ECSE 362 - Fundamentals of Power Engineering

Lab 2: AC Power Transmission

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Lab section: 003

Introduction:

The experiment is divided into two distinct segments. The first section is dedicated to explore the power transmission scenarios in cases where both the sending and receiving ends are able to regulate voltage. The angle difference between the power supply and the synchronous machine are both measured and calculated for comparison purposes. In addition, the effect of impedance over power transmission will be observed. The subsequent section investigates power transmission cases where the voltage is floating at the receiving end.

Analysis

Part I: Slack to PV node

Table 1: Transmission Line Performance for a 60 Ω line							
Electrodyn. Power(W)	$V_{sup.}$ (V)	$V_{mach.}$ (V)	P (W)	Q (var)	Δδ (°)	$\widehat{\Delta\delta}$ (°)	ΔV (60Ω)
53	210.9	208	73.23	-5.437	5.626	5.75	2.9
70	210.9	208	90.11	-11.46	8.438	7.08	2.9
140	211.0	208	168.8	-35.34	14.06	13.35	3.0
210	210.8	208	252.6	-69.79	22.5	20.23	2.8
250	x	208	x	x	x	x	x
53	211.5	198	71.67	30.11	5.627	5.90	13.5
70	211.2	198	88.17	25.68	8.435	7.27	13.2
140	210.5	198	168.1	-2.909	14.06	14.01	12.5
210	211.0	198	251.0	-39.36	22.5	21.14	13.0
250	211.4	198	301.7	-67.02	28.13	25.64	13.4
53	210.9	218	75.2	-44.64	5.626	5.63	-7.1
70	210.1	218	92.29	-48.54	8.432	6.95	-7.9
140	211.1	218	169.8	-68.71	14.06	12.80	-6.9
210	x	218	x	x	x	x	x
250	x	218	x	x	x	x	x

Figure 1: Transmission Line Performance for a 60 Ω Line.

Table 2: Transmission line performance for a 120 Ω line							
Electrodyn. Power(W)	**V_{sup}. (V)**	**V_{mach} (**	**P (W)**	**Q (var)**	**Δδ (°)**	$\widehat{\Delta\delta}$ (°)	**ΔV (120Ω)**
53	210.8	208	71.02	-10.05	11.25	11.21	2.8
70	210.8	208	89.05	-16.68	14.06	14.11	2.8
140	211.2	208	166.5	-54.33	28.13	27.07	3.2
200		208					
0	211.4	198	68.92	8.036	11.25	11.40	13.4
70	211.0	198	86.98	0.811	14.07	14.48	13.0
140	211.0	198	165.6	-39.54	28.12	28.42	13.0
210		198					
280		198					
53	211.0	218	72.55	-29.46	11.25	10.92	-7.0
70	210.8	218	90.52	-34.97	14.06	13.68	-7.2
140	211.0	218	167.8	-71.63	28.12	25.97	-7.0
160		218					

Figure 2 Transmission Line Performance for a 120 Ω Line.

Table 3: Transmission line performance for a 180 Ω line							
Electrodyn. Power(W)	V_{sup}. (V)	$V_{mach.}$ (V)	P (W)	Q (var)	Δδ (°)	$\widehat{\Delta\delta}$ (°)	ΔV (180Ω)
53	211	208.4	69.77	-14.35	16.87	16.60	2.6
70	211.4	208	86.57	-20.08	22.51	20.77	3.4
140	211.4	208.4	164.5	-81.06	47.82	42.25	3.0
150		208					
53	211.4	198.3	68.22	-2.183	16.96	17.04	13.1
70	211.1	198.3	85.92	-10.53	22.58	21.69	12.8
140	211.2	198	164.9	-75.4	47.8	45.24	13.2
150		198					
53	211.1	218.6	71.49	-27.24	16.87	16.20	-7.5
70	211.2	217.9	88.12	-33.33	22.5	20.17	-6.7
140		218					
150		218					

Figure 3 Transmission Line Performance for a 180 Ω Line

7.

