Introduction to Self-Contained Metering

THE EASTERN SPECIALTY COMPANY

Pennsylvania Rural Electric Association

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The Eastern Specialty Company

for PREA Metering School

March 10, 2020

8:15 a.m. – 9:30 a.m.

Questions to Answer

- Why do we test?
- How do we test?
- What types of meter tests are there?
- How do utility tests differ from customer request tests?
- What is In-Service Testing?
- How do we know meter tests are good?
- What do we do with the test data?
- What is the electrical theory behind the testing we do?

Why Do We Test?

Our regulatory commissions require us to test meters.

But only for accuracy. State regulatory commissions want electric utilities to ensure that no customer is being billed unfairly and that no subset of customers is being unfairly subsidized by the rest of the rate payers. Some states mandate only accuracy tests and others require demand and time of use accuracy tests.

Any tests beyond accuracy tests are tests that are simply good business practice.

Complaint Testing

Customers always have the right to request a meter test.

Some utilities and some jurisdictions allow for testing at the customer site, others require a test in a laboratory environment.

Some allow the customer to witness the test and others require the utility commission to witness the test.

Utilities must show that the meter tests well and must demonstrate that they have a test program in place to ensure the meters in service are performing well.

General Meter Testing Requirements

- New Meters
  - Manufacturers tests
  - In-house tests on new shipments
- Return to Service Testing
- In-Service Meters
  - Periodic Tests
  - Selective, random, or statistical testing
- Retirement tests
- Testing of related metering equipment

New Meter Testing Programs

- Accept the Manufacturer's Test results
- Perform a Statistical Test of an incoming shipment
- Perform a 100% test of an incoming shipment

Return to Service Testing

- Meters to be returned to service must always (virtually every utility commission requires this) be accuracy tested before being returned to service.
- Best business practices also require that the meter is functionally tested as well.

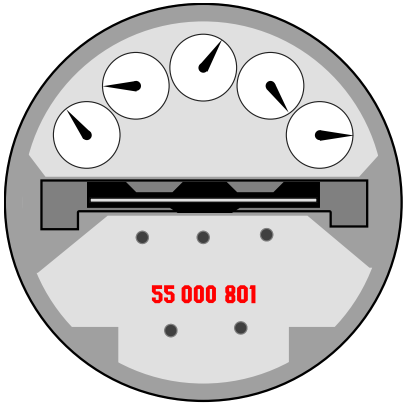
In Service Testing

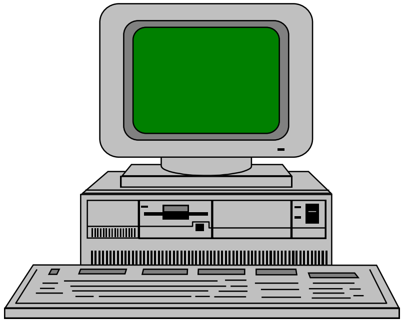
Meter Testing for new and in-service meters is specified in ANSI C12.1-2015, *American National Standard for Electric Meters, Code for Electricity Metering*. Most utility commissions use this Standard a reference or the basis for their meter testing requirements.

Test Plans for Meters

Four test plan options available:

- Periodic
- Statistical





Periodic Test Plans

- Periodic
  - Varies by State
  - Example provided by ANSI C12.1:
    - Each Electro Mechanical meter is tested once every 8 years
    - All other Meters are tested every 16 years
    - Appendix D provides details for other meters & devices
    - No guidance for AMI meters
  - G verage of 12.5% o ted per year

8 Years

16 Years

Statistical Test Plans
The Best Approach

ANSI C12.1-2001 Code for Electricity Metering Guidance

Paragraph 5.1.4.3.3 Statistical sampling plan

"The statistical sampling plan used shall conform to accepted principles of statistical sampling based on either variables or attributes methods. Meters shall be divided into homogeneous groups, such as manufacturer and manufacturer's type. The groups may be further divided into subdivision within the manufacturer's type by major design modifications."

NOTE - Examples of statistical sampling plans can be found in ANSI/ASQC Z1.9, the ANSI version of MIL-STD-414 and ANSI/ASQC Z1.4, the ANSI version of MIL-STD-105.

Why Use a Statistical Testing Plan?

- Focuses testing on the proper meters
- Minimizes number of meters to be tested; usually requires less than 30% of what a periodic testing plan requires
- Provides data and analysis tools for use in understanding what is happening with installed meters or for use in the purchasing of new meters

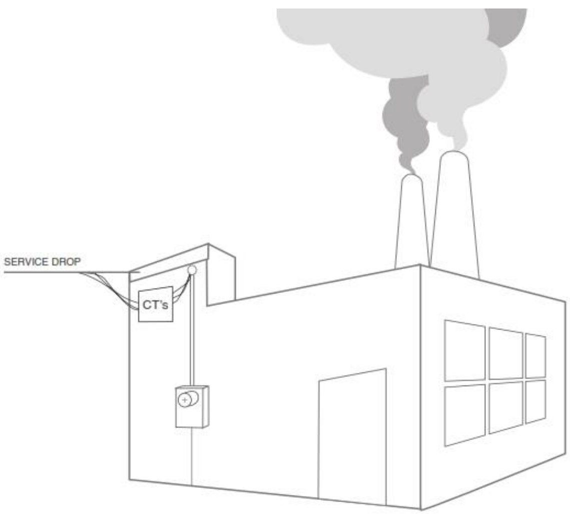
Homogeneous Population(s)

- The groups or populations being sampled and tested are made up of the same or similar items, items which operate in the same way and were made in the same manner.
- For electric meters, this has traditionally been interpreted as being meters of a specific meter type from a manufacturer (i.e. AB1, J5S, MX, etc.).
- AMR & AMI programs have helped to make the overall populations more homogenous. This makes a utility with AMR & AMI meters better prepared to take advantage of a statistical sampling plan.

