TRANSFORMER LOSS COMPENSATION

FOR METERMEN

PRESENTED BY:

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TRANSFORMER LOSS COMPENSATION
THE
WHAT, WHEN, WHO, WHERE AND HOW

WHAT are transformer losses?

Transformer losses can be viewed as the power consumed (used) by the transformer when performing work. The harder the transformer works, the more power consumed by the transformer and the larger the losses. The transformer losses can be looked at as if the transformer was a variable load connected to the load side of the meter. The load is made up of two parts; the fixed portion, which keeps the transformer alive (no-load losses) and the variable part, which changes with the load (load losses).

WHEN are transformer loss calculations performed?

Transformer loss calculations are normally performed when the meter is located on the "wrong" side of the transformer (not at the ownership point or point of delivery). Two of the most common reasons for the meter not to be located at the point of delivery are installation costs and a changing point of delivery or supplier (deregulation).

WHO is responsible for the transformer losses?

There are two widely accepted practices: 1) the owner of the transformer is responsible for the transformer losses and should pay for the losses. This can be seen in billing rates, which allow customers to receive transformer credits or the energy pricing has been adjusted to compensate for the losses. 2) The supplier of the active power is responsible for the transformer losses. This can be seen at tie points where the power can flow in both directions. This situation is becoming more common with deregulation.

WHERE can the losses be calculated?

The two most common places for transformer loss calculations to be done are in a computer after the fact or within the meter in real time. Transformer loss calculations are based on voltage and current, not Watt-hours or Var-hours. The after-the-fact calculations method requires the computer not only to have Delivered and Received Watt-hours and Var-hours, but to also have the per-phase voltages and the per-phase currents to accurately calculate the transformer losses. This method would require the system to have up to ten (10) recorder channels for data if the computer calculates the losses after the fact. On the other hand, the PSI Quad 4 meter has all of the per-phase voltage and current values required for the calculation of transformer losses in real time. The meter provides both compensated and uncompensated values at the same time, which allows for easy testing.

HOW, are the losses of a transformer measured?

The no-load (iron) losses and the percent exciting current will normally be measured using a voltmeter, ammeter and wattmeter connected per figure 1. The voltage source will be set to the rated voltage and frequency of the transformer (normally the L.V. side), and the H.V. side of the transformer will be open circuited. The no-load (iron) losses will be taken from the wattmeter, and in the case of a three-phase transformer, the algebraic sum of the wattmeter readings will provide the total no-load (iron) losses in watts. The ammeter reading will be used to provide the no-load current, which will be used for the calculation of percent exciting current. The percent exciting current is the applied current expressed as a percent of the full load current. The no-load (iron) loss and percent exciting current tests are normally done on the low voltage side of the transformer because the current readings are larger, and therefore easier to read. Additionally a lower voltage power source will be easier to obtain.

The load (copper) losses and the percent impedance can be measured using a voltmeter, ammeter and wattmeter connected per figure 2. The voltage source is normally connected to the H.V. side of the transformer and the L.V. side of the transformer will be shorted (poor shorting links can affect the loss measurement). The voltage will be adjusted until the ammeter reads the full load current rating of the transformer. The load (copper) losses will be taken from the wattmeter, and in the case of a three-phase transformer, the algebraic sum of the wattmeter reading will provide the total load (copper) losses watts loss. The voltmeter readings will be used to provide the impedance voltage, which will be used to calculate the percent impedance. The percent impedance is the applied test voltage expressed as a percent of the normal operating voltage. The load (copper) losses would be the same if they were measured on the low side of the transformer. The high side of the transformer is used because it will require the voltage source to deliver less current.
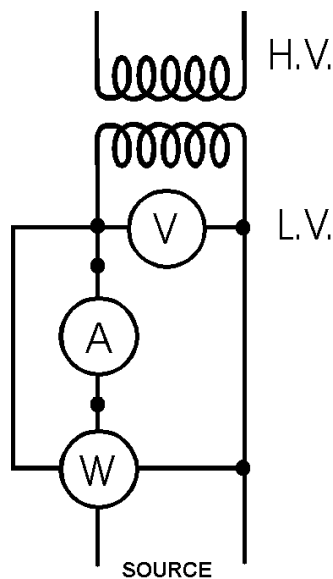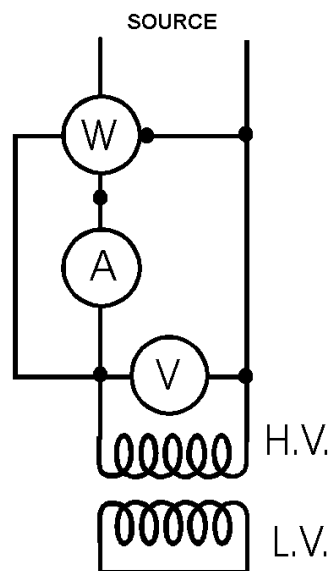

FIG. 1   FIG. 2

Note: The above load loss test is normally run on power transformers having low or normal impedance (less than 10%). Because of this, the flux in the core is so small in the short circuit test that the iron losses can be ignored. When testing high impedance power transformers, the no-load losses would be subtracted from the load loss test and the difference would be the load (copper) losses for the transformer.

HOW can you calculate transformer losses? (how the Quad 4 calculates losses)

The first requirement will be the transformer data sheet. This sheet will provide you with all of the information required for the calculation of the percent losses within the transformer at different load points.

KWH

The calculation of no-load (Iron) losses is based on the ratio of the voltages being measured and the rated voltage squared and the results multiplied by the no-load value from the data sheet. The Quad 4 meter has what is referred to as an Iron constant (KWFe). This constant will be multiplied by the voltage squared and the results will equal the KW losses of the transformer due to voltage (No-Load or Iron Losses).

The no-load (Iron) losses of a 4160-volt, 3000 KVA, Delta connected transformer with Iron Losses of 9200 watts, Copper Losses of 21720 watts, Impedance of 6.25%, exciting current of 1.54% and an actual measured voltage of 4020 volts.

The example below shows the no-load (Iron) losses will change only with changes in voltage, <u>not</u> current or power factor. Based on the transformer test sheet, the no-load (Iron) losses of 9200 watts was at rated transformer voltage.

Iron Loss calculations at 4160 and 4020 Volts.

Example:

Calculated loss @ 4160 volts $(4160/4160)^2 \times 9200 = 9200.0$ watts
Quad 4 calculation @ 4160 volts $(4160^2) \times 2 \times 2.6581E-7 = 9.200$ KW
      Number of voltages available within the meter ↗
      KWHFe constant used by the meter ——————

Calculated loss @ 4020 volts $(4020/4160)^2 \times 9200 = 8591.1$ watts
Quad 4 calculation @ 4020 volts $(4020^2) \times 2 \times 2.6581E-7 = 8.5911$ KW
      Number of voltages available within the meter ↗
      KWFe constant used by the meter ——————

The calculation of load (Copper) losses are based on the ratio of the current being measured and the rated full load current squared and the results multiplied by load (copper) losses from the data sheet. The Quad 4 meter has what is referred to as a Copper constant (KWCu). This constant will be multiplied by the current squared, and

the results will equal the KW losses of the transformer due to current load (Copper) losses.

The examples which follow are based on the following transformer and load data: the load (Copper) losses of a 4160-volt, 3000 KVA, Delta connected transformer with load (Copper) losses of 21720 watts, no-load (Iron) losses of 9200 watts, Impedance of 6.25% and 1.54% exciting current. The example below shows the Load (Copper) Losses will change only with changes in current, _not_ voltage or power factor. The first requirement is to calculate the full load transformer current before the Load (Copper) Losses can be calculated. Based on the transformer test sheet, the Load (Copper) Losses are 21720 watts at full transformer rated current.

