SATEC
Powerful Solutions

APPLICATION NOTE:

ACCURACY CLASS: A SMALL "S" THAT MAKES A BIG DIFFERENCE

When it comes to energy metering, accurate reading is important since a fraction of a percent can end up in thousands of dollars. Due to the fact that the accuracy of an energy meter depends on the loading of a network (full load condition will always be more accurate than partial load) as well as the power factor, standards were put into effect. However, standards may often mislead customers who are unaware of the details, and instead of helping customers guarantee better accuracy, they end up helping manufacturers in misleading them. This article explains the difference between various definitions.

The physics of accuracy

Accuracy depends on the design and build-quality of the meter's input channels: higher quality of materials will provide better accuracy but will naturally increase pricing.

Three major parameters determine accuracy:

1. Fluctuation of the reading value, expressed in percentage of the actual value ("reading")
2. A fixed error ("noise"), normally expressed as percentage of full scale ("FS") as it is a constant value
3. For power and energy measurement the phase shift between the voltage and current also affects accuracy, since power equals voltage multiplied by current, multiplied by the cosine of the phase angle. This phase shift error is expressed in minutes (60 minutes equal one degree) and appears in current transformer specification, which increase the error of power meters.

Accuracy standards

A power meter declared as featuring 0.5% FS accuracy means that its inherent margin of error is half percent of the full scale. For example, if the full scale of a meter is 50A, its maximum error is 0.25A. If the network load is 25A, the maximum error, still 0.25A, is now actually 1% (0.25/25). Since accuracy depends on loading, IEC set several standards for determining accuracy under various load conditions. This is known as "Accuracy Class". Class 0.5 means that the accuracy is 0.5% of the reading under full load and unity power factor, similar to 0.5% FS above, yet sets a standard for accuracy under lower (typical) loads and different power factor. Table 1 shows the levels of Class 0.5, according to IEC 62053-11.

Value of current		Power factor	Percentage error limits for meters		
for direct connected meters	for transformer operated meters		0,5	1	2
$0,05\ I_b \le I < 0,1\ I_b$	$0,02\ I_n \le I < 0,05\ I_n$	1	±1,0	±1,5	±2,5
$0,1\ I_b \le I \le I_{max}$	$0,05\ I_n \le I \le I_{max}$	1	±0,5	±1,0	±2,0
$0,1\ I_b \le I < 0,2\ I_b$	$0,05\ I_n \le I < 0,1\ I_n$	0,5 inductive 0,8 capacitive	±1,3 ±1,3	±1,5 ±1,5	±2,5 -
$0,2\ I_b \le I \le I_{max}$	$0,1\ I_n \le I \le I_{max}$	0,5 inductive 0,8 capacitive	±0,8 ±0,8	±1,0 ±1,0	±2,0 –
When specially requested by the user: from $0,2\ I_b \le I \le I_b$	$0,1\ I_n \le I \le I_n$	0,25 inductive 0,5 capacitive	±2,5 ±1,5	±3,5 ±2,5	– –

Table 1: Class 0.5 Meter Accuracy

As can be seen from the table, when the power factor is unity and the load is above 10% the accuracy is held at 0.5%. However, when the power factor is less than unity, which is the case in every single site due to harmonics (harmonics lower the power factor), the accuracy deteriorates to 0.8%. This means that a Class 0.5 meter will feature an allowed error of 0.8% under normal conditions.

In order to provide more accurate information, IEC published standard 62053-22 which defines Class 0.5S accuracy as shown in table 2 below.

Value of current	Power factor	Percentage error limits for meters of class	
		0,2 S	0,5 S
$0,01\ I_n \le I < 0,05\ I_n$	1	±0,4	±1,0
$0,05\ I_n \le I \le I_{max}$	1	±0,2	±0,5
$0,02\ I_n \le I < 0,1\ I_n$	0,5 inductive 0,8 capacitive	±0,5 ±0,5	±1,0 ±1,0
$0,1\ I_n \le I \le I_{max}$	0,5 inductive 0,8 capacitive	±0,3 ±0,3	±0,6 ±0,6
When specially requested by the user: from $0,1\ I_n \le I \le I_{max}$	0,25 inductive 0,5 capacitive	±0,5 ±0,5	±1,0 ±1,0

Table 2: Class 0.5S Meter Accuracy

This means that Class 0.5S meters will feature improved accuracy of 0.6% compared to 0.8% of the Class 0.5 under normal load conditions (the difference is even greater at lower load).

