but will measure accurately under balanced voltage conditions.
Electricity Metering Circuits

1 Phase Metering

Questions?
Comments?

Next: 3 Phase 4-Wire Open Delta

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.

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

'A' phase power is supplied to the consumer.
The consumer is provided with a 240 volt 3 phase open delta power supply.

A current sensor and voltage sensor are added.

The A phase voltage sensor receives 208 volts.

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.

Blondel's Theorem requires N-1 elements.
A 3 element meter is recommended.
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 Phase Metering

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

Supply Transformer

Consumer Load

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

The 2.5 element meter is not recommended

Electricity Metering Circuits

3 Phase 4-Wire Wye Service

2.5 element meter

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

Supply Transformer

Consumer Load

3 Phase 3-Wire Wye supply (grounded)
**Electricity Metering Circuits**

*3 Phase 3-Wire Grounded Wye*

Supply Transformer  
A  
B  
C  
Neutral

3 Element Meter  

Consumer Load

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**Electricity Metering Circuits**

*3 Phase 3-Wire Grounded Wye*

Supply Transformer  
A  
B  
C  
Neutral

2 Element Meter  

Consumer Load

2 element metering is accurate if there is no ground current

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**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

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**Electricity Metering Circuits**

*3 Phase 3-Wire Network Service*

Supply Transformer  
A  
B  
C  
Neutral

2 Element Meter  

Consumer Load

120 / 208 volt load

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**Electricity Metering Circuits**

*3 Phase 3-Wire Network Service*

Supply Transformer  
A  
B  
C  
Neutral

2 Element Meter  

Consumer Load

120 / 208 volt load

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2 Element Meter is required

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3 Phase 3-Wire Network Service

120 / 208 volt load

Supply Transformer

Consumer Load

2 Element Meter

A

B

C

Neutral

208 volts

120 volts

= Current Sensor

= Voltage Sensor

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
Single Phase and Polyphase Load Analysis

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

Single Phase 2-Wire Load

Supply Transformer
C
B
A

Watt Meter

Consumer Load

Motor

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

Supply Transformer
C
B
A

Watt Meter

Consumer Load

Motor

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.

Note: $E = \text{volts}$
$I = \text{amperes}$

Apparent Power = $E \times I$

= 120 volts $\times$ 10 amps

= 1200 VA

30 degrees

Single Phase 2-Wire Load

Supply Transformer
C
B
A

Watt Meter

Consumer Load

Motor

E = 120 volts

Note: $E = \text{volts}$
$I = \text{amperes}$

Apparent Power = $E \times I$

= 1200 VA

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

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.

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 Load Analysis

Single Phase 2-Wire Service

1 Element Meter

Supply Transformer

Consumer Load

B

C

A

110 volts

10 amps

What is the apparent power delivered to this consumer's single phase 2-wire service?

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

Apparent Power = E x I

Apparent Power = 110 volts x 10 amps

Apparent Power = 1100 va

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

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

Active Power = E x I x \cos \theta

Active Power = 110 volts x 10 amps x 1.0

Active Power = 1100 watts

\theta = \text{phase angle of the current}

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

Energy = \text{Active Power} \times \text{Time}

= 1100\text{watts} \times 1.5\text{hrs}

= 1650\text{ watthours}
Questions?

Comments?

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

Single Phase 3-Wire Service, 2 Element Meter

Supply Transformer

C

110 volts

110 volts

B

Neutral

A

10 amps

5 amps

20 amps

110 volts

110 volts

Line 1

220 volts

Neutral

Line 2

Active Power = Load 1 + Load 2 + Load 3
= (E x I x cos $\theta$) + (E x I x cos $\theta$) + (E x I x cos $\theta$)

E = Voltage, I = Current, PF = 1.0, $\theta$ = theta = phase angle of the current

How much active power is the consumers load drawing?

Note : Unity power factor

Active Power = (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

How much active power is the 2 element meter measuring?
Active Power calculated for the load = 6050 watts
Active Power indicated by the meter = 6050 watts

Active Power (load) = 6050 watts

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

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

Only one voltage sensor is required, connected between Line 1 and Line 2.

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

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

Active Power measured = \((E \times I_{L1}/2 \times \cos \theta)\) + \((E \times I_{L2}/2 \times \cos \theta)\)

= \((220v \times 30/2 \times 1.0) + (220v \times 25/2 \times 1.0)\)

= \((3300 \text{ watts}) + (2750 \text{ watts})\)

= 6050 watts

Active Power calculated = 6050 watts
In order to describe how polyphase meters operate, it is necessary to have a common understanding of how phasors are used. Phasors are a visual representation of the various voltage and current values, and their relationship to each other during one cycle.

This diagram can be used to plot voltage phasors and establish their relationship to each other. The phasor Ean shows the position of voltage A in relation to Neutral.
Other phasors are added to represent the other line to neutral voltage values in the polyphase circuit.

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

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

The phasor positions of other voltages can be added as required.
3 Phase 4-Wire Wye Service, 3 Element Meter

Polyphase Phasors

Questions?
Comments?

