Advanced Metering Topics

CT/PT Correction
System Loss Compensation

2018 | Northwest Electric Meter School | Arlen Everist

Agenda

➢ CT/PT Correction
➢ System Loss/Transformer Loss Compensation
This diagram shows the concept of quadrants for noting W, VAR, VA:

- There is a correlation to the meter's vector diagram

Relation to Power Factor:
- Q1 = Lag(+W, +VAR)
- Q2 = Lead(-W, +VAR)
- Q3 = Lag(-W, -VAR)
- Q4 = Lead(+W, -VAR)
Terms of Accuracy Performance:

- **Ratio Correction Factor**: Ratio of true ratio to marked ratio
  - Burden (secondary load) will affect the true ratio
  - In the case of a CT, the primary current magnitude will affect the true ratio. (i.e. 10% or 100% current)

- **Phase Angle of an Instrument Transformer**
  - The phase angle is the difference in minutes between the primary voltage or current and the secondary voltage and current

- **Phase Angle (continued)**
  - Phase angle is important because in order to calculate Watts, the angle is needed as shown in the equation below:
  - \( W = E \times I \times \cos(\phi) \), where \( \phi \) is the phase angle

- **Transformer Correction Factor (TCF)**
  - Correction for overall error due to both ratio and phase angle error
CT/PT Correction

Accuracy Class Definitions

<table>
<thead>
<tr>
<th>Accuracy Class</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3 Accuracy Class</td>
<td>&lt;10%</td>
<td>10% - 100%</td>
<td>100% - Rating Factor</td>
</tr>
<tr>
<td>N/A</td>
<td>0.6%</td>
<td>0.8%</td>
<td>0.8%</td>
</tr>
<tr>
<td>0.15 Accuracy Class</td>
<td>5% - 100%</td>
<td>100% - Rating Factor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.3%</td>
<td>0.15%</td>
<td></td>
</tr>
<tr>
<td>0.15S Accuracy Class</td>
<td>&lt;5%</td>
<td>5% - Rating Factor</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15%</td>
<td></td>
</tr>
<tr>
<td>Alta Series High Accuracy Extended Range</td>
<td>&lt;1%</td>
<td>1% - Rating Factor</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.15%</td>
<td></td>
</tr>
</tbody>
</table>

Current Transformer Parallelograms

- The results of the test must be within the outer parallelogram for the transformer to meet the 0.3 accuracy class at 10% of rated current.
- The results of the test must be within the inner parallelogram for the transformer to meet the 0.3 accuracy class at 100% of rated current.
Applying Corrections

- Correct for instrument transformer inaccuracies
- Corrections are typically applied to all values in the meter
- Values to enter in the meter software come from the instrument transformer test card
- Improves system accuracy
CT/PT Correction

Correcting for CT/PT in the meter:

<table>
<thead>
<tr>
<th>TEST DATA</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration Point</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test Load (Primary A)</td>
<td>1</td>
<td>10</td>
<td>20</td>
<td>50</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>Ideal Secondary Current (A)</td>
<td>0.01</td>
<td>0.10</td>
<td>0.20</td>
<td>0.50</td>
<td>1.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Measured Secondary Current (A)</td>
<td>0.0088</td>
<td>0.0985</td>
<td>0.1972</td>
<td>0.4950</td>
<td>0.9950</td>
<td>1.9980</td>
</tr>
<tr>
<td>Phase Angle Error (Degrees)</td>
<td>4.50</td>
<td>4.00</td>
<td>1.20</td>
<td>1.10</td>
<td>1.00</td>
<td>0.95</td>
</tr>
</tbody>
</table>

METER SETTINGS

| Ratio Correction Factor | 1.02 | 1.015 | 1.0142 | 1.0101 | 1.0050 | 1.0010 |
| Phase Angle (Minutes)   | 270  | 240   | 72     | 66     | 60     | 57     |

RCF = SC/MS

1 degree = 60 min

What if the original test card is not available? :

- Shop Test
- Field Test
In each load profile, the NES study showed that high accuracy CTs increased revenue for the utility. The range was from 0.24% to 0.82% revenue gain.