Testing of a Meter vs Testing a Site

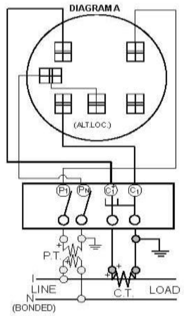
Test an installation and system and not just a meter!

Test programs may need to involve testing and checking the meter performance as well as checking and testing the installation. This more extensive test check list needs to be done especially for the higher revenue C&I customers.

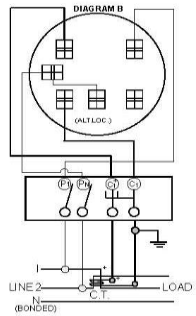


METER FORMS

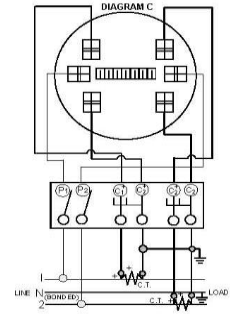
1Ø2W with 1 P.T. & 1 C.T.
Single Stator Meter(2W1Ø) - Form 3S
5T Socket



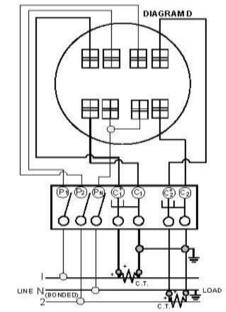
1Ø3W with 1 C.T.
Single Stator Meter(2W1Ø) - Form 3S
5T Socket



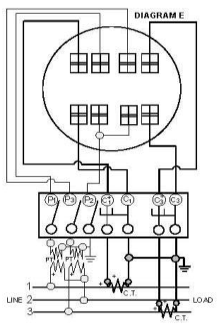
1Ø3W with 2 C.T.'s
Single Stator Meter(3W1Ø) - Form 4S
6T Socket



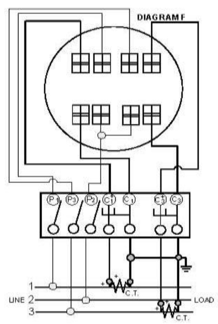
1Ø3W or 3W Network with 2 C.T.'s
2 Stator Meter - Form 5S
8T Socket



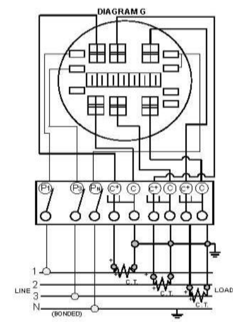
3Ø3W "Δ" with 2 P.T.'s & 2 C.T.'s
2 Stator Meter - Form 5S
8T Socket



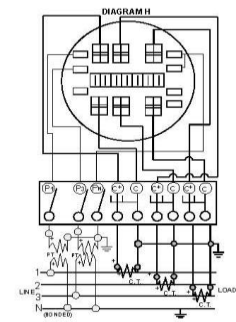
3Ø3W "Δ" with 2 C.T.'s
2 Stator Meter - Form 5S
8T Socket



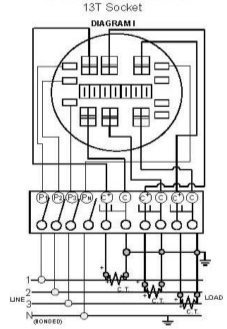
3Ø4W "Y" with 3 C.T.'s
2 ½ Stator Meter - Form 6S
13T Socket



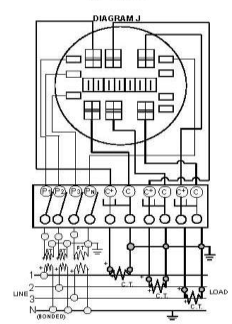
3Ø4W "Y" with 2 P.T.'s & 3 C.T.'s
2 ½ Stator Meter - Form 6S
13T Socket



3Ø4W "Y" or "Δ" with 3 C.T.'s
"Y" 3 Stator Meter - Form 9S
"Δ" 2 Stator Meter - Form 8S
13T Socket



3Ø4W "Y" with 3 P.T.'s & 3 C.T.'s
3 Stator Meter - Form 9S
13T Socket



Meter Testing Traceability

- ♦ Test equipment to NIST standards
- ♦ Tracking number of meters to be tested per State Commission requirements
- ♦ Tracking meter test data
  - Meter Records
  - Meter Data Management System (MDMS)

Meter Testing Traceability

- *Traceability is defined as ability to link the results of the calibration and measurement to related standard and/or reference (preferably national or international standard) through an unbroken chain of comparisons.*

- Calibration is typically performed by measuring a test unit against a known standard or reference.

- Master standard (i.e. gages) are kept by National Measurement Institute (NMI) of each country.

