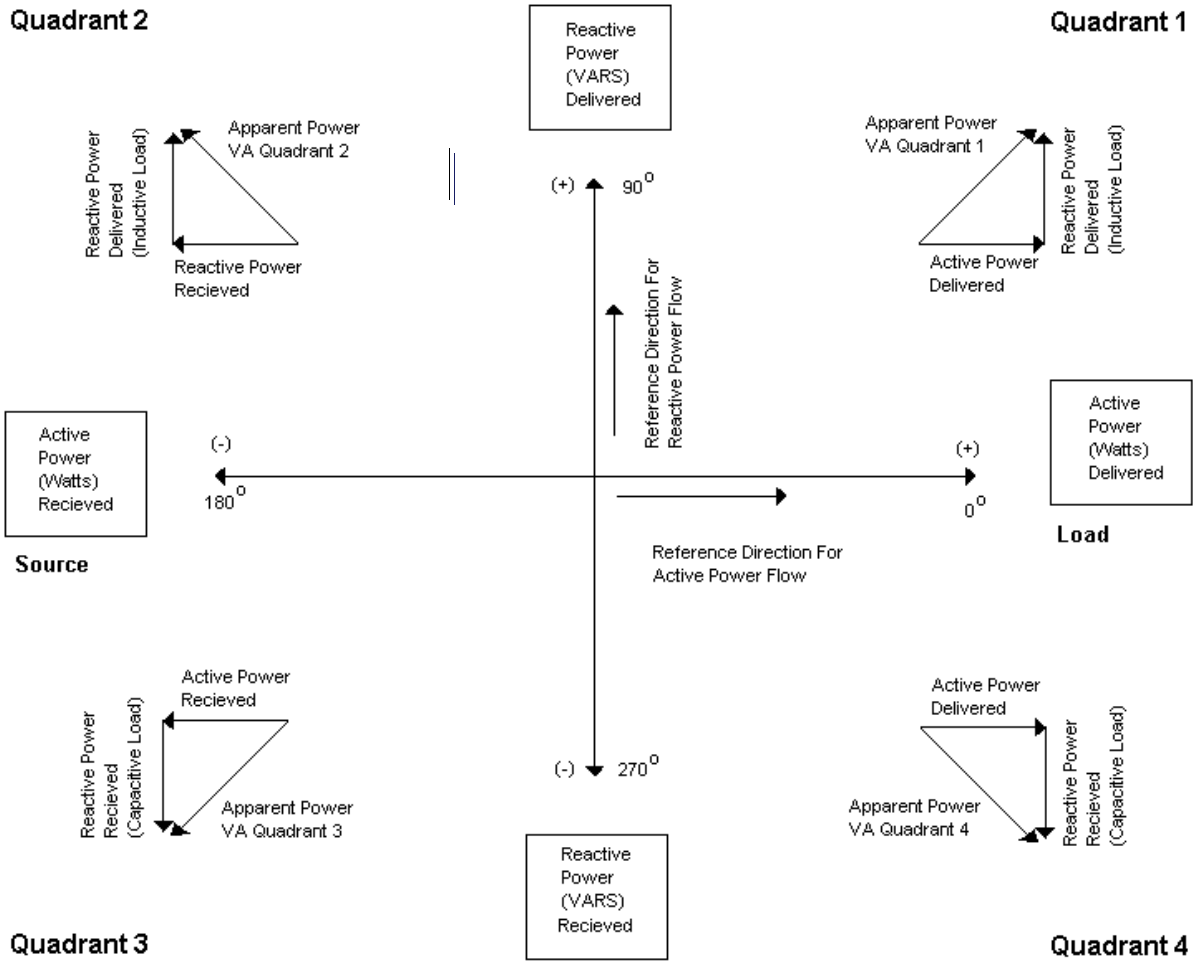
The Intelligence to Power Your Future

KiloVAR & Kilovolt Ampere Metering

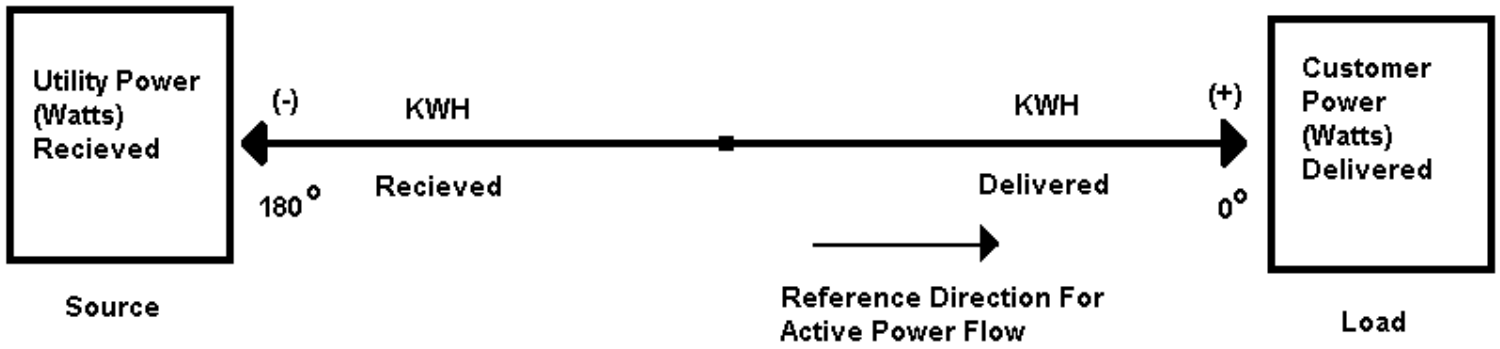
Quadrant Conventions

- **Note:**

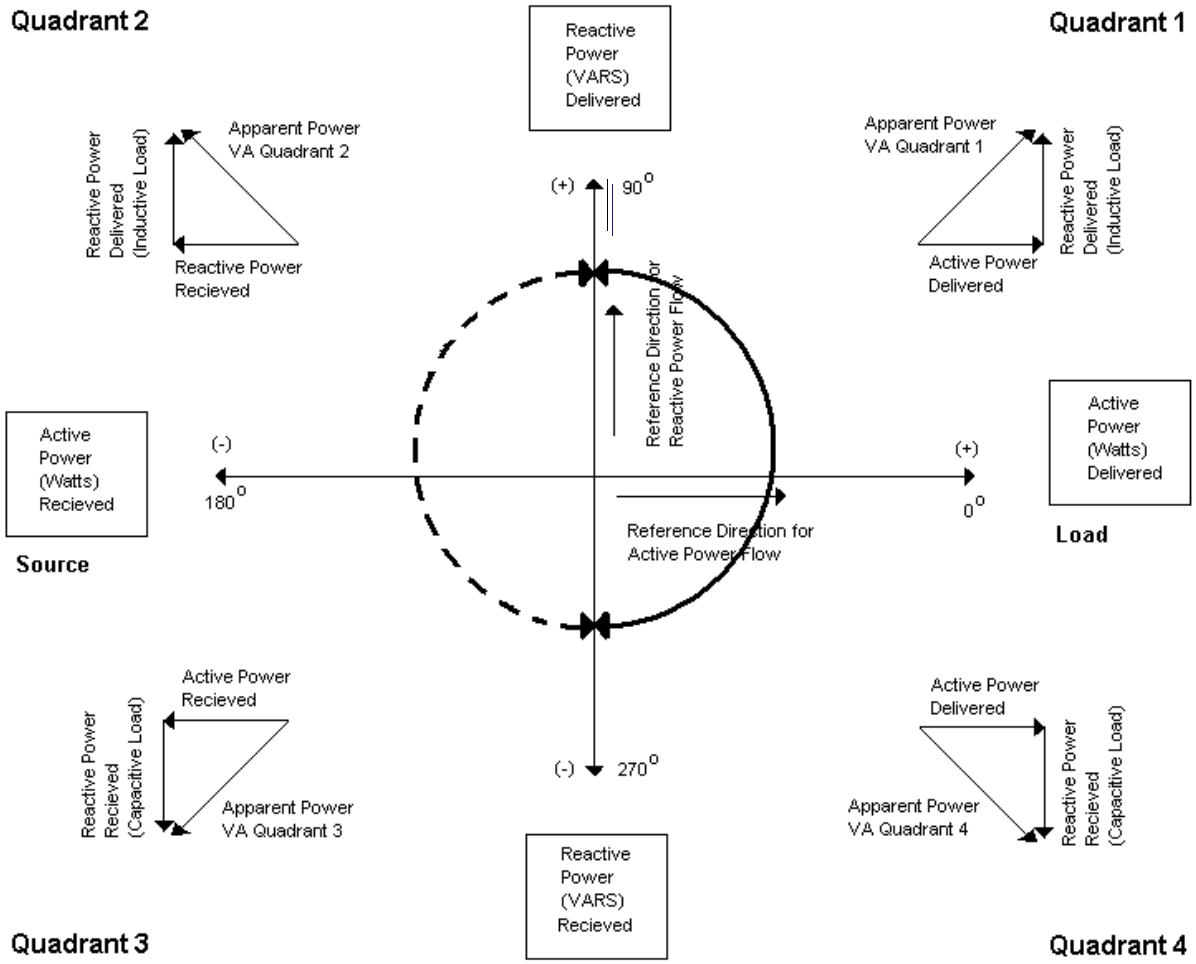
Once the reference direction is established for the metering point, it must not change. In this relationship, CLOCKWISE ROTATION has been used.