• The reason is simple and mathematical
• KWH = Current x Voltage x Time
• If you increase any of these, KWH increases
• A high accuracy CT increases the amount of current metered in this equation

➢ Is an average of 0.5% even worth it?
• Southern California Edison did $7B in revenue to C&I in 2015
• Capturing 0.5% more revenue would be $35M!!
Cost Benefit

- The long term benefits far outweigh the short term savings

![Graph showing benefit to cost ratio vs. meter % error.]

Transformer Loss Compensation (TLC)

- Why use TLC
  - Billing point different from metering point
  - Impractical/costly to meter at billing point
  - Change in infrastructure and want to save costs by using existing metering

![Diagram illustrating transformer loss compensation system.]
Transformer Loss Compensation (TLC)

- Transformer loss compensation (TLC) is used when the billing point is on the high voltage side of a transformer and the metering point is on the low voltage side.
- Through calculations in the meter, it is possible to account for the iron (core) loss and copper (load) loss associated with the transformation.
- Line losses can also be used when the billing point is not at the metered point (interchange metering).
- Both can be used in combination with instrument transformer correction to maximize system accuracy.
Transformer Loss Compensation (TLC)

What Kind of Losses are there?
- Electrical losses are found in many areas in the system:
  - Generators, motors
  - Transformers
  - Power Lines
- Transformer Losses Consist of:
  - Copper (Cu) \( I^2R \) Losses (short circuit test)
  - Iron (Fe)/Core Losses (open-circuit test)
- Line Losses Consist of:
  - Copper (Cu) \( I^2R \) Losses (load losses)
  - Inductive/Capacitive Losses

How Advanced Meters Compensate
- Loss compensation is typically enabled through meter configuration software
- Vendor approaches differ:
  - Some provide a program to calculate compensation values
  - Some use transformer data
- Compensated meter values are typically calculated every second
- The meters usually have compensated and uncompensated registers for verification
Transformer Loss Compensation (TLC)

- Vastly simplified model of Electric meter

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PT & CT Connections → A/D Converter → ITC → Power Meter
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- Possible combinations of metering and billing point.
Possible combinations of metering and billing point:

- For BP4 – Loss Compensation not required
- For BP3 – We need to subtract Supply Side Line Losses
- For BP2 – We need to subtract TL and SSL
- For BP1 – We need to subtract SSL, TL and LSLL

Transformer Loss Compensation (TLC)

-Calculated values

Where: $Xmtr.~Sec.~test~amps = \frac{(Xmtr.~rating~in~VA) \times (Xmtr.~secondary~test~p-p~volts \times \sqrt{3})}{\text{Nominal CT Primary Amp}}$

Total Line Loss = Line Length \times Line Res. (per mile)

Line Loss = $\frac{3 \times \text{Total Line Res.} \times (Xmtr.~Primary~Amp@1/2~\text{Meter~Class}~amp) \times \text{Number of elements}}{2}$

Transformer Loss = (Transformer secondary test $\text{volts} \times (\text{P} \times \text{T})$) for 3 elm. (\text{Volts} \times \text{sec} \times \text{volts} \times \text{P} \times \text{T}) for 2 elm

Nominal Primary $\text{Watt} = \text{CTIR} \times \text{PTR} \times \text{Meter~Nominal~Watts}$

No Load VA loss = (Xmtr. Excitation current x Xmtr. rating in VA) / 100

No Load loss phase angle = acos((Xmtr. No Load watts loss) / No Load VA loss)

No Load Var Loss = No Load VA loss x sin(No Load loss phase angle (alpha))

Load VA loss = (Xmtr. Impedance x Xmtr. rating in VA) / 100

Load loss ph angle (beta) = acos((Load load loss)) / Load VA loss

Load Var loss = Load VA loss x sin(beta) x Load loss phase angle (beta)

