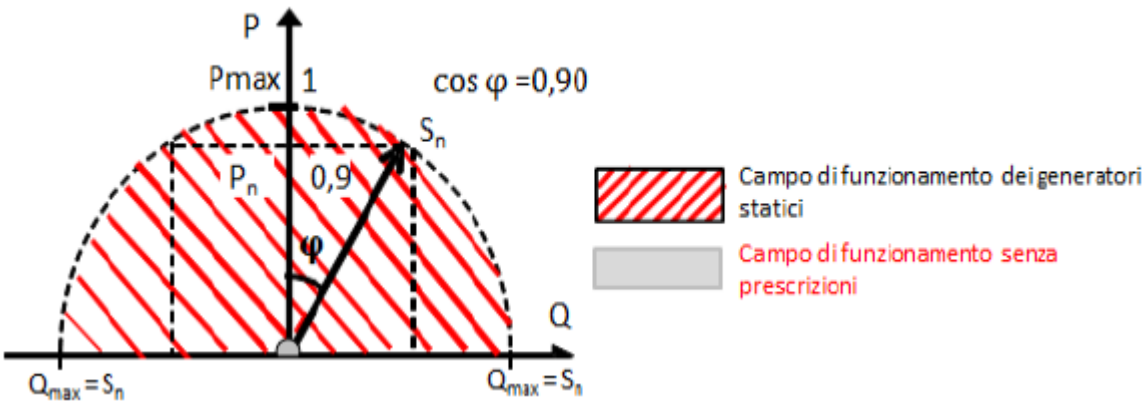
4.4. Verification of Constructional Requirements Relating to Exchange of Reactive Power

4.4.1. Verification of reactive power supply capability

The verification of reactive power supply capability test has been measured according to the paragraph N.6.1 of the standard, at the required power levels (0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%).

Four different tests have been done:

- Test 1: Q Zero (Q = 0 %Sn)
- Test 2: Rectangular Curve (Q = ±48.43 %Sn)
- Test 3: Triangular Curve (PF = ±0.8)
- Test 4: Semicircular Curve (S = 110 %Sn)



Test 1: Q Zero (Q = 0 %Sn)

This test verifies the capability of the inverter to provide a fixed value of reactive power. In addition, it is verified the Q control mode.

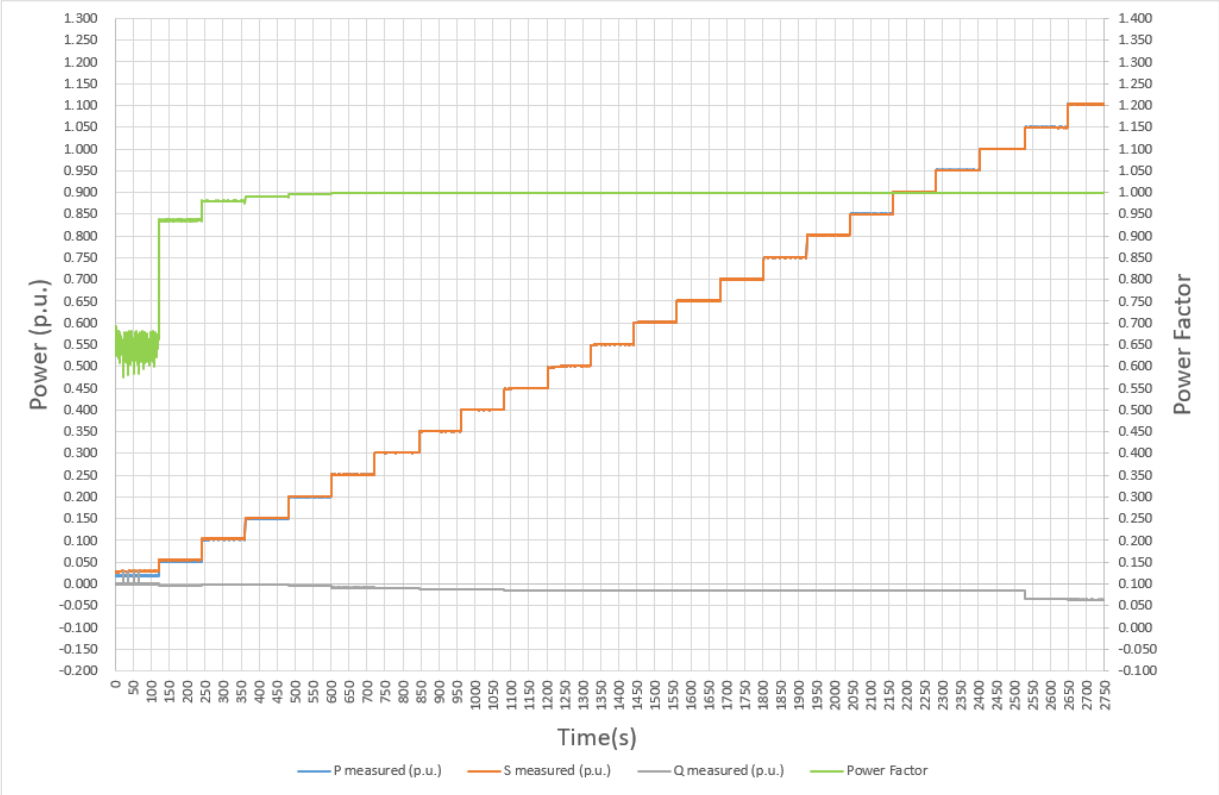
Allowed tolerance for reactive power measurements is to be considered inside ±5 %Sn.