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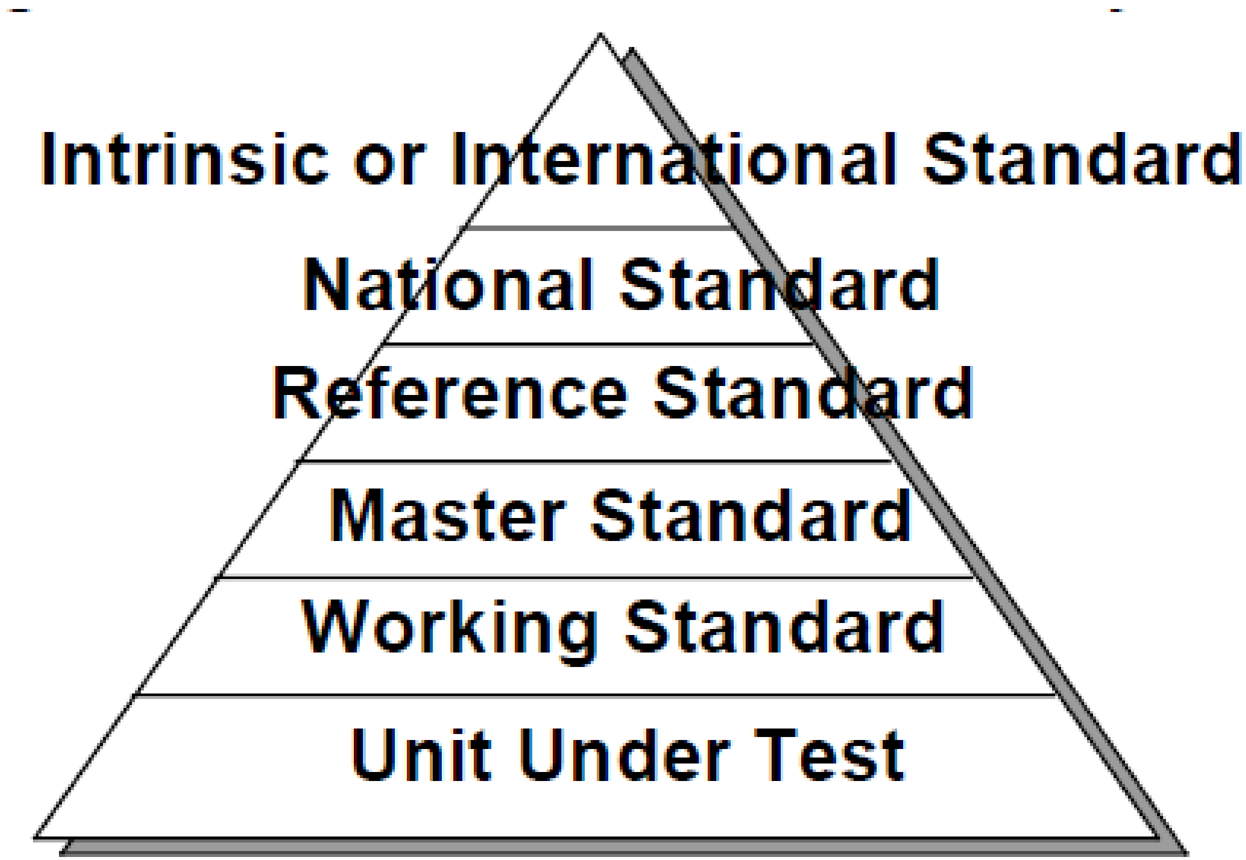
Meter Testing Traceability

- National Institute of Standards and Technology (NIST) provides internal tracking numbers, which are often used as evidence of traceability.

- **WARNING!** NIST does not certify or guarantee that calibration and measurements are correct, nor does it provide any kind of certification of accuracy and calibration. NIST only provides certifications for the work performed by them.

Meter Testing Traceability - Standards



Meter Testing Traceability - Standards

- *National Standard*
  In the US, this is maintained by NIST, in Canada by NRC. Not all countries have a National Standards group and even the US does not have a group for every item of interest to an electric utility (e.g. voltage transformers)

- *Reference/Master Standard*
  Item of highest metrological quality located at a site where calibration is being conducted.

  Transfer Standard
  Lower level of Reference Standard and used for calibration of lower level calibration requirements measuring devices.

- *Working Standard*
  Lower level of Reference Standard and used for calibration of lower level calibration requirements measuring devices. Should be compared to Master Standard or Reference Standard on regular basis; used for daily checks comparisons of the calibrated devices.

Test Equipment Calibration

Primary Requirement: Traceable to NIST Standards

- Meter Test Boards, Field Test Kits calibrated to a known master standard maintained at Meter Shop.
  - ✓ Some periodicity such as monthly or quarterly
- Reference or Master standard calibrated by outside vendor traceable to NIST or directly by NIST.
  - ✓ Usually annually

Tracking Meter Records

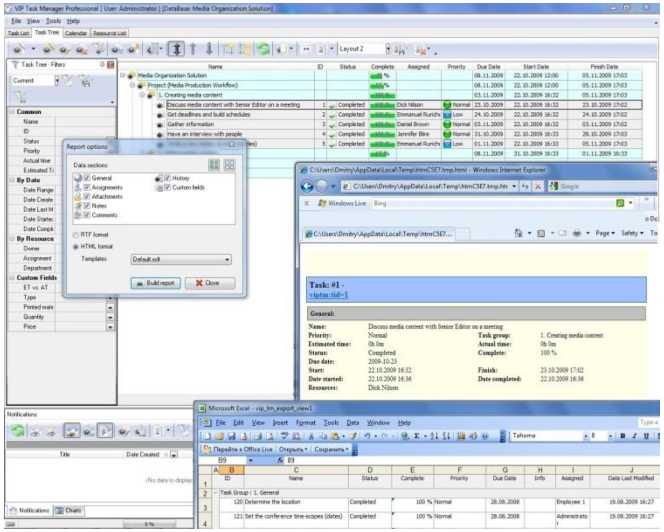
- AMI programs help to update and overhaul meter record systems.
- Having the records for the entire meter population updated allows for a better chance that test data is available to answer questions and that any meter may be selected as part of the sample for testing.