System accuracy vs. meter accuracy

The accuracy of an energy measurement system is the total error of all its components. A typical system includes a power meter and current transformers (CTs). Similarly to power meters, standard IEC 60044-1 defines the accuracy classes of CTs as shown below:

Accuracy class	± Percentage current (ratio) error at percentage of rated current shown below				± Phase displacement at percentage of rated current shown below							
					Minutes				Centiradians			
	5	20	100	120	5	20	100	120	5	20	100	120
0.1	0,4	0,2	0,1	0,1	15	8	5	5	0,45	0,24	0,15	0,15
0.2	0,75	0,35	0,2	0,2	30	15	10	10	0,9	0,45	0,3	0,3
0.5	1,5	0,75	0,5	0,5	90	45	30	30	2,7	1,35	0,9	0,9
1.0	3,0	1,5	1,0	1,0	180	90	60	60	5,4	2,7	1,8	1,8

Table 3: Class 0.5 Current Transformers Accuracy

Accuracy class	± Percentage current (ratio) error at percentage of rated current shown below					± Phase displacement at percentage of rated current shown below									
						Minutes					Centiradians				
	1	5	20	100	120	1	5	20	100	120	1	5	20	100	120
0.2 S	0,75	0,35	0,2	0,2	0,2	30	15	10	10	10	0,9	0,45	0,3	0,3	0,3
0.5 S	1,5	0,75	0,5	0,5	0,5	90	45	30	30	30	2,7	1,35	0,9	0,9	0,9

Table 4: Class 0.5S Current Transformers Accuracy

As seen from the tables, under full load conditions both Classes have similar accuracy. However, loading must not be 100%, which means Class 0.5 CT is only 0.75% accurate but Class 0.5S is accurate as long as the load is above 20%. Moreover, there is a maximum allowed phase shift, which may significantly affect accuracy (depending on the Power Factor): For Class 0.5 the maximum displacement allowed is 45 minutes (0.75 degree) while for Class 0.5S it is 30 minutes only (0.5 degrees). Table 5 compares the effect of phase shift on accuracy, depending on Power Factor according to the formula

$$\Delta\% = 100\% \cdot \left| \frac{Cos\varphi - Cos(\varphi + Shift)}{Cos\varphi} \right|.$$

Table 5 below includes the highest, lowest and average Power Factor, as per the IEC 62053-22 standard.

Power Factor	Class 0.5	Class 0.5S
1.00	*0.009%*	*0.004%*
0.75	*1.16%*	*0.77%*
0.50	*2.28%*	*1.52%*

Table 5: Phase Shift Effect on Accuracy

Total system accuracy is the sum of three margins of error ($U(x+y+z)=\sqrt{U^2(x)+U^2(y)+U^2(z)}$). Table 6 shows system accuracy for typical Power Factor.

	Class 0.5	Class 0.5S	Class 0.5S with Direct Connect or HACS
Meter typical accuracy	*0.80*	*0.60*	*0.60*
CT typical accuracy	*0.75*	*0.50*	*Included*
Phase Shift	*1.16*	*0.77*	*Included*
System typical accuracy	*1.60*	*1.10*	*0.60*

Table 6: Overall System Accuracy

As seen from the above table, a class 0.5 system is typically 1.6% accurate, which is not sufficient. A Class 0.5S system is 1.1% accurate, and with HACS (or with direct connection) it is 0.6% accurate - almost three times better! Moreover, this compares the accuracy under typical PF, while the differences are even higher under lower PF.