Quadrant Conventions



Quadrant Conventions



KWH Meters

Delivered KWH

Received KWH

Net Delivered KWH

Net Received KWH

Total (Absolute) KWH

Quadrant Conventions

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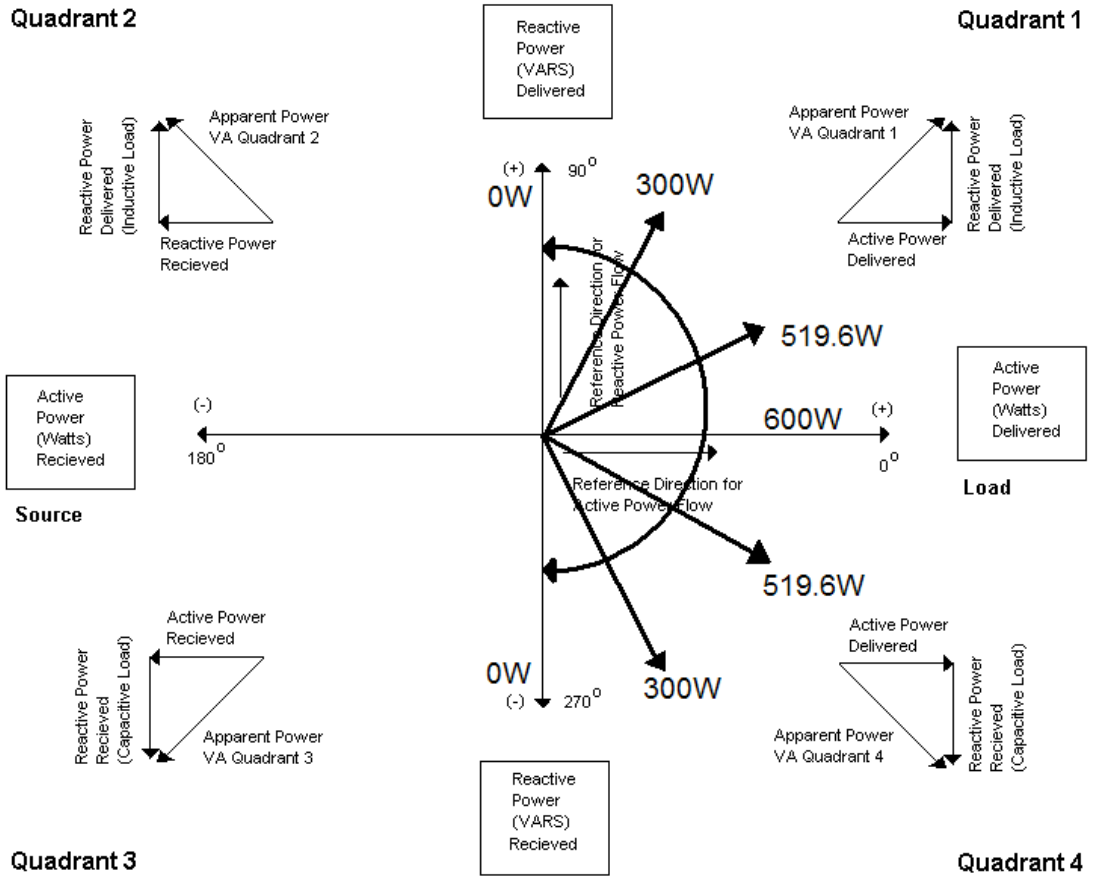


KWH Meters

- E = 120V, I = 5A, PF = 1.0 $\angle 0^0$

  W = E*I*PF(Cos$\angle 0^0$)

  W = 600
- E = 120V, I = 5A, PF = .866 $\angle 30^0$

  W = E*I*PF(Cos$\angle 30^0$)

  W = 519.6
- E = 120V, I = 5A, PF = .500 $\angle 60^0$

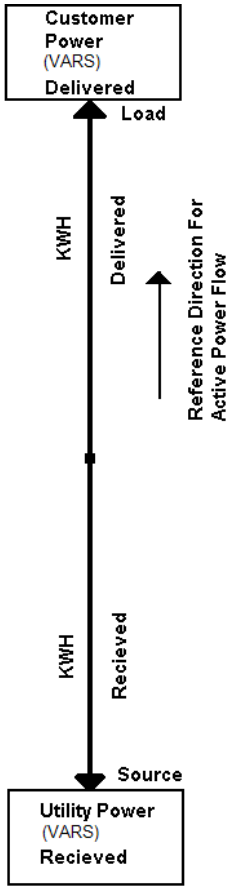
  W = E*I*PF(Cos$\angle 60^0$)