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

Power Formula:

\[
\text{Active Power} = (E_{an} \times I_a \times \cos \theta) + (E_{bn} \times I_b \times \cos \theta) + (E_{cn} \times I_c \times \cos \theta)
\]

\[\cos \theta = \text{cosine of the current phase angle relative to unity power factor}\]
Polyphase Load Analysis

3 Phase 4-Wire Wye Service
2.5 Element Meter

3 Phase 4-Wire Wye Service, 2.5 Element Meter

Phasor Representation
ABC Rotation

Active Power = (Ean x Ia x (cosθ°)) + (Ean x -Ib x (cos60-θ°))
+ (Ecn x Ic x (cosθ°)) + (Ecn x -Ib x (cos60+θ°))

θ° = theta = phase angle of the current relative to unity power factor

Questions?

Comments?

Next: 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 = \( \frac{10}{\sqrt{3}} \) = 5.7735 amperes

**Calculate the Active Power:**

Active Power = \( 3 \times E_{phase} \times I_{phase} \times \cos(\theta) \)

or: \( \text{Active Power} = \sqrt{3} \times E_{line} \times I_{line} \times \cos(\theta) \)

\( \cos(\theta) = \) cosine of the current phase angle relative to unity power factor

**Active Power** = \( 600 \times 10 \times 0.866 \) + \( 600 \times 10 \times 0.866 \)

= 5196 + 5196

= 10392 watts

Active Power is correctly measured by the meter.
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

10,392 Watts
6,000 VARs
12,000 VA

VA = Square root of (10,392 W squared + 6,000 VARs squared)
= 12,000 VA

Measurement Concepts

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

Quadrant 1: Watts delivered, Lagging Vars
Quadrant 2: Watt deliv, PF lag
Quadrant 3: Received Watts
Quadrant 4: Delivered Watts
Watthour Measurement

Watthour measurement can be calculated by multiplying total Watts X time

Watthours = Watts × Time (in hours)

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

Watt Measurement

An unbalanced polyphase load:

\[ E_{an} = 120 \text{ V}, \quad I_a = 100 \text{ A, 30 degree lag} \]
\[ E_{bn} = 120 \text{ V}, \quad I_b = 100 \text{ A, 30 degree lead} \]
\[ E_{cn} = 120 \text{ V}, \quad I_c = 50 \text{ A, In phase} \]
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.

### Watt Measurement

- **Ia** is plotted
- **Ib** is added
- **Ic** is added

Total Watts: 10,392 + 10,392 + 6,000 = 26,784 Watts total

### Watt Measurement

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

Total Watts: 10,392 + 10,392 = 20,784 Watts total

### Watt Measurement

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

Total Watts: 10,392 + 6,000 = 16,392 Watts total

### Watt Measurement

- All phases combined on the "x" axis: total Watts are calculated

Total Watts: 10,392 + 10,392 + 6,000 = 26,784 Watts total

### Watthour Measurement

The meter can then use the total Watts to determine Watthours

Watthours = Watts X Time (in hours)
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.
Net VARS are calculated by adding them algebraically. Net VARS: +6,000
-6,000
0 VARS

Gross VARS are calculated by adding absolute values. Gross VARS: 6,000
+6,000
0
12,000 VARS

VARhours = VARS \times\ 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.

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

The meter can then use the total VARS to determine VARhours.

VARhours = VARS \times\ Time (in\ hours)
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) Addition
2) Arithmetic Addition

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

**Phasor Addition involves the addition of the phasor value of VA in each of the phases.**
All phases combined using Phasor Addition:

$\text{I}_a = 12,000 \text{ VA}$

$\text{I}_b = 12,000 \text{ VA}$

$\text{I}_c = 6,000 \text{ VA}$

$\text{VA}_{\text{Measurement}} = 26,784 \text{ VA}$

Net VARs $= 0 \text{ VARs}$

Gross VARs $= 12,000 \text{ VARs}$

Arithmetic VA $= 30,000 \text{ VA}$

Difference $= +12\%$

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

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

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

$\text{VA hours} = \text{VA} \times \text{Time (in hours)}$
Electricity Metering

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.

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.

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.

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

What is Demand?

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

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

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

Basic Power formula

Energy = Power x Time

or

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

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)

Consider Customer A's Load

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

Consider Customer B's Load

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

Consider Customer C’s Load

\[ \text{Power (kw)} = \frac{\text{Energy (kwh)}}{\text{Time (hours)}} \]

Energy consumed remains at 2000 kwh.

Demand Measurement

Review All Three Customers

\begin{align*}
\text{A} & : 1800 \text{ kw} \\
\text{B} & : 2000 \text{ kw} \\
\text{C} & : 300 \text{ kw}
\end{align*}

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

Maximum Demand?

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

<table>
<thead>
<tr>
<th>Power Kilowatts</th>
<th>Maximum Demand Reached</th>
<th>Average Measured Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 kw</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000 kw</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 kw</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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.

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
(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.

Questions?
Comments?

Principle Methods of Determining Maximum Demand

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.

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.