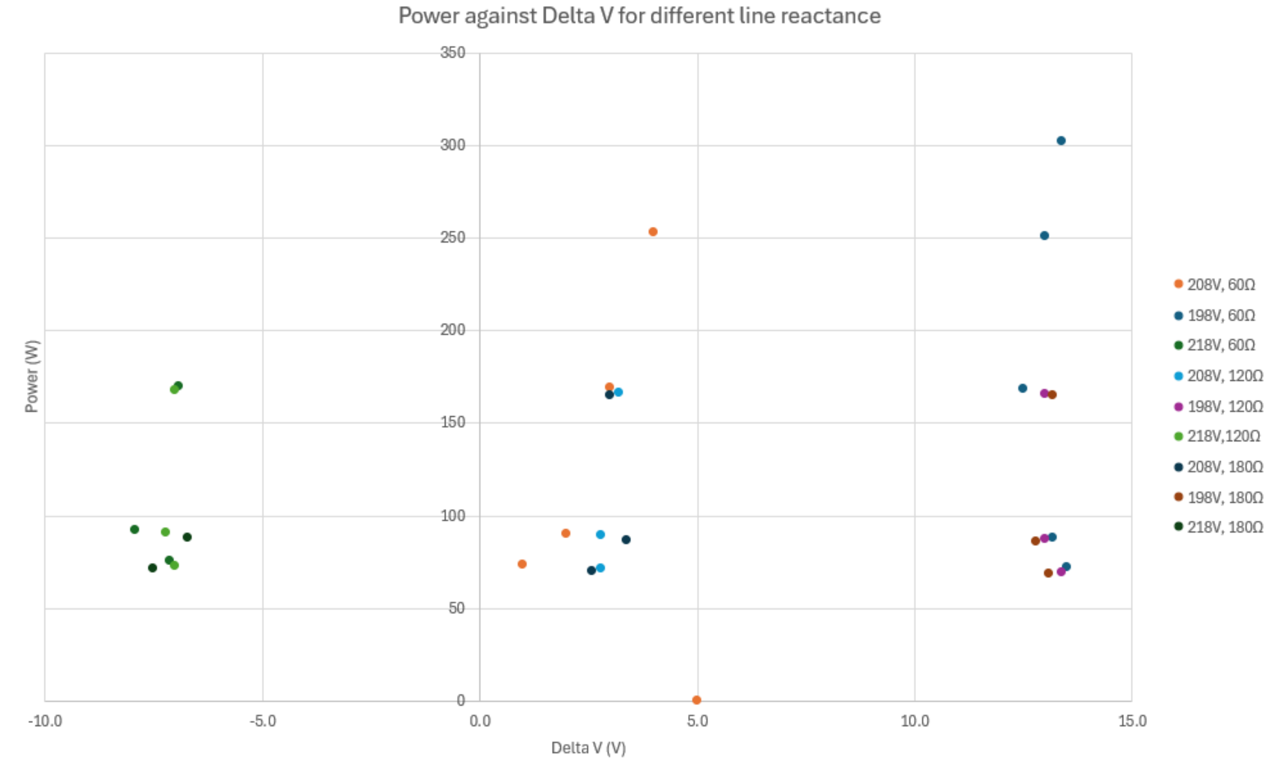


Figure 4 Power against Delta V for different line reactance

8. How do you observe angle difference values vary from theoretical values?

The measured values and calculated/theoretical values are close to each other.

9.

