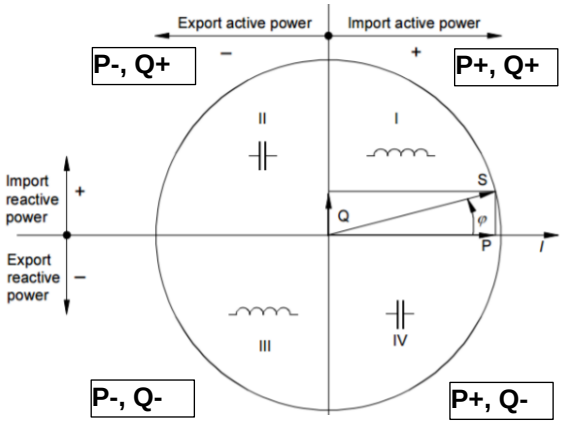
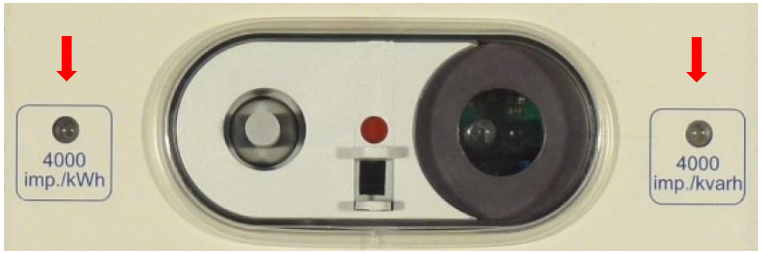
4-quadrant energy meter testing with TS33 Automatic Test System

Application Note No20

1. Testing 4-quadrant meter theory

Testing 4-quadrant electricity meters requires forcing an active and reactive energy flow in all directions and possible combinations. From the point of view of an energy supplier (utility), energy can be imported by (delivered to) the customer or exported by the customer (received by the utility service). Typical four-quadrant energy meters have 2 pulse LEDs: one for active energy, one for reactive energy, corresponding to the units of the meter constant: imp/kWh and imp/kvarh.

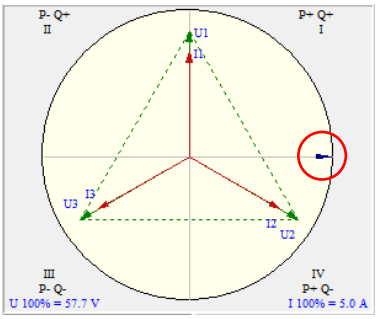




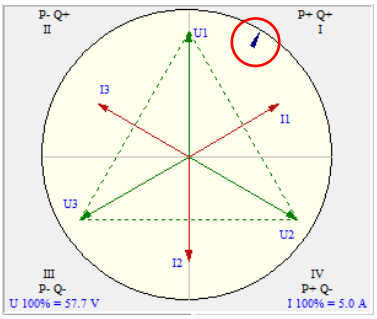
During testing, the scanning head should be placed and scan the proper LED depending on the load point under test.

A 3-phase, 4-wire, 4-quadrant meter is used as an example for testing: U_b=57.7V, I_n=5A, Imax=6A, accuracy class C (0.5) for active energy and 1 for reactive energy and meter constant C=15000 imp/kWh (imp/kvarh). According to the standards (EN50470-1,2,3, IEC62053-22,23), the meter is tested for load current from 1% to 120% I_n , for power factor 1, 0.8C and 0.5L (sinus factor 1, 0.8C and 0.5L) in all four quadrants. Below are vector diagrams for 100% load point at 57.7V base voltage and various power factors and quadrants.