Meter Test Data Tracking

Test data should be tracked throughout meter life

– Certification testing, first article, acceptance testing, in-service (field & shop), retirement

- Meter test data should be linked to meter record data such as meter form, amps, voltage, display type, etc.
- Best time to start to develop the program is before the meters are being installed.
- Accuracy test data is usually collected automatically as new meters are tested in meter shops or cross docks.



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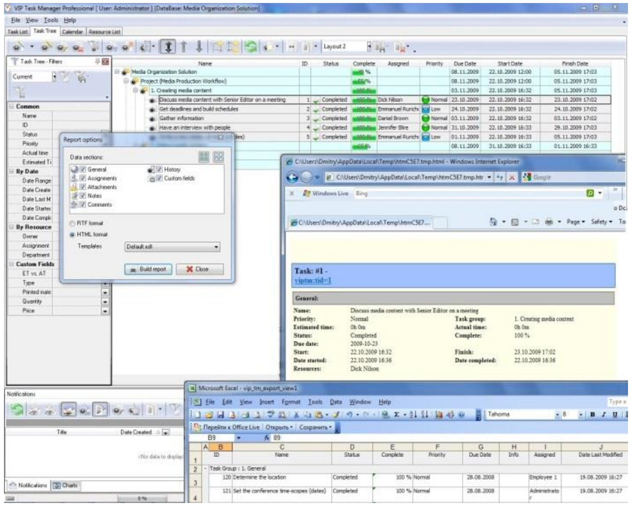
Meter Test Data Tracking

- Need to consider tracking non-accuracy functional testing (meter software configuration, service disconnect testing, voltage, etc.)
- Use installation reports to determine if there is any initial concerns about the meters being installed.
- Typical reports that should be available:
  - Failed Meter Report, Project to Date
  - Electric Meters on Network Report



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Meter Test Data Tracking System

- System should track meter test results for ease of future reference or for response to public or Utility Commission inquiries.

- Maybe part of Meter Data Management System (MDMS) or a separate Meter Records system.

- Requires discipline in collecting & entering data, especially field tests.