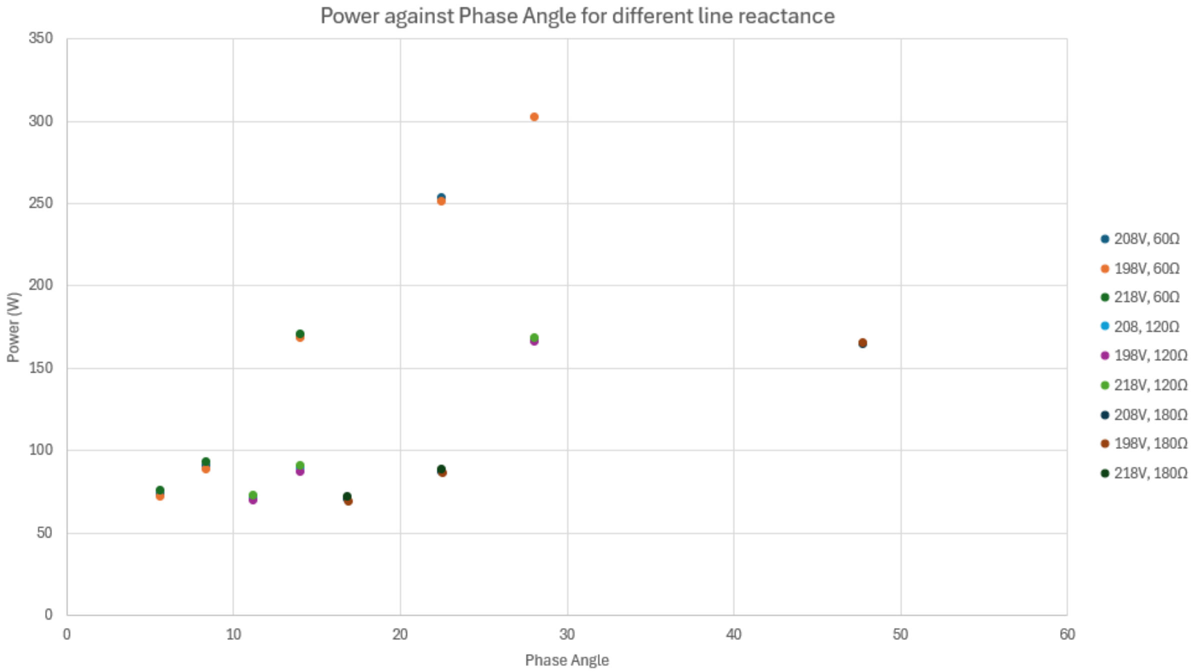


Figure 5 Power against Phase Angle for different line reactance

10.

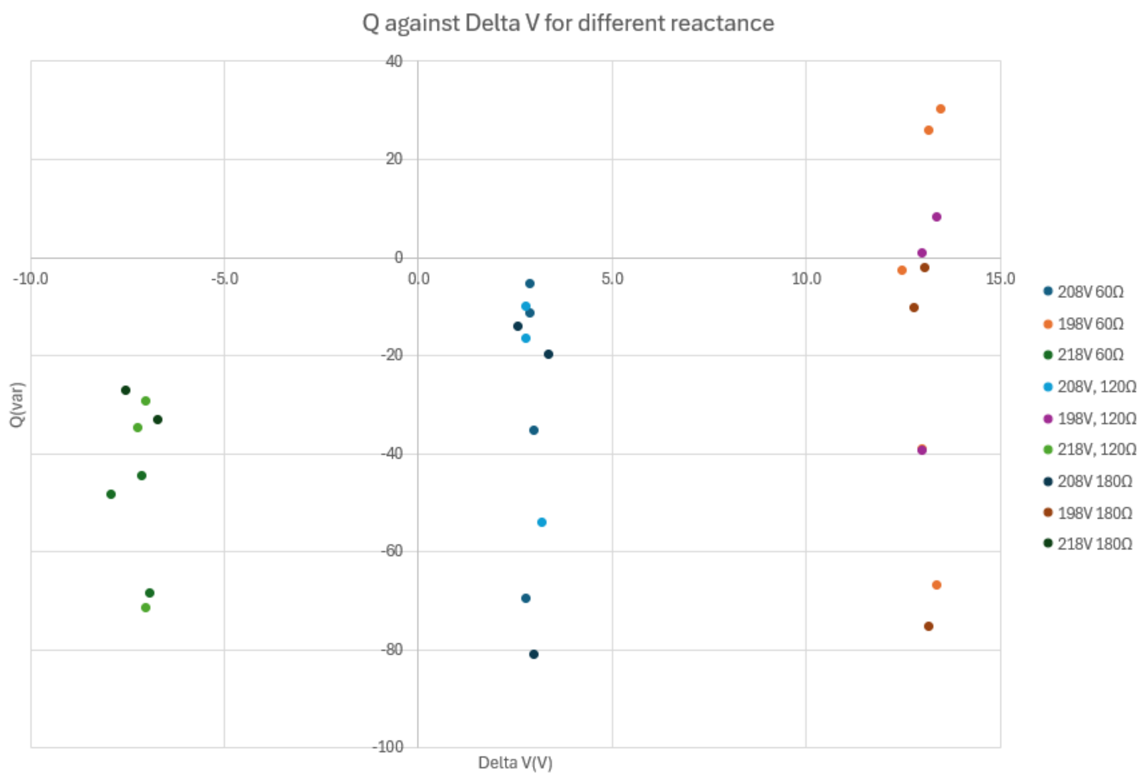


Figure 6 Q against delta V for different line reactance

11.