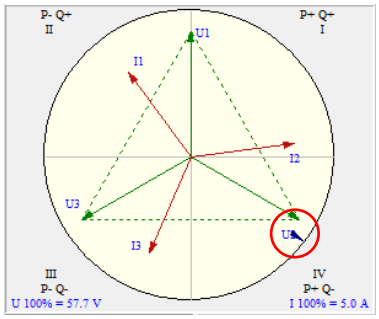
PF=1 P+



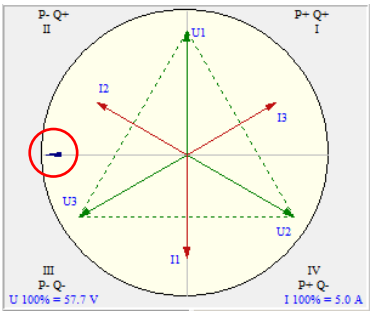
PF=0.5L P+



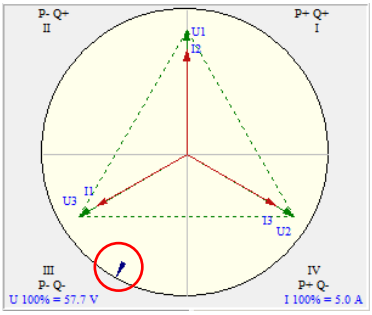
PF=0.8C P+



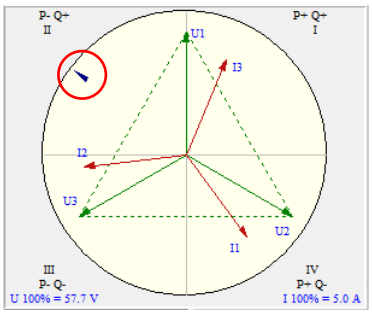
PF=-1 P-



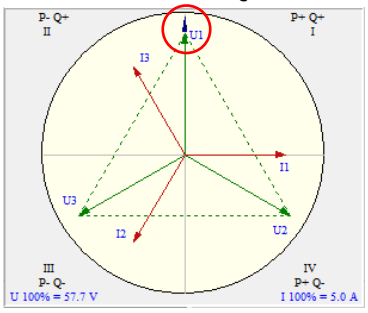
PF=-0.5L P-



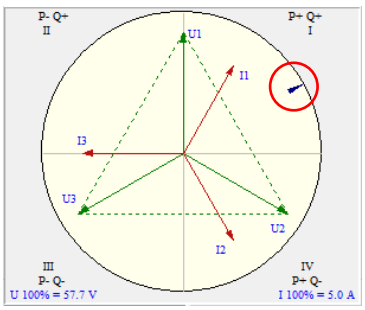
PF=-0.8C P-



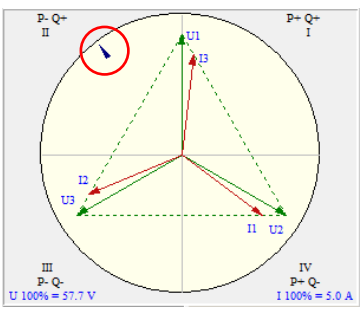
Sin=1 Q+



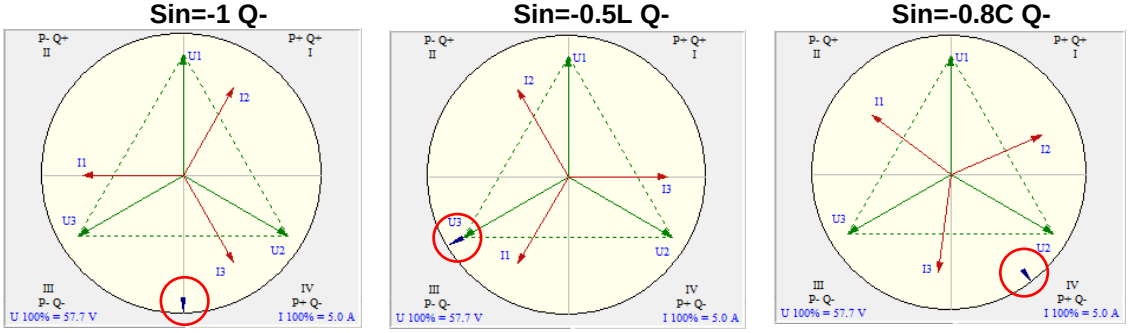
Sin=0.5L Q+



Sin=0.8C Q+

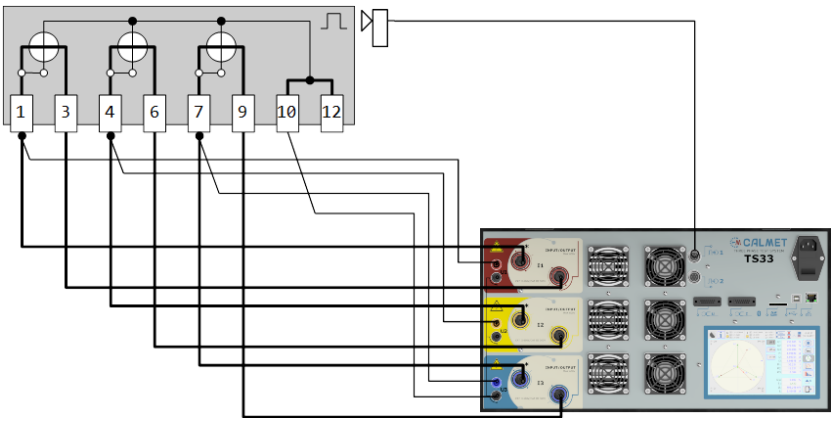


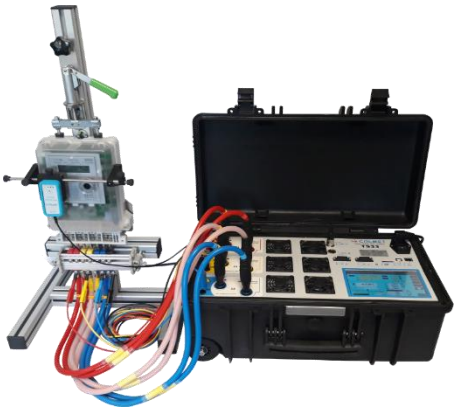
Sin=-1 Q- **Sin=-0.5L Q-** **Sin=-0.8C Q-**



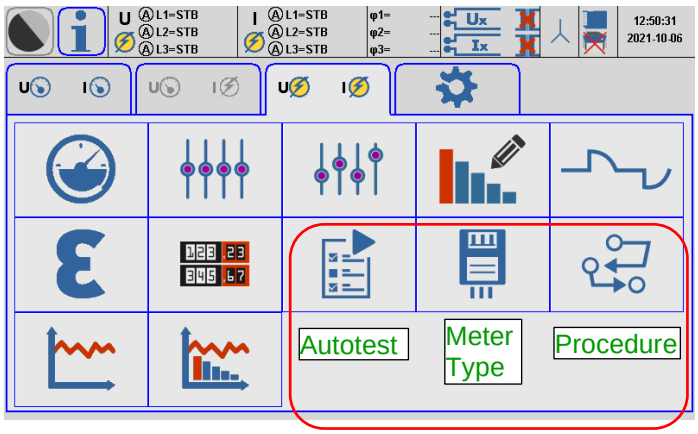
2. Connection of the meter under test to the TS33

The meter is connected to the TS33 as in diagram and picture below.





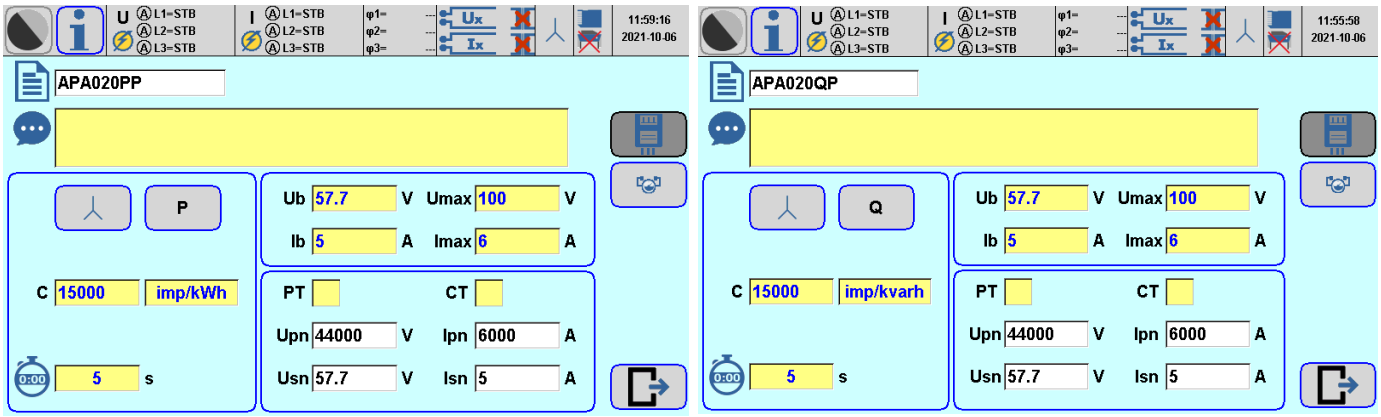
3. Setting testing procedures



The TS33 should be set to source of voltage and current generation mode. The automatic testing of electricity meters requires us to prepare the Meter Type parameters, testing Procedure and then perform the test – Autotest. Before we set the Meter Type, we have to recognize the basic technical data of the meter under test from its data sheet or front plate. The most important parameters are:

- U_b – base voltage (57.7V in this example);
- I_n – nominal current (5A in this example);
- U_{max} – maximum voltage (to protect the meter);
- I_{max} – maximum current (6A in this example);
- Meter constant C=15000 imp/kWh (kvarh);
- Connection type, e.g.: 3-phase, 4–wire;
- Type of energy: active, reactive, apparent.