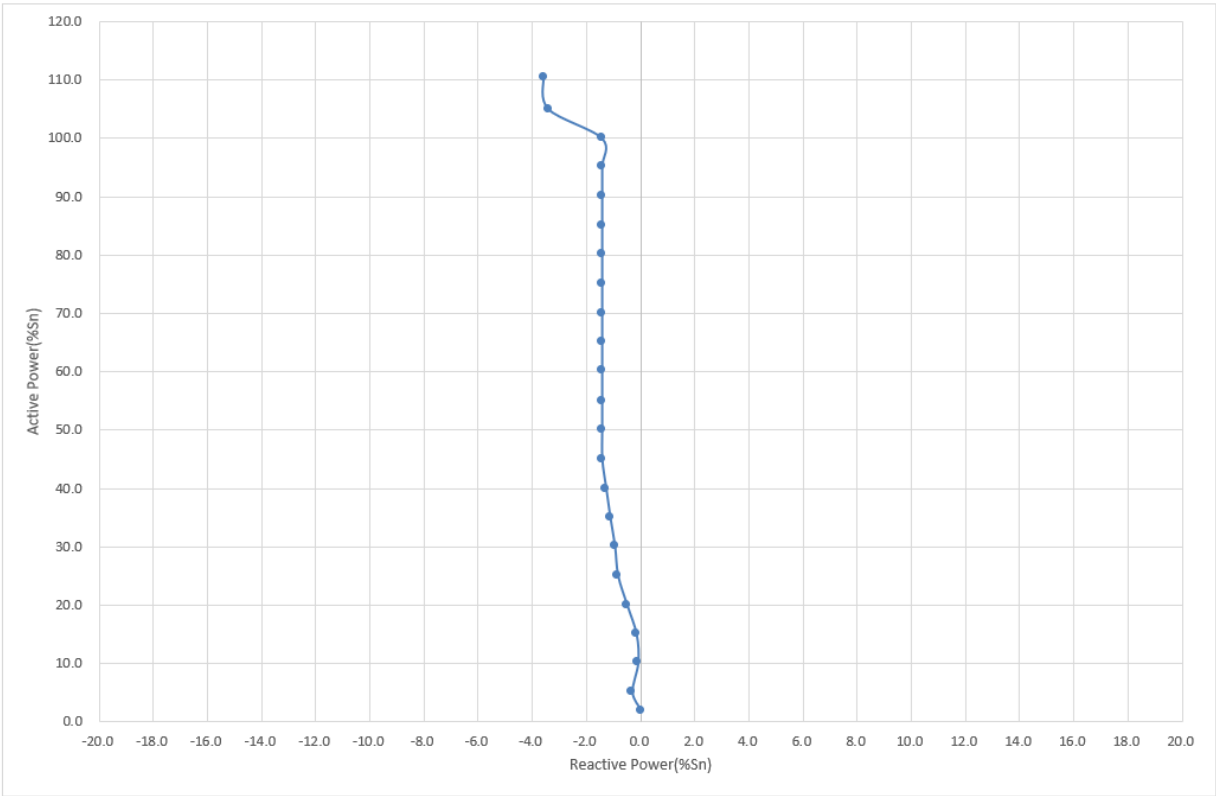
Test results are offered in table below.

Rectangular Curve (Q = 0 %Sn)						
P Desired (%Sn)	**Power DC (kW)**	**P measured (%Sn)**	**Q desired (%Sn)**	**Q measured (%Sn)**	**Q Deviation (%Sn)**	**Power Factor (cos φ)**
0	2.7	1.9	--	0.0	--	0.652
5	7.3	5.1	--	-0.3	--	0.936
10	14.2	10.2	0.0	-0.1	-0.1	0.981
15	20.8	15.0	0.0	-0.2	-0.2	0.991
20	27.7	20.0	0.0	-0.5	-0.5	0.997
25	34.7	25.1	0.0	-0.8	-0.8	1.000
30	41.7	30.2	0.0	-1.0	-1.0	1.000
35	48.5	35.1	0.0	-1.1	-1.1	1.000
40	55.2	40.0	0.0	-1.3	-1.3	1.000
45	62.2	45.0	0.0	-1.4	-1.4	1.000
50	69.1	50.0	0.0	-1.4	-1.4	1.000
55	76.0	55.0	0.0	-1.4	-1.4	1.000
60	83.2	60.2	0.0	-1.4	-1.4	1.000
65	90.0	65.1	0.0	-1.4	-1.4	1.000
70	96.9	70.1	0.0	-1.4	-1.4	1.000
75	104.0	75.1	0.0	-1.4	-1.4	1.000
80	111.1	80.2	0.0	-1.4	-1.4	1.000
85	117.9	85.1	0.0	-1.4	-1.4	1.000
90	124.9	90.1	0.0	-1.4	-1.4	1.000
95	131.9	95.2	0.0	-1.4	-1.4	1.000
100	138.7	100.0	0.0	-1.4	-1.4	1.000
105	145.0	105.0	104.9	-3.4	1.0	0.000
110	153.2	110.4	110.3	-3.6	1.0	0.000

Test results are represented in diagrams below.

Rectangular Curve (Q = 0 %Sn)





Test 2: Semicircular Curve (S = 48.43 %Sn)

This test verifies the capability of the inverter to provide a fixed value of reactive power. In addition, it is verified the Q control mode.

Allowed tolerance for reactive power measurements is to be considered inside ±5 %Sn.

Test results are offered in tables below.

Rectangular Curve (Q = 48.43 %Sn - Inductive)						
P Desired (%Sn)	**Power DC (kW)**	**P measured (%Sn)**	**Q measured (%Sn)**	**Q desired (%Sn)**	**Q Deviation (%Sn)**	**Power Factor (cos φ)**
0	2.6	1.7	48.7	--	--	0.035
5	7.2	5.0	48.6	--	--	0.103
10	13.9	10.0	48.5	48.4	-0.1	0.202
15	21.0	15.1	48.5	48.4	-0.1	0.298
20	27.7	20.0	48.6	48.4	-0.2	0.382
25	34.6	25.1	48.6	48.4	-0.1	0.459
30	41.3	30.0	48.6	48.4	-0.2	0.526
35	48.2	35.0	48.5	48.4	-0.1	0.586
40	54.9	39.9	48.5	48.4	0.0	0.637
45	62.0	45.1	48.5	48.4	-0.1	0.682
50	69.0	50.2	48.5	48.4	-0.1	0.721
55	75.9	55.2	48.6	48.4	-0.2	0.752
60	82.6	60.1	48.6	48.4	-0.1	0.780
65	90.0	65.4	48.5	48.4	-0.1	0.806
70	96.4	70.1	48.5	48.4	0.0	0.826
75	103.4	75.2	48.6	48.4	-0.2	0.844
80	110.4	80.2	48.6	48.4	-0.2	0.865
85	116.3	84.6	48.6	48.4	-0.2	0.865
90	123.6	89.9	48.6	48.4	-0.1	0.876
95	130.8	95.1	48.6	48.4	-0.2	0.889
100	137.7	100.2	48.6	48.4	-0.2	0.899