  W = 300
- E = 120V, I = 5A, PF = 0 $\angle 90^0$

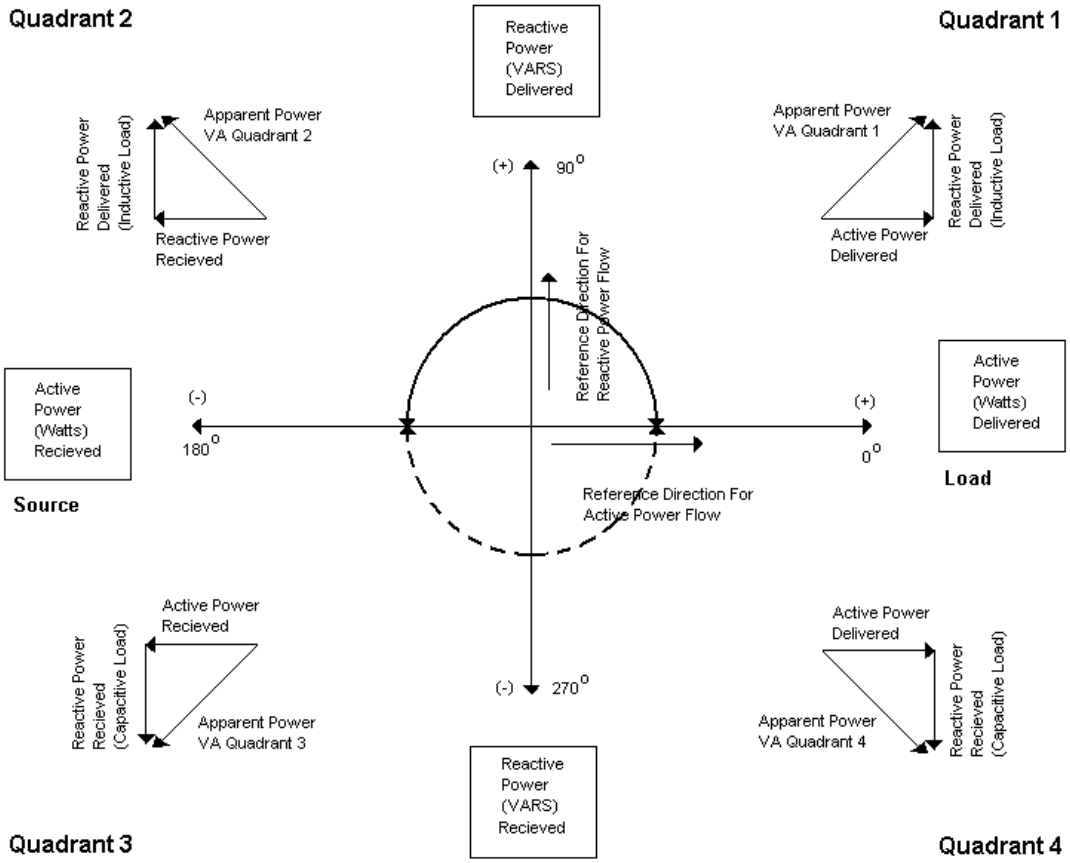
  W = E*I*PF(Cos$\angle 90^0$)

  W = 0

Quadrant Conventions



Quadrant Conventions



KVARH Meters

- Delivered KVARH (Q1 + Q2)
- Received KVARH (Q3 + Q4)
- Quadrant 1
- Quadrant 2
- Quadrant 3
- Quadrant 4
- Net KVARH (Q1 + Q2) – (Q3 + Q4)
- KVARH Delivered Power (Q1 + Q4)abs
- KVARH Received Power (Q2 + Q3) abs
- KVARH Delivered Power (Q1 – Q4)net
- KVARH Received Power (Q3 – Q2)net

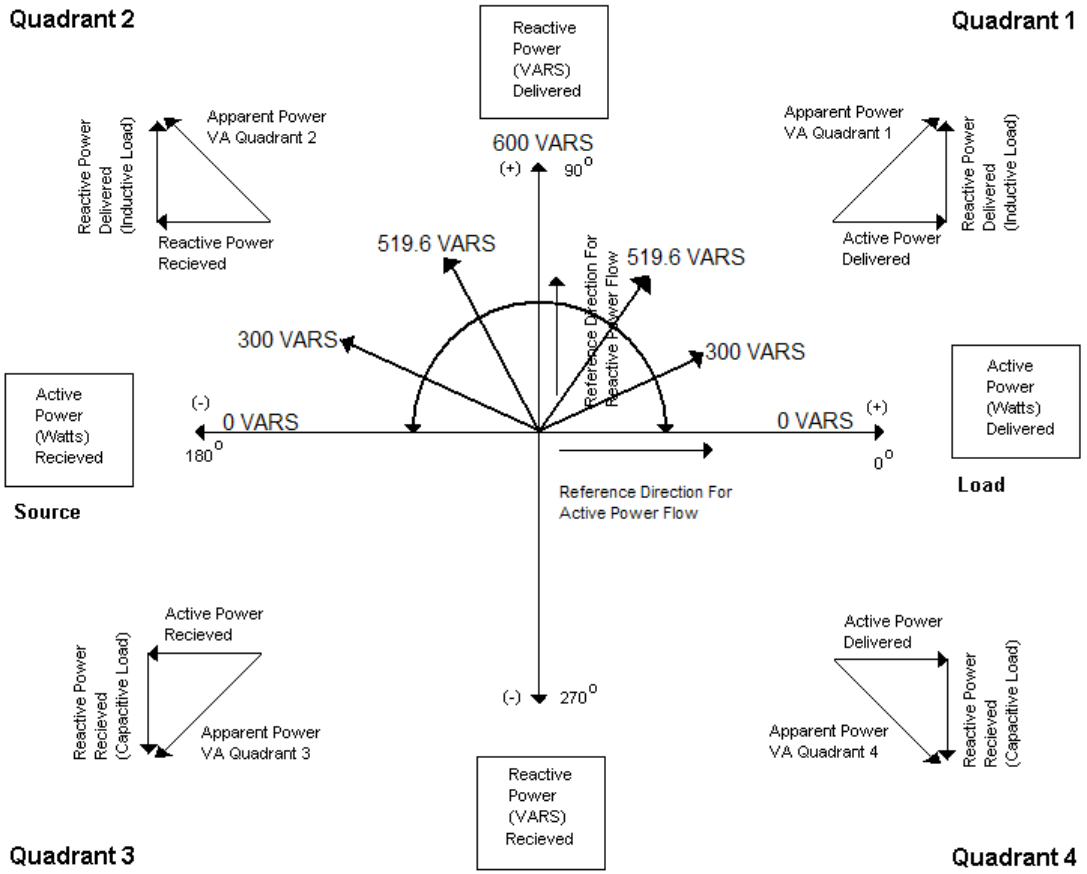
KVARH Meters

- **All of the Values from the previous slide, CONTROLS**
- **Power Factor Results**
- **Apparent Power (Kva) Values**
- **Effects Revenue (Billing) Values**