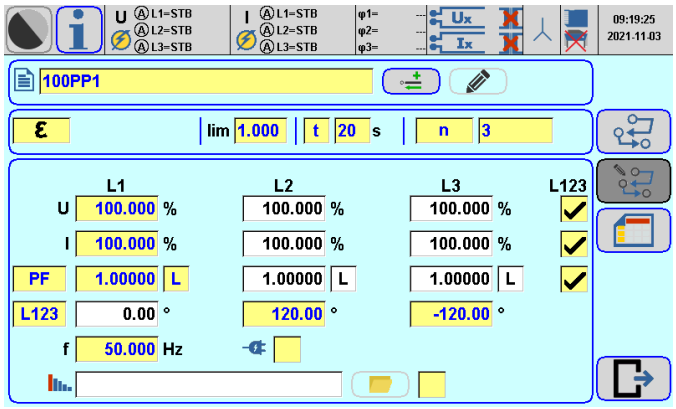
Based on the above information, we can prepare and store two Meter Types: one for active energy and one for reactive energy. The pictures below show Meter Types with entered data. Then they have to be saved under separate Meter Type names, e.g.: APA020PP and APA020QP as in the example.

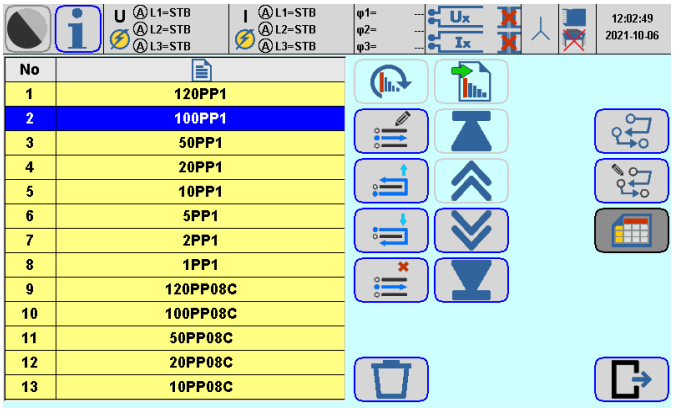


The testing Procedure should be prepared next. According to the standards, for the meter tested as an example, the accuracy should be tested for loads in the range of 1% to 120% of nominal current, active energy for power factor PF=±1 and in the range of 5% to 120% for power factor PF=±0.8C and PF=±0.5L. Reactive energy flow

should be tested in the range of 2% to 120% for Sin=±1 and 5% to 120% for Sin=±0.8C and Sin=±0.5L. Thus, the meter is tested in all four quadrants.

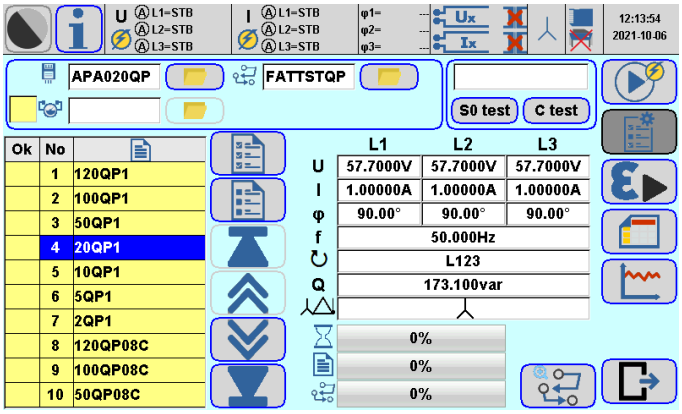
Preparing a Procedure consists of setting the parameters of each load point and the test conditions. In the example below, the load point (named 100PP1) is set for 100% of I_n (5A) at 100% of base voltage U (57.7V), power factor PF=1 (φ=0°), frequency 50Hz in a symmetric circuit. The accuracy (error ε) of the meter is tested during t=20s for each test cycle repeated three times n=3.