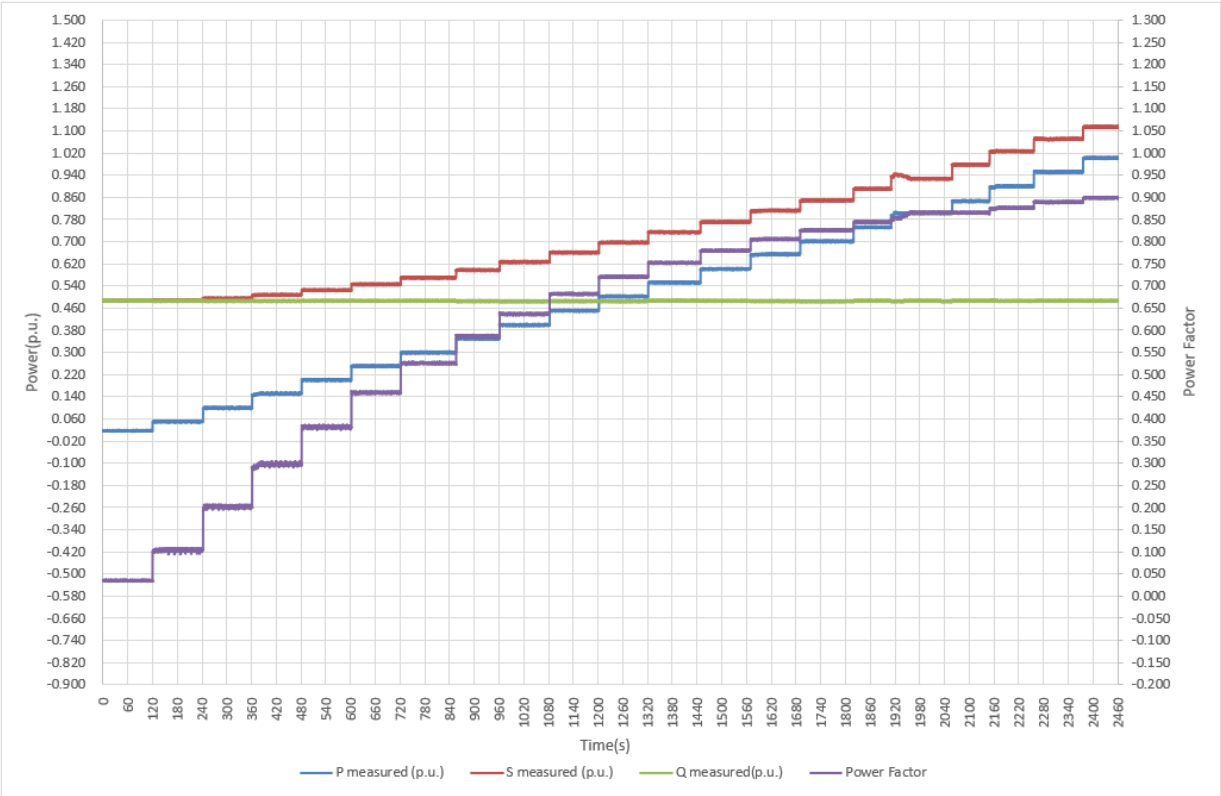
Note: according to point N.6.1 for lower values of generated active power (P≤10 %Sn), deviations in the reactive power are allowed up to a 10 %Sn.

Rectangular Curve (Q = 48.43 %Sn - Capacitive)						
P Desired (%Sn)	**Power DC (kW)**	**P measured (%Sn)**	**Q measured (%Sn)**	**Q desired (%Sn)**	**Q Deviation (%Sn)**	**Power Factor (cos φ)**
0	2.8	0.8	-48.7	--	--	0.017
5	7.9	4.6	-48.4	--	--	0.096
10	14.9	9.8	-48.4	-48.4	0.0	0.199
15	22.2	15.2	-48.4	-48.4	0.0	0.299
20	29.0	20.1	-48.4	-48.4	0.0	0.384
25	35.9	25.2	-48.4	-48.4	0.0	0.462
30	43.0	30.4	-48.4	-48.4	0.0	0.532
35	50.0	35.4	-48.6	-48.4	-0.1	0.590
40	56.7	40.3	-48.5	-48.4	-0.1	0.640
45	63.2	45.1	-48.5	-48.4	-0.1	0.682
50	70.2	50.1	-48.5	-48.4	-0.1	0.720
55	77.2	55.3	-48.5	-48.4	-0.1	0.753
60	84.1	60.2	-48.5	-48.4	-0.1	0.780
65	90.9	65.1	-48.5	-48.4	-0.1	0.804
70	97.8	70.2	-48.5	-48.4	-0.1	0.824
75	104.7	75.1	-48.5	-48.4	-0.1	0.843
80	111.6	80.1	-48.6	-48.4	-0.2	0.859
85	118.5	85.1	-48.1	-48.4	0.4	0.868
90	125.4	90.2	-48.5	-48.4	-0.1	0.881
95	132.2	95.1	-48.6	-48.4	-0.2	0.891
100	139.1	100.1	-48.7	-48.4	-0.2	0.900