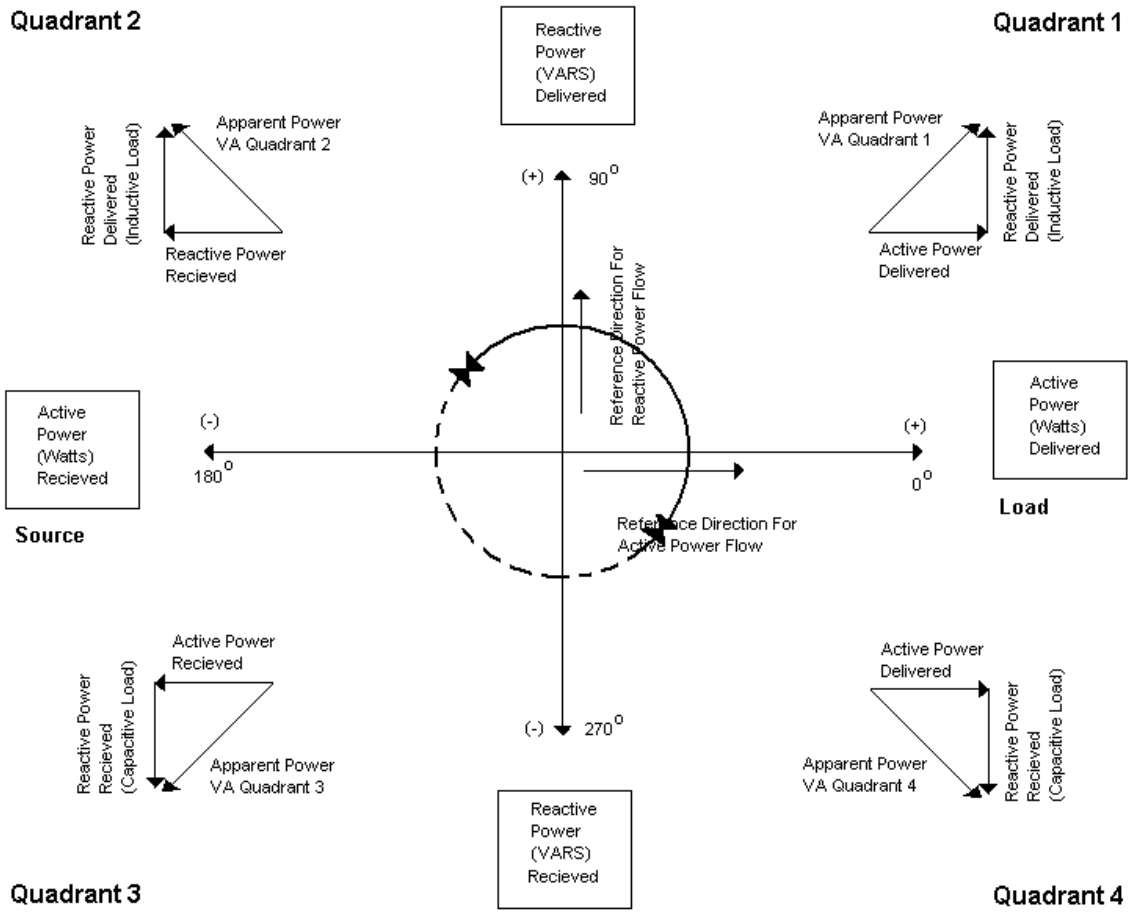
Quadrant Conventions

- Note:

Once the reference direction is established for the metering point, it must not change. In this relationship, CLOCKWISE ROTATION has been used.



Quadrant Conventions



Why use Q-hour metering?

- Technology of the time (Mechanical meters)
  - Q-hour metering systems could produce the maximum amount of information for the minimum investment (“Dollars”). Note: Nets Kvarh Delivered & Received.
    - Requires only two meters (Kwh & Kqh)
    - Requires no phase shifting transformer
    - Requires only a two channel data recorder
- Provides data required for revenue billing
  - Nets delivered and received Kvarh
    - This will automatically give equal credit for Received Kvar
    - Allows for Power Factor and Kva Calculations

Quadrant Conventions

- Note:

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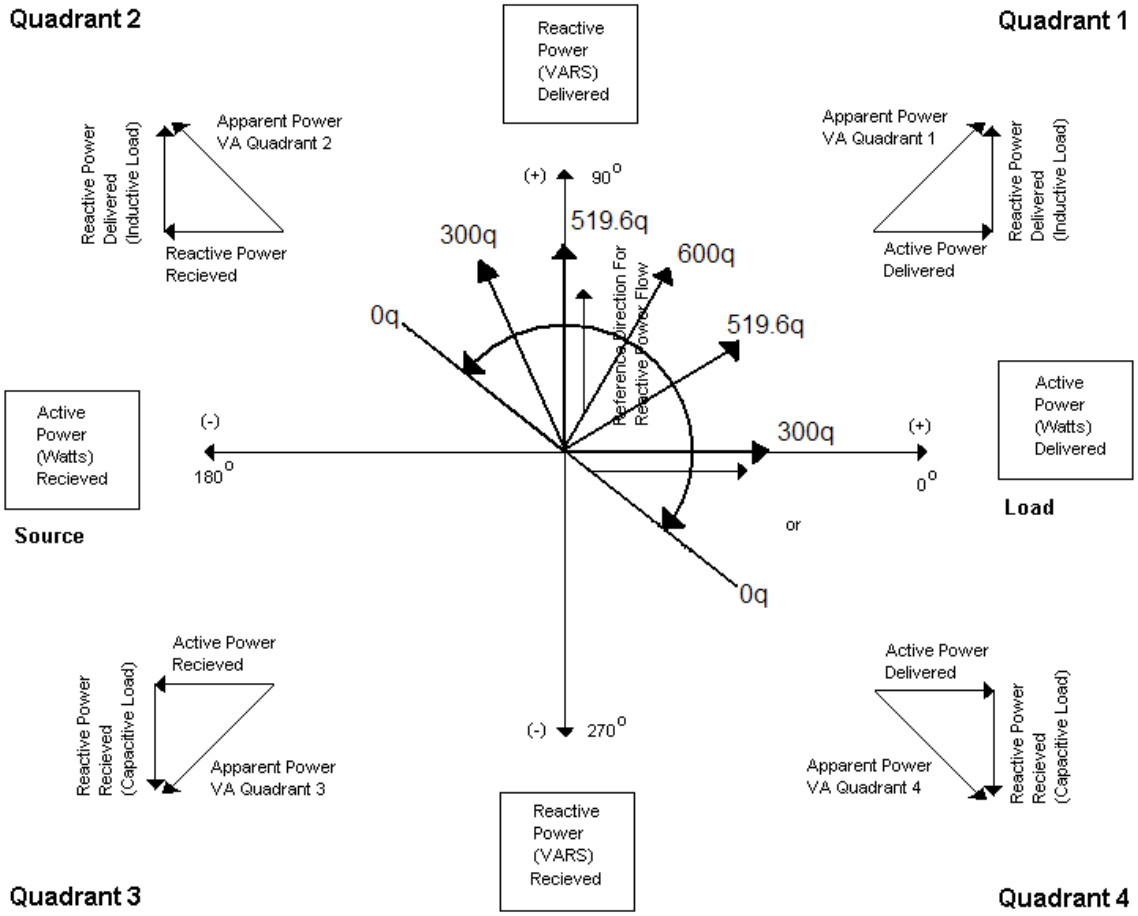


Multifunction Meter's Possible Kqh Registers

- Kqh Delivered Power
  - Net Kvarh Delivered Power (Q1-Q4)
  - Limited to 30 degrees Leading current (Q4)
- Kqh Received Power
  - Net Kvarh Received Power (Q3-Q2)
  - Limited to 30 degrees Leading current (Q2)

How to use data from the Kqh meter
Formula for Kvars using a Kqh metering package

$$\text{Vars} = (2q - \text{Watts}) / \sqrt{(3)}$$

- The following relationships may be used to determine the net affect on Kvars for leading and lagging current over a period of time. Requires having a Kwh meter.

  If (2q – Watts) is Positive (+), Vars (Q1) Lagging Current

  If (2q – Watts) is Zero, No Vars

  If (2q – Watts) is Negative (-), Vars (Q4) Leading Current

  If q/W > 0.5, Vars are (Q1) Lagging Current

  If q/W = 0.5, No Vars

  If q/W < 0.5, Vars are (Q4) Leading Current

How to use data from the Kqh meter
Formula for Kvars using a Kqh metering package

$$\text{Vars} = (2q - \text{Watts}) / \sqrt{(3)}$$

- Example 1:

Kvarh = (2 x 259.5 Kqh – 259.5 Kwh / 1.732

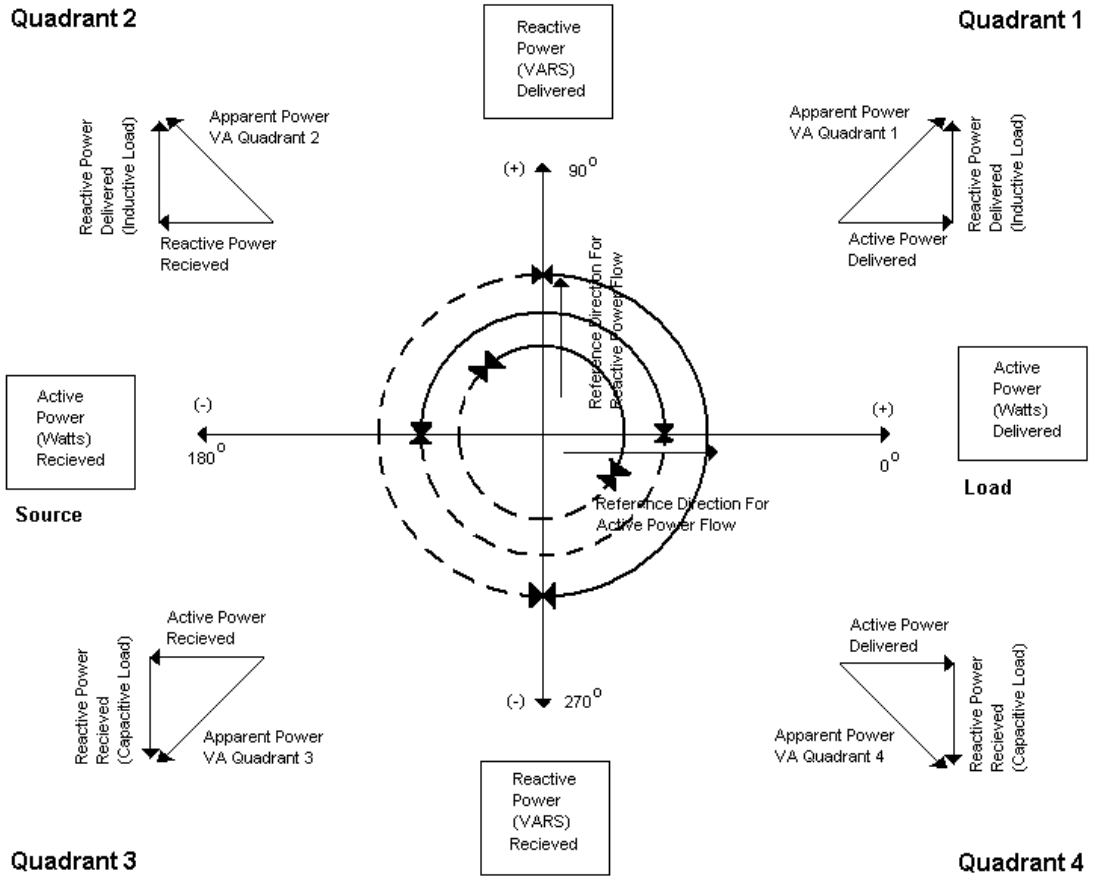
Kvarh = 149.8

- Example 2:

Kvarh = (2 x 259.5 Kqh – 519 Kwh) / 1.732

Kvarh = 0

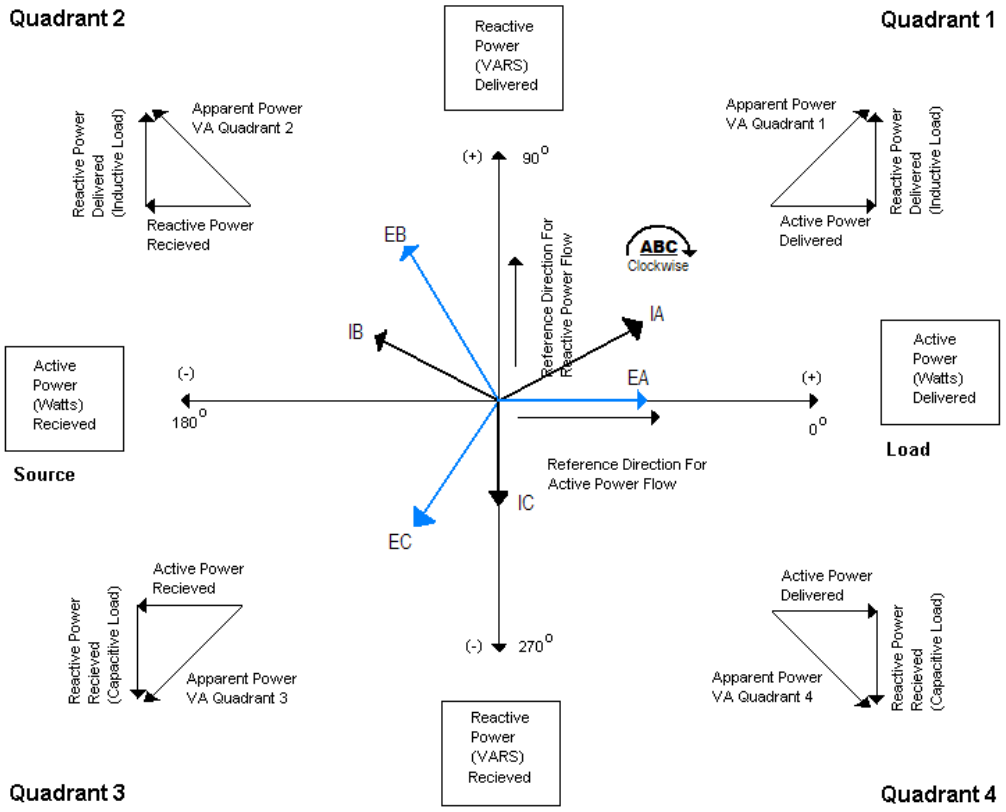
Quadrant Conventions



Quadrant Conventions As Used By the Quad 4 Meter

- Note:

The image to the right, based on capacitive and inductive loads, is for quadrant definitions only. The Quad 4 Meter is not sensitive to phase rotation.



Comparison Tests

Q-hour metering verses Kvarh metering

- A one (1) hour test will be run.
- For the first 30 minutes the current will lag by 30 degrees.
- For the last 30 minutes the current will lead by 30 degrees.

- The voltage will be set at 120 volts.
- The current will be at 5 amps.
- The phase angle will be at 30 degrees for the test.
- All of the values will be multiplied by 1000.

Reactive Package 1 (new installation)
Using 1 Kwh meter & 1 Del. Kvarh meter

♦ Results Package 1		
♦ Time 00:00	00:30	01:00
♦ Kwh Reading 00000	259.5	519.0
♦ Kvarh (Q1+2)00000	150.0	150.0
♦ Calculated		
♦ Kvah	300.0	540.2
♦ Pf	0.86	0.96

Reactive Package 2 (old installation)
Using 1 Kwh meter & 1 Kqh meter

♦ Results Package 2		
♦ Time 00:00	00:30	01:00
♦ Kwh Reading 00000	259.5	519.0
♦ Kqh Reading 00000	259.5	259.5
♦ Calculated		
♦ Kvarh	150.0	000.0
♦ Kvah	300.0	519.0
♦ Pf	0.86	1.00

Test Comparison

Test results

- New Meter 519 Kwh 150 Kvarh 540 Kvah 000 Kqh 0.96Pf
- Old Meter 519 Kwh 000 Kvarh 519 Kvah 259 Kqh 1.00Pf

- Why are they not the same?
  - The new meter is not looking at the Kvarh in (Q4) Leading current
  - The old meter (Kqh) nets the Kvarh between (Q1 and Q4)

- Could there be other reasons for the difference (change)? YES
  - The UOM code in the data collection system didn't get changed to Kvarh
  - The customer's load had changed
  - The new meter had been wired incorrectly

Reactive Package 3
Using 1 Kwh meter & 2 Kvarh meters Delivered - Received Kvarh

♦ Results Package 3		
♦ Time 00:00	00:30	01:00
♦ Kwh Reading 00000	259.5	519.0
♦ Kvarh (Q1-4) 00000	150.0	000.0
♦ Calculated		
♦ Kvah	300.0	519.0
♦ Pf	0.86	1.00

Reactive Package 4
Using 1 Kwh meter & 2 Kvarh meters
Delivered + Received Kvarh

♦ Results Package 4		
♦ Time 00:00	00:30	01:00
♦ Kwh Reading 00000	259.5	519.0
♦ Kvarh (Q1+4)00000	150.0	300.0
♦ Calculated		
♦ Kvah	300.0	600.0
♦ Pf	0.86	0.86