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 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 Indication

Demand Method Comparison

5 Minute Duration
Exponential Method = 790
Average Method = 500

Demand Indication

Demand Method Comparison

8 Minute Duration
Exponential Method = 1050
Average Method = 800

Demand Indication

Demand Method Comparison

10 Minute Duration
Exponential Method = 1180
Average Method = 1000

Demand Indication

Demand Method Comparison

13 Minute Duration
Exponential Method = 1300
Average Method = 1300

Demand Indication

Demand Method Comparison

15 Minute Duration
Exponential Method = 1360
Average Method = 1500

Demand Indication
Demand Measurement

Demand Meter Response Characteristics (Considerations)

Similar 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

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) Addition
   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.
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.

**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.
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 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 independent 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?
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.

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.
Potential Coil Flux Interaction

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)

Current Coil Flux Interaction

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)

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.

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.
In the 2nd quarter, current flux is now at its maximum rate of change in the cycle.

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 its maximum rate of change.
- flux flowing opposite direct through the disc.

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

- 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.

Applied Torque:

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

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.
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.

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.

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

Therefore;

\[ Kh = \text{Power} \times \text{Time} = \text{Watt hours} \]

\[ \text{Speed} \ / \ \text{Revolutions} \]

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

Formula: \[ \text{Revolutions} = \frac{\text{Energy}}{\text{Kh}} \]

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

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

\[ = 138.889 \text{ revolutions of the disc} \]
Basic Induction Meter

Gear Trains (Registers)

In the gear train section of the meter, there are three ratios to consider:

- Shaft Ratio
- Register Ratio
- Gear Ratio

Register Ratio

\[
\text{Register Ratio} = \frac{\text{number of revolutions of take-off gear}}{\text{one revolution of unit dial pointer}}
\]

Gear Ratio

\[
\text{Gear Ratio} = \frac{\text{number of disc revolutions}}{\text{one revolution of unit dial pointer}}
\]

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.

Adjustments and Compensation

Full Load Adjustment:

This is a coarse 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.

![Light Load Adjustment Diagram](image)

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

![Anti Creep Adjustment Diagram](image)

**Temperature Compensation:**
Any change in temperature can affect the strength of the braking magnets or change any resistance found in the meter.

![Temperature Compensation Diagram](image)
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.

Questions?
Comments?
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.

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.

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.

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

Electronic
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.

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

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)

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

Measurement Capabilities:
The VA function can be programmed to measure:
- Arithmetic VA, or
- Phasor (Vector) VA

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

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

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

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

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

**REGISTERS**
The devices that store and display the metering quantities.
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

**Methods of Measurement:**

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

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

**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.

![Physical Parameter](Width) x (Height) = Area

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.
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

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

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:

- 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:

- 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:

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

Sampling Process

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

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

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.

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)

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

Transformer / Multiplexing Board

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

A/D Converters

Transformer

Measurement Circuit

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

Microprocessor (Computation Circuitry)

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

Main Display

Registers

Theory of Operation:
- The power to energize the electronic portion is taken from A phase potential circuit

A phase Potential

Power Supply Board

Typical Electronic Meter Block Diagram
Typical Electronic Meter Block Diagram

Inputs
Ia
Ib
Ic
Ea
Eb
Ec

Transformer / Multiplexing Board
Measurement Circuit
A / D Converters
Microprocessor
(Computation Circuitry)

Communication Optical Ports
I / O Board

Registers
Watts / Watthour
VA / VA hour
VAR / VAR hour
Power Factor
Volts
Amps

Main Display
Registers
Watts / Watthour
VA / VA hour
VAR / VAR hour
Power Factor
Volts
Amps

Power Supply
To All Electronics

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

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

Questions?
Comments?
TYPE APPROVAL

OF

ELECTRICITY METERS

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 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

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

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.

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.

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)

Accuracy in relation to current range:
Meter accuracy can vary considerably over the range from zero current to maximum current.
Terminology 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

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Class A</th>
<th>Class B</th>
<th>Class C</th>
<th>Class D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current from $I_{tr}$ to $I_{max}$, power factor variation from 0.8 cap to 0.5 ind</td>
<td>2.0%</td>
<td>1.0%</td>
<td>0.5%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Current between $I_{tr}$ and $I_{low}$, at unity power factor</td>
<td>0.2%</td>
<td>1.5%</td>
<td>1.0%</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

(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 $I_{low}$ / $I_{tr}$ shall be 0.4 for class A and B and 0.2 for class C and D.

The meter shall be able to carry $I_{max}$ 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
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.

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

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)

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)

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

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.

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

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

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.

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%.

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 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

Error Calculations:

The meter error is generally calculated using the following equation:

\[ \% \text{Error} = \left( \frac{R}{T} - 1 \right) \times 100 \]

R = the quantity registered (indicated) by the meter under test
T = the true value of the quantity indicated by the reference meter.
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%I\text{max} and 25%I\text{max}.

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

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%

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.

