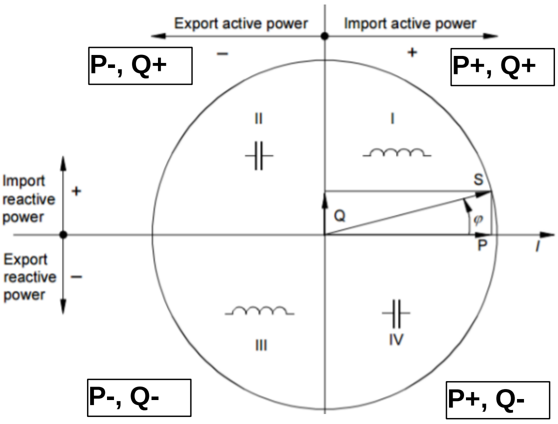
Testing 4-Quadrant energy meter by TS33 Automatic Test System

1. Testing 4-quadrant meter theory

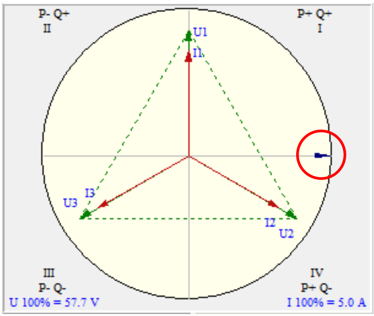
Testing 4-Quadrant electricity meter requires to force active and reactive energy flow in all directions and possible combinations. From point view of energy supplier (utility) energy can be imported (delivered) by (to) customer or exported by customer (received by utility). Typical four Quadrant energy meter has 2 pulse LED: one for active, one for reactive power and energy correspondingly with the units of the meter constant: imp/kWh and imp/kvarh.



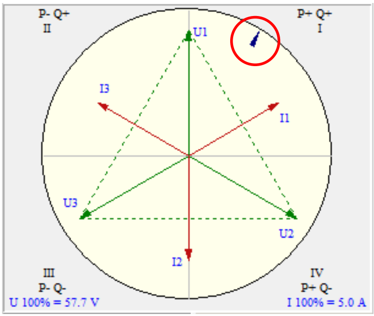
During testing, the scanning head should be placed and sense a proper LED depending on the load point under test.

As an example for testing is used 3-phase, 4-wire, 4-Quadrant meter: 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) 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 presented vector diagrams for load point 100% at 57.7V base voltage and different power factors and quadrants.