Comparison Tests

Expected test results

- **Kvah**
- 120 Volts x 5 Amps x 1000 x 1 hour = 600 Kvah
- **Kwh**
- 120 Volts x 5 Amps x 0.8666 x 1000 x 1 hour = 519 Kwh
- **Kvarh**
- 120 Volts x 5 Amps x 0.5 x 1000 x 1 hour = 300 Kvarh
- **Power Factor**
- 519 Kwh / 600 Kvah = 0.86 Pf (Average)

Test Comparison

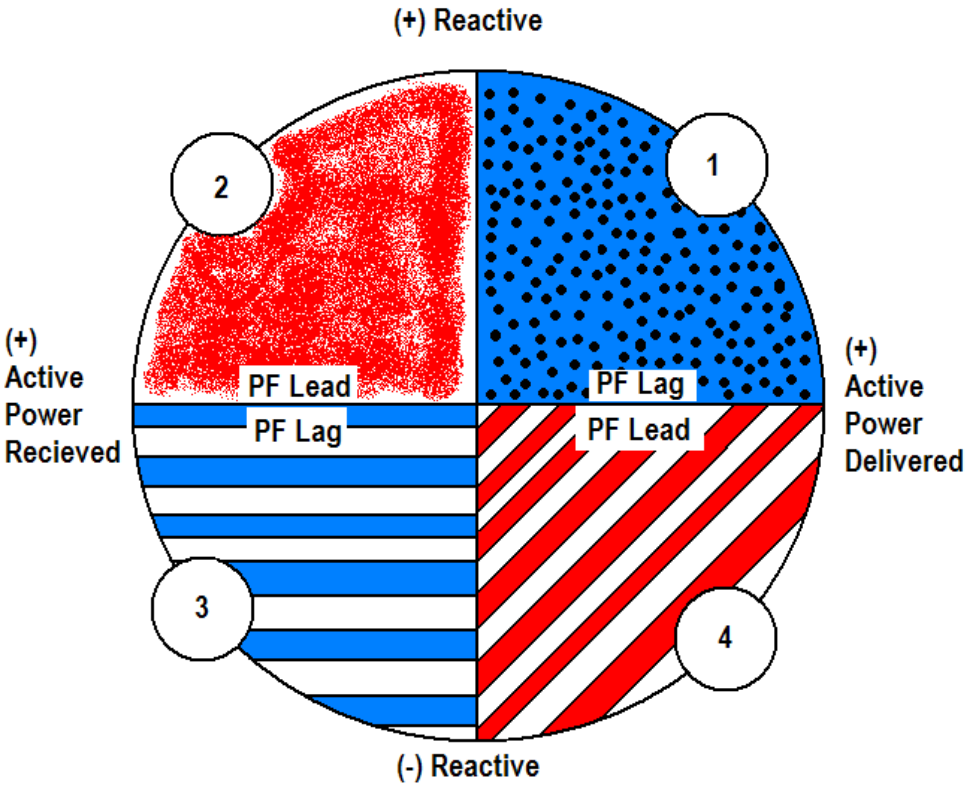
Expected test results

♦ Package 1	519 Kwh	150 Kvarh	540 Kvah	0.96 Pf
♦ Package 2	519 Kwh	000 Kvarh	519 Kvah	1.00 Pf
♦ Package 3	519 Kwh	000 Kvarh	519 Kvah	1.00 Pf
♦ Package 4	519 Kwh	300 Kvarh	600 Kvah	0.86 Pf
♦ Expected	519 Kwh	300 Kvarh	600 Kvah	0.86 Pf

- Note: Package 1, uses only a Delivered Kvarh meter
- Package 2, uses a Kqh meter
- Package 3, nets both the Del. & Rec. Kvarh meters
- Package 4, sum (Abs) the Del. & Rec Kvarh meters

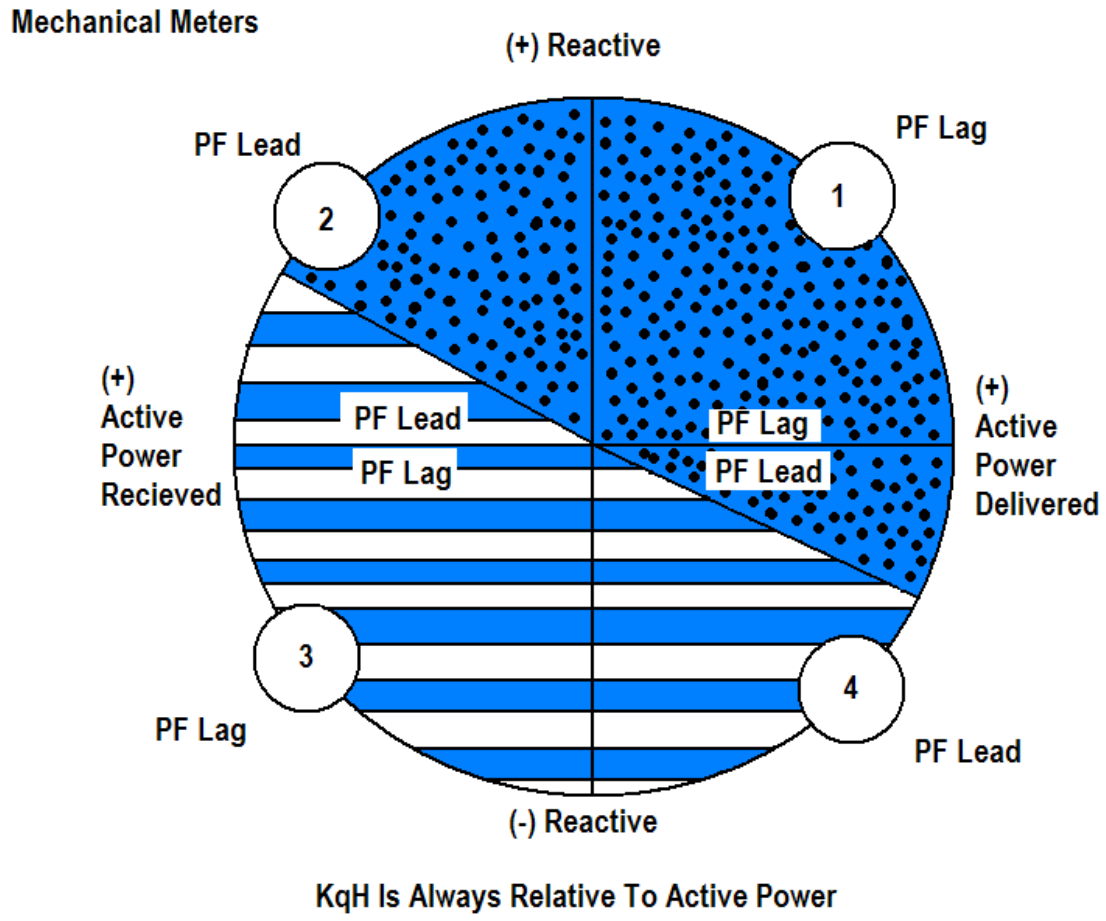
- Which is correct?