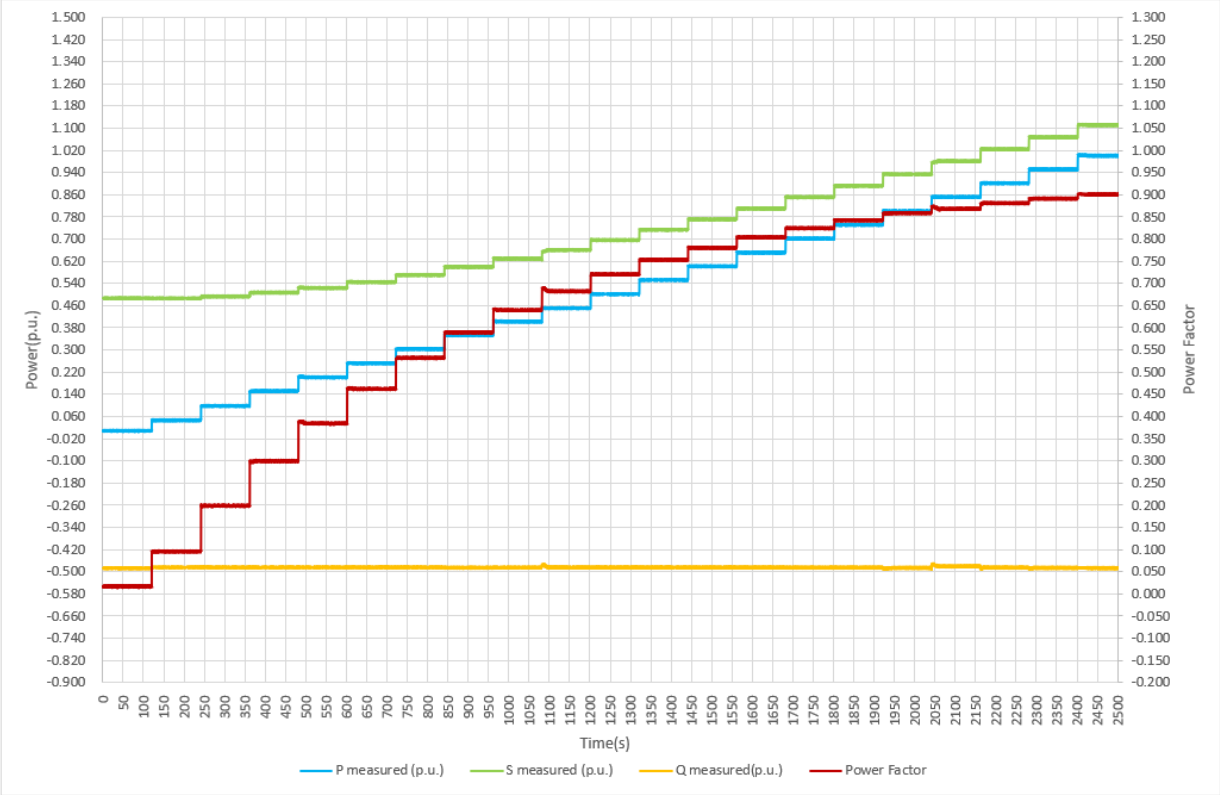
Note: according to point N.6.1 for lower values of generated active power (P ≤ 10%Sn), deviations in the reactive power are allowed up to a 10%Sn.

Test results are represented in diagrams below.

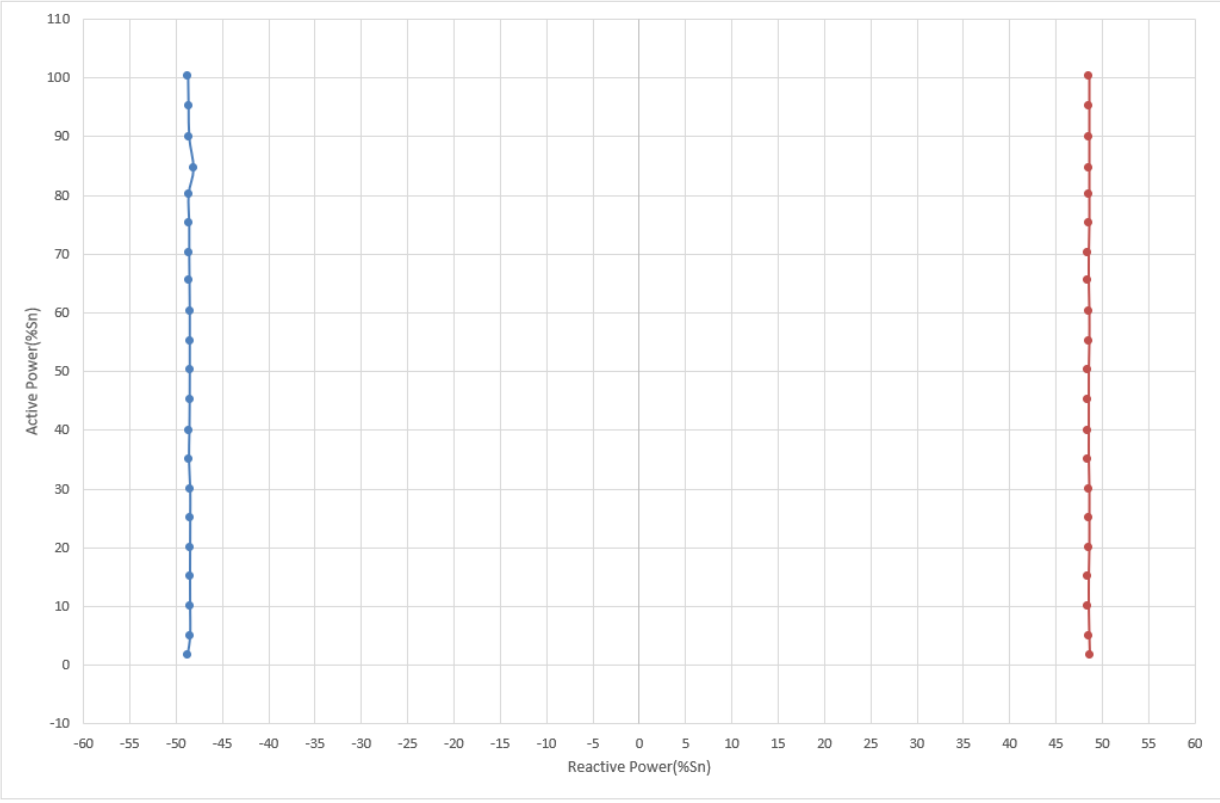
Rectangular Curve (Q = 48.43 %Sn / Inductive)



Rectangular Curve (Q = 48.43 %S_n / Capacitive)



Rectangular Curve (Capacitive vs Inductive)



Test 3: Triangular Curve (PF = ±0.8)

This test verifies the capability of the inverter to provide a fixed value of power factor. In addition, it is verified the PF control mode.