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

<table>
<thead>
<tr>
<th>Test Configuration</th>
<th>Current</th>
<th>Power Factor</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series Test</td>
<td>25% I\text{max}</td>
<td>1.0</td>
<td>±1.0%</td>
</tr>
<tr>
<td>Series Test</td>
<td>25% I\text{max}</td>
<td>0.5</td>
<td>±1.0%</td>
</tr>
<tr>
<td>Series Test</td>
<td>2.5% I\text{max}</td>
<td>1.0</td>
<td>±1.0%</td>
</tr>
</tbody>
</table>

Energy Tests: Polyphase 2 Element and 3 Element meters

<table>
<thead>
<tr>
<th>Test Configuration</th>
<th>Current</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series Test</td>
<td>25% I\text{max}</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Each Element</td>
<td>25% I\text{max}</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Each Element</td>
<td>25% I\text{max}</td>
<td>0.5</td>
<td>0.866</td>
<td>1.0</td>
</tr>
</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>Test Configuration</th>
<th>Current</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series Test</td>
<td>25% Imax</td>
<td>1.0</td>
<td>0.5</td>
<td>±0.0%</td>
</tr>
<tr>
<td>Series Test</td>
<td>2.5% Imax</td>
<td>1.0</td>
<td>0.5</td>
<td>±0.0%</td>
</tr>
<tr>
<td>Each element</td>
<td>50% Imax</td>
<td>1.0</td>
<td>0.5</td>
<td>±0.0%</td>
</tr>
<tr>
<td>Each element</td>
<td>50% Imax</td>
<td>0.5</td>
<td>0.866</td>
<td>±0.0%</td>
</tr>
<tr>
<td>Split coil element</td>
<td>50% Imax</td>
<td>1.0</td>
<td>0.5</td>
<td>±0.0%</td>
</tr>
</tbody>
</table>

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.

**Demand Tests: Electromechanical 1 and 1½ Element Thermal Demand Meters**

<table>
<thead>
<tr>
<th>Test Configuration</th>
<th>Test Point</th>
<th>Power Factor</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series</td>
<td>66.6% F.S.</td>
<td>1.0</td>
<td>±1.0% F.S.</td>
</tr>
<tr>
<td>VA only, Series</td>
<td>66.6% F.S.</td>
<td>0.5</td>
<td>±1.0% F.S.</td>
</tr>
<tr>
<td>Any one element</td>
<td>26% F.S.</td>
<td>1.0</td>
<td>±1.0% F.S.</td>
</tr>
</tbody>
</table>

**Energy Tests: Polyphase 2½ Element Delta Meters**

<table>
<thead>
<tr>
<th>Test Configuration</th>
<th>Current</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series Test</td>
<td>25% Imax</td>
<td>1.0</td>
<td>0.5</td>
<td>±0.0%</td>
</tr>
<tr>
<td>Series Test</td>
<td>2.5% Imax</td>
<td>1.0</td>
<td>0.5</td>
<td>±0.0%</td>
</tr>
<tr>
<td>Each Element</td>
<td>50% Imax</td>
<td>1.0</td>
<td>0.5</td>
<td>±0.0%</td>
</tr>
<tr>
<td>Each Element</td>
<td>20% Imax</td>
<td>0.5</td>
<td>0.866</td>
<td>±0.0%</td>
</tr>
<tr>
<td>Each Element</td>
<td>2.5% Imax</td>
<td>1.0</td>
<td>0.5</td>
<td>±0.0%</td>
</tr>
</tbody>
</table>

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.

**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
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 characteristics, it may be possible to refine and standardize the test points for electronic meter verification.

Electronic Energy Meters:

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

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

<table>
<thead>
<tr>
<th>Test Configuration</th>
<th>Current</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W•h</td>
<td>VA•h</td>
<td>Var•h</td>
<td>Q•h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Series Test</td>
<td>25% Imax</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
<td>±1.0%</td>
<td></td>
</tr>
<tr>
<td>Series Test</td>
<td>25% Imax</td>
<td>0.5</td>
<td>0.5</td>
<td>0.866</td>
<td>±1.0%</td>
<td></td>
</tr>
<tr>
<td>Series Test</td>
<td>2.5% Imax</td>
<td>1.0</td>
<td>0.5</td>
<td>0.866</td>
<td>±1.0%</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Test Configuration</th>
<th>Current</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W•h</td>
<td>VA•h</td>
<td>Var•h</td>
<td>Q•h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Series Test</td>
<td>25% Imax</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
<td>±1.0%</td>
<td></td>
</tr>
<tr>
<td>Series Test</td>
<td>25% Imax</td>
<td>0.5</td>
<td>0.5</td>
<td>0.866</td>
<td>±1.0%</td>
<td></td>
</tr>
<tr>
<td>Each Element</td>
<td>25% Imax</td>
<td>0.5</td>
<td>0.5</td>
<td>0.866</td>
<td>±1.0%</td>
<td></td>
</tr>
<tr>
<td>Series Test</td>
<td>2.5% Imax</td>
<td>1.0</td>
<td>0.5</td>
<td>0.866</td>
<td>±1.0%</td>
<td></td>
</tr>
</tbody>
</table>

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.