Power Factor Lead/Lag

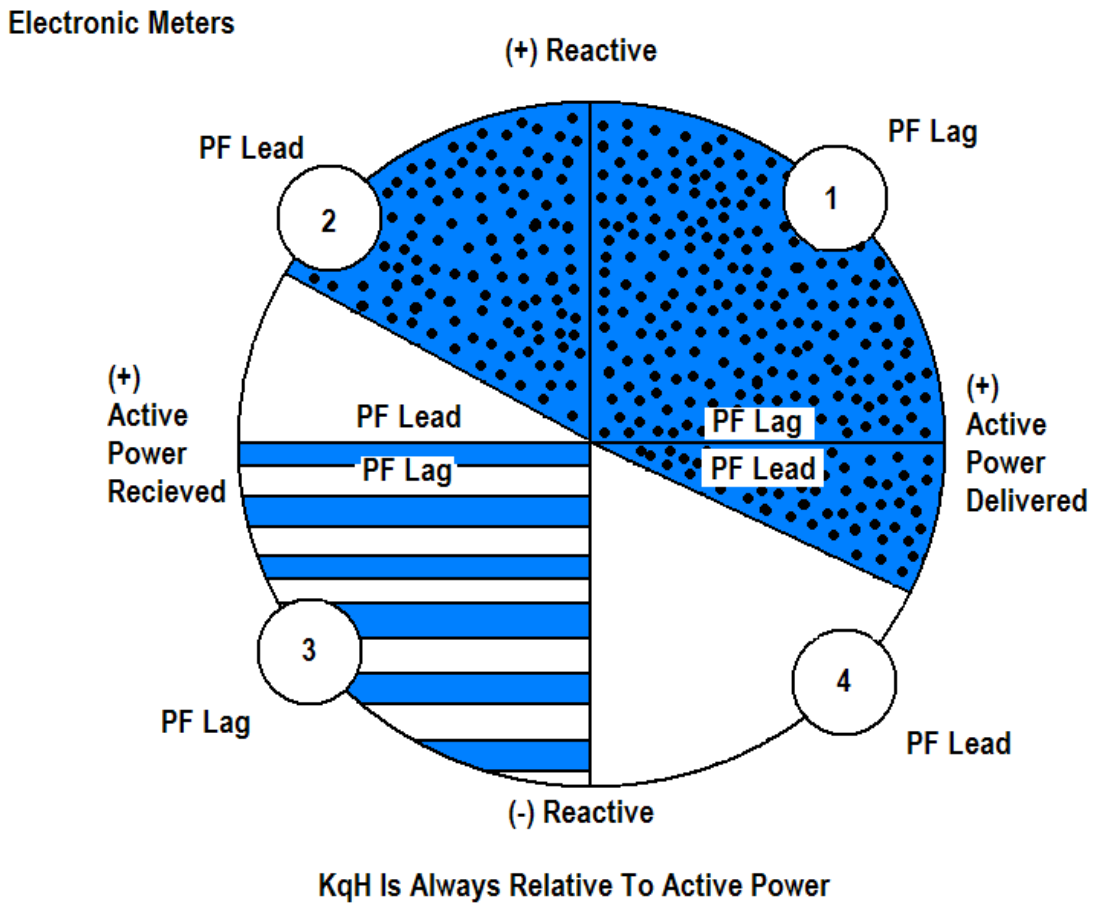


Power Factor is Relative to Active Power

Power Factor Lead/Lag



Power Factor Lead/Lag



Power Factor Metering

- What is Power Factor

PF = Cos ∟Θ

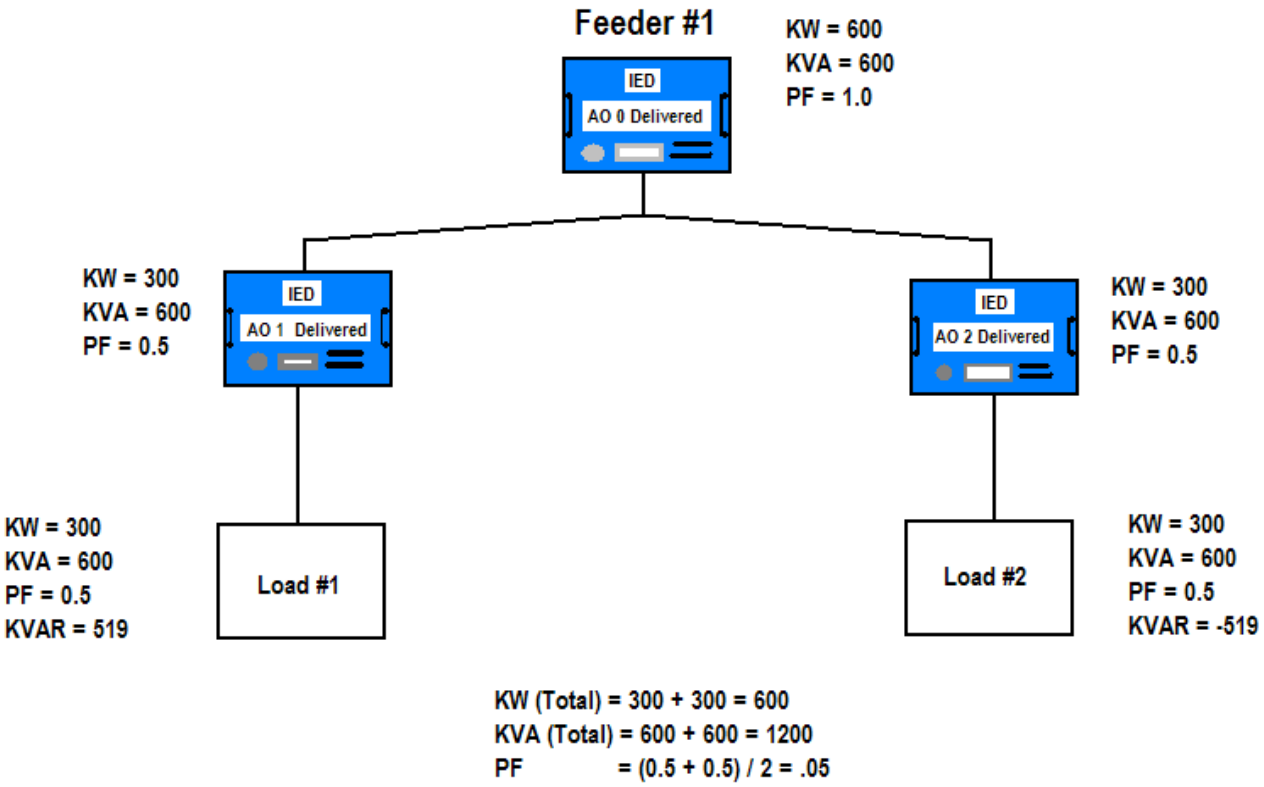
PF = The Ratio of W / VA

PF Will Always be a Number Between 0.0 and 1.0

Volt-Ampere

- In AC Circuits where the Power Factor is other than Unity, the Volt-Amperes equal the square root of Watts squared plus the reactive Volt-Amperes squared.

Summing Power Values Single Load



Review
Vars from Q-Meter

- VARS = ((2 * q) – Watts) / √(3)

  VARS = ((2 * 519.6) – 1039.2) / √(3)

  VARS = 0

How Many Vars ???

- 15 Minute Interval

  7 ½ Minutes

  300 VARS q1 = 519q

  7 ½ Minutes

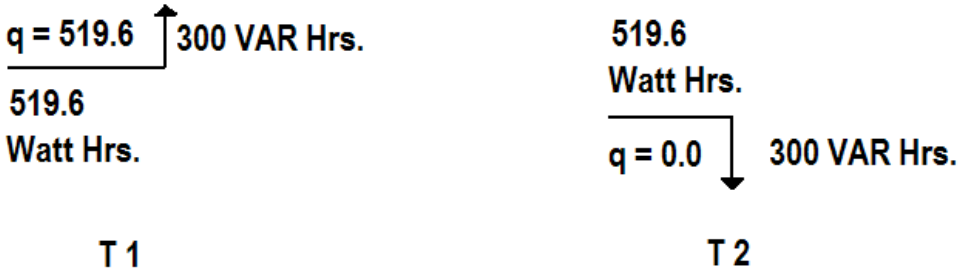
  300 VARS q4 = 0q

VARS = 300 q1

VARS = 300 q4

Total = 600 VARS

Power Factor Using q Hours



VARS = ((2 * q) - W) / √(3)