The maximum tolerance considered for the measured Power Factor is ±0.01, for measurements above 10 %Pn.

Test results are offered in the tables below.

Triangular Curve (PF = 0.8 / inductive)						
P desired (%Sn)	**Power DC (kW)**	**P measured (%Sn)**	**Q measured (%Sn)**	**Power factor measured (cos φ)**	**Power factor desired (cos φ)**	**Power factor deviation (cos φ)**
0 (*)	4.2	2.8	4.2	0.544	--	--
10 (*)	13.5	9.7	8.4	0.801	--	--
20	28.1	20.4	16.1	0.803	0.800	0.003
30	41.4	30.1	23.2	0.802	0.800	0.002
40	55.2	40.2	30.4	0.802	0.800	0.002
50	68.9	50.1	38.0	0.800	0.800	0.000
60	82.6	60.1	45.2	0.801	0.800	0.001
70	96.4	70.2	52.6	0.802	0.800	0.002
80	110.1	80.1	60.2	0.801	0.800	0.001
90 (**)	123.9	90.1	67.5	0.802	0.800	0.002
100 (**)	123.9	90.1	67.5	0.802	0.800	0.002

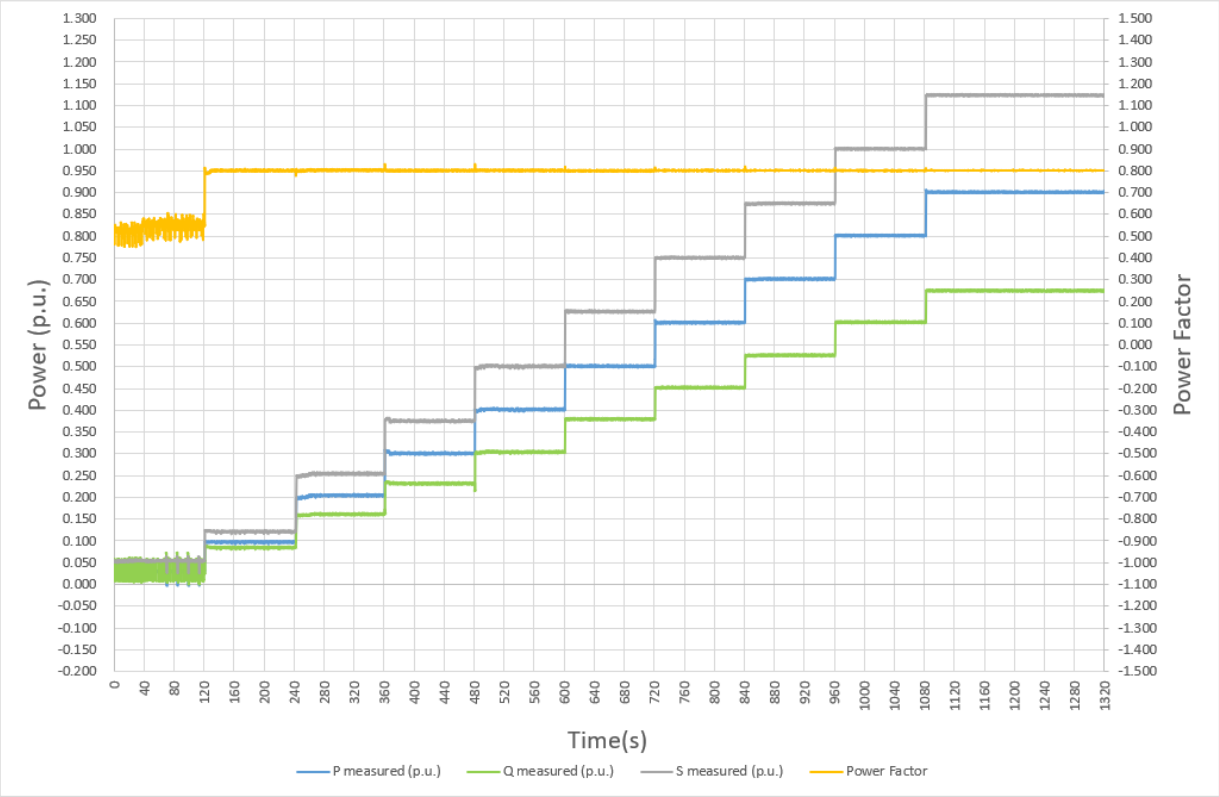
(*) No tolerance of Power Factor was defined when active power level below 10%Sn
(**) The desired value of active power has not been reached due to power factor is 0.8 of the inverter.