Basic Electrical Laws

Ohms Law

Voltage = Current times Resistance

$$V = I \times R$$

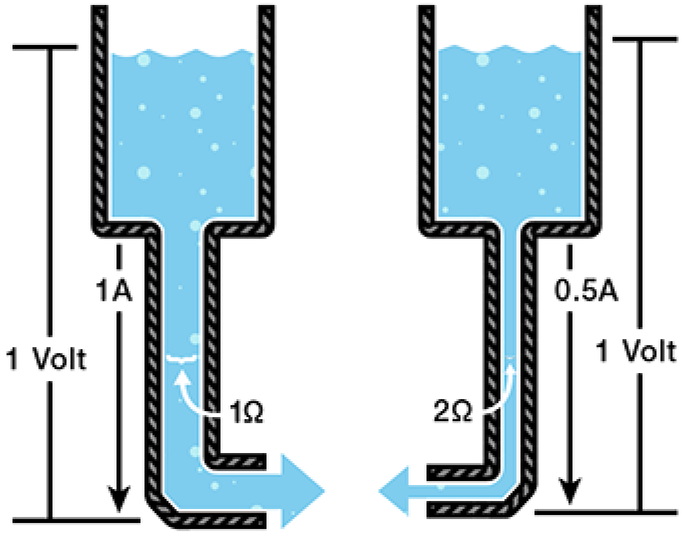
THE MOST USEFUL AND THE MOST FUNDAMENTAL OF THE ELECTRICAL LAWS

Basic Concepts: Electricity and Water

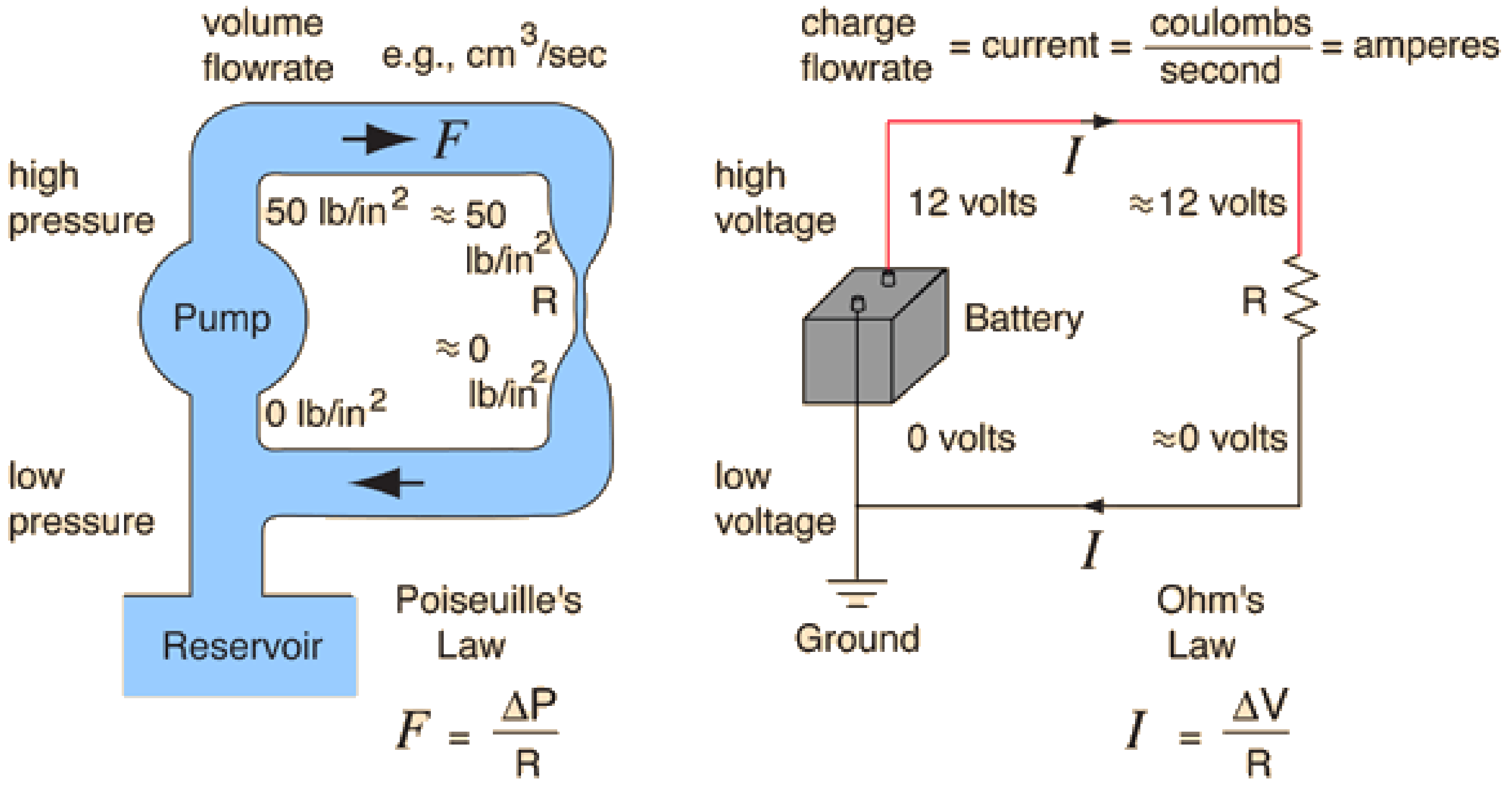
Comparing Electricity to Water flowing from a hose

- Voltage is the equivalent of the pressure in the hose
- Current is water flowing through a hose (coulombs/sec vs gal/sec). The water in a system is the "charge" (coulombs)
- Impedance(Resistance) is the size of the hose. The nozzle would provide a change in resistance.
- Power is how fast water flows from a pipe (gallons per minute vs kilowatts). Power is a rate of energy consumption

Basic Concepts: Electricity and Water



Practical Electricity



Basic Electrical Laws

- Ohms Law Examples
  - If V = 20 volts and I = 5 amperes what is the resistance?

    R = V / I = 20 / 5 = 4 ohms
  - If R = 20 ohms and V = 120 volts what is the current?

    I = V / R = 120 / 20 = 6 amps
  - If I = 10 amperes and R = 24 ohms what is the voltage?

    V = I x R = 10 x 24 = 240 volts

  - Problem: If V = 240 volts and R = 6 ohms what is the current?

    I = V / R = 240 / 6 = 40 amps

Basic Electrical Laws

Power is Voltage x Current

- Power = Voltage x Current = V x I = I^2R = $V^{2/}R$

Voltage (volts):	Current (amps):	Resist.(ohms):	Power:
V=I x R	I = V/R	R = E/I	P=VxI
V=P/I	I = P/V	R = P/I^2	P=I^2xR
V=√(P x R)	I = √(P/R)	R = V^2/P	P= V^2/R

Basic Electrical Laws

- Power = Voltage x Current = V x I = I^2R = $V^{2/}R$
  - If V = 20 volts and I = 8 amperes what is the power?

    P = V x I = 20 x 8 = 160 watts
  - If R = 5 ohms and V = 120 volts what is the power?

    P = $V^{2/}R$ = 120 x 120 / 5 = 2880 watts
  - If I = 10 amperes and R = 20 ohms what is the power?

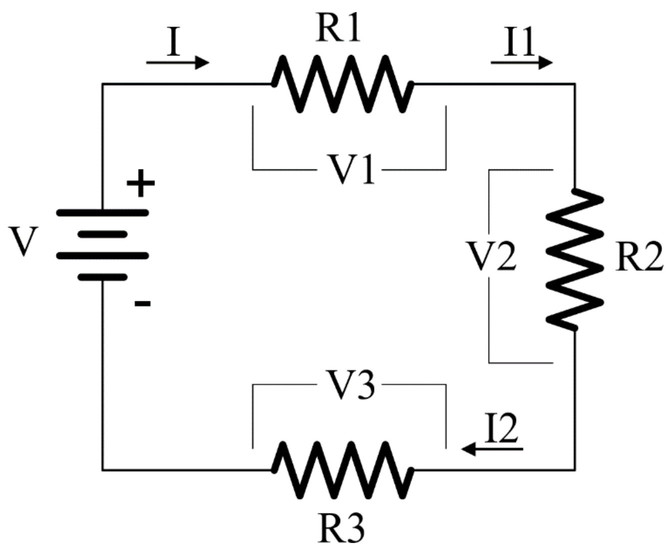
    P = I^2R = 10 x 10 x 20 = 2000 watts

1 kilowatt (kW) = 1,000 watts

1 megawatt (MW) = 1,000,000 watts

Basic Electrical Laws

- Kirchoff's Voltage Law (KVL)
- The sum of the voltages around a circuit loop is zero.