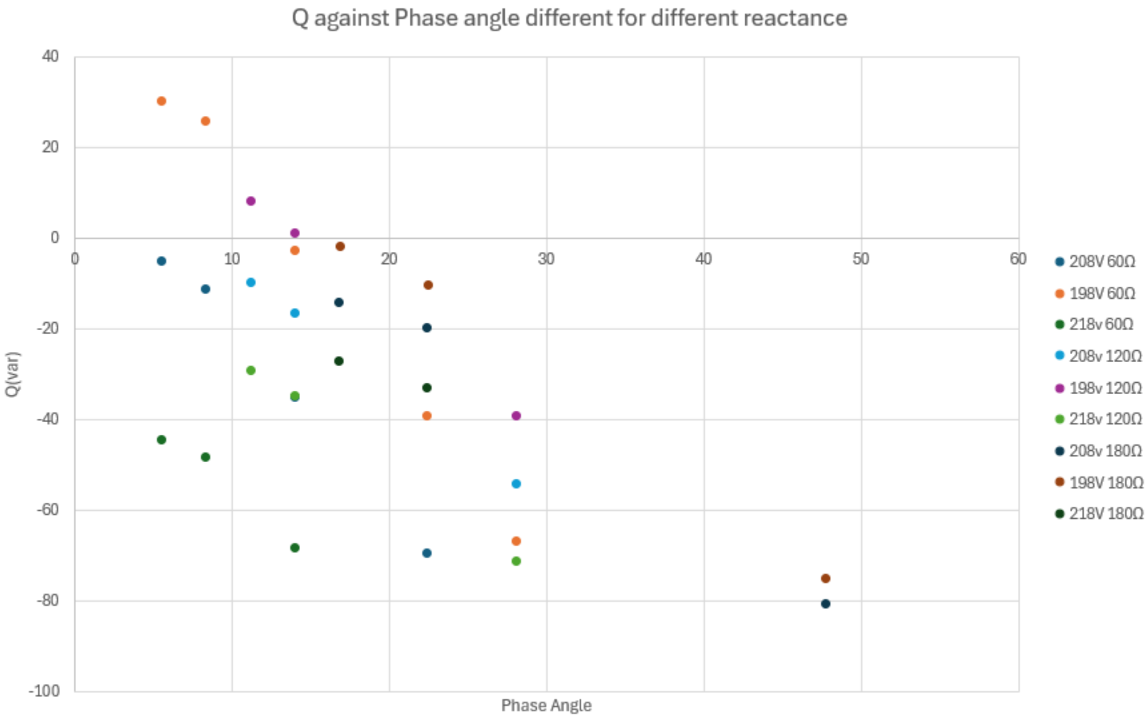


Figure 7 Q against phase angle difference for different line reactance

12. As X increases from 60Ω to 120Ω, both active power and reactive power decreases. But from 120Ω to 180Ω, there is no major difference. The active power is not affected by ΔV. The reactive power increases as ΔV increases. As Δδ increases, active power increases and the reactive power decreases.

13. For the flow of active and reactive power to be in opposite directions, they need to have different signs. The case when electrodynamical power is 70W and machine voltage is 208V is an example that satisfies this requirement. ΔV is a negative value of -7.5 and Δδ is measured to be 16.87 degrees which is very close to the calculated desire value.

Part II: Slack to PQ node

Table 4 : Transmission line performance for a 180 Ω line; PQ receiving end

R (Ω)	X (Ω)	$V_{sup.}$ (V)	$V_{load.}$ (V)	$I_{load.}$ (A)	P (W)	Q (var)	Δδ (°)	S (VA)
0	0	210.4	210.5	0.007	0.227	-0.119	0	2.09
300	0	210.8	172.9	0.34	101.7	-0.597	28.1	101.7
0	300	210.5	175.9	0.339	8.856	102.7	0	103.2
300	300	210.5	119.5	0.341	52.71	46.99	22.52	70.64
2	0	210.2	149	0.433	111.7	-0.751	39.35	111.7
200	300	210.4	110.2	0.398	64.64	39.74	30.94	75.91
171	0	210.2	139	0.466	112.1	-0.738	45	112.1

Figure 8 Transmission line performance for a 180 Ω Line, PQ receiving end

4.