Triangular Curve (PF = 0.8 / Capacitive)						
P desired (%Sn)	**Power DC (kW)**	**P measured (%Sn)**	**Q measured (%Sn)**	**Power factor measured (cos φ)**	**Power factor desired (cos φ)**	**Power factor deviation (cos φ)**
0 (*)	4.2	2.7	-3.0	0.633	--	--
10 (*)	13.9	9.9	-8.9	0.797	--	--
20	28.2	20.2	-16.0	0.800	0.800	0.000
30	42.1	30.1	-23.2	0.802	0.800	0.002
40	56.0	40.1	-30.5	0.800	0.800	0.000
50	69.9	50.0	-38.0	0.799	0.800	-0.001
60	83.8	60.0	-45.1	0.801	0.800	0.001
70	98.1	70.2	-52.9	0.801	0.800	0.001
80	111.8	80.0	-60.0	0.801	0.800	0.001
90 (**)	125.5	89.9	-67.3	0.802	0.800	0.002
100 (**)	125.5	89.9	-67.3	0.802	0.800	0.002

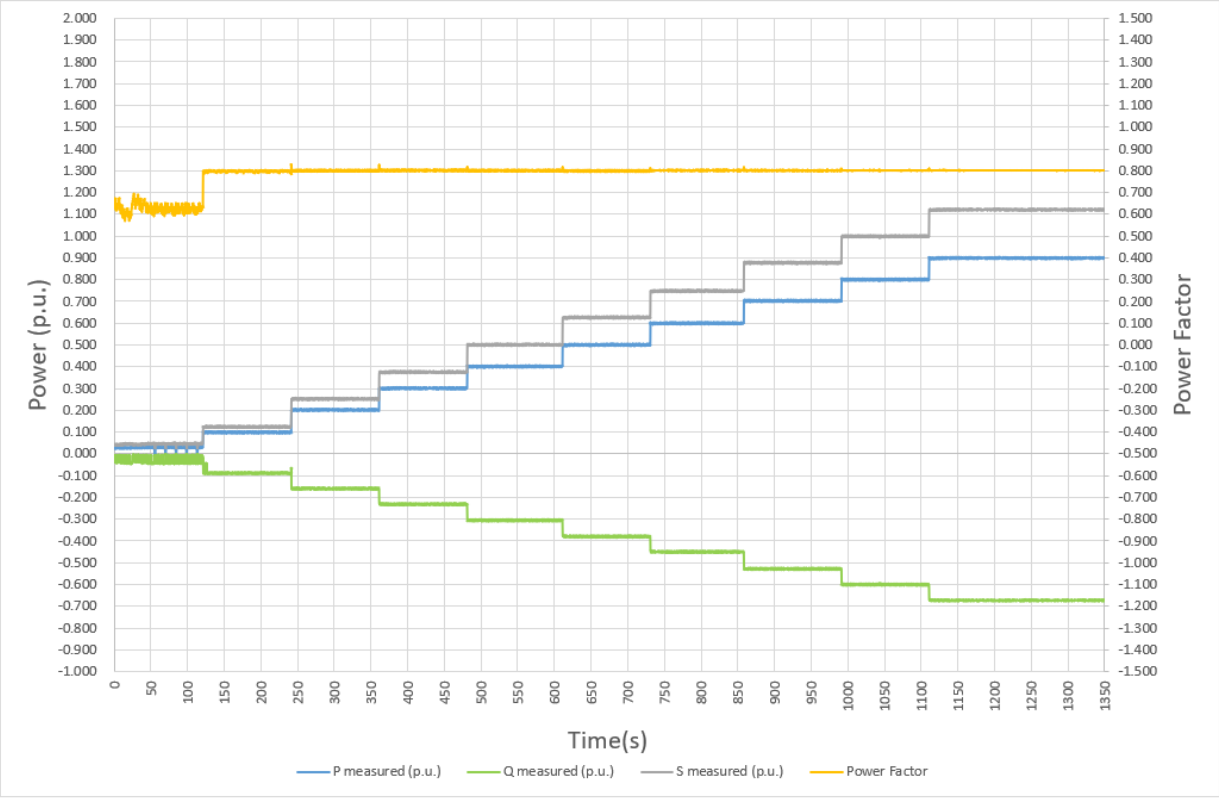
(*) No tolerance of Power Factor was defined when active power level below 10%Sn
(**) The desired value of active power has not been reached due to power factor is 0.8 of the inverter.

Test results are represented in the diagrams below.

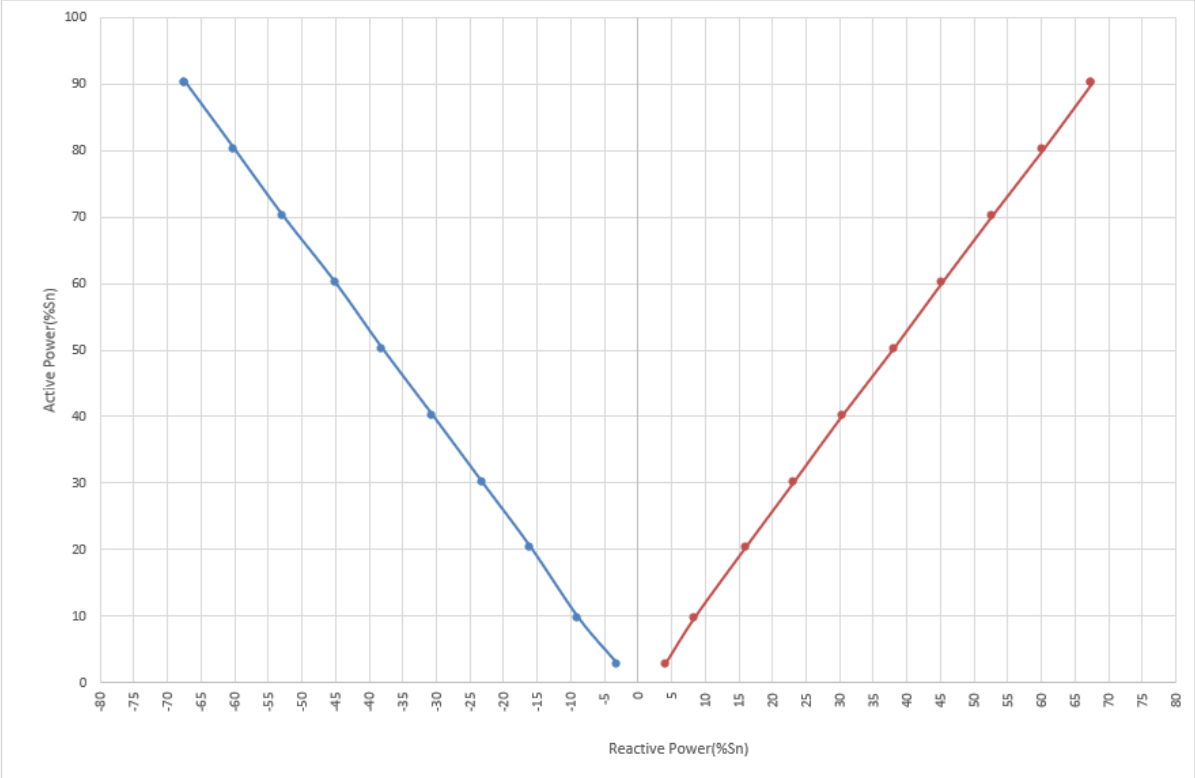
Triangular Curve (PF = 0.8 / inductive)