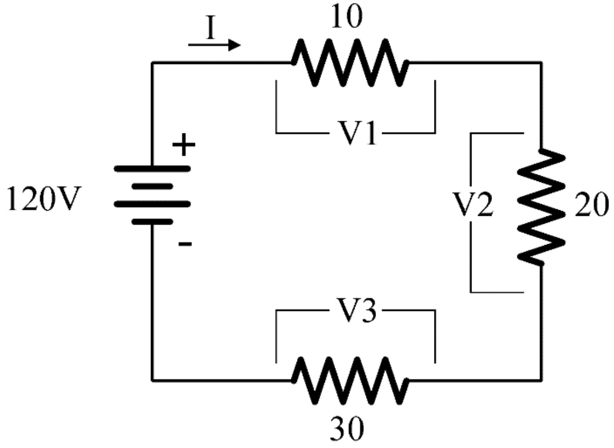
Resistors in series add

V = V1 + V2 + V3 = I * (R1 + R2 + R3) = I1 * R1 + I2 * R2 + I3 * R3

I = I1 = I2 = I3

Basic Electrical Laws

♦ Kirchoff's Voltage Law (KVL) – PROBLEM #1



What is the current in the circuit?

What are V1, V2, V3?

I = V / R = V / (R1 + R2 + R3) = 120/(10+20+30) = 2 amperes

V1 = I*R1 = 2 *10 = 20 volts

V2 = I*R2 = 2 *20 = 40 volts

V3 = I*R3 = 2 *30 = 60 volts

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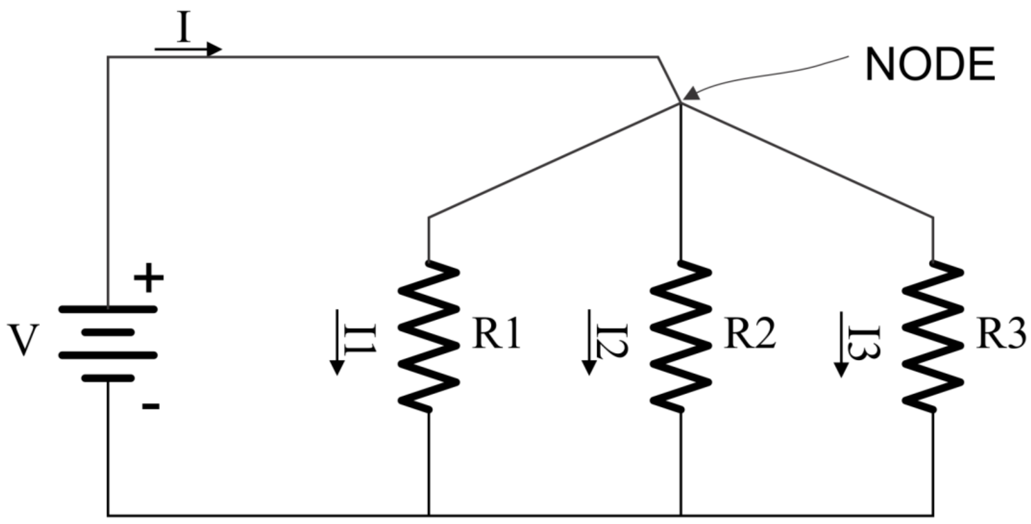
Basic Electrical Laws

- Kirchoff's Current Law (KCL)
- The sum of the currents at a node in a circuit is zero.



I = I1 + I2 + I3

- If Loads are placed in parallel they sum up.
- So does power

P = V x I = V x I1 + V x I2 + V x I3

Basic AC Theory
Power – The Simple View

E = Voltage (rms)

I = Current (rms)

PF = Power Factor

Power = Watts = E x I x PF

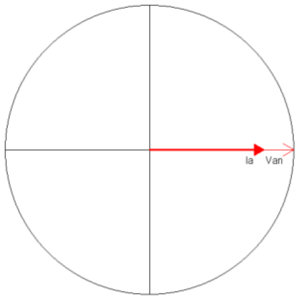
Power is sometimes referred to as Demand

Sinusoidal Waveforms Only

NO Harmonics

For a 120 Volt service drawing 13 Amps at Unity (1.0) PF, how much power is being drawn?

Power = 120 x 13 x 1.0 = 1560 Watts



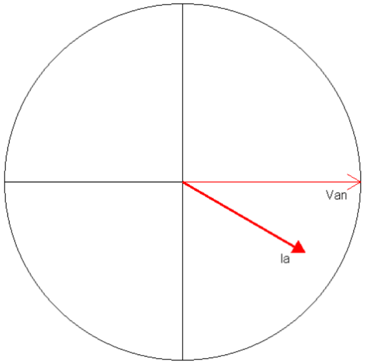
Basic Meter Math
Power – The Simple View

For a 120 Volt service drawing

13 Amps at 0.866 PF,

how much power is being drawn?