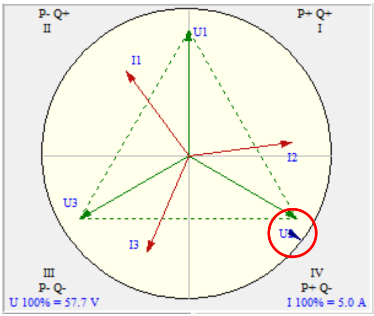
PF=1 P+



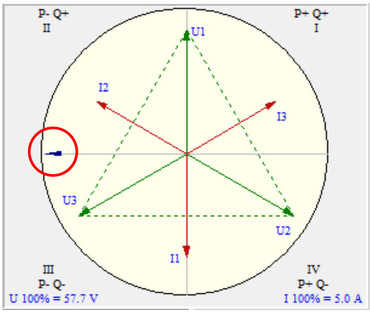
PF=0.5L P+



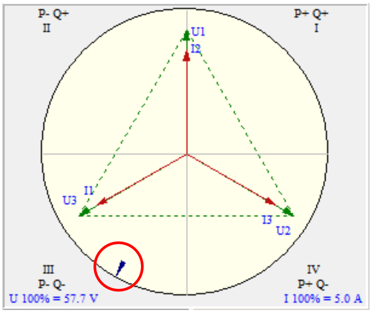
PF=0.8C P+



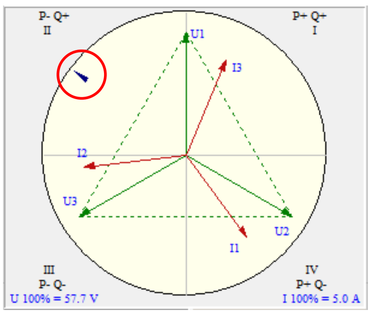
PF=-1 P-



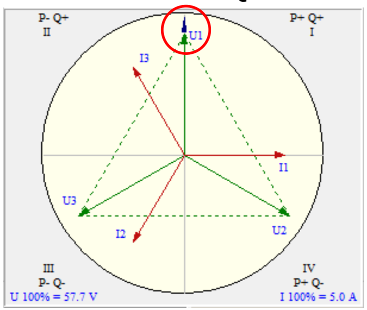
PF=-0.5L P-



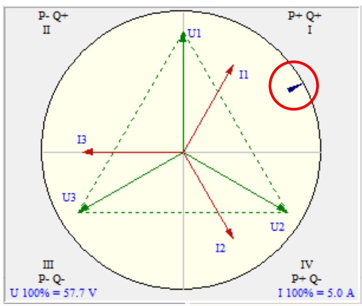
PF=-0.8C P-



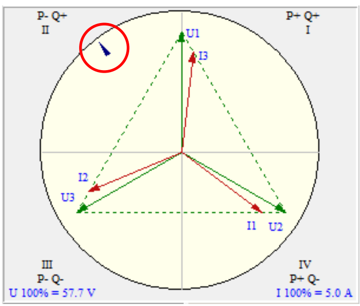
Sin=1 Q+



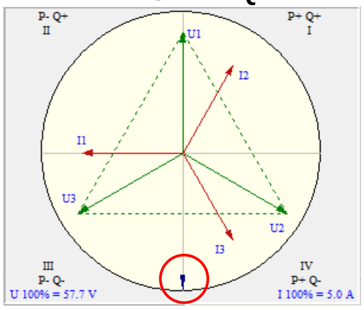
Sin=0.5L Q+



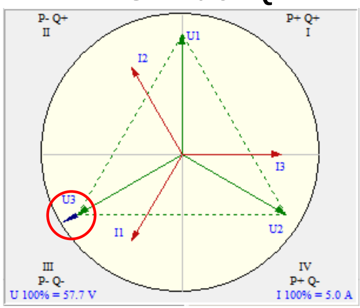
Sin=0.8C Q+



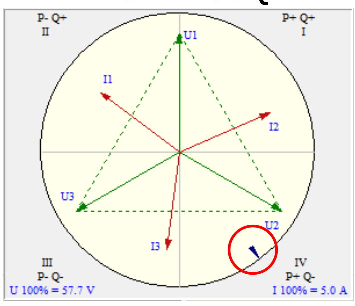
Sin=-1 Q-



Sin=-0.5L Q-

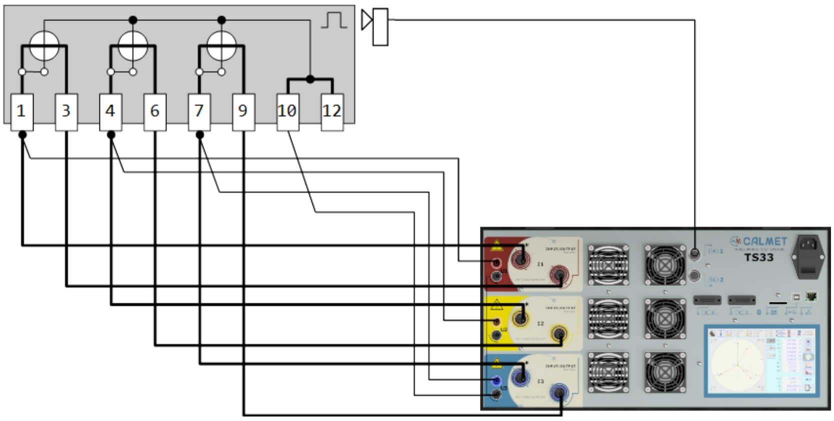


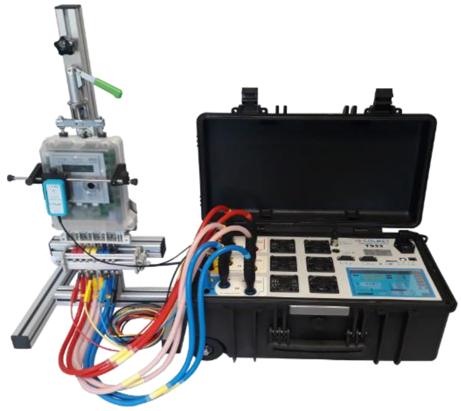
Sin=-0.8C Q-



2. Connection of meter under test to TS33

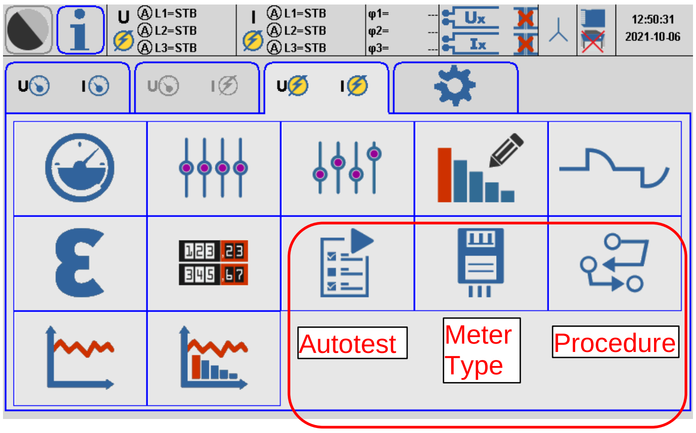
The meter is connected to the TS33 as in diagram and picture below.





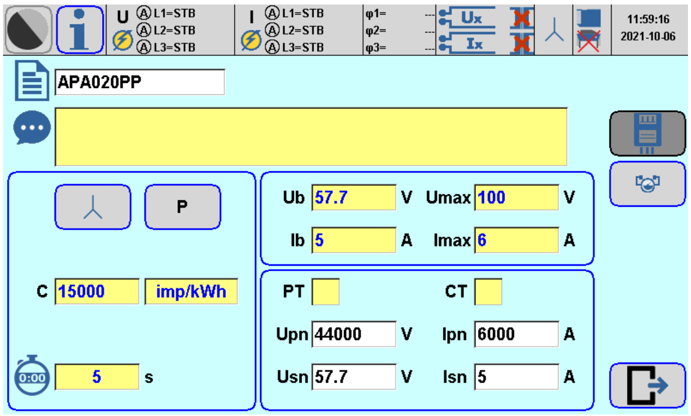