Triangular Curve (PF = 0.8 / Capacitive)



Triangular Curve (Inductive vs Capacitive)



Test 4: Semicircular Curve (S = 110 %Sn)

This test verifies the capability of the inverter to provide a fixed value of apparent power.

Test results are offered in the tables below.

Semicircular Curve (Inductive)							
P Desired (%Sn)	**Power DC (kW)**	**P measured (%Sn)**	**S measured (%Sn)**	**Power Factor (cos φ)**	**Q measured (%Sn)**	**Q desired (%Sn)**	**Q deviation (%Sn)**
0	4.5	2.9	110.3	0.029	109.8	110.0	--
5	7.9	5.2	110.3	0.052	109.4	109.9	--
10	14.6	10.1	110.3	0.101	109.1	109.5	-0.4
15	21.6	15.3	110.3	0.152	109.0	109.0	0.0
20	28.1	20.0	110.3	0.198	107.5	108.2	-0.7
25	35.0	25.1	110.3	0.246	107.0	107.1	-0.1
30	41.8	30.1	110.3	0.292	105.8	105.8	0.0
35	48.5	35.0	110.3	0.335	104.3	104.3	0.0
40	55.3	40.0	110.3	0.383	102.5	102.5	0.0
45	62.2	45.1	110.3	0.432	100.3	100.4	-0.1
50	69.1	50.1	110.3	0.480	98.0	98.0	0.0
55	75.7	54.9	110.3	0.526	95.3	95.3	0.0
60	82.7	60.1	110.3	0.576	92.2	92.2	0.0
65	89.6	65.1	110.3	0.624	88.6	88.7	-0.1
70	96.2	70.0	110.3	0.670	84.7	84.9	-0.2
75	103.2	75.1	110.3	0.718	81.4	80.5	0.9
80	109.9	80.0	110.3	0.765	77.5	75.5	2.0
85	116.8	85.0	110.3	0.812	71.2	69.8	1.4
90	123.7	89.9	110.3	0.840	66.4	63.2	3.2
95	130.6	95.0	110.3	0.869	58.5	55.5	3.0
100	137.9	100.2	110.3	0.888	45.2	45.8	-0.6
110	152.4	110.1	110.0	1.000	0.0	0.0	0.0

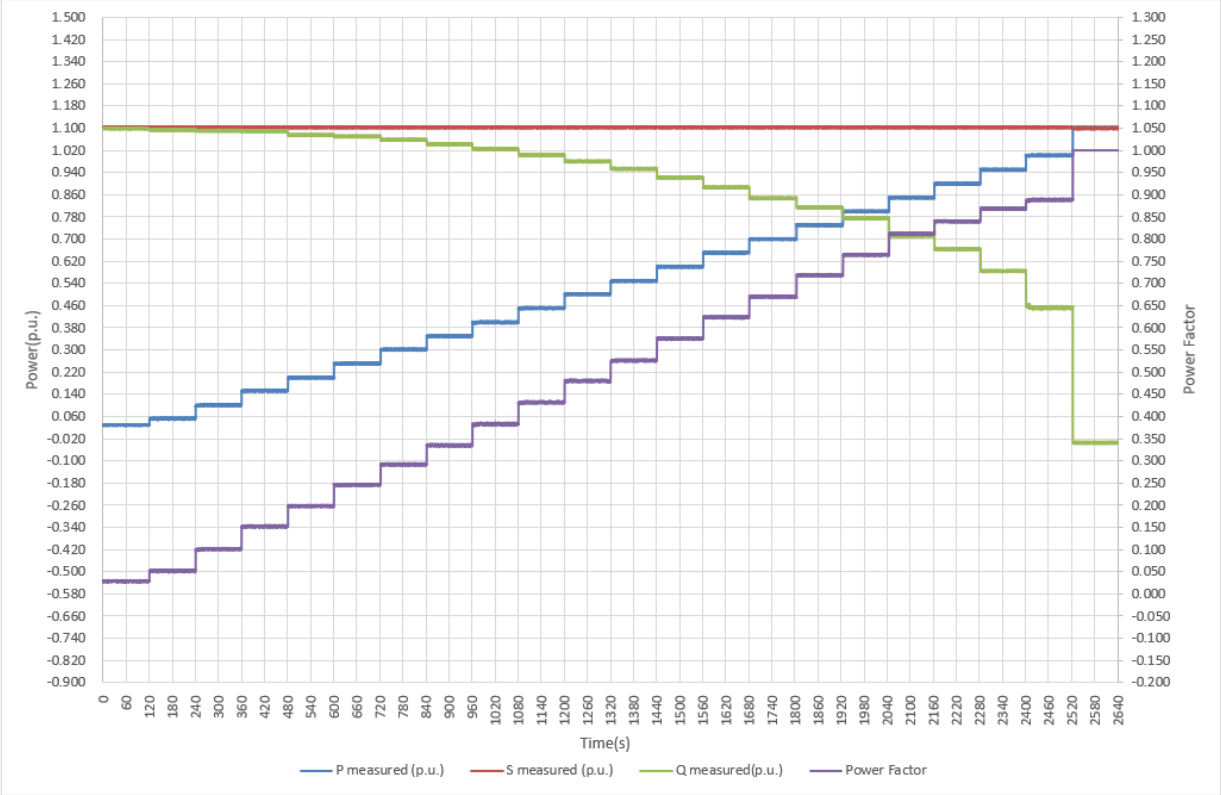
Note: according to point N.6.1 for lower values of generated active power (P≤10 %Sn), deviations in the reactive power are allowed up to a 10 %Sn.

Semicircular Curve (Capacitive)							
P Desired (%Sn)	**Power DC (kW)**	**P measured (%Sn)**	**S measured (%Sn)**	**Power Factor (cos φ)**	**Q measured (%Sn)**	**Q desired (%Sn)**	**Q deviation (%Sn)**
0	4.5	0.8	110.9	0.008	-110.3	-110.0	--
5	10.4	5.2	111.2	0.052	-109.9	-109.9	--
10	17.1	10.1	111.2	0.101	-109.5	-109.5	0.0
15	23.7	14.9	111.2	0.148	-109.0	-109.0	0.0
20	30.9	20.2	111.2	0.199	-108.0	-108.2	0.2
25	37.4	25.0	111.2	0.243	-107.1	-107.1	0.0
30	44.6	30.3	111.2	0.291	-105.8	-105.8	0.0
35	51.3	35.2	111.2	0.338	-104.3	-104.3	0.0
40	57.7	39.9	111.2	0.384	-102.5	-102.5	0.0
45	64.6	45.1	111.2	0.433	-100.3	-100.4	0.1
50	71.4	50.1	111.2	0.481	-98.0	-98.0	0.0
55	78.3	55.2	111.2	0.529	-95.3	-95.3	0.0
60	85.3	60.3	111.2	0.578	-92.0	-92.2	0.2
65	92.1	65.4	111.2	0.627	-88.7	-88.7	0.0
70	99.0	70.5	111.2	0.676	-84.9	-84.9	0.0
75	104.9	74.9	111.2	0.717	-81.5	-80.5	-1.0
80	111.6	79.9	111.2	0.764	-77.5	-75.5	-2.0
85	118.4	85.0	111.2	0.811	-71.2	-69.8	-1.4
90	125.3	90.1	111.2	0.839	-66.3	-63.2	-3.1
95	131.8	95.0	111.2	0.855	-55.8	-55.5	-0.3
100	138.4	99.9	111.2	0.883	-45.5	-45.8	0.3
110	152.4	110.1	110.0	1.000	0.0	0.0	0.0

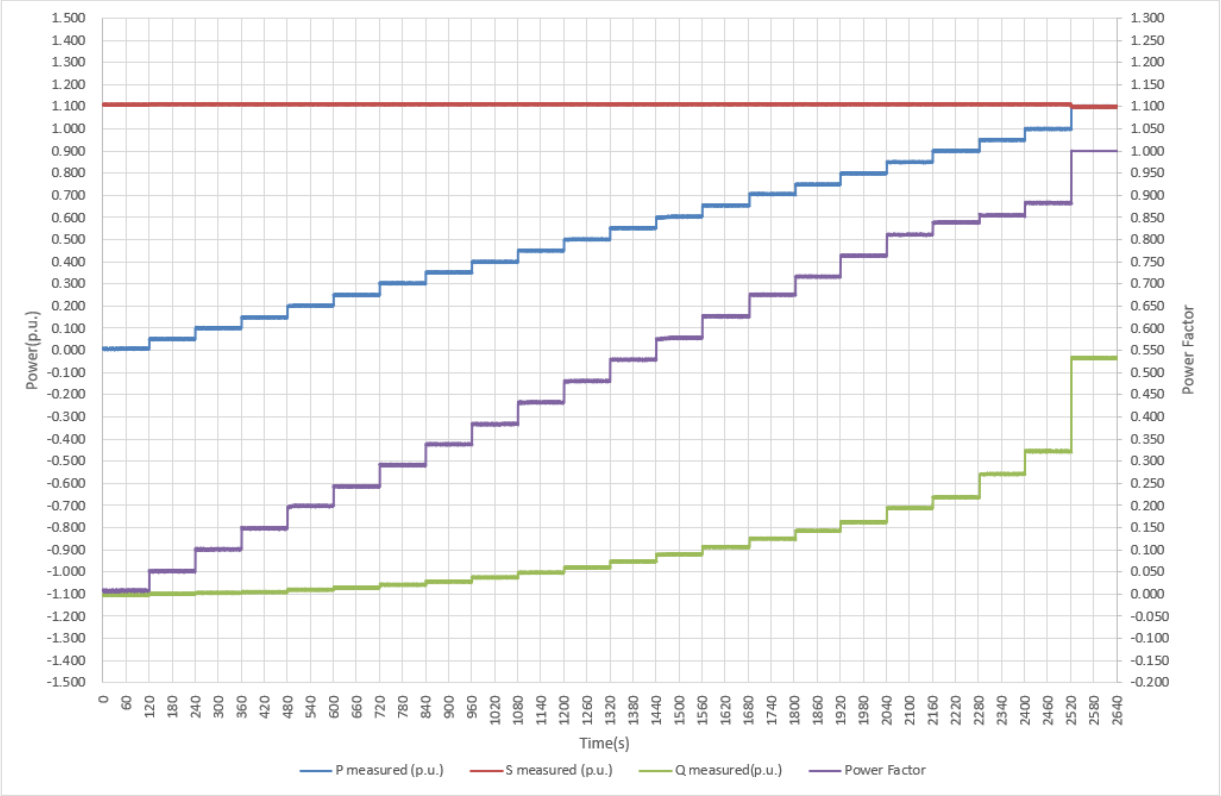
Note: according to point N.6.1 for lower values of generated active power (P≤10 %Sn), deviations in the reactive power are allowed up to a 10 %Sn.

Test results are represented in the diagrams below.

Semicircular Curve, Q inductive



Semicircular Curve, Q capacitive



Semicircular Curve; Capacitive vs Inductive