### Energy Tests: Electronic Polyphase 2 ½ Element Wye Energy Meters

<table>
<thead>
<tr>
<th>Test Configuration</th>
<th>Current</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W•h</td>
<td>VA•h</td>
<td>Var•h</td>
<td>Q•h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Series Test</td>
<td>25% Imax</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
<td>±1.0%</td>
<td></td>
</tr>
<tr>
<td>Series Test</td>
<td>25% Imax</td>
<td>0.5</td>
<td>0.5</td>
<td>0.866</td>
<td>±1.0%</td>
<td></td>
</tr>
<tr>
<td>Each element</td>
<td>25% Imax</td>
<td>0.5</td>
<td>0.5</td>
<td>0.866</td>
<td>±1.0%</td>
<td></td>
</tr>
<tr>
<td>Series Test</td>
<td>2.5% Imax</td>
<td>1.0</td>
<td>0.5</td>
<td>0.866</td>
<td>±1.0%</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Test Configuration</th>
<th>Current (Imax)</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series Test</td>
<td>25%</td>
<td>0.5</td>
<td>0.5</td>
<td>0.866</td>
<td>±1.0%</td>
</tr>
<tr>
<td>Any one element</td>
<td>25%</td>
<td>1.0</td>
<td>1.0</td>
<td>0.5</td>
<td>±1.0%</td>
</tr>
</tbody>
</table>

Meter Verification Process

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

<table>
<thead>
<tr>
<th>Test Configuration</th>
<th>Current (Imax)</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Power Factor</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series Test</td>
<td>25%</td>
<td>0.5</td>
<td>0.5</td>
<td>0.866</td>
<td>±1.0%</td>
</tr>
</tbody>
</table>

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.
Reverification Intervals

Reverification Intervals
Reverification Process

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

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 or Seal Periods are pre-determined periods of time in which a meter type, design or functionality is allowed to remain in service, before requiring some type of re-accessessment of its continuing performance.

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

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 device's performance is completed prior to any component or system failures. (life expectancy)

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

Reverification Intervals (Examples)

<table>
<thead>
<tr>
<th>Electro-mechanical</th>
<th>Hybrid</th>
<th>Electronic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Phase Energy</td>
<td>Poly Phase Energy</td>
<td>Single/ Polyphase Demand</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td>Single/ Polyphase Energy/Demand, TDM and Slot Technology</td>
</tr>
<tr>
<td>Single/ Polyphase Energy/Demand, Digital Technology</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

1) Screening (inspection of all meters), or
2) Sample inspection

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.

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

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

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

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

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.

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
Electricity meter homogeneous criteria may include:
- manufacturer,
- model,
- number of elements
- voltage,
- current range
- metering functions
- year of manufacture
- year of reserving
- reserving organization

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.

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.

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

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

The results of the assessment determine the length of extension to the 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.
Electricity Metering

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

Other considerations include:
- Sensitivity
- Resolution
- Stability
- Reproducibility

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 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

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.
## Calibration Consoles

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

Calibration consoles are subject to a variety of operational characteristics:

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

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.

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

Meter Mounting Arrangements:

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

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

Accuracy and Repeatability of Calibration Consoles
- capable of setting all currents, voltages, phase angles, and loads within the tolerances

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

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)

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.

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.
| Burden Effects:  
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>high burden vs low burden test deviation &lt;0.1%</td>
</tr>
<tr>
<td>perform tests using the burden producing the highest error</td>
</tr>
</tbody>
</table>

| Variations from Position to Position:  
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>errors &lt; 0.1% allows testing in one position only when determining console errors.</td>
</tr>
<tr>
<td>0.1 to 0.2% requires testing in all positions for determining individual position errors.</td>
</tr>
</tbody>
</table>

| Sources of Errors  
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervening current transformer errors:</td>
</tr>
<tr>
<td>Intervening voltage transformer errors:</td>
</tr>
</tbody>
</table>

| 1:1 isolation transformers:  
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>for testing single phase 3-wire meters</td>
</tr>
<tr>
<td>each position,</td>
</tr>
<tr>
<td>each test point</td>
</tr>
</tbody>
</table>

| 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 |  

| USE REQUIREMENTS  
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Certified calibration consoles require periodic accuracy checks to ensure accuracy deviations do not exceed specified tolerances.</td>
</tr>
<tr>
<td>Daily or weekly accuracy checks, with a tolerance of ± 0.20% are recommended.</td>
</tr>
</tbody>
</table>

| During use, accuracy deviations may occur for many reasons including:  
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>equipment degradation</td>
</tr>
<tr>
<td>inadequate maintenance</td>
</tr>
<tr>
<td>inadequate accuracy checks</td>
</tr>
<tr>
<td>inappropriate accuracy checks</td>
</tr>
<tr>
<td>inadequate test procedures</td>
</tr>
<tr>
<td>inadequate training</td>
</tr>
</tbody>
</table>

| Quality Management System Audits are recommended to evaluate the process, and ensure the following:  
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>the appropriate test equipment is used</td>
</tr>
<tr>
<td>the test equipment is used appropriately</td>
</tr>
<tr>
<td>use requirements are performed</td>
</tr>
<tr>
<td>additional processes required to fulfill use requirements are performed</td>
</tr>
<tr>
<td>the complete process achieves the intent of meter verification</td>
</tr>
</tbody>
</table>
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 Dispute Investigations

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

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.

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.

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

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

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

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.

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.

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.

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.