3. Setting testing procedures

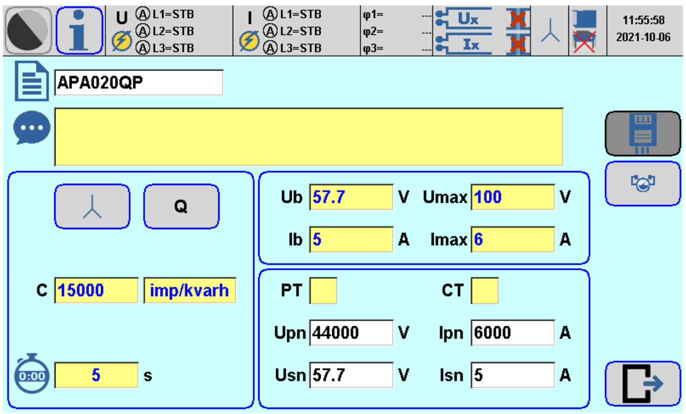
The TS33 should be set to source of voltage and current generation mode. Automatic testing of electricity meter requires to prepare Meter Type parameters, testing Procedure and then the test execution – Autotest. Before we set Meter Type we have to recognize basic technical data of meter under test from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



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

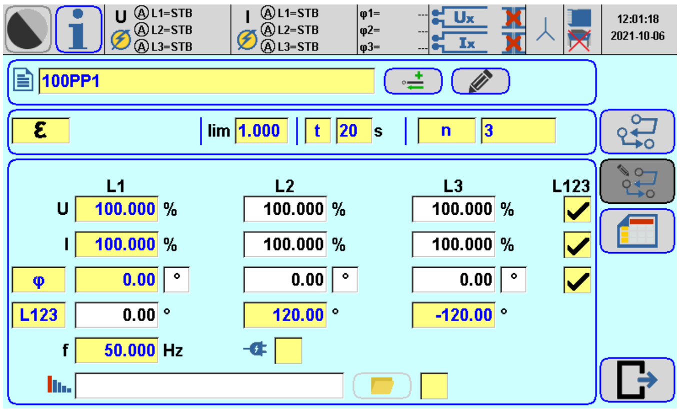
On base of information mentioned above prepared and saved can be two Meter Types: one for active energy, one for reactive energy. In pictures below are presented Meter Types with entered data. Then they have to be saved under separate names of Meter Type eg: APA020PP and APA020QP as in example.