The full load line current on the low side of the transformer (4160 volts) is calculated as follows based on the data sheet.

3000Kva x 1000/(4160Volts x 1.732) = 416.35 Amps.

Copper loss calculation at 416.35 and 200 Amps.

Example:

Calculated loss @ 416.35 Amps   (416.35/416.35)^2 x 21720 = 21720.0 watts
Quad 4 calculation @ 416.35 Amps(416.35^2) x 2 x 6.26463E-5 = 21.72 KW
   Number of currents available within the meter
   KWHCu constant used by the meter

Calculated loss @ 200.0 Amps   (200.00/416.35)^2 x 21720 = 5011.9 watts
Quad 4 calculation @ 200.0 Amps (200.00^2) x 2 x 6.26463E-5 = 5.011 KW
   Number of currents available within the meter
   KWHCu constant used by the meter

KVARH

The calculation of Vars of Iron Loss is based on the ratio of the voltages being measured and the rated voltage being taken to the fourth power and the results are multiplied by theVars Iron Loss from the data sheet. The Quad 4 meter has what is referred to as an Iron constant (KVFe). This KVFe constant will be multiplied by the voltage to the fourth power and the results will equal the Kvar losses of the transformer due to voltage (Vars of Iron Loss).

The examples which follow are based on the following transformer and load data. The Vars of Iron Loss of a 4160-volt, 3000 KVA, Delta connected transformer with Iron Losses of 9200 watts, Copper Losses of 21720 watts, Impedance of 6.25%, exciting current of 1.54% and a actual measured voltage of 4020 volts. The Vars of Iron Losses will change only with changes in voltage, <u>not</u> current or power factor. Based on the transformer test sheet, the Vars of Iron Loss was 45,274 Vars at rated transformer voltage. WHERE did you get 45,274 Vars?

Example:

Calculation of Vars at rated transformer voltage (4160 Volts).

> **VA = 3000kva x 1000 x .0154 excitation = 46,200 (VA @ test point)**
> **Cos. of Angle = 9200/46200 = 0.1991, sin of Angle = 0.9799**
> **Vars = 46,200 x 0.9799 = 45,274 vars at 4160 Volts (Vars @ test point)**

Example:

Vars of Iron Losses, calculations @ 4160 and 4020 Volts.

Calculated loss @ 4160 Volts   **(4160/4160)^4 x 45274 = 45274.0 Var**
Quad 4 calculation @ 4160 Volts   **(4160^4) x 2 x 7.55879E-14 =45.274 KVar**
     Number of voltages available within the meter ➚   ➚
     KVARFe constant used by the meter————————

Calculated loss @ 4020 Volts   **(4020/4160)^4 x 45274.0 = 39,480 Var**
Quad 4 calculation @ 4020 Volts   **(4020^4) x 2 x 7.55879E-14 = 39.480 KVar**
     Number of voltages available within the meter ➚   ➚
     KVARFe constant used by the meter————————

The calculation of Vars Copper Losses is based on the ratio of the current being measured and the rated full load current squared and the results multiplied by the Vars Copper Losses from the data sheet. The Quad 4 meter has what is referred to as a Copper constant (KVCu). This KVCu constant will be multiplied by the current squared and the results will equal the Vars losses of the transformer due to current (Vars Copper Losses).

The examples which follow are based on the following transformer and load data. The Vars Copper Loss of a 4160-volt, 3000 KVA, Delta connected transformer with Copper Losses of 21,720 watts, Iron Losses of 9,200 watts, Impedance of 6.25% and 1.54% exciting current. The Vars copper losses will change only with changes in current, <u>not</u> voltage or power factor. The first requirement is to calculate the full load transformer current before the Vars copper losses can be calculated. Based on the transformer test sheet, the Vars copper loss of 186,237 Vars was at rated full transformer current. WHERE did you get 186,237 Vars?

Example:

The full load line current on the low side (metering side) of the transformer (4160 volts).

3000Kva x 1000/(4160Volts x 1.732) = 416.35 Amps.

Example:

The calculation of Vars at full rated transformer current (416.35 Amps).

> **VA = 3000kva x 1000 x 0.0625 impedance = 187,500 (VA @ test point)**
> **Cos. of Angle = 21727/187500 = 0.11854, sin of Angle = 0.99326**
> **Vars = 187,500 x 0.99326 = 186,237 (Vars @ transformer full load current)**

Vars of Copper Losses, calculations @ 416.35 and 200 Amps.

Calculated loss @ 416.35 Amps   (416.35/416.35)^2 x 186,237 = 186,237.0 Var
Quad 4 calculation @ 416.35 Amps(416.35^2) x 2 x 5.371E-4(KVCu) =186.237 KVar
      Number of currents available within the meter ➚

Calculated loss @ 200.0 Amps   (200/416.35)^2 x 186,237 = 42,974.0 Var
Quad 4 calculation @ 200.0 Amps (200^2) x 2 x 5.371E-4(KVCu) = 42.974 KVar
      Number of currents available within the meter ➚

HOW do you enter data into the Quad 4 meter?

The Quad 4 meter is programmed using the PSI utility program, Q4COM.

The Q4COM program will prompt for the transformer loss data, then calculate the Watts, Iron and Copper Constants and the Vars, Iron and Copper Constants used within the meter and download the constants to the meter.

Example of Q4COM download list for transformer loss calculations.

Q4COM will check the per-phase power card before calculating the loss constants. Therefore, if you reconfigure the per-phase card after you program TLC, you will need to re-enter the transformer data. The selection affects Delta meters or Wye meters which have or has been wired as a Delta meter and had one of the Delta options (Inscribed Wye, B-Phase Current) turned on. When B-Phase current is selected, the QUAD4 meter will calculate B-Phase and the constants will be adjusted based on the meter providing three current values to the compensation calculation (this will affect the expected series test results, see testing section). The other meter, which will give different losses in the series test set-up, would be the FORM 6A or 36S meters.

Loss Calculations .... : <u>Transformer and Line Loss</u>
(You can select Line Losses Only or With Transformer Losses)

Transformer Connection, Meter Side....................................... : **<u>Delta</u>**
(Select the way the meter sees the transformer)
Type of Transformer .... : **<u>Single 3-Phase Transformer</u>**
(How is the transformer bank constructed)
Delivered Real Power Transformer Loss Sign .... : **<u>Plus</u>**
(When you add losses to Delivered they will be subtracted from Received)
Total Connection Resistance, Phase Current .... : **<u>0 Ohms</u>**
(This is the total resistance of the interconnects between transformers in a delta bank)
Total Connection Resistance, Line Current .... : **<u>0 Ohms</u>**
(This is the total series line resistance)
Total Values:
Rate Voltage, Meter Side .... : **<u>4160 Volts</u>**
(The Power transformer voltage)
Rate KVA .... : **<u>3000 KVA</u>**
(The rated transformer size)
Copper Loss .... : **<u>21720 Watts</u>**
(Load Losses)
Iron Loss .... : **<u>9200 Watts</u>**
(No-load Losses)
Exciting Current .... : **<u>1.54 %</u>**
(Percent of rated current @ No-load test)
Impedance at operating temp .... : **<u>6.25 %</u>**
(Percent of rated voltage @ Load Test)
CT Primary Current .... : **<u>400 Amps</u>**
(Current Transformer rated size)
CT Secondary Current .... : **<u>5 Amps</u>**
(Secondary current at rated primary current)
PT Primary Voltage .... : **<u>4200 Volts</u>**
(Primary voltage rating of transformer)
PT Secondary Voltage .... : **<u>120 Volts</u>**
(Secondary voltage at rate primary voltage)
Use CT * VT Ratio For Line Value Displays .... : **<u>NO</u>**
(Select No for secondary readings and Yes for primary or scaled readings)

Example of Q4COM download list for transformer loss coefficients.