It goes without saying that classes of lower performance are irrelevant for energy management: a Class 1 meter with a Class 1 CT will feature inaccuracy of up to 4.9% (3%, typically), not to mention CTs of Class 1 or higher.

Additional Parameters

Additionally, to verify accuracy under certain loading conditions, IEC 62053-22 limits the allowed error, factored for additional conditions (Table 7) such as: ambient temperature, frequency variations, voltage variations, unbalance, harmonics, inter harmonics, electromechanical influence and reverse phase rotation. For example, the accuracy stated is at 23°C and allows an additional deviation of 0.05% per 1°C (Class 0.5S, PF<1). This means that at 35°C an additional deviation of 0.6% is permitted, and more important – tests show that in high temperatures many non-certified meters feature significantly higher inaccuracy.

Influence quantity	Value of current (balanced unless otherwise stated)	Power factor	Mean temperature coefficient %/K for meters of class 0,2 S	Mean temperature coefficient %/K for meters of class 0,5 S
Ambient temperature variation [9]	$0{,}05\ I_n \le I \le I_{max}$	1	0,01	0,03
	$0{,}1\ I_n \le I \le I_{max}$	0,5 inductive	0,02	0,05
			Limits of variation in percentage error for meters of class 0,2 S	**Limits of variation in percentage error for meters of class 0,5 S**
Voltage variation ±10 % [1) 8)]	$0{,}05\ I_n \le I \le I_{max}$	1	0,1	0,2
	$0{,}1\ I_n \le I \le I_{max}$	0,5 inductive	0,2	0,4
Frequency variation ±2 % [8)]	$0{,}05\ I_n \le I \le I_{max}$	1	0,1	0,2
	$0{,}1\ I_n \le I \le I_{max}$	0,5 inductive	0,1	0,2
Reversed phase sequence	$0{,}1\ I_n$	1	0,05	0,1
Voltage unbalance [3)]	I_n	1	0,5	1,0
Auxiliary voltage ±15 % [4)]	$0{,}01\ I_n$	1	0,05	0,1
Harmonic components in the current and voltage circuits [5)]	$0{,}5\ I_{max}$	1	0,4	0,5
Sub-harmonics in the a.c. current circuit [5)]	$0{,}5\ I_n$ [2)]	1	0,6	1,5
Continuous magnetic induction of external origin [5)]	I_n	1	2,0	2,0
Magnetic induction of external origin 0,5 mT [6)]	I_n	1	0,5	1,0
Electromagnetic RF fields	I_n	1	1,0	2,0
Operation of accessories [7)]	$0{,}01\ I_n$	1	0,05	0,1
Conducted disturbances, induced by radio-frequency fields	I_n	1	1,0	2,0
Fast transient burst	I_n	1	1,0	2,0
Damped oscillatory waves immunity	I_n	1	1,0	2,0

Table 7: Influencing Quantities

SATEC accuracy

SATEC invests significantly in the design and manufacturing of accurate meters, including:

1. Minimal accuracy of Class 0.5**S** for all devices, Class 0.2**S** for mid-range and Class A for high-end products (Class A is a higher accuracy class for real time measurement)

2. HACS: optional for most meters, ensuring comprehensive Class 0.5S accuracy for the entirety of the system: power meter and the solid core HACS (Class 1 for split core)

3. Full testing and calibrating of all products - meters and current sensors

The result of the above is that SATEC meters are extremely accurate, allowing us to guarantee their accuracy for 5 years without calibration or periodic testing.

Example

High accuracy meters provide fast Return On Investment (ROI) as can be shown in the following example: the difference between 1.6% and 0.6% accuracy for a 1000kVA load, 0.90 power factor and 80% loading at US$0.15/kWh, comes out to US$ 9,461 per year (1000×0.8×0.9×8760×0.15×(1.6%-0.6%)), which means the investment is returned in single month.

Conclusion

Class 0.5S is a minimal requirement for any energy monitoring application while Class 0.5 (without S) is not good enough and Class 1 provides no more than a fair estimate. The use of direct measurement or HACS guarantees unbeatable accuracy, complying with the challenges of modern energy management and billing applications.