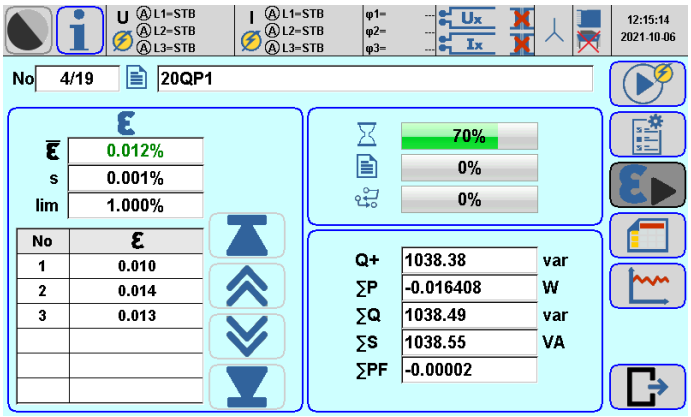


The settings are entered for each load point, then added to the list so that we have a list of points to get results in a whole range of meter characteristics. The Procedure can be stored in a database for future use.

4. Test execution

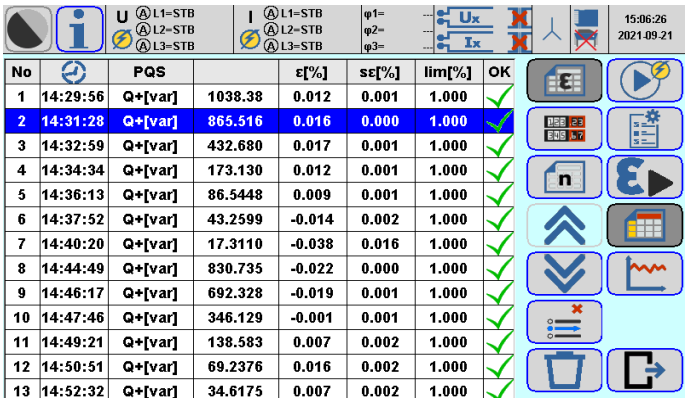


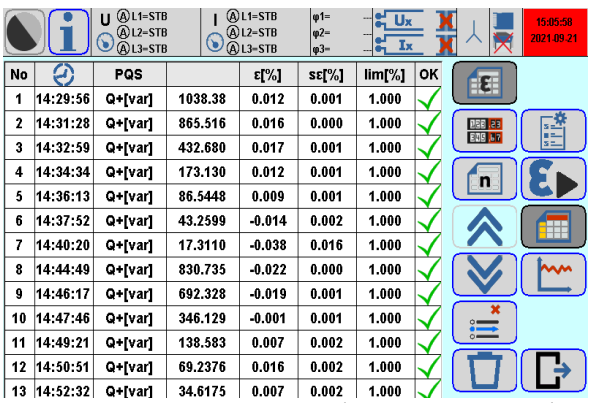
The next step is to execute the test by selecting the correct Meter Type (for the meter we want to test - APA020QP in the example) and the testing Procedure (FATTSQP). The Autotest function allows us to select the test range by selecting one or all load points. The settings of the selected load point are displayed to confirm the settings of voltage, current, phase shift, and power. After the test is started, its actual status is shown in the progress bars as a percentage of the settling time, a percentage of the load point test, and a percentage of the overall procedure execution. The test should be performed separately for active energy and scanning head with imp/kWh LED and then reactive energy with imp/kvarh LED.



The test results can be observed during the test for a single load point with an average error value ε, standard deviation value s and the result of evaluation by comparison with the limit lim and marked with the color: green if **ε ≤ l imit** or red if **ε ≥ lim**. Also, partial errors used for averaging are available.

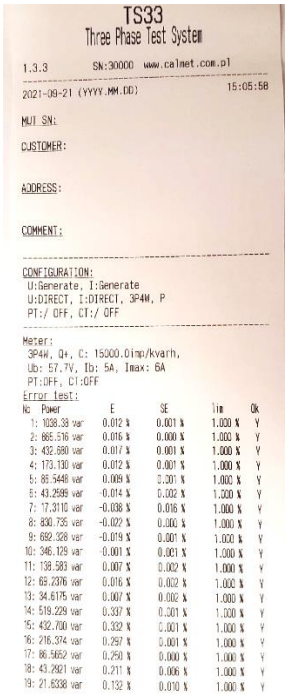
The final results of the complete test are presented in the form of a table with the number of load points, the kind and value of power, the error value, the standard deviation value, the limit, and the final evaluation of OK / Not OK. The results can be saved in device memory for later recall or transferred to a PC for further processing or database storage. For recalled results, the date and time field is marked in red.