Q4COM will check the per-phase power card before calculating the loss constants. Therefore, if you reconfigure the per-phase card after you program TLC, you will need to re-enter the transformer data. The selection affects Delta meters or Wye meters, which have been wired as a Delta meter and had one of the Delta options (Inscribed Wye, B-Phase Current) turned on. When B-Phase current is selected, the QUAD4 meter will calculate B-Phase and the constants will be adjusted based on the meter providing three current values to the compensation calculation (this well affect the expected series test results, see testing section). The other meter, which will give different losses in the series test set-up, would be the FORM 6A or 36S meters.

Transformer Metering Arrangement: <u>3W Delta, 2 CTs & 2 PTs (True Delta Losses)</u>
(This selection wants to know if the percent corrections are referenced to series or three phase values. Remember, losses are based on voltage and current, not power factor or watts. Therefore,

if the losses were 12.47 watts and the reference was a 3-phase value of 1039 watts, you have a 1.2 % correction. If the reference was a series value of 1200 watts, you have a 1.04- % correction. Both answers are correct, the losses (12.47 watts) didn't change because they were based on voltage and current, which remained the same, only the value of the reference changed.)

Delivered Real Power Transformer Loss Sign .... : <u>Plus</u>
(When you add losses to Delivered they will be subtracted from Received)
Secondary Rate Voltage .... : <u>120 Volts</u>
(This should be the meter test voltage or the meter voltage used to calculate the percent losses)
Percent Full Load Watts Iron Loss... : <u>0.279 %</u>
(This value must be based on five (5) Amps and the above voltage.)
Percent Full Load Watts Copper Loss .... : <u>0.596 %</u>
(This value must be based on five (5) Amps and the above voltage.)
Percent Full Load Vars Iron Loss .... : <u>1.400 %</u>
(This value must be based on five (5) Amps and the above voltage.)
Percent Full Load Vars Copper Loss .... : <u>5.115 %</u>
(This value must be based on five (5) Amps and the above voltage.)

HOW do you test TLC in the Quad4?

The Quad 4 is the easiest meter for testing the accuracy of transformer loss compensation. The main reason behind the ease of testing the Quad 4 meter is that the meter can have both Compensated and Un-compensated values within the meter at the same time. The two most common ways of testing TLC would be; (1) compare instantaneous compensated and un-compensated values, or (2) let the meter calculate the percent accuracy with losses for you (this is the easiest option). **HOW** does the meter calculate percent accuracy? The meter can calculate the accuracy by dividing compensated by the uncompensated and multiplying the results by 100. The results are averaged over one minute. **WHAT** will the tester need to know? The tester will need to know what the expected losses are for each of the test conditions (series or 3-phase testing) and how the meter operates under series and 3-phase conditions. The following three examples will help with the thought process in understanding on how the TLC process works.

Find the percent losses of a transformer at a meter test point of 5Amps and 120 volts. The transformer is a 4160-volt, 3000 KVA, Delta connected transformer with load (Copper) losses of 21720 watts, Iron Losses of 9200 watts, Impedance of 6.25% and 1.54% exciting current. The meter is connected to the system through 4200/120-volt VTs and 400/5 amp CTs. The example of a delta metering system was chosen because of the effect on series testing which may not be seen in all metering systems and because the per-phase card can be configured three (3) different ways when metering delta systems. The configurations of the per-phase card will affect series test results. The other meter, which will give different losses in the series test set-up, would be the FORM 6A or 36S meters.

The first suggestion is to select un-compensated watts, compensated watts, per-phase volts and per-phase Amps as display items.
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Circuit Description

The losses of the transformer should be calculated for the point at which the test will be run. Using our example, we will test the meter at 120 Volts, 5 Amps and 0.5 Pf, which will be equivalent to 4200 Volts and 400 Amps at the transformer. Testing at a 0.5 Pf will allow you to test the compensation for both Watts and Vars at the same time. The losses at unity and fifty percent power factor will be the same because the current and voltage will be the same for both tests. The percent of losses will be different because the watt load will be different.

Example: 1

The first two illustrations are based on the Form 5 meter having no B-phase current available within the meter.

Calculated transformer Watts losses.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts $(4200/4160)^2 \times 9200 = 9377.77$ **Watts**
LOAD (Copper) losses
Calculated loss @ 400.00 Amps $(400.00/416.35)^2 \times 21720 =$ <u>**20047.61 Watts**</u>
Total **Primary Losses = 29425.38 Watts**
Total **Secondary Losses = 29425.38/2800 = 10.5 Watts = .0105 Kw**

Meter Calculation of Watts losses based on the measured voltage and current.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts $(4200^2)+(4200^2) \times 2.6581\text{E-}4 = 9377.77$ **Watts**
LOAD (Copper) losses (3-Phase Test)
Calculated loss@ 400 A $(400^2)+(400^2) \times 6.2648789\text{E-}2 =$ <u>**20047.61 Watts**</u>
Total **Primary Losses = 29425.38 Watts**
Total **Secondary Losses = 29425.38/2800 = 10.5 Watts = .0105 Kw**

Calculated transformer Vars lose.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts $(4200/4160)^4 \times 45274 = 47040.58$ **Vars**
LOAD (Copper) losses
Calculated loss @ 400.00 Amps $(400.00/416.35)^2 \times 186237 =$ <u>**171897.20 Vars**</u>

Total   **Primary Losses = 218937.78 Vars**
Total   **Secondary Losses = 218937.78/2800 = 78.19 Vars = .07819 KVAR**

Meter Calculation of Vars losses based on the measured voltage and current.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts $(4200^4)+(4200^4)$ x 7.5586728E-11 = 47040.58 Vars
LOAD (Copper) losses (3-Phase Test)
Calculated loss @ 400 A $(400^2)+(400^2)$ x 5.371787E-1 = <u>171897.18 Vars</u>
Total   **Primary Losses = 218937.78 Vars**
Total   **Secondary Losses = 218937.78/2800 = 78.19 Vars = .07819 KVAR**

The first (1) illustration shows the test results from a meter being 3-phase tested.

Calculated Load 5Amps x 120 Volts x 1.732 x 0.5 Pf =519.6 Watts
% TLC = 10.5 Watts / 519.6 Watts x 100 = 2.02 %

Calculated Load 5Amps x 120 Volts x 1.732 x 0.866 Pf =899.9 Vars
% TLC = 78.19 Vars / 899.9 Vars x 100 = 8.68 %

Illustration 1

CUSTOMER DISPLAYS	UTILITY DISPLAYS
----------------------------------	----------------------------------
PHASES CBA = YNY	INST. PHASE A = 120.186187 VLTS
INST. DELIVERED = 0.528000 KW	INST. PHASE B = 0.000000 VLTS
INST. RECEIVED = 0.000000 KW	INST. PHASE C = 120.000672 VLTS
INST. KW = 0.528000 KW	INST. PHASE A = 4.996612 AMPS
INST. COMP KW = 0.538510 KW	INST. PHASE B = 0.000000 AMPS
INST. COMP. DEL. = 0.538510 KW	INST. PHASE C = 5.000524 AMPS
INST. COMP REC = -0.000000 KW	WATTS LOSS CU = 0.007155 KW
INST. DEL. Q1 = 0.899962 KVAR	WATTS LOSS FE = 0.003354 KW
INST. DEL. Q2 = 0.000000 KVAR	VARS LOSS CU = 0.061354 KVAR
INST. DEL. Q3 = 0.000000 KVAR	VARS LOSS FE = 0.016854 KVAR
INST. DEL. Q4 = 0.000000 KVAR	% KW WITH LOSS = 102.012549 %
INST. KVAR = 0.899962 KVAR	% KVAR WITH LOSS = 108.686540 %
INST.COMP KVAR = 0.978170 KVAR	
INST.COMP DEL.Q1 = 0.978170 KVAR	
INST.COMP DEL.Q2 = 0.000000 KVAR	
INST.COMP DEL.Q3 = 0.000000 KVAR	
INST.COMP DEL.Q4 = 0.000000 KVAR	
INST.COMP. Q1+Q2 = 0.978170 KVAR	
INST.COMP. Q3+Q4 = -0.000000 KVAR	

The second (2) illustration shows the test results from a meter being Series tested. The calculated load has changed (in the series test), while the losses have remained the same because the voltage and current are unchanged.