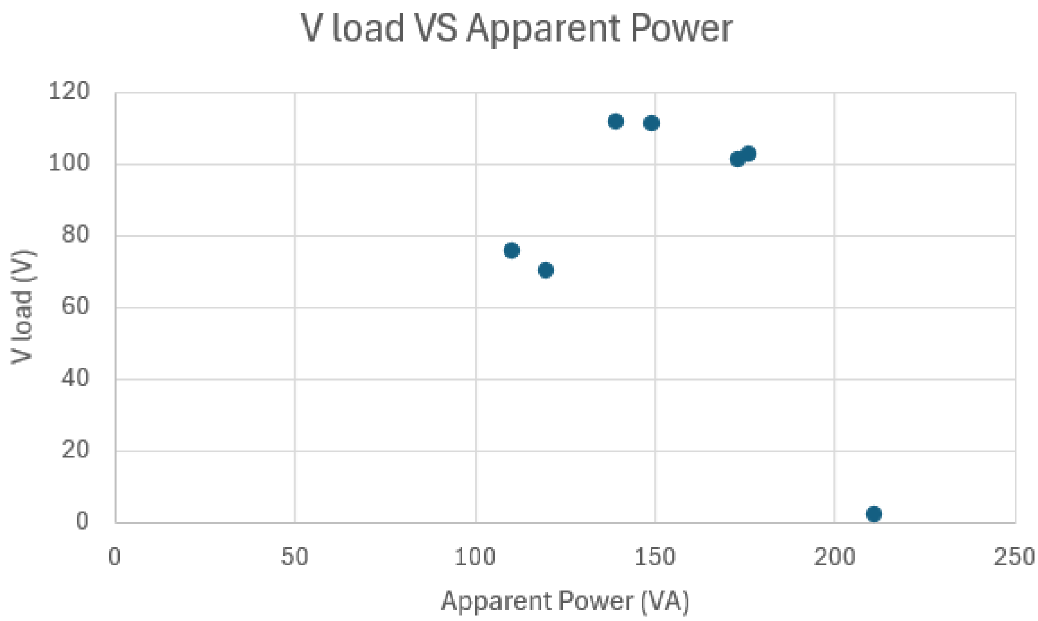


Figure 9 V load vs. Apparent Power

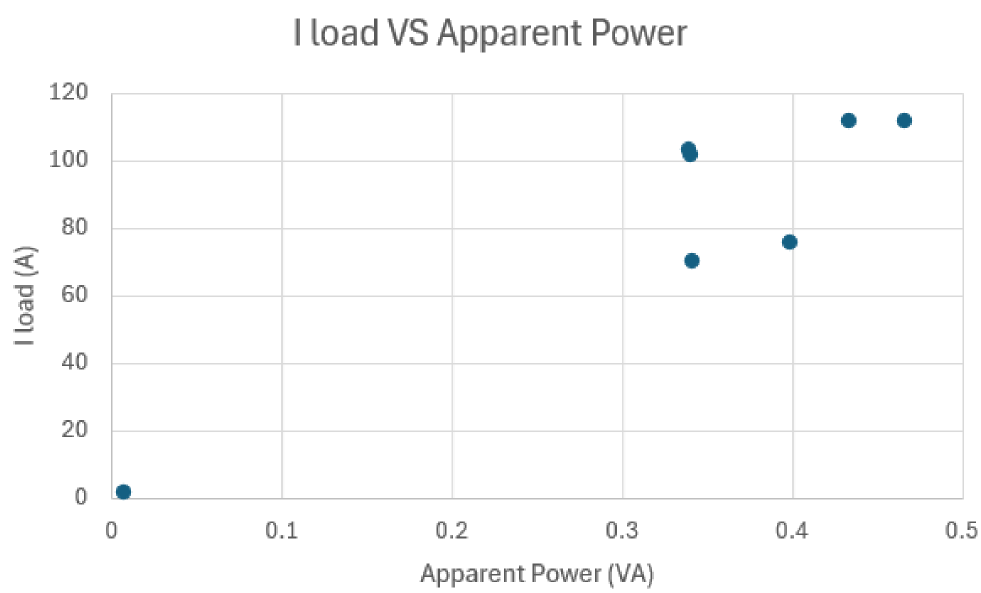


Figure 10 I load VS Apparent power

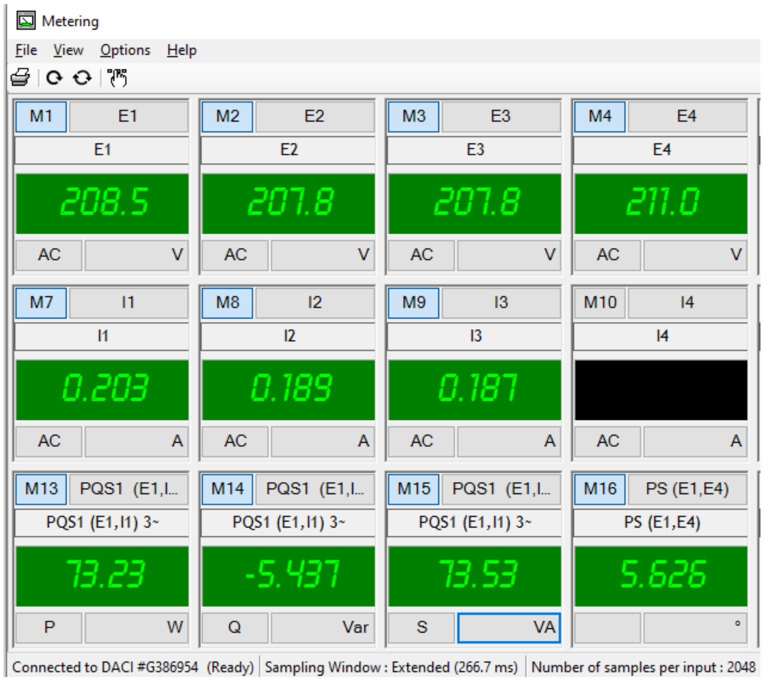
As the current I increases, apparent power increases. As the voltage V increases, apparent power decreases.

5. The active and reactive power are consistently in opposite direction in Part I of the experiment for 180 Ohm line. For a floating voltage in this section, it is not necessarily true. The general principles of ac power flow are the same regardless of the transmission line termination.