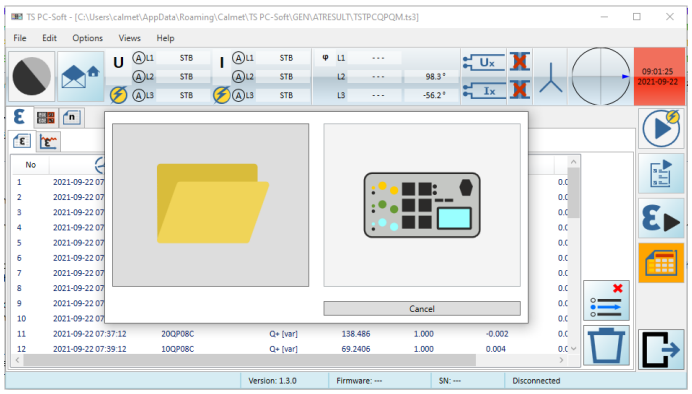
5. Printing the results on-site

The test results can be printed directly on-site by means of a wireless, miniature thermal printer. Results and screen shot can be printed. Sample printouts are shown in the images below.

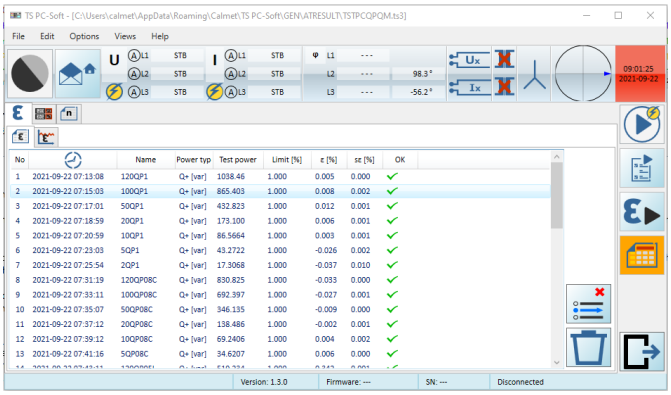


6. Processing the results in the TS PC Soft

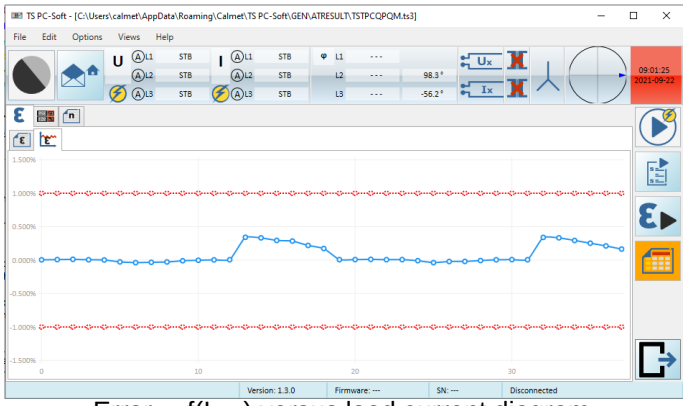
The results stored in the TS33's memory or simply captured using TS PS Soft, which controls the TS33, can be further processed. The results stored in TS33's memory can be transferred to the PC in two ways: by removing the SD memory card from the TS33 and reading the data on the PC, or by connecting the PC to the TS33 via USB, Bluetooth, or Ethernet. The selected file is opened in the form of a table with results or a diagram. The results can also be printed on any printer connected to the PC.