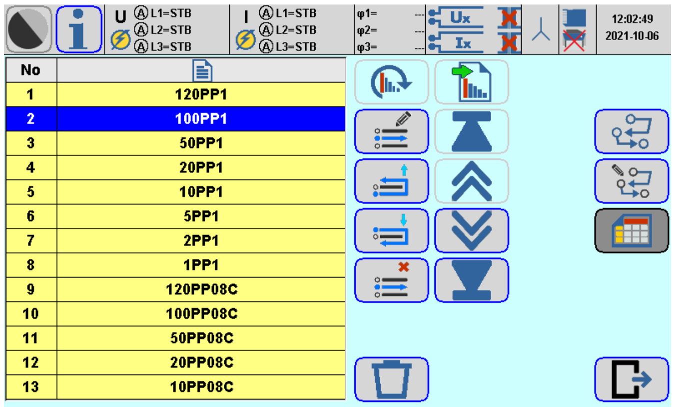




Then testing Procedure should be prepared as next. According to the standards, for the meter tested as example, the accuracy should be tested for loads in range 1% to 120% of nominal current, active energy for power factor PF=±1 and in range 5% to 120% for power factor PF=±0.8C and PF=±0.5L. Reactive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

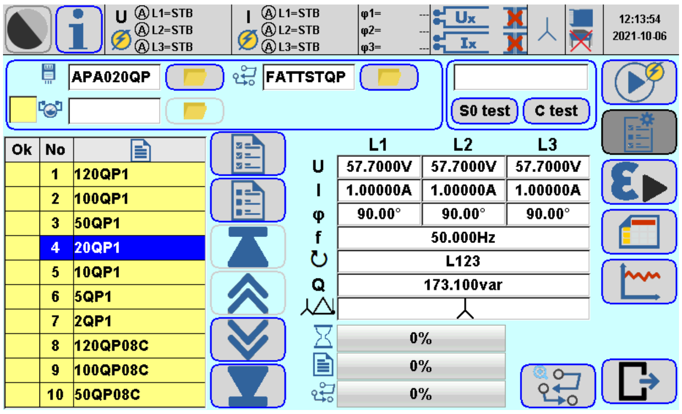
Preparing Procedure consists of setting parameter of each load point and testing conditions. In example below is set load point (name 100PP1) for 100% of I_n (5A) at 100% of base voltage U (57.7V), power factor PF=1 (φ=0°), frequency 50Hz in symmetric circuit. Tested is accuracy (error ε) of meter during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



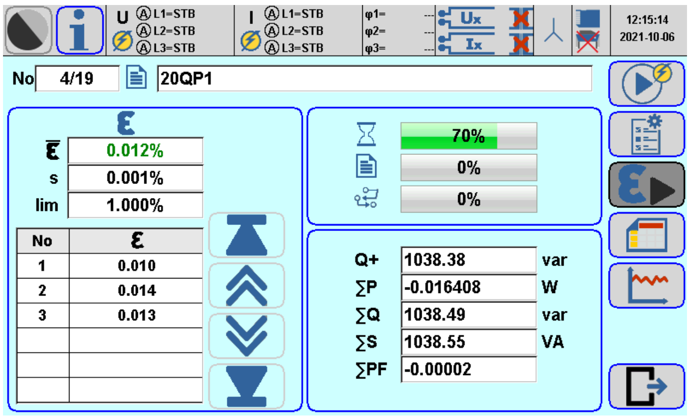


The settings are entered for each load point, then added to the list so we get a list of points to get results in whole range of meter characteristics. The Procedure can be saved in data base for future using.