Power = 120 x 13 x 0.866 = 1351 Watts

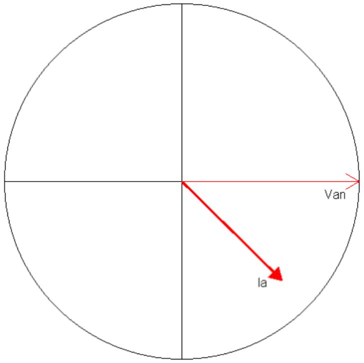


For a 480 Volt service drawing

156 Amps at 0.712 PF,

how much power is being drawn?

Power = 480 x 156 x 0.712 = 53,315 Watts



Basic AC Theory
Power – The Simple View

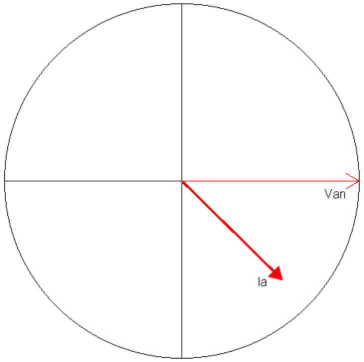
In the previous example we had:

Power = 480 x 156 x 0.712 = 53,315 Watts

Normally we don't talk about Watts, we speak in Kilowatts

1000 Watts = 1 Kilowatt = 1 kW

Watts / 1000 = Kilowatts



For a 480 Volt service drawing
156 Amps at Unity (0.712) PF,
how many Kilowatts are being drawn?

Power = 480 x 156 x 0.712 / 1000 = 53.315 kW

Basic AC Theory
Energy – What We Sell

If power is how fast water flows from a pipe,

then energy is how much water we have in a bucket

after the water has been flowing for a specified time.

Energy = Power x Time

1 kW for 1 Hour = 1 Kilowatt-Hour = 1 kWh

Energy (Wh) = E x I x PF x T

where T = time in hours

Energy (kW) = (E x I x PF / 1000) x T

Basic Meter Math
Energy – What We Sell

For a 120 Volt service drawing 45 Amps at a Power Factor of 0.9 for 1 day,

how much Energy (kWh) has been used?

Energy = (120 x 45 x 0.9 / 1000) x 24 = 116.64 kWh

For a 240 Volt service drawing 60 Amps at a Power Factor of 1.0 for 5.5 hours,

how much Energy (kWh) has been used?

Energy = (240 x 60 x 1.0 / 1000) x 5.5 = 79.2 kWh

Basic Meter Math
Energy – What We Sell

For a 120 Volt service drawing 20 Amps at a Power Factor of 0.8 from 8:00AM to 6:00PM,

and 1 Amp at PF=1.0 from 6:00PM to 8:00AM

how much Energy (kWh) has been used?

8:00AM to 6:00PM = 10 hours

6:00PM to 8:00AM = 14 hours

Energy = (120 x 20 x 0.8 / 1000) x 10 = 19.2 kWh

Energy = (120 x 1 x 1 / 1000) x 14 = 1.68 kWh

Energy = 19.2 kWh + 1.68 kWh = 20.88 kWh

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Basic AC Theory
What is VA?

Power was measured in Watts. Power does useful work. The power that does useful work is referred to as

"Active Power."

VA is measured in Volt-Amperes. It is the capacity required to deliver the Power. It is also referred to as the "Apparent Power."

Power Factor = Active Power / Apparent Power

VA = E x I

PF = W/VA

Basic Meter Math
Power – VA

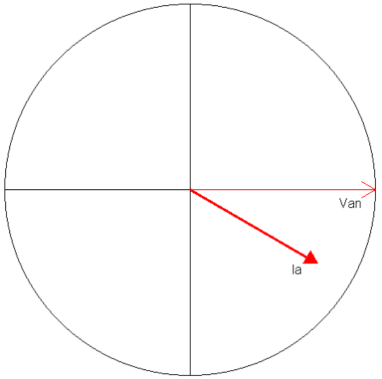
For a 120 Volt service drawing 13 Amps at 0.866 PF

How much power is being drawn?

Power = 120 x 13 x 0.866 = 1351 Watts

How many VA are being drawn?

VA = 120 x 13 = 1560 Volt-Amperes



Basic Meter Math
Power – VA

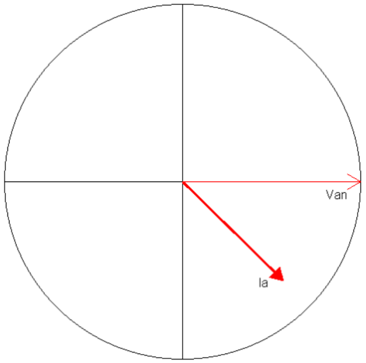
For a 480 Volt service drawing 156 Amps at 0.712 PF

How much power is being drawn?

Power = 480 x 156 x 0.712 = 53,315 Watts

How many VA are being drawn?

VA = 480 x 156 = 74,880 Volt-Amperes



Basic Meter Math
Power – VA

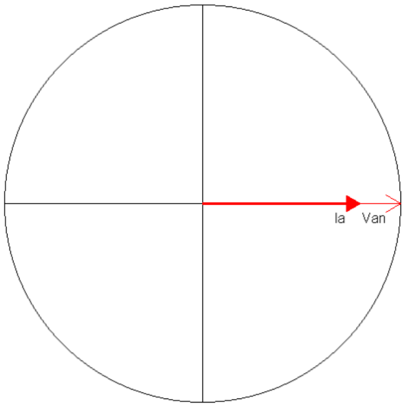
For a 120 Volt service drawing 60 Amps at 1.00 PF

How much power is being drawn?