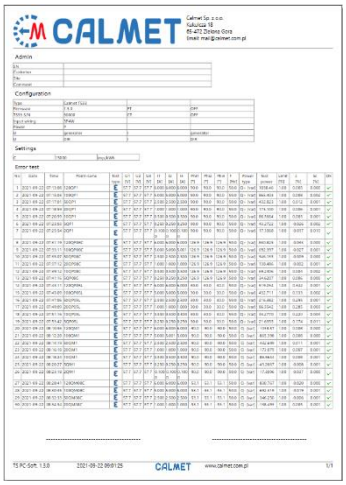
Downloading results to the PC



Opened results on the PC



Error $\varepsilon=f(I_{load})$ versus load current diagram



Report printout

7. Exporting the results to Excel

Results are stored in the database as XML files. Results data can also be exported to an Excel spreadsheet for easy report creation. All results collected during the test are exported, including administrative data..


```
        <Cycle>
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                </DataList>
        </Cycle>
</PartialResults>
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        <Base>
                <DataList>
                        <Data Name='Valid' Value='1'/>
                        <Data Name='U1' Value='57.699120'/>
                        <Data Name='U2' Value='57.699425'/>
                        <Data Name='U3' Value='57.700420'/>
                        <Data Name='I1' Value='5.999742'/>
                        <Data Name='I2' Value='6.000058'/>
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                        <Data Name='Phi12' Value='119.999535'/>
                        <Data Name='Phi13' Value='-119.999672'/>
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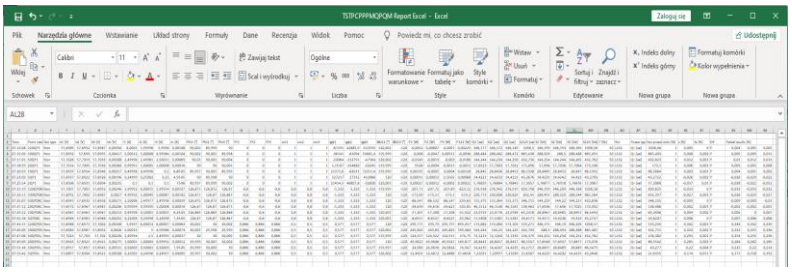
Result data in XML format



All data exported to Excel spreadsheet

8. Preparing a final report in Excel

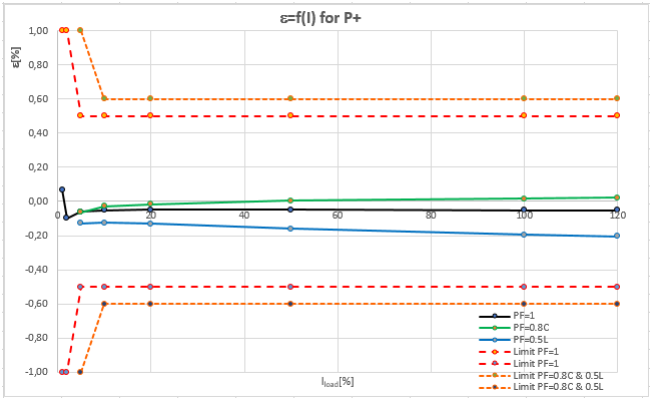
Based on the results data, the final report can be prepared in Excel, with tables and graphs presented in a clear manner.

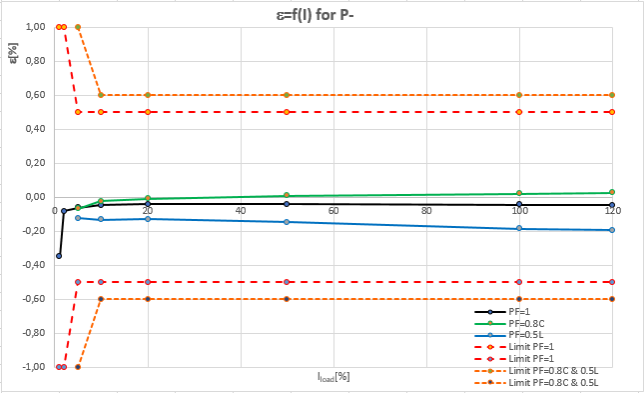
Test report of 4-quadrant meter APA P020

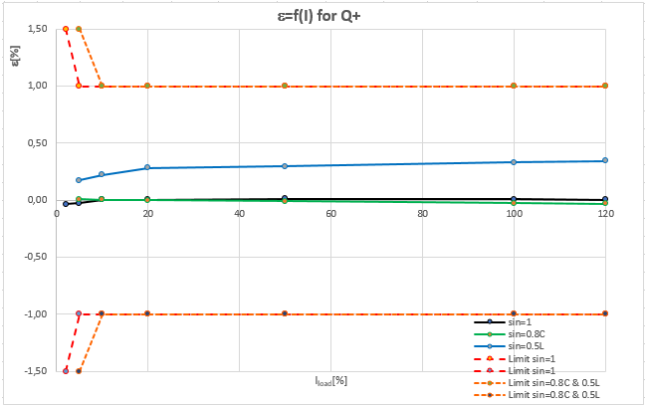
In=5A. Imax=6A, Ub=57.7V C=15000imp/kWh(kvarh), class (P)=C, class (Q)=1

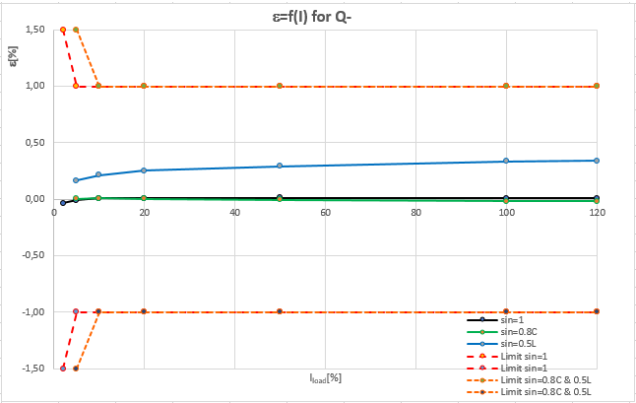
Id	In [%]	In [A]	cosφ=1 ε [%]	Limit	cosφ=0.8C ε [%]	Limit	cosφ=0.5L ε [%]	Limit	Energy flow	Power [W] PF=1
1	1	0,050	0,070	1,00					P+	8,654
2	2	0,100	-0,100	1,00					P+	17,309
3	5	0,250	-0,061	0,50	-0,062	1,00	-0,128	1,00	P+	43,278
4	10	0,500	-0,053	0,50	-0,027	0,60	-0,126	0,60	P+	86,543