% Watt Fe Loss = (Xmtr. No-load loss x (Meter rated volts x Meter test volts) / (Nominal Primary VA) x 100

% Watt Cu Loss = (Xmtr. Load loss x (Meter Class amp x (CTR x (mtr. sec. test amp)) / (Nominal Primary VA) x 100

% Var Fe Loss = (No Load Var loss x (Meter rated volts x Meter test volts) / (Nominal Primary VA) x 100

% Var Cu Loss = (Load Var loss x (Meter Class amp x (CTR x (mtr. sec. test amp)) / (Nominal Primary VA) x 100

% Line Cu Loss = (Line Loss in VA x (Nominal Primary VA)) / 100

% Total Losses = %Mtr. (Fe or Cu) losses + %Line (Fe or Cu) losses
Transformer Loss Compensation (TLC)

What you must have

Transformer Info
- 3000 KVA 4160 Delta
- No Load Iron Losses 9,200 Watts
- 1.54% Excitation
- Load Copper Losses 21,720 Watts
- 6.25% Impedance

Site Information
- CT's 400:5 VT's 4200:120
* Site Information For Meter Test Points

We need the following parameters for to determine the % loss constants:

- Transformer Rating = 30MVA
- Transformer Rated Voltage = 43,800V
- Meter Rated Voltage = 115V
- ½ meter class current = 10A
- # of stator elements (9S) = 3
- CTR = 80, VTR = 240,
- %Exciting current = 0.418
- %Impedance = 5.57
- Copper Loss = 75732 W
- Iron Loss = 29000 W
Transformer Loss Compensation (TLC)

Loss Constant Formulas

\[ h_{\text{FCU}} = \frac{L \times \text{TLP}}{P_{\text{FCU}}} \]

\[ h_{\text{FPE}} = \frac{P_{\text{FPE}} - P_{\text{LSP}}}{P_{\text{LSP}}} \times h_{\text{FPE}} \]

\[ h_{\text{PCU}} = \frac{V_{\text{PCU}} \times P_{\text{PCU}}}{P_{\text{LSP}}} \]

\[ h_{\text{TPE}} = \frac{P_{\text{TPE}} - P_{\text{LSP}}}{P_{\text{LSP}}} \times h_{\text{TPE}} \]

Motor Efficiency (ME)

\[ \eta = \frac{P_{\text{LSP}}}{P_{\text{Nom}} \times \text{TLP}} \]

\[ \eta = \frac{100}{\% \text{ME}} \]

Transformer Loss Compensation (TLC)
Transformer Loss Compensation (TLC)

Total System Losses

- Total load watt losses
  - TLW = FLW + LLW + CLW
- Total load VAR losses
  - TLV = FLV + LLV + CLV

<table>
<thead>
<tr>
<th>Type</th>
<th>Source</th>
<th>Watt Losses</th>
<th>Var Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>No load losses</td>
<td>Transformer Core</td>
<td>NLW = 45 kW</td>
<td>NLV = 22.05 kVAR</td>
</tr>
<tr>
<td>Load losses</td>
<td>Transformer Windings</td>
<td>FLW = 135 kW</td>
<td>FLV = 737.75 kVAR</td>
</tr>
<tr>
<td></td>
<td>Transmission Line</td>
<td>LLW = 83.30 kW</td>
<td>LLV = 122.77 kVAR</td>
</tr>
<tr>
<td></td>
<td>Substation Conductors</td>
<td>CLW = 0.167 kW</td>
<td>CLV = 3.01 kVAR</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>TLW = 218.5 kW</td>
<td>TLV = 883.5 kVAR</td>
</tr>
</tbody>
</table>

Its Programmed, how do I know its working?

- Verify in the meter with tests
  - \[\frac{(\text{Uncompensated Watts} - \text{Compensated Watts})}{\text{Uncompensated Watts}} \times 100 = \% \text{tot Watts Loss}\]
  - Compare test accuracy with expected accuracy from test calculation sheet
  - The value will be close but not exact. Why?
Advanced Metering Topics

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System Loss Compensation

Questions?