Calculated Load 5Amps x 120 Volts x 2 x 0.5Pf = 600.0 Watts
% TLC = 10.5 Watts / 600.00 Watts x 100 = 1.75 %

Calculated Load 5Amps x 120 Volts x 2 0.866 Pf = 1039.2 Vars
% TLC = 78.19 Vars / 1039.2 Vars x 100 = 7.52 %

Note: The losses are the same in both illustrations 1 and 2. The reason for the difference in % TLC is the actual load on the meter has not remained the same. The reference (load) point (Watts) has changed, while the voltage and current have remained the same for both tests. REMEMBER, losses are based on Voltage and Current, NOT measured Watts.

Illustration 2

CUSTOMER DISPLAYS	UTILITY DISPLAYS
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PHASES CBA = YNY	INST. PHASE A = 120.235745 VLTS
INST. DELIVERED = 0.600000 KW	INST. PHASE B = 0.000000 VLTS
INST. RECEIVED = 0.000000 KW	INST. PHASE C = 119.935382 VLTS
INST. KW = 0.600000 KW	INST. PHASE A = 4.998568 AMPS
INST. COMP KW = 0.610511 KW	INST. PHASE B = 0.000000 AMPS
INST. COMP. DEL. = 0.610511 KW	INST. PHASE C = 4.999852 AMPS
INST. COMP REC = -0.000000 KW	WATTS LOSS CU = 0.007157 KW
INST. DEL. Q1 = 1.043906 KVAR	WATTS LOSS FE = 0.003354 KW
INST. DEL. Q2 = 0.000000 KVAR	VARS LOSS CU = 0.061370 KVAR
INST. DEL. Q3 = 0.000000 KVAR	VARS LOSS FE = 0.016849 KVAR
INST. DEL. Q4 = 0.000000 KVAR	% KW WITH LOSS = 101.751881 %
INST. KVAR = 1.043906 KVAR	% KVAR WITH LOSS = 107.521645 %
INST.COMP KVAR = 1.122125 KVAR	
INST.COMP DEL.Q1 = 1.122125 KVAR	
INST.COMP DEL.Q2 = 0.000000 KVAR	
INST.COMP DEL.Q3 = 0.000000 KVAR	
INST.COMP DEL.Q4 = 0.000000 KVAR	
INST.COMP. Q1+Q2 = 1.122125 KVAR	
INST.COMP. Q3+Q4 = -0.000000 KVAR	

EXAMPLE: 2

The next two illustrations (3 &4) are based on the form 5 meter having B-phase current turned on. Because this is a vector calculation in the series test set-up, B-phase will be doubled.

Calculated transformer Watts Loss.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts $(4200/4160)^2$ x 9200 = 9377.77 Watts
LOAD (Copper) losses
Calculated loss @ 400.00 Amps $(400.00/416.35)^2$ x 21720 = 20047.61 Watts
Total   Primary Losses = 29425.38 Watts
Total   Secondary Losses = 29425.38/2800 = 10.5 Watts = .0105 Kw

Meter Calculation of Watts losses based on the measured voltage and current.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts $(4200^2)+(4200^2)$ x 2.6581E-4 = 9377.77 Watts
LOAD (Copper) losses (3-Phase Test)
Calculated loss @ 400 A $(400^2)+(400^2)+(400^2)$ x 4.17658E-2 = 20047.58 Watts
Total   Primary Losses = 29425.38 Watts
Total   Secondary Losses = 29425.38/2800 = 10.5 Watts = .0105 Kw

Calculated transformer Vars loss.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts $(4200/4160)^4$ x 45274 = 47040.58 Vars
LOAD (Copper) losses
Calculated loss @ 400.00 Amps $(400.00/416.35)^2$ x 186237 = 171897.20 Vars
Total   Primary Losses = 218937.78 Vars
Total   Secondary Losses = 218046.03/2800 = 78.19 Vars = .07819 KVAR

Meter Calculation of Vars losses based on the measured voltage and current.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts $(4200^4)+(4200^4)$ x 7.5586728E-11 = 47040.58 Vars
LOAD (Copper) losses (3-Phase Test)
Calculated loss @ 400 A $(400^2)+(400^2)+(400^2)$ x 3.58119E-1 = 171897.18 Vars
Total   Primary Losses = 218937.78 Vars
Total   Secondary Losses = 2180937.78/2800 = 78.19 Vars = .07819 KVAR

The third (3) illustration shows the test results from a meter being 3-phase tested with B-phase current turned on. Note: In the 3-phase (normal) operating mode, the results are the same as they were in illustration 1.

Calculated Load 5Amps x 120 Volts x 1.732 x 0.5 Pf =519.6 Watts
% TLC = 10.5 Watts / 519.6 Watts x 100 = 2.02 %

Calculated Load 5Amps x 120 Volts x 1.732 x 0.866 Pf =899.9 Vars
% TLC = 78.19 Vars / 899.9 Vars x 100 = 8.68 %

Illustration 3

CUSTOMER DISPLAYS	UTILITY DISPLAYS
--------------------------------	----------------------------------
PHASES CBA = YNY	INST. PHASE A = 120.313539 VLTS
INST. DELIVERED = 0.516000 KW	INST. PHASE B = 0.000000 VLTS
INST. RECEIVED = 0.000000 KW	INST. PHASE C = 119.983967 VLTS
INST. KW = 0.516000 KW	INST. PHASE A = 4.995927 AMPS
INST. COMP KW = 0.526518 KW	INST. PHASE B = 5.005810 AMPS
INST. COMP. DEL. = 0.526518 KW	INST. PHASE C = 4.998810 AMPS
INST. COMP REC = -0.000000 KW	WATTS LOSS CU = 0.007160 KW
INST. DEL. Q1 = 0.899939 KVAR	WATTS LOSS FE = 0.003358 KW
INST. DEL. Q2 = 0.000000 KVAR	VARS LOSS CU = 0.061394 KVAR
INST. DEL. Q3 = 0.000000 KVAR	VARS LOSS FE = 0.016885 KVAR
INST. DEL. Q4 = 0.000000 KVAR	% KW WITH LOSS = 102.024817 %
INST. KVAR = 0.899939 KVAR	% KVAR WITH LOSS = 108.697977 %
INST.COMP KVAR = 0.978218 KVAR	
INST.COMP DEL.Q1 = 0.978218 KVAR	
INST.COMP DEL.Q2 = 0.000000 KVAR	
INST.COMP DEL.Q3 = 0.000000 KVAR	
INST.COMP DEL.Q4 = 0.000000 KVAR	
INST.COMP. Q1+Q2 = 0.978218 KVAR	
INST.COMP. Q3+Q4 = -0.000000 KVAR	

The fourth (4) illustration shows the test results from a meter being Series tested and having B-phase current turned on. The transformer losses measured by the meter will be different because the B-phase current will be doubled. To calculate the % losses in the series test, we will need to re-calculate the losses based on the voltage and current the meter is measuring.

