Instrument Transformer Errors
As a component of Metering System

A method for analysis

Intro

- Active Power Formula (watts)

$$P = E \times I \times \cos\theta$$

- IT Errors of Magnitude and Phase Angle affect Power registration.
- Metering CTs & VTs are Designed, Built, and Tested so that error from each component is less than a limit.
  - **Transformer Correction Factor** is the ratio of true watthours to the measured secondary watthours, divided by the marked ratio.
  - Determined based on: **Ratio Correction Factor** and **Phase Angle Correction Factor** of an instrument transformer, and the power factor of the load.
  - Accuracy is defined for load power factors from 1.0 to 0.6 lagging.

IT Error Data Availability

- Every Metering CT & VT are factory tested
  - Data on Test Card or a Report
  - Test at 2 or more operating points
    - Max rated burden (& min current for CT)
    - Min rated burden (& max current for CT)
- Manufactures may provide typical data for mass market designs.

Error Terminology

- Ratio Correction Factor

$$Primary\ measure = Secondary\ measure \times RCF \times Marked\ Ratio$$

- Phase Angle Error
  - β, CT phase error measured in minutes of angle
  - γ, VT phase error measured in minutes of angle

Combining CT & VT Errors

$$RCF_{IT} = RCF_{CT} \times RCF_{VT}$$

$$PACF_{IT} = \frac{\cos(\theta_{secondary} + \beta - \gamma)}{\cos\theta_{secondary}}$$

$$TCF_{IT} = RCF_{IT} \times PACF_{IT}$$

$$\%\ Error\ due\ to\ ITs = \frac{1 - TCF_{IT}}{TCF_{IT}}$$

Variables to Watch

- TCF is a function of the Phase angle of the load
- CT Error values change with:
  - CT secondary Burden and
  - Current magnitude
- VT Error values change with:
  - VT secondary Burden
  - VT magnitude range ±5% does not significantly affect

Worksheet

- Assumptions
  - Balanced Voltage
  - Balanced Loading
  - CT errors match (all ϕ)
  - VT errors match (all ϕ)
- Green boxes are Accuracy defined by IEEE C57.13
- 13 kV, <5MW example

Watthour measurement % Error due to Instrument Transformers as θ & Current change

	θ Secondary (degrees)	PF Secondary	Secondary Current (amps) 0.1	0.25	0.5	2.5	5	7.5
	89	0.017		10.32%	8.35%	4.62%	3.73%	2.84%
	85	0.087		2.08%	1.74%	1.10%	0.94%	0.77%
L	80	0.174		1.13%	0.97%	0.68%	0.60%	0.52%
a	70	0.342		0.65%	0.58%	0.46%	0.43%	0.39%
g	60	0.500		0.49%	0.45%	0.39%	0.37%	0.35%
g	53.184	0.599		0.43%	0.40%	0.36%	0.35%	0.33%
i	50	0.643		0.40%	0.38%	0.35%	0.34%	0.32%
n	40	0.766		0.35%	0.33%	0.32%	0.32%	0.31%
g	30	0.866		0.30%	0.30%	0.30%	0.30%	0.30%
	20	0.940		0.27%	0.27%	0.29%	0.29%	0.29%
	10	0.985		0.24%	0.24%	0.27%	0.28%	0.28%
	0	1.000		0.21%	0.22%	0.26%	0.27%	0.27%
	-10	0.985		0.18%	0.20%	0.25%	0.26%	0.26%
	-20	0.940		0.15%	0.17%	0.23%	0.25%	0.25%
L	-30	0.866		0.12%	0.14%	0.22%	0.24%	0.25%
e	-40	0.766		0.08%	0.11%	0.20%	0.22%	0.23%
a	-50	0.643		0.02%	0.06%	0.17%	0.20%	0.22%
d	-60	0.500		-0.07%	-0.01%	0.13%	0.17%	0.19%
i	-70	0.342		-0.23%	-0.14%	0.06%	0.11%	0.15%
n	-80	0.174		-0.69%	-0.52%	-0.15%	-0.06%	0.02%
g	-85	0.087		-1.59%	-1.26%	-0.57%	-0.39%	-0.23%
	-89	0.017		-8.20%	-6.77%	-3.75%	-2.96%	-2.17%

- Error = Under Registration, + Error = Over Registration

Review

- Effect of IT Errors on Watt or Wh measurement
- Understanding of installation Burden necessary.
- Gives a sense of range of errors as Load Current & Power Factor change.
- Easily applied to typical data for mass market ITs.
- Method could be used with actual Factory test data if Optional Test points were ordered.