4. Test execution

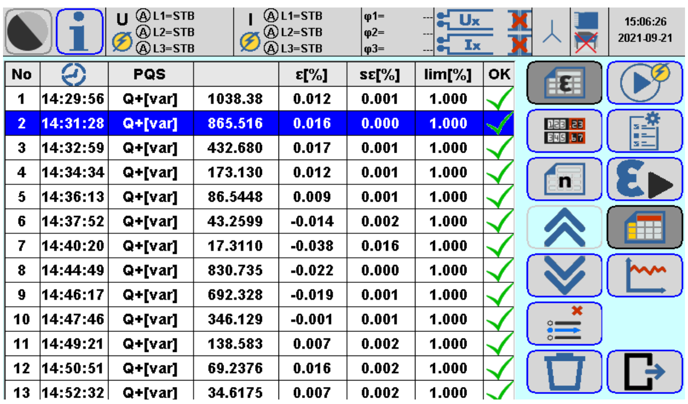


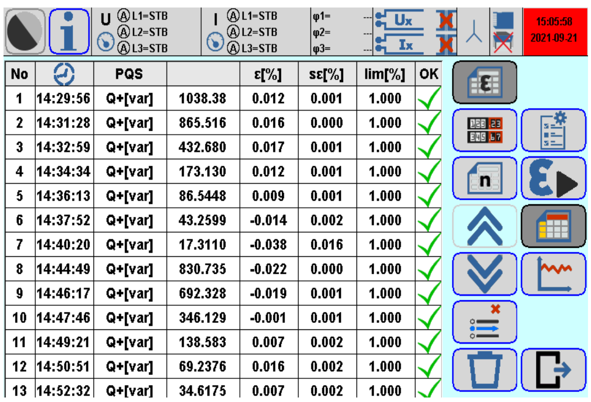
Then we can execute testing by selecting proper Meter Type (for meter we want to test - APA020QP in example) and Procedure of testing (FATTSQP). In the Autotest can be selected range of testing by marking one or selected or all of load points. The settings of selected load point are displayed to confirm settings of voltage, current, phase shift and power. After starting the test the actual status of test is shown in progress bars as percent of settling time, percent of load point testing and percent of whole procedure realization. The test should be performed separately for active energy and scanning head at imp/kWh LED and then reactive energy at imp/kvarh LED.



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

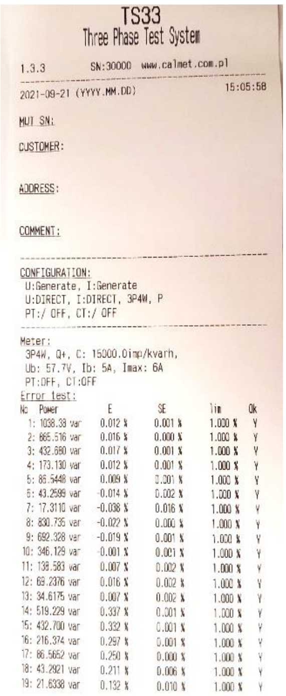
The final results of whole test are presented in form of table with number of load point, kind and value of power, error value, standard deviation value, limit and final evaluation OK / Not OK. The results can be saved in device memory for later recall or transfer to PC computer for further processing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





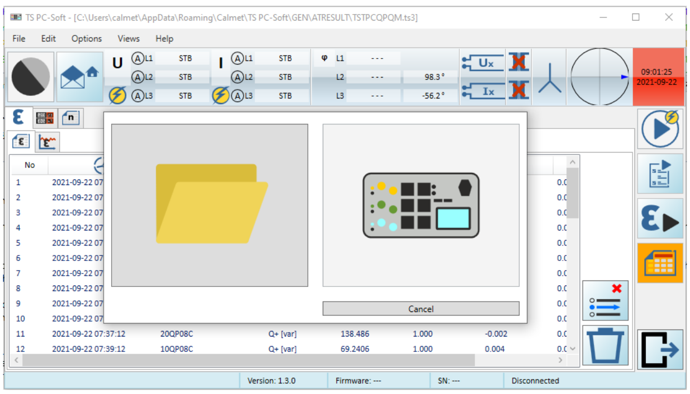
5. Printing the results on site

The results of testing can be printed directly on site by means of wireless, miniature thermal printer. Printed can be results and screen shot. Example printouts are shown in pictures below.