Calculated transformer Watts Loss.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts   (4200/4160)^2 x 9200 = 9377.77 Watts
LOAD (Copper) losses
Calculated loss @ 400.00 Amps   (400.00/416.35)^2 x 21720 = <u>20047.61 Watts</u>
Total   Primary Losses = 29425.38 Watts
Total   Secondary Losses = 29425.38/2800 = 10.5 Watts = .0105 Kw

Meter Calculation of losses based on the measured voltage and current.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts $(4200^2)+(4200^2)$ x 2.6581E-4 = 9377.77 Watts
LOAD (Copper) losses Series Test
Calculated loss @ 400 A $(400^2)+(800^2)+(400^2)$ x 4.176458E-2= <u>40094.00 Watts</u>
Total   **Primary Losses = 49471.77 Watts**
Total   **Secondary Losses = 49471.77/2800 = 17.66 Watts = .01766 Kw**

Calculated transformer Vars loss.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts $(4200/4160)^4$ x 45274 = 47040.58 Vars
LOAD (Copper) losses
Calculated loss @ 400.00 Amps $(400.00/416.35)^2$ x 186237 = <u>171897.20 Vars</u>
Total   **Primary Losses = 218937.78 Vars**
Total   **Secondary Losses = 218937.78/2800 = 78.19 Vars = .07819 KVAR**

Meter Calculation of Vars losses based on the measured voltage and current.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts $(4200^4)+(4200^4)$ x 7.5586728E-11 = 47040.58 Vars
LOAD (Copper) losses Series Test
Calculated loss @ 400 A $(400^2)+(800^2)+(400^2)$ x 3.58119E-1 = <u>343794.40 Vars</u>
Total   **Primary Losses = 390834.98 Vars**
Total   **Secondary Losses = 390834.98/2800 = 139.58 Vars = .13958 KVAR**

Calculated Load 5Amps x 120 Volts x 2 x 0.5Pf =600.0 Watts
% TLC = 17.66 Watts / 600 Watts x 100 = 2.94 %

Calculated Load 5Amps x 120 Volts x 2 x 0.866 Pf = 1039.2 Vars
% TLC = 139.58 Vars / 1039.2 Vars x 100 = 13.43 %

Illustration 4

CUSTOMER DISPLAYS	UTILITY DISPLAYS
----------------------------------	----------------------------------
PHASES CBA = YNY	INST. PHASE A = 120.280457 VLTS
INST. DELIVERED = 0.600000 KW	INST. PHASE B = 0.000000 VLTS
INST. RECEIVED = 0.000000 KW	INST. PHASE C = 119.927836 VLTS
INST. KW = 0.600000 KW	INST. PHASE A = 4.998225 AMPS
INST. COMP KW = 0.617667 KW	INST. PHASE B = 9.997425 AMPS
INST. COMP. DEL. = 0.617667 KW	INST. PHASE C = 4.999217 AMPS
INST. COMP REC = -0.000000 KW	WATTS LOSS CU = 0.014312 KW

INST. DEL. Q1   = 1.043856 KVAR   WATTS LOSS FE   = 0.003355 KW
INST. DEL. Q2   = 0.000000 KVAR   VARS LOSS CU   = 0.122716 KVAR
INST. DEL. Q3   = 0.000000 KVAR   VARS LOSS FE   = 0.016860 KVAR
INST. DEL. Q4   = 0.000000 KVAR   % KW WITH LOSS   = 102.944104 %
INST. KVAR   = 1.043856 KVAR   % KVAR WITH LOSS = 113.446334 %
INST.COMP KVAR   = 1.183432 KVAR
INST.COMP DEL.Q1 = 1.183432 KVAR
INST.COMP DEL.Q2 = 0.000000 KVAR
INST.COMP DEL.Q3 = 0.000000 KVAR
INST.COMP DEL.Q4 = 0.000000 KVAR
INST.COMP. Q1+Q2 = 1.183432 KVAR
INST.COMP. Q3+Q4 = -0.000000 KVAR

Note: The losses are not the same in illustrations 3 and 4. The reason for the difference in losses and % TLC is that the actual load and currents on the meter change from the series and 3-phase set-up. The reference (load) point (Watts) currents have changed, while the voltage remained the same. REMEMBER, losses are based on Voltage and Current, NOT measured Watts. In all three-phase tests (normal operation), the losses and percent correction are the same, and when voltage or current change, the losses change and are correct based on the measured voltages and currents.

EXAMPLE: 3
The next two illustrations (5 &6) are based on the form 5 meter having Inscribed Wye turned on. With Inscribed Wye turned on, the meter will now calculate Wye voltages and all three currents. Because this is a vector calculation in the series test set-up, B-phase will be doubled.

The fifth (5) illustration shows the test results from a meter being 3-phase tested with Inscribed Wye turned on. Note: In the 3-phase (normal) operating mode, the results are the same as they were in illustration 1 & 3.

Calculated transformer Watts Loss.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts   (4200/4160)^2 x 9200 = 9377.77 Watts
LOAD (Copper) losses
Calculated loss @ 400.00 Amps   (400.00/416.35)^2 x 21720 = 20047.61 Watts
Total   Primary Losses = 29425.38 Watts
Total   Secondary Losses = 29425.38/2800 = 10.5 Watts = .0105 Kw

Meter Calculation of losses based on the measured voltage and current.

NO-LOAD (Iron) losses
Calculated loss @ 4200 V $(2425^2)+(2425^2)+(2425^2)$ x 5.315E-4 = 9377.77 Watts
LOAD (Copper) losses 3-Phase Test
Calculated loss @ 400 A $(400^2)+(400^2)+(400^2)$ x 4.1764586E-2= <u>20047.61 Watts</u>
Total   **Primary Losses = 29425.38 Watts**
Total   **Secondary Losses = 29425.38/2800 = 10.50 Watts = .01050 Kw**

Calculated transformer Vars loss.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts $(4200/4160)^4$ x 45274 = 47040.58 Vars
LOAD (Copper) losses
Calculated loss @ 400.00 Amps $(400.00/416.35)^2$ x 186237 = <u>171897.20 Vars</u>
Total   **Primary Losses = 218937.78 Vars**
Total   **Secondary Losses = 218937.78/2800 = 78.19 Vars = .07819 KVAR**

Meter Calculation of Vars losses based on the measured voltage and current.

NO-LOAD (Iron) losses
Calculated loss @ 4200 V $(2425^4)+(2425^4)+(2425^4)$ x 4.53E-10 = 47040.58 Vars
LOAD (Copper) losses (3-Phase Test)
Calculated loss @ 400 A $(400^2)+(400^2)+(400^2)$ x 3.58119E-1 = <u>171897.18 Vars</u>
Total   **Primary Losses = 218937.78 Vars**
Total   **Secondary Losses = 2180937.78/2800 = 78.19 Vars = .07819 KVAR**

Calculated Load 5Amps x 120 Volts x 1.732 x 0.5Pf = 519.6 Watts
% TLC = 10.50 Watts / 519.6 Watts x 100 = 2.02 %

Calculated Load 5Amps x 120 Volts x 1.732x 0.866 Pf = 899.9 Vars
% TLC = 78.19 Vars / 899.9 Vars x 100 = 8.68 %

Illustration 5

CUSTOMER DISPLAYS	UTILITY DISPLAYS
----------------------------------	----------------------------------
PHASES CBA = YNY	INST. PHASE A = 69.380846 VLTS
INST. DELIVERED = 0.528000 KW	INST. PHASE B = 69.276107 VLTS
INST. RECEIVED = 0.000000 KW	INST. PHASE C = 69.347608 VLTS
INST. KW = 0.528000 KW	INST. PHASE A = 4.997325 AMPS
INST. COMP KW = 0.538521 KW	INST. PHASE B = 5.008004 AMPS
INST. COMP. DEL. = 0.538521 KW	INST. PHASE C = 5.001848 AMPS
INST. COMP REC = -0.000000 KW	WATTS LOSS CU = 0.007166 KW
INST. DEL. Q1 = 0.899962 KVAR	WATTS LOSS FE = 0.003354 KW
INST. DEL. Q2 = 0.000000 KVAR	VARS LOSS CU = 0.061448 KVAR
INST. DEL. Q3 = 0.000000 KVAR	VARS LOSS FE = 0.016852 KVAR
INST. DEL. Q4 = 0.000000 KVAR	% KW WITH LOSS = 102.005560 %