**Expressions of Measurement Accuracy**

<table>
<thead>
<tr>
<th>EXPRESSION</th>
<th>FORMULA</th>
<th>APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Absolute Error = ( R - T )</td>
<td>e.g. meter registers ½ of true value</td>
</tr>
<tr>
<td>2</td>
<td>( % ) True Error = ( \frac{R - T}{T} \times 100 )</td>
<td>- 50 units * (see below)</td>
</tr>
<tr>
<td></td>
<td>or ( % ) True Error = ( \frac{R - T}{T} \times 100 )</td>
<td>= 50%</td>
</tr>
<tr>
<td>3</td>
<td>( % ) Field Note Error = ( \frac{R - T}{R} \times 100 )</td>
<td>= 100%</td>
</tr>
<tr>
<td>4</td>
<td>( % ) Fiducial Error = ( \frac{R - T}{F} \times 100 )</td>
<td>= 25%</td>
</tr>
<tr>
<td>5</td>
<td>% Proof = ( \frac{R}{T} \times 100 )</td>
<td>= 200%</td>
</tr>
<tr>
<td>6</td>
<td>Registration Factor = ( \frac{R}{F} \times 100 )</td>
<td>= 0.5</td>
</tr>
<tr>
<td>7</td>
<td>% Registration = ( \frac{R}{T} \times 100 )</td>
<td>= 50%</td>
</tr>
<tr>
<td>8</td>
<td>Correction = ( T - R )</td>
<td>= + 50 units * (see below)</td>
</tr>
<tr>
<td>9</td>
<td>Correction Factor = ( \frac{T}{R} )</td>
<td>= 2.0</td>
</tr>
<tr>
<td>10</td>
<td>% Correction = ( \frac{T - R}{R} \times 100 )</td>
<td>= + 100%</td>
</tr>
</tbody>
</table>

* \( R \) = Registered value as indicated by the device under test  
* \( T \) = True value determined using certified traceable standards  
* \( F \) = Fiducial (Full Scale) range of the device

**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. RF₁, RF₂, RF₃, etc.)

2) Calculate the Overall Registration Factor (RFₒ)  
   \( RFₒ = RF₁ \times RF₂ \times RF₃, \text{ etc.} \)

3) The Overall Correction Factor (CFₒ) can then be calculated;  
   \( CFₒ = \frac{1}{RFₒ} \)

**Measurement Dispute Investigations**

The legislation should be supported by a documented Measurement Dispute Investigation Process and an official Appeal Process in the event that either of the parties are not satisfied with the findings.

Questions?

Comments?
Overview of the Electricity Meters in Japan

Takao Oki
Masatoshi Tetsuka
Japan Electric Meters Inspection Corporation

Contents
1. Legislation
2. Type Approval
3. Verification
4. Verification Standards

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

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 (2)

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

- JIS: Standards for Mechanical Type Electricity Meters
- Measurement Law
- Enforcement of Measurement Law
- Inspection of Verification Standard
- JEMIC Regulation for Type Approval and Verification

<table>
<thead>
<tr>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watt-hour meters</td>
</tr>
<tr>
<td>Var-hour meters</td>
</tr>
<tr>
<td>Maximum demand meters</td>
</tr>
</tbody>
</table>

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?

**JEMIC Activities**

[Calibration Services]
1. JCSS Cal. Service
2. Calibration Service
3. Mobile Cal.Service

[Legal Metrology Services]
1. Type Approval for Electricity Meters
2. Type Approval for Illuminance Meters
3. Verification of Electricity Meters
4. Verification of Illuminance Meters
5. Inspection of Legal Standards

**R & D**

**Technical Cooperation**

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

---

**Organization Structure**

**Head Office**

- President
- Vice President
- Managing Directors
- Planning Office
- General Affairs Division
- Verification Management Div.
- Verification Division
- Calibration Laboratory
- Technical Research Laboratory
- Auditor
- Auditor’s Office

**Regional Offices**

- Hokkaido
- Tohoku
- Chubu
- Hokuriku
- Kansai
- Chugoku
- Shikoku
- Kyushu
- Okinawa

---

**Location of Lab.s**

- Hokkaido
- Tohoku
- Chubu
- Hokuriku
- Kansai
- Chugoku
- Shikoku
- Kyushu
- Okinawa

---

**Classifications of the Electricity Meters in Japan**

- **Principle**
  1. Induction type
  2. Electronic type

- **Distribution System**
  1. Single-phase
  2. Three-phase

- **Faculty**
  1. Single-rate
  2. Multi-rate

- **House meter**
  1. Watt-hour meter class 2.0
  2. Var-hour meter
  3. Maximum demand meter

- **Consumers**
  1. Ordinary meter class 2.0
  2. Precision meter class 1.0
  3. High-precision meter class 0.5

- **Industrial use**
  1. Transformer Operated Meter
  2. Watt-hour meter
  3. Var-hour meter

---

**Relationship Between JEMIC and METI**

**METI**

- Agency of Natural Resources and Energy
- Industrial Science and Technology Policy and Environment Bureau
- Measurement and Intellectual Infrastructure Division
  - Weight and Measures Office

**JEMIC**

- Supervisor for JEMIC
- Measurement Law
- AIST
- National Institute of Advanced Industrial Science and Technology

---

**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)
Type Approval

Type Approval General Flowchart (1)

Type Approval General Flowchart (2)