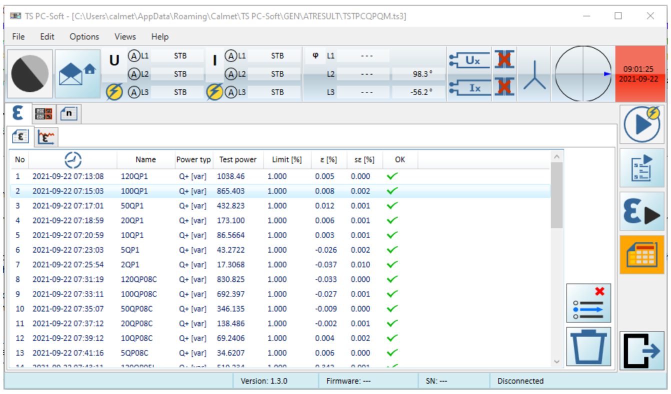


6. Processing the results in the TS PC Soft

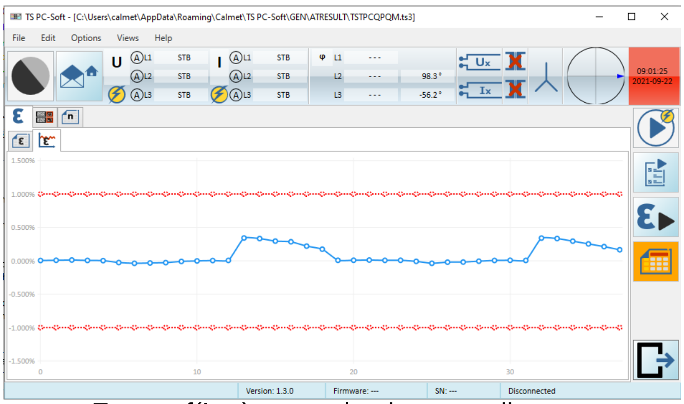
The results saved in the TS33 device memory or just taken by means of TS PS Soft which controls TS33 can be further processed. The result in TS33 memory can be transferred to the PC in two ways: by removing SD Memory Card from TS33 and data readout in PC or by connecting PC to TS33 by means of USB, Bluetooth or Ethernet. The selected file is opened in form of table with results or diagram. The results can be also printed on every printer connected to the PC.