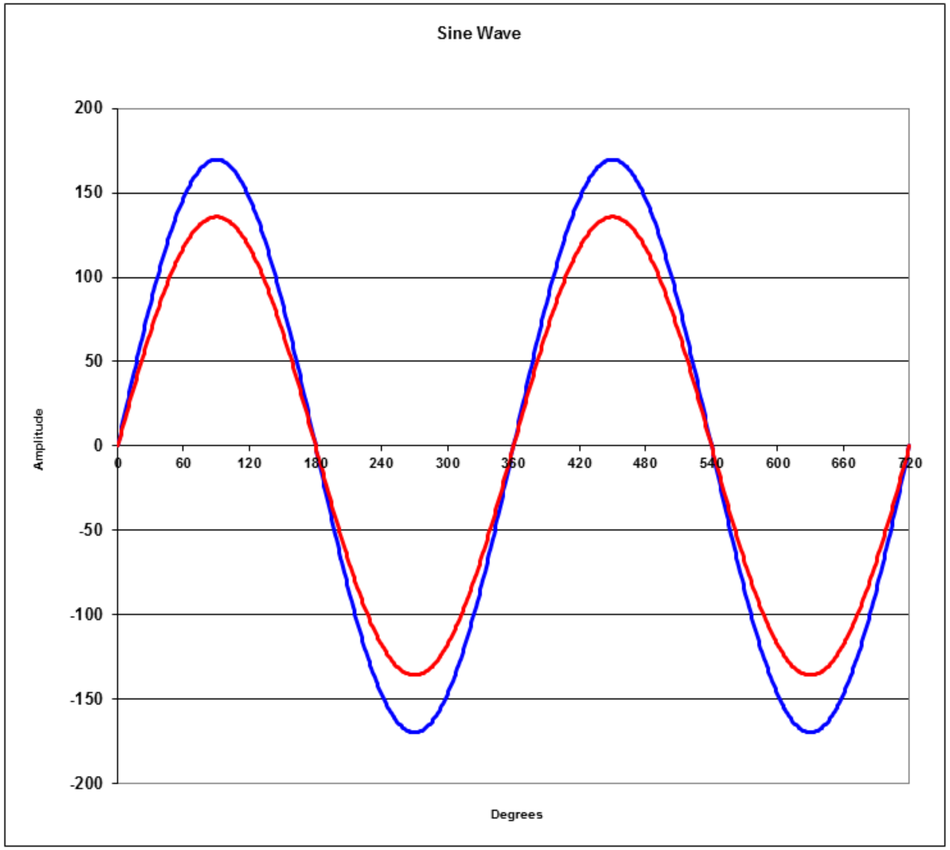
Power = 120 x 60 x 1.00 = 7,200 Watts

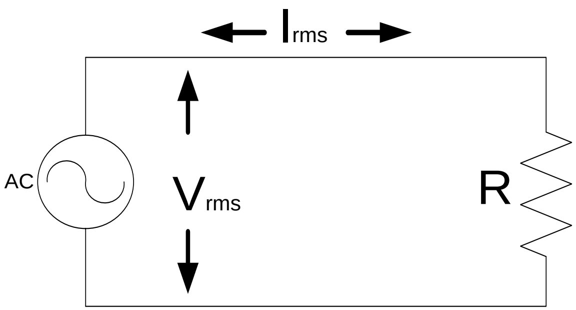
How many VA are being drawn?

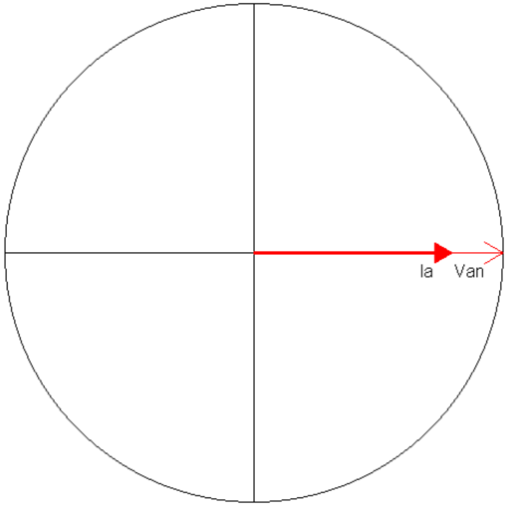
VA = 120 x 60 = 7,200 Volt Amperes



Basic AC Theory
Power Factor = 1.0







Basic Energy Formula

- The essential specification of a watthour meter's measurement is given by the value
  K_h [Watthours per disk revolution]

- The watthour meter formula is as follows:

$$E\left[\textbf{Watthours}\right] = K_h\left[\frac{\textbf{watthours}}{\textbf{disk revolution}}\right] * n\left[\textbf{disk revolutions}\right]$$

Meter Shop Accuracy Test Demo

Questions to Answer

- Why do we test?
- How do we test?
- What types of meter tests are there?
- How do utility tests differ from customer request tests?
- What is In-Service Testing?
- How do we know meter tests are good?
- What do we do with the test data?
- What is the electrical theory behind the testing we do?

Questions?

Tom Lawton

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