Type Approval General Flowchart (3)

Type Approval General Flowchart (4)

Type Approval General Flowchart (5)
Type Approval General Flowchart (6)

Outline of Type Test (1) - Appearance, Mechanism

Outline of Type Test (2) - Insulation

Outline of Type Test (3) - Basic Performance

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

Outline of Type Test (5) - Disturbances (2)
Outline of Type Test (6) - Disturbances(3)

SHOCK TEST

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

<table>
<thead>
<tr>
<th>EMC</th>
<th>IEC61000series</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESS</td>
<td>4-2</td>
</tr>
<tr>
<td>RF fields</td>
<td>4-3, (4-6)</td>
</tr>
<tr>
<td>Impulse noise</td>
<td>4-4</td>
</tr>
<tr>
<td>Voltage-dip</td>
<td>4-11</td>
</tr>
<tr>
<td>Magnetising field</td>
<td>4-8</td>
</tr>
<tr>
<td>Harmonics</td>
<td>4-12, 4-13</td>
</tr>
</tbody>
</table>

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)

<table>
<thead>
<tr>
<th>Durability</th>
<th>Imax, 1000h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other tests</td>
<td></td>
</tr>
<tr>
<td>- over-current</td>
<td>Imax*30</td>
</tr>
<tr>
<td>- tilt</td>
<td>3 degrees</td>
</tr>
<tr>
<td>- glow-wire</td>
<td>960 deg C</td>
</tr>
<tr>
<td>- spring hammer</td>
<td>0.2 N</td>
</tr>
</tbody>
</table>

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

glow-wire test
spring hammer test
## 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.

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.

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 ºC
   (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)
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.

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)
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

- Application of the Electricity Meters
  - Visual check
  - Insulation test
  - Test of an-load condition
  - Starting test
  - Self-heating & Registering test
  - Error test
  - Judgment
  - Verification mark and sealing

- Time Limit to Perform Verification

- Manufacturer, Repairer
- Application of the Electricity Meters
- Manufacturers
  - Mass-produced Electricity Meter
- Repairers
  - Reconditioning
- Power Utilities
  - Consumers

The daily Verification process

- Manufacturers
  - Mass-produced Electricity Meter
- Repairers
  - Reconditioning
- Power Utilities
  - Consumers

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.

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

- Cycle 1
  - Step 1: Power supply
  - Step 2: Infrared sensor
  - Step 3: CRT Display
  - Step 4: Printer

- Cycle 2
  - Step 1: Power supply
  - Step 2: Infrared sensor
  - Step 3: CRT Display
  - Step 4: Printer

- Cycle 3
  - Step 1: Power supply
  - Step 2: Infrared sensor
  - Step 3: CRT Display
  - Step 4: Printer

- Cycle 4
  - Step 1: Power supply
  - Step 2: Infrared sensor
  - Step 3: CRT Display
  - Step 4: Printer

A Test Method

- Power supply
- Infrared sensor
- CRT Display
- Printer
- Keyboard
- Standard Watt-hour Meter
- Pulse Output

Example: Rating 100V, 5A, PF 1.0, IX 0.5
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 output pulse of the standard watt-hour meter.

Different types of electricity meters

Static type
3P3W, 1P3W

Mechanical type
1P2W, 1P3W

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.
2. Transformer operated meters

<table>
<thead>
<tr>
<th>Type of Meter</th>
<th>Maximum Permissible</th>
<th>Power Factor</th>
<th>Test Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinary watt-hour meters</td>
<td>2.0% (1.4%)</td>
<td>1</td>
<td>5%In, 50%In, 100%In</td>
</tr>
<tr>
<td>Ordinary watt-hour meters</td>
<td>2.5% (1.7%)</td>
<td>1</td>
<td>3%In, 50%In, 100%In</td>
</tr>
<tr>
<td>Precision watt-hour meters</td>
<td>1.0% (0.7%)</td>
<td>1</td>
<td>5%In, 50%In, 100%In</td>
</tr>
<tr>
<td>Precision watt-hour meters</td>
<td>1.5% (1.1%)</td>
<td>1</td>
<td>5%In, 50%In, 100%In</td>
</tr>
<tr>
<td>High precision watt-hour meters</td>
<td>0.5% (0.3%)</td>
<td>1</td>
<td>5%In, 50%In, 100%In</td>
</tr>
<tr>
<td>Var-hour meters</td>
<td>2.5% (1.4%)</td>
<td>0</td>
<td>100%In</td>
</tr>
<tr>
<td>Maximum demand meters</td>
<td>1.0% (0.7%)</td>
<td>1</td>
<td>5%In, 50%In, 100%In</td>
</tr>
</tbody>
</table>

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 customer’s premises for charging purposes, an error of the meter is required to remain within the maximum permissible errors for the entire duration of verification.