INST. KVAR = 0.899962 KVAR   % KVAR WITH LOSS = 108.650892 %
INST.COMP KVAR = 0.978262 KVAR
INST.COMP DEL.Q1 = 0.978262 KVAR
INST.COMP DEL.Q2 = 0.000000 KVAR
INST.COMP DEL.Q3 = 0.000000 KVAR
INST.COMP DEL.Q4 = 0.000000 KVAR
INST.COMP. Q1+Q2 = 0.978262 KVAR
INST.COMP. Q3+Q4 = -0.000000 KVAR

The sixth (6) illustration shows the test results from a meter being series tested with Inscribed Wye turned on. Note: The voltage and current readings will cause a different amount of losses to be calculated. The answers are correct based on the voltages that have been calculated. Therefore, the results will be correct in normal operation (see illustration 5).

Calculated transformer Watts Loss.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts $(4200/4160)^2$ x 9200 = 9377.77 Watts
LOAD (Copper) losses
Calculated loss @ 400.00 Amps $(400.00/416.35)^2$ x 21720 = <u>20047.61 Watts</u>
Total   Primary Losses = 29425.38 Watts
Total   Secondary Losses = 29425.38/2800 = 10.5 Watts = .0105 Kw

Meter Calculation of losses based on the measured voltage and current.

NO-LOAD (Iron) losses
Calculated loss @ 4200 V $(1406^2)+(2812^2)+(1406^2)$ x 5.315E-4 = 6304.37 Watts
LOAD (Copper) losses (Series Test)
Calculated loss @ 400 A $(400^2)+(800^2)+(400^2)$ x 4.1764586E-2= <u>40094.00 Watts</u>
Total   Primary Losses = 46398.37 Watts
Total   Secondary Losses = 46398.37/2800 = 16.57 Watts = .01657 Kw

Calculated transformer Vars loss.

NO-LOAD (Iron) losses
Calculated loss @ 4200 Volts $(4200/4160)^4$ x 45274 = 47040.58 Vars
LOAD (Copper) losses
Calculated loss @ 400.00 Amps $(400.00/416.35)^2$ x 186237 = <u>171897.20 Vars</u>
Total   Primary Losses = 218937.78 Vars
Total   Secondary Losses = 218937.78/2800 = 78.19 Vars = .07819 KVAR

Meter Calculation of Vars losses based on the measured voltage and current.

NO-LOAD (Iron) losses
Calculated loss @ 4200 V (1406^4)+(2812^4)+(1406^4) x 4.53E-10 = 31889.62 Vars
LOAD (Copper) losses (3-Phase Test)
Calculated loss @ 400 A   (400^2)+(800^2)+(400^2) x 3.58119E-1 = 343794.24 <u>Vars</u>
Total   Primary Losses = 375683.86 Vars
Total   Secondary Losses = 375683.86/2800 = 134.17 Vars = .13417 KVAR

Calculated Load 5Amps x 120 Volts x 2 x 0.5Pf = 600 Watts
% TLC = 16.57 Watts / 600 Watts x 100 = 2.76 %

Calculated Load 5Amps x 120 Volts x 2 x 0.866 Pf = 1039.2 Vars
% TLC = 134.17 Vars / 1039.2 Vars x 100 = 12.91 %

Illustration 6
CUSTOMER DISPLAYS   UTILITY DISPLAYS
---------------------------------   ---------------------------------
PHASES CBA   = YNY   INST. PHASE A   = 40.308715 VLTS
INST. DELIVERED = 0.600000 KW   INST. PHASE B   = 80.093439 VLTS
INST. RECEIVED   = 0.000000 KW   INST. PHASE C   = 39.829021 VLTS
INST. KW = 0.600000 KW   INST. PHASE A   = 4.997818 AMPS
INST. COMP KW   = 0.616545 KW   INST. PHASE B   = 9.995613 AMPS
INST. COMP. DEL. = 0.616545 KW   INST. PHASE C   = 4.997813 AMPS
INST. COMP REC = -0.000000 KW   WATTS LOSS CU   = 0.014307 KW
INST. DEL. Q1   = 1.031908 KVAR   WATTS LOSS FE   = 0.002239 KW
INST. DEL. Q2   = 0.000000 KVAR   VARS LOSS CU   = 0.122672 KVAR
INST. DEL. Q3   = 0.000000 KVAR   VARS LOSS FE   = 0.011256 KVAR
INST. DEL. Q4   = 0.000000 KVAR   % KW WITH LOSS   = 102.735714 %
INST. KVAR   = 1.031908 KVAR   % KVAR WITH LOSS = 112.918563 %
INST.COMP KVAR   = 1.165836 KVAR
INST.COMP DEL.Q1 = 1.165836 KVAR
INST.COMP DEL.Q2 = 0.000000 KVAR
INST.COMP DEL.Q3 = 0.000000 KVAR
INST.COMP DEL.Q4 = 0.000000 KVAR
INST.COMP. Q1+Q2 = 1.165836 KVAR
INST.COMP. Q3+Q4 = -0.000000 KVAR

HOW does the Quad4 meter arrive at compensated values?

The Quad 4 meter uses internal totalizers to add or subtract the calculated losses from the measured kWh or kvarh every second to arrive at the compensated value. The output of the totalizer will have the compensated value, and the uncompensated value remains

available within the meter allowing for the display of compensated, uncompensated, iron losses, copper losses and percent accuracy with losses.

COMPENSATED DELIVERED KWH TOTALIZER

When, or if, the results of the one-second total are negative, the one second compensated value of this totalizer will be set to zero. The negative compensated value will be transferred to the compensated received kWh totalizer as a positive value, and the output of the received compensated kWh totalizer will cause compensated received values to increment. When, or if, the result of the one second totalizer is positive, the output of the delivered compensated kWh totalizer will cause compensated delivered values to increment.

COMPENSATED RECEIVED KWH TOTALIZER

When, or if, the result of the one-second total is negative, the one second compensated value of this totalizer will be set to zero. The negative compensated value will be transferred to the compensated delivered kWh totalizer as a positive value and the output of the delivered compensated kWh totalizer will cause compensated delivered values to increment. When, or if the results of the one-second totalizer are positive, the output of the received compensated kWh totalizer will cause compensated received values to increment.

COMPENSATED QUADRANT 1 KVARH TOTALIZER

When the uncompensated VARS are in Q4, the VFe and VCu (Delivered Power) inputs are not added in the totalizer. When the one-second total is negative, the output value of the one-second totalizer will be set to zero. The negative value will be transferred to either the Q4 totalizer or Q3 totalizer as a positive value. When the compensated power is Delivered, the results goes to Q4 totalizer, if not, to the Q3 totalizer (Received Power).

COMPENSATED QUADRANT 2 KVARH TOTALIZER

When the uncompensated VARS are in Q3, the VFe and VCu (Received Power) inputs are not added in the totalizer. When the uncompensated VARS are in Q2, the VFe and VCu (Received Power) are subtracted instead of added (i.e. the sign is reversed). When the one-second total is negative, the output value of the one-second totalizer will be set to zero. The negative value will be transferred to either the Q3 totalizer or Q4 totalizer as a positive value. When the compensated power is Delivered, the results goes to Q4 totalizer, if not, to the Q3 totalizer (Received Power).