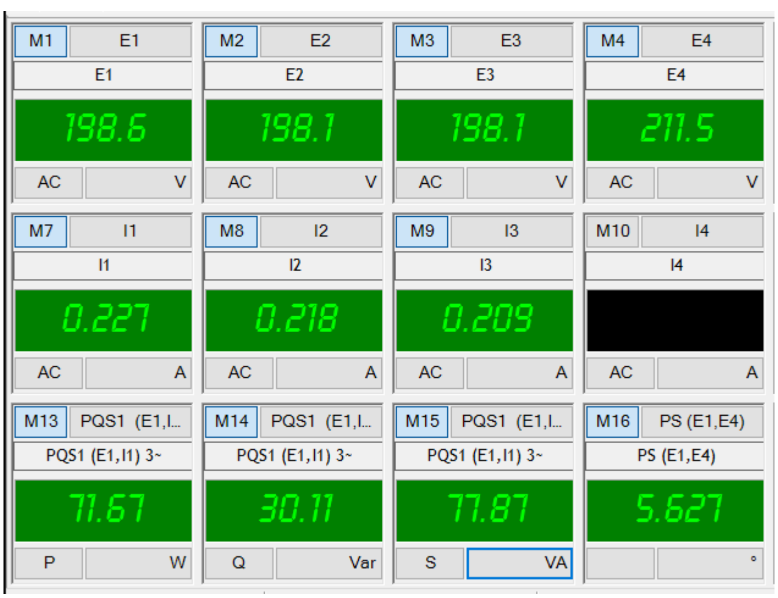
Appendix

1. $R_{line} = 60\ \Omega$

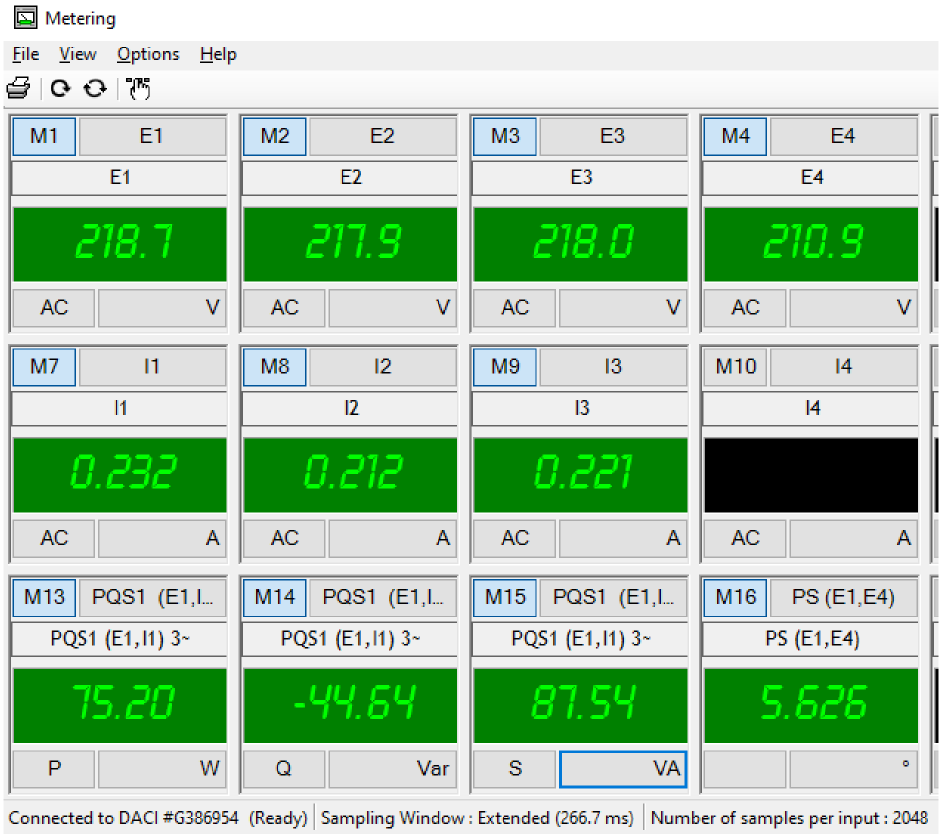
$P_{dynamometer}$ 53.12 W, $V_{mach} = 208$ V



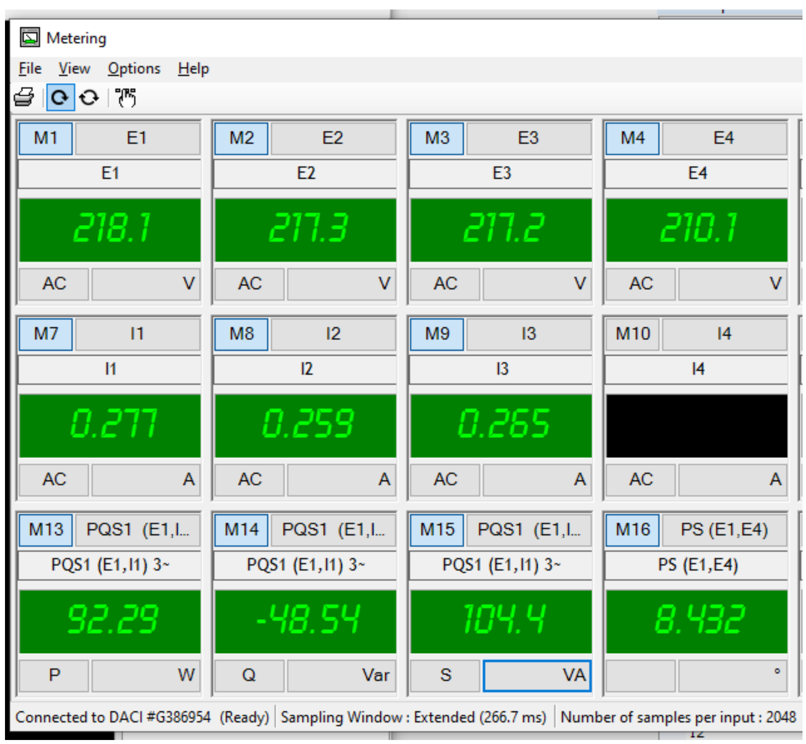
$P_{dynamometer}$ 53.13W, $V_{mach} = 198$ V