<table>
<thead>
<tr>
<th>Electricity meters</th>
<th>Maximum permissible errors in-service</th>
<th>Verification period (in years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Watt-hour meter</td>
<td>+1.0% (1.0%)</td>
<td>7 (20, 60A)</td>
</tr>
<tr>
<td>Precision watt-hour meter</td>
<td>+1.5% (1.5%)</td>
<td>Sy:mechanical Type) (T:static Type)</td>
</tr>
<tr>
<td>High precision watt-hour meter</td>
<td>+1.0% (1.0%)</td>
<td>Sy:mechanical Type) (T:static Type)</td>
</tr>
<tr>
<td>Var-hour meter</td>
<td>+1.5% (1.5%)</td>
<td>Sy:mechanical Type) (T:static Type)</td>
</tr>
<tr>
<td>Maximum demand meter</td>
<td>+1.5% (1.5%)</td>
<td>Sy:mechanical Type) (T:static Type)</td>
</tr>
</tbody>
</table>

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
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

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.
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)

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 generation 1957~)

2. Stationary standard watt-hour meter
   (second generation 1968~)

3. Static standard watt-hour meter
   (third generation 1980~)

4. Self calibration wide band watt-hour meter
   (fourth generation 1999~)

Inspection of Verification Standards (2)

1. The JEMIC carries out calibration of power and energy standards 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 standard.

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

<table>
<thead>
<tr>
<th>Scope of the Calibration Service</th>
<th>Best Uncertainty (k=2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power</strong></td>
<td></td>
</tr>
<tr>
<td>Watt Converter</td>
<td>&lt;110V, &lt;50A, 45 - 65Hz</td>
</tr>
<tr>
<td>Power Measuring Instrument</td>
<td>&lt;110V, &lt;50A, 45 - 65Hz</td>
</tr>
<tr>
<td>Energy</td>
<td>Watt-hour Meter</td>
</tr>
</tbody>
</table>

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

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

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.

The power calibration system generates U and I with phase angle $\alpha$, measures $U$, $I$ and $\alpha$ individually, calculates $P$ and $Q$ from the measurement results of $U$, $I$ and $\alpha$ according to the “basic principle”.

System Overview

Basic Principle
Active power ($P$) and reactive power ($Q$) can be calculated from voltage ($U$), current ($I$) and phase angle ($\alpha$).

$$P = UI \cos \alpha$$
$$Q = UI \sin \alpha$$
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 $\phi$. 

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 $\phi$.

Active power

$$P = UI \cos \phi = \frac{U_1 I_1 \cos \phi}{R}$$

Reactive power

$$Q = UI \sin \phi = \frac{U_1 I_1 \sin \phi}{R}$$

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
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 Kingdom, United States, 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
- WT7’s Report
  WG11, 13, 14, 15
- Liaison Report
  OIML
  TC26, 66, 8, 581
  STS, DILMA 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

WG14: Communication
- data modeling & data exchange

WG15: Payment systems (prepayment)
- metering systems for electricity payment

WG11 Documents (1)

Type Test

- IEC 62052-11 Metering equipment
- IEC 62052-21 Multi-functional metering equipment
- IEC 62052-23 Energy metering equipment
- IEC 62052-25 Energy metering equipment
- IEC 62052-31 Energy metering equipment

Test Conditions

- IEC 62053-52 SYNOP
- IEC 62053-31 Pure passive devices
- IEC 62053-22 Energy metering equipment
- IEC 62053-24 Energy metering equipment
- IEC 62054-11 IEC 62054-31 Injected current

IEC 60211 Measurement equipment

IEC 60211 Measurement equipment

IEC 60211 Measurement equipment
### WG11 Documents (2) - IEC62052-11,62053s

- **window**
- **name-plate**
- **symbols**
- **covers**
- **terminal**
- **putout pulse devices**

### WG11 Documents (3) - IEC62053s

- **kWh**
- **kvarh**

#### Requirements

- **Mechanical Electrical Accuracy**
- **Accuracy class**
  - 2, 1, 0.5, 0.2

#### 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
- **IEC 62059-41**
  - Reliability prediction
  - FDES(13/1348)
- **IEC 62059-51 TR**
  - Software aspects of reliability

### WG14 Documents (1)

- **IEC 62059-2**
  - Direct local data exchange
- **IEC 62059-31**
  - Use of local area networks on behalf of customers
- **IEC 62059-42**
  - Data transfer using CCITT V.24 interface
- **IEC 62059-51**
  - Data exchange using IP network (Internet Protocol) with LAN protocol
- **IEC 62059-61**
  - Application layer protocols
  - FIPS(13/1347)
- **IEC 62059-62**
  - Interface classes
  - PWG(13/1347)
- **IEC 62059-63**
  - CCITT transport layers for layer

### WG14 Documents (2)

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### WG15 Documents (1)

- **IEC/PR 60255-21**
  - Framework for standardization
  - IEC 60255-31
  - Particular requirements - Static payment meters for active energy classes 1 and 2
- **IEC/PR 60255-41**
  - Standard Transfer Specification(STS)
  - IEC 60255-41
  - STS - Application layer protocol for one-way systems
  - IEC 60255-51
  - STS - Physical layer protocol for one-way numeric and magnetic card token carriers
  - IEC 60255-52
  - STS - Virtual Token Carrier for Direct Local Connection (includes two-way transfers)
  - Future work
Conclusion

On-going & Future work

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

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

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

- IEC 62055-41, -51
- IEC 62055-52
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"

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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

  \( \text{var-hour, VA-hour, etc} \)