COMPENSATED QUADRANT 3 KVARH TOTALIZER

When the uncompensated VARS are in Q2, the VFe and VCu (Received Power) inputs are not added in the totalizer. When the one-second total is negative, the output value of the one-second totalizer will be set to zero. The negative value will be transferred to either the Q2 totalizer or Q1 totalizer as a positive value. When the compensated power is Delivered, the results goes to Q1 totalizer, if not, to the Q2 totalizer (Received Power).

COMPENSATED QUADRANT 4 KVARH TOTALIZER

When the uncompensated VARS are in Q1, the VFe and VCu (Delivered Power) inputs are not added in the totalizer. When the uncompensated VARS are in Q4, the VFe and VCu (Received Power) are subtracted instead of added (i.e. the sign is reversed). When the one-second total is negative, the output value of the one-second totalizer will be set to zero. The negative value will be transferred to either the Q1 totalizer or Q2 totalizer as a positive value. When the compensated power is Delivered, the results goes to Q1 totalizer, if not, to the Q2 totalizer (Received Power).

COMPENSATED QUADRANT 1 + 4 KVARH TOTALIZER

When the uncompensated VARS are in Q4, the VFe and VCu (Delivered Power) inputs are subtracted instead of being added (i.e. the sign is reversed) in the totalizer. When the one-second total is negative, the output value of the one-second totalizer will be added to this totalizer or transferred to the Q2 + Q3 totalizer as a positive value. When the compensated power is Delivered, the results will be added in this totalizer, if not, to the Q2 + Q3 totalizer (Received Power).

When the one second total is positive and the power is not delivered, the one second value is transferred to the Q2 + Q3 totalizer (Received Power).

COMPENSATED QUADRANT 2 + 3 KVARH TOTALIZER

When the uncompensated VARS are in Q2, the VFe and VCu (Delivered Power) inputs are subtracted instead of being added (i.e. the sign is reversed) in the totalizer. When the one-second total is negative, the output value of the one-second totalizer will be added to this totalizer or transferred to the Q1 + Q4 totalizer as a positive value. When the compensated power is Delivered, the results will be transferred Q1 + Q4 totalizer, if not, the results will be added to this totalizer (Received Power).

When the one second total is positive and the power is not delivered, the one second value is transferred to the Q1 + Q4 totalizer (Delivered Power).

COMPENSATED QUADRANT 1 + 2 KVARH TOTALIZER

When the uncompensated VARS are in Q3 or Q4, the VFe and VCu (Delivered Power) and (Received Power) inputs are not add in the totalizer. When the uncompensated

VARS are in Q2, the VFe and VCu (Received Power) will be subtracted instead of being added (i.e. the sign is reversed). (Note: The VFe and VCu (Delivered Power) are both zero when the VARS are in Q2.) If the one second results are negative, the one second value is transferred to the Q3 + Q4 totalizer as a positive value.

COMPENSATED QUADRANT 3 + 4 KVARH TOTALIZER

When the uncompensated VARS are in Q1 or Q2, the VFe and VCu (Delivered Power) and (Received Power) inputs are not added in the totalizer. When the uncompensated VARS are in Q4, the VFe and VCu (Delivered Power) will be subtracted instead of being added (i.e. the sign is reversed). (Note: The VFe and VCu (Received Power) are both zero when the VARS are in Q4.) If the one second results are negative, the one second value is transferred to the Q1 + Q2 totalizer as a positive value.

When negative values are transferred to another totalizer as a positive value, they are only done so when the negative value is more negative than two units of the meter Ke value multiplied by the transformer ratio. This is to allow for the "quantizing" of the meter. Losses can accumulate for one second without a power (or VAR) pulse in that second, but in subsequent second, power pulses can arrive to offset the loss. The losses can yield a short term negative value which should not be shifted to another totalizer. These short-term negative values are remembered. Due to this "memory", very, very small values can be time shifted (delayed) but these delayed values will always be less than two units of the meters Ke (compensated for the transformer ratio).

If there are VARHs accumulated in the totalizers before there are two (2) units of Ke power Delivered or Received, the VARHs may be put in the wrong totalizer, as the "previous power flow" is incorrect. This small error would only occur on startup.

TOTALIZER SET-UP

```
To get
Compensated:    totalizer inputs:                    (Input numbers)
                                                     (See notes below)


Deliv'd PWR    + Watts Del + WFEd + WCUd              (2,20,21)
                                                     (2,63,64)


Receiv'd PWR   + Watts Rec + WFEr + WCUr              (1,22,23)
                                                     (1,65,66)


Q1 Vars        + Q1 + VFEd + VCUd                     (6,24,25)
                                                     (6,67,68)


Q2 Vars        + Q2 + VFEr + VCUr                     (4,26,27)
                                                     (4,69,70)


Q3 Vars        + Q3 + VFEr + VCUr                     (3,26,27)
```

```
                                                      (3,69,70)

Q4 Vars          + Q4 + VFEd + VCUd                   (5,24,25)
                                                      (5,67,68)


Q1 + Q4 Vars     + Q1 + Q4 + VFEd + VCUd              (6,5,24,25)
                                                      (6,5,67,68)


Q2 + Q3 Vars     + Q2 + Q3 + VFEr + VCUr              (4,3,26,27)
                                                      (4,3,69,70)


Q1 + Q2 Vars     + Q1 + Q2 + VFEd + VCUd + VFEr + VCUr (6,4,24,25,26,27)
                                                      (6,4,67,68,69,70)


Q3 + Q4 Vars     + Q3 + Q4 + VFEd + VCUd + VFEr + VCUr (3,5,24,25,26,27)
                                                      (3,5,67,68,69,70)


NOTES:
1.THESE ARE THE ONLY VALID TLC TOTALIZERS SUPPORTED BY THE METER.

2.THERE CAN BE ONLY ONE EACH OF THE ABOVE TLC TOTALIZERS DEFINED IN A
METER.

3.THE TOP SET OF INPUT NUMBERS FOR METERS WITH 39 METER INPUTS;
   THE BOTTOM SET OF INPUT NUMBERS FOR METERS WITH 85 METER INPUTS.
```

The following are "normal" totalizer functions and no special action is taken. They can be considered as "NET VARs". They are only listed here for reference. These could have a negative value and thus can not be used as inputs to recorder channels and not be routed to output relays.

```
Q1 - Q4 Vars     + Q1 - Q4 + VFEd + VCUd              (6,11,24,25)

Q3 - Q2 Vars     + Q3 - Q2 + VFEr + VCUr              (3,10,26,27)
```

THIS IS THE LIST OF TOTALIZERS USED FOR TLC TESTING

> **Firmware Version: 2737**
> **Max Meter Inputs: 85**
> **Max Totalizations: 16**