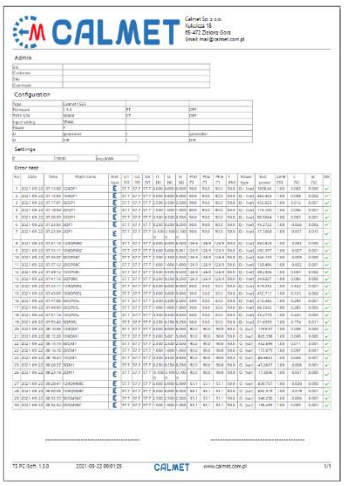
Downloading results to PC



Opened results in PC



Error ε=f(I_{load}) versus load current diagram



Report printout

7. Export results to Excel

The results are kept in data base in files in text XML format. The results data can be also exported to the Excel sheet for easy Report preparation. Exported are all of results taken during testing including administrative data.


```
        <Cycle>
                <DataList>
                        <Data Name='Epsilon' Value='0.012862'/>
                </DataList>
        </Cycle>
</PartialResults>
<FinalResult Date='2021-09-21' Time='14:29:56'>
        <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'/>
                        <Data Name='I3' Value='5.999462'/>
                        <Data Name='U12' Value='99.937141'/>
                        <Data Name='U23' Value='99.939972'/>
                        <Data Name='U13' Value='99.947350'/>
                        <Data Name='Phi1' Value='90.003357'/>
                        <Data Name='Phi2' Value='89.997963'/>
                        <Data Name='Phi3' Value='90.001442'/>
                        <Data Name='Phi12' Value='119.999535'/>
                        <Data Name='Phi13' Value='-119.999672'/>
                        <Data Name='F' Value='50.000000'/>
                        <Data Name='P1' Value='-0.020000'/>
                        <Data Name='P2' Value='0.012307'/>
                        <Data Name='P3' Value='-0.008715'/>
                        <Data Name='PSum' Value='-0.016408'/>
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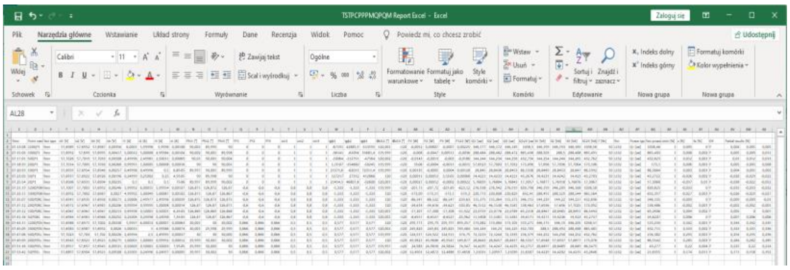
Result data in XML format



All data exported to Excel sheet

8. Final Report prepared in Excel

On base of results data the final Report can be prepared in Excel including clear table and diagrams.

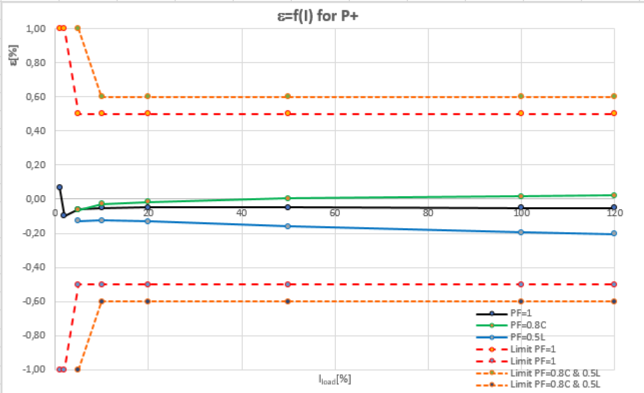
Test report of 4-quadrant meter APA P020

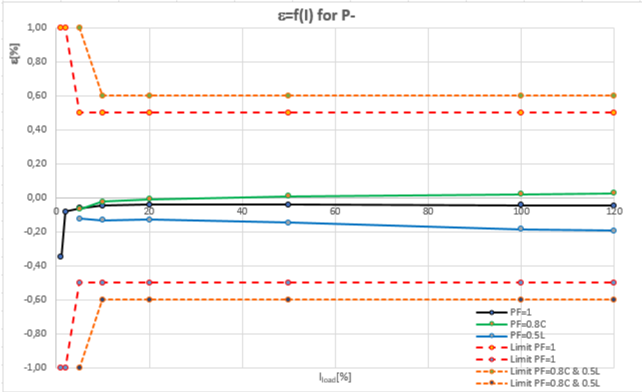
In=5A. Imax=6A, Ub=57.7V C=15000imp/kWh(kvarh), class (P)=C, class (Q)=1

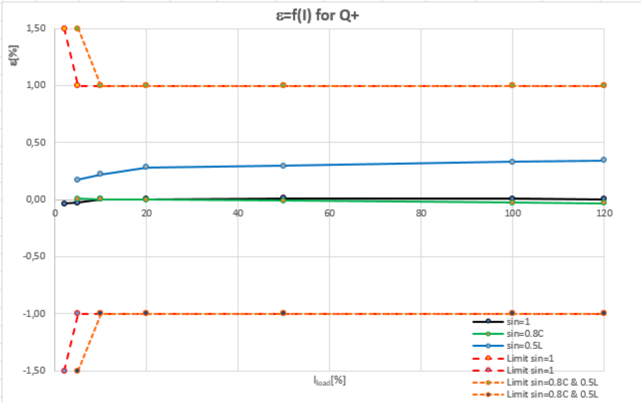
Id	In [%]	In [A]	cosφ=1 ε [%]	Limit	cosφ=0.8C ε [%]	Limit	cosφ=0.5L ε [%]	Limit	Energy flow	Power [W] PF=1
1	1	0,050	0,070	1,00					P+	8,654
2	2	0,100	-0,100	1,00					P+	17,309
3	5	0,250	-0,061	0,50	-0,062	1,00	-0,128	1,00	P+	43,278
4	10	0,500	-0,053	0,50	-0,027	0,60	-0,126	0,60	P+	86,543
5	20	1,000	-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

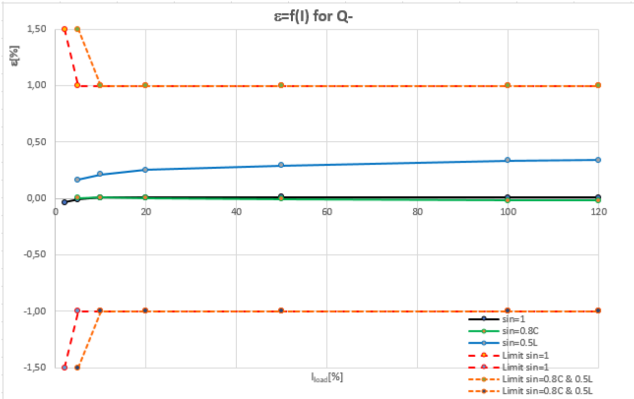
Testing Report

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









9. Conclusions

Automatic test system TS33 enables to test 4-Quadrant meters in whole range of currents, power factors and energy flow directions in automatic way. As results we can get full characteristics of electricity meter. It is especially important for new windmill generators and photovoltaic installations.