VARS = ((2 * 519.6) - 1039.2) / √(3)

VARS = 0

PF = 1.0

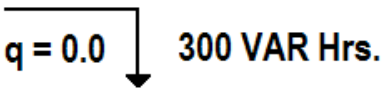
Power Factor Using VAR-Hours

(Using 1 Meter)

519.6
Watt Hrs.

T 1

519.6
Watt Hrs.



T 2

PF = W / VA

PF = 1039.2 / 1081.6

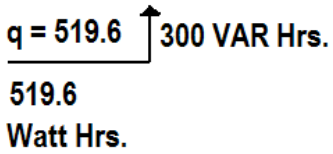
PF = 96

VA = √(1039.2 * 1039.2 + 300 * 300)

VA = 1081.6

Power Factor Using VAR-Hours

(Using 2 Meters)

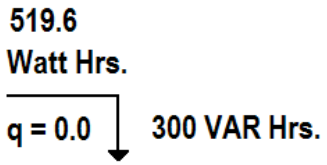


T 1

PF = W / VA

PF = 1039.2 / 1199.9

PF = .866



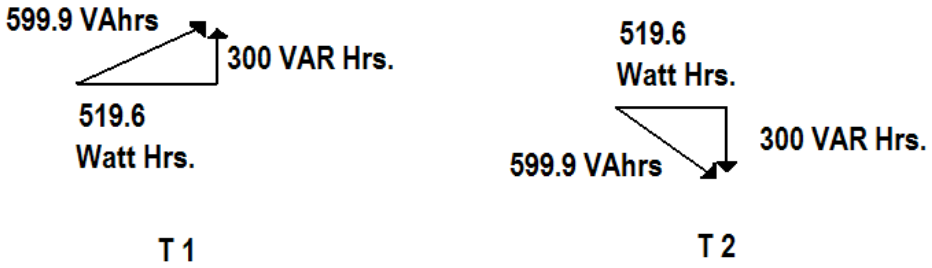
T 2

VA = √(1039.2 * 1039.2 + 600 * 600)

VA = 1199.9

Power Factor Using VA Hours

$VA = VA_{T1} + VA_{T2}$



PF = W / VA

PF = 1039.2 / 1199.8

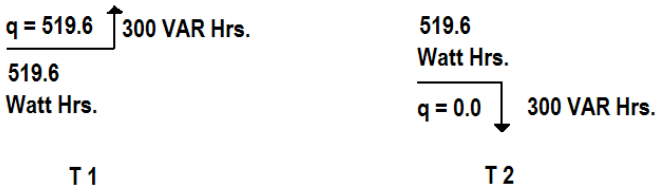
PF = .866

Power Factor Answers

- A. PF = 1.0 (q-Hour)
- B. PF = .96 (1-VAR-Hour)
- C. PF = .866 (2-VAR-Hour)
- D. PF = .866 (Sum VA-Hour)

KVA Metering Using q Hours

$VA = \sqrt{(Watts^2 + VARS^2)}$



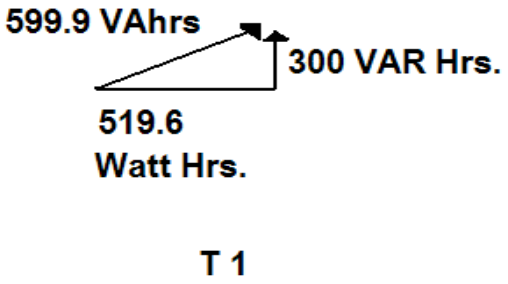
VARS = ((2q) - W) / √(3)
VARS = ((2 * 519.6) - 1039.2) / √(3)
VARS = 0
PF = 1.0

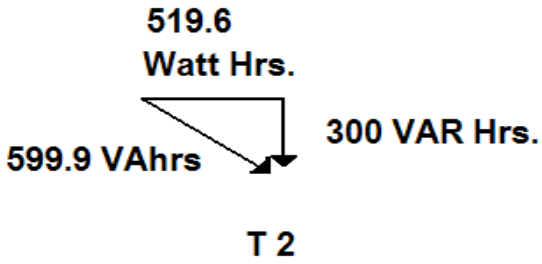
$$VA = \sqrt{(Watts^2 + VARS^2)}$$

$$VA = \sqrt{(1039.2^2 + 0^2)}$$

$$VA = 1039.2$$

KVA Metering Using VAR Hours
(Using 1 Meter)
VA = √(Watts2 + VARS2)



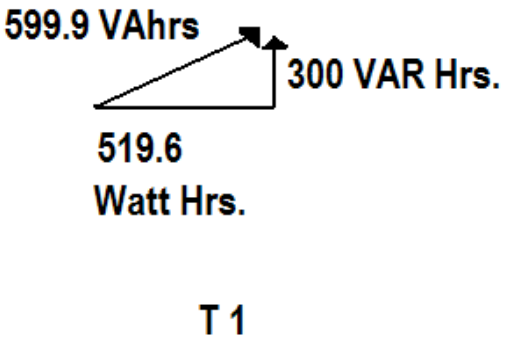


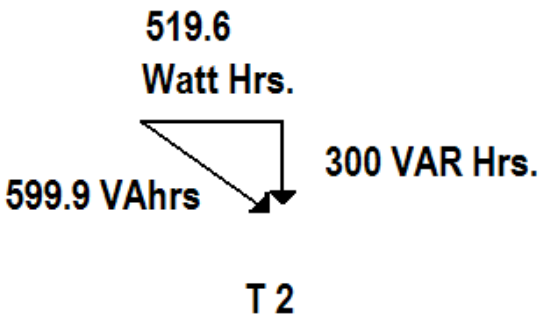
$$VA = \sqrt{(Watts^2 + VARS^2)}$$

$$VA = \sqrt{(1039.2^2 + 300^2)}$$

$$VA = 1081.6$$

KVA Metering Using VAR Hours
(Using 2 Meters)
VA = √(Watts2 + VARS2)





$$VA = \sqrt{(Watts^2 + VARS^2)}$$

$$VA = \sqrt{(1039.2^2 + 600^2)}$$

$$VA = 1199.9$$

KVA Answers

- A. 1039.2 (q-Hour)
- B. 1081.6 (1-VAR-Hour)
- C. 1199.9 (2-VAR-Hour)
- D. 1199.9 (Sum VA-Hour)

KVA METERING

KQH = 519.6 **KQH = 600** **KQH = 0**

T1 **T2** **T3**

KWH = 1339.2 KQH = 1119.6 $KVARH = \frac{2(1119.6)-1339.2}{\sqrt{3}}$

(A)KVARH = 519.6(KQH)

(B)KVARH = 819.6(1 METER)

(C)KVARH = 1119.6(2 METERS)

(D)$KVAH = \sqrt{519.6^2 + 1339.2^2}$
KVAH = 1436.3

(E)$KVAH = \sqrt{819.6^2 + 1339.2^2}$
KVAH = 1570

(F)$KVAH = \sqrt{1119.6^2 + 1339.2^2}$
KVAH = 1745.50

(G)KVAH = 599.9 + 599.9 + 599.9
KVAH = 1799.70

(H)$PF = \frac{1339.2}{1436.3}$

PF = 0.932

(I)$PF = \frac{1339.2}{1570}$

PF = 0.852

(J)$PF = \frac{1339.2}{1745.5}$

PF = 0.767

(K)$PF = \frac{1339.2}{1799.9}$

PF = 0.744

KVA Answers

D. 1436.3 KVAH PF = 0.93 (q-Hour)

E. 1570.0 KVAH PF = 0.85 (1 VAR-Hour)

F. 1745.5 KVAH PF = 0.76 (2 VAR-Hour)

G. 1799.7 KVAH PF = 0.74 (Sum VA-Hour)