TOTALIZATION CONTROL DEFINITIONS (table10)
==
TOTALIZER: 1 COMPENSATED KVARH QUADRANT ONE
     Meter Input: 6   (3   Kilovar hours)
     Meter Input: 67   (3   Kilovar hours)

```
     Meter Input: 68              ( 3     Kilovar hours )

        Limit to Positive = NO
        Limit to Negative = NO
           Absolute Value = NO
            Negate Output = NO
-----------------------------------------------------------------
TOTALIZER: 2 COMPENSATED KVARH QUADRANT TWO
     Meter Input: 4               ( 3     Kilovar hours )
     Meter Input: 69              ( 3     Kilovar hours )
     Meter Input: 70              ( 3     Kilovar hours )

        Limit to Positive = NO
        Limit to Negative = NO
           Absolute Value = NO
            Negate Output = NO
-----------------------------------------------------------------
TOTALIZER: 3 COMPENSATED KVARH QUADRANT THREE
     Meter Input: 3               ( 3     Kilovar hours )
     Meter Input: 69              ( 3     Kilovar hours )
     Meter Input: 70              ( 3     Kilovar hours )

        Limit to Positive = NO
        Limit to Negative = NO
           Absolute Value = NO
            Negate Output = NO
-----------------------------------------------------------------
TOTALIZER: 4 COMPENSATED KVARH QUADRANT FOUR
     Meter Input: 5               ( 3     Kilovar hours )
     Meter Input: 67              ( 3     Kilovar hours )
     Meter Input: 68              ( 3     Kilovar hours )

        Limit to Positive = NO
        Limit to Negative = NO
           Absolute Value = NO
            Negate Output = NO
-----------------------------------------------------------------
TOTALIZER: 5 COMPENSATED KVARH QUADRANTS ONE + TWO (
DELIVERED )
     Meter Input: 4               ( 3     Kilovar hours )
     Meter Input: 6               ( 3     Kilovar hours )
     Meter Input: 67              ( 3     Kilovar hours )
     Meter Input: 68              ( 3     Kilovar hours )
     Meter Input: 69              ( 3     Kilovar hours )
     Meter Input: 70              ( 3     Kilovar hours )

        Limit to Positive = NO
```

```
        Limit to Negative = NO
          Absolute Value = NO
           Negate Output = NO
---------------------------------------------------------------
TOTALIZER: 6 COMPENSATED KVARH QUADRANTS THREE + FOUR WITH
NEGATIVE SIGN ( RECEIVED )
     Meter Input: 3              ( 3     Kilovar hours )
     Meter Input: 5              ( 3     Kilovar hours )
     Meter Input: 67            ( 3     Kilovar hours )
     Meter Input: 68            ( 3     Kilovar hours )
     Meter Input: 69            ( 3     Kilovar hours )
     Meter Input: 70            ( 3     Kilovar hours )

        Limit to Positive = NO
        Limit to Negative = NO
          Absolute Value = NO
           Negate Output = YES
---------------------------------------------------------------
TOTALIZER: 7 KVARH QUADRANTS ONE + TWO ( DELIVERED )
     Meter Input: 4              ( 3     Kilovar hours )
     Meter Input: 6              ( 3     Kilovar hours )

        Limit to Positive = NO
        Limit to Negative = NO
          Absolute Value = NO
           Negate Output = NO
---------------------------------------------------------------
TOTALIZER: 8 COMPENSATED KWH ( DELIVERED )
     Meter Input: 2              ( 1     Kilowatt hours )
     Meter Input: 63            ( 1     Kilowatt hours )
     Meter Input: 64            ( 1     Kilowatt hours )

        Limit to Positive = NO
        Limit to Negative = NO
          Absolute Value = NO
           Negate Output = NO
---------------------------------------------------------------
TOTALIZER: 9 COMPENSATED KWH ( RECEIVED ) WITH NEGATIVE
SIGN
     Meter Input: 1              ( 1     Kilowatt hours )
     Meter Input: 65            ( 1     Kilowatt hours )
     Meter Input: 66            ( 1     Kilowatt hours )

        Limit to Positive = NO
        Limit to Negative = NO
          Absolute Value = YES
           Negate Output = YES
```

```
-----------------------------------------------------------------
TOTALIZER: 10 KVARK QUADRANTS THREE + FOUR ( RECEIVED )
    Meter Input: 3              ( 3     Kilovar hours )
    Meter Input: 5              ( 3     Kilovar hours )

       Limit to Positive = NO
       Limit to Negative = NO
          Absolute Value = NO
           Negate Output = NO
-----------------------------------------------------------------
TOTALIZER: 11 KWH COPPER LOSS
    Meter Input: 64             ( 1     Kilowatt hours )
    Meter Input: 66             ( 1     Kilowatt hours )

       Limit to Positive = NO
       Limit to Negative = NO
          Absolute Value = NO
           Negate Output = NO
-----------------------------------------------------------------
TOTALIZER: 12 KWH IRON LOSS
    Meter Input: 63             ( 1     Kilowatt hours )
    Meter Input: 65             ( 1     Kilowatt hours )

       Limit to Positive = NO
       Limit to Negative = NO
          Absolute Value = NO
           Negate Output = NO
-----------------------------------------------------------------
TOTALIZER: 13 KVARH QUADRANTS ONE,TWO,THREE & FOUR WITH
SIGN
    Meter Input: 4              ( 3     Kilovar hours )
    Meter Input: 6              ( 3     Kilovar hours )
    Meter Input: 9              ( 3     Kilovar hours )
    Meter Input: 11             ( 3     Kilovar hours )

       Limit to Positive = NO
       Limit to Negative = NO
          Absolute Value = NO
           Negate Output = NO
-----------------------------------------------------------------
TOTALIZER: 14 KWH ( DELIVERED - RECEIVED ) WITH SIGN
    Meter Input: 2              ( 1     Kilowatt hours )
    Meter Input: 7              ( 1     Kilowatt hours )

       Limit to Positive = NO
       Limit to Negative = NO
          Absolute Value = NO
```

```
                    Negate Output = NO
-----------------------------------------------------------------
TOTALIZER: 15 KVARH COPPER LOSS
    Meter Input: 68            ( 3     Kilovar hours )
    Meter Input: 70            ( 3     Kilovar hours )

       Limit to Positive = NO
       Limit to Negative = NO
          Absolute Value = NO
          Negate Output = NO
-----------------------------------------------------------------
TOTALIZER: 16  KVARH IRON LOSS
    Meter Input: 67            ( 3     Kilovar hours )
    Meter Input: 69            ( 3     Kilovar hours )

       Limit to Positive = NO
       Limit to Negative = NO
          Absolute Value = NO
          Negate Output = NO

THIS IS THE LIST OF TRANSFORMATIONS USED FOR TLC TESTING
```

Firmware Version: 2737
Max Meter Inputs: 85
Max Transformations: 16

TRANSFORMATION CONTROL DEFINITIONS (table10)
==

TRANSFORMATION: 1 COMPENSATED KVARH DELIVERED AND RECEIVED WITH SIGN
  Unit of Measure: 113 sumation xform
       Source 1: Totalizer #5 (3   Kilovar hours)
       Source 2: Totalizer #6 (3   Kilovar hours)

       Transform Interval Length: 5 (Subint * Num of Subint)
             Subinterval Length: 5
Number of Subintervals per Demand Interval: 1
       Add Transform Interval Length: 1

TRANSFORMATION: 2 COMPENSATED KWH DELIVERED AND RECEIVED WITH SIGN
  Unit of Measure: 113 sumation xform
       Source 1: Totalizer #8 (1   Kilowatt hours)
       Source 2: Totalizer #9 (1   Kilowatt hours)

       Transform Interval Length: 5 (Subint * Num of Subint)
             Subinterval Length: 5

Number of Subintervals per Demand Interval: 1
Add Transform Interval Length: 1

TRANSFORMATION: 3 USED FOR % KVAR WITH LOSSES
  Unit of Measure: 97   Percent Ratio [A/B] * 100
        Source 1: Transform #1 (Compensated KVARH)
        Source 2: Totalizer #13 (Uncompensated KVARH)

         Transform Interval Length: 5 (Subint * Num of Subint)
              Subinterval Length: 5
Number of Subintervals per Demand Interval: 1
        Add Transform Interval Length: 1

TRANSFORMATION: 4 USED FOR % KW WITH LOSSES
  Unit of Measure: 97   Percent Ratio [A/B] * 100
        Source 1: Transform #2 (Compensated KWH)
        Source 2: Totalizer #14 (Uncompensated KWH)

         Transform Interval Length: 5 (Subint * Num of Subint)
              Subinterval Length: 5
Number of Subintervals per Demand Interval: 1
        Add Transform Interval Length: 1