5	20	1,000	-0,049	0,50	-0,017	0,60	-0,132	0,60	P+	173,090
6	50	2,500	-0,048	0,50	0,005	0,60	-0,159	0,60	P+	432,734
7	100	5,000	-0,052	0,50	0,016	0,60	-0,195	0,60	P+	865,510
8	120	6,000	-0,051	0,50	0,021	0,60	-0,204	0,60	P+	1038,580
9	1	0,050	-0,349	1,00					P-	-8,654
10	2	0,100	-0,082	1,00					P-	-17,310
11	5	0,250	-0,060	0,50	-0,066	1,00	-0,122	1,00	P-	-43,273
12	10	0,500	-0,047	0,50	-0,022	0,60	-0,130	0,60	P-	-86,543
13	20	1,000	-0,041	0,50	-0,007	0,60	-0,128	0,60	P-	-173,094
14	50	2,500	-0,039	0,50	0,011	0,60	-0,147	0,60	P-	-432,718
15	100	5,000	-0,042	0,50	0,022	0,60	-0,184	0,60	P-	-865,549
16	120	6,000	-0,046	0,50	0,027	0,60	-0,193	0,60	P-	-1038,530
Id	**In [%]**	**In [A]**	**sinφ=1 ε [%]**	**Limit**	**sinφ=0.8C ε [%]**	**Limit**	**sinφ=0.5L ε [%]**	**Limit**	**Energy flow**	**Power [var] Sin=1**
17	2	0,100	-0,037	1,50					Q+	17,306
18	5	0,250	-0,026	1,00	0,006	1,50	0,174	1,50	Q+	43,268
19	10	0,500	0,003	1,00	0,004	1,00	0,220	1,00	Q+	86,534
20	20	1,000	0,006	1,00	-0,002	1,00	0,285	1,00	Q+	173,096
21	50	2,500	0,012	1,00	-0,009	1,00	0,295	1,00	Q+	432,734
22	100	5,000	0,008	1,00	-0,027	1,00	0,333	1,00	Q+	865,438
23	120	6,000	0,005	1,00	-0,033	1,00	0,342	1,00	Q+	1038,500
24	2	0,100	-0,037	1,50					Q-	-17,310
25	5	0,250	-0,008	1,00	0,006	1,50	0,165	1,50	Q-	-43,258
26	10	0,500	0,008	1,00	0,008	1,00	0,212	1,00	Q-	-86,545
27	20	1,000	0,007	1,00	0,005	1,00	0,253	1,00	Q-	-173,079
28	50	2,500	0,011	1,00	-0,006	1,00	0,294	1,00	Q-	-432,687
29	100	5,000	0,008	1,00	-0,019	1,00	0,334	1,00	Q-	-865,455
30	120	6,000	0,008	1,00	-0,020	1,00	0,340	1,00	Q-	-1038,530

The diagram of error ε as a function of the load current I_{load} expressed in [%] of nominal current I_n for various energy flows and power factors is presented below.









9. Conclusions

The TS33 Automatic Test System enables 4-quadrant meters to be automatically tested in a full range of currents, power factors, and energy flow directions. As a result, we can get full characteristics of electricity meter. It is especially important for new windmill generators and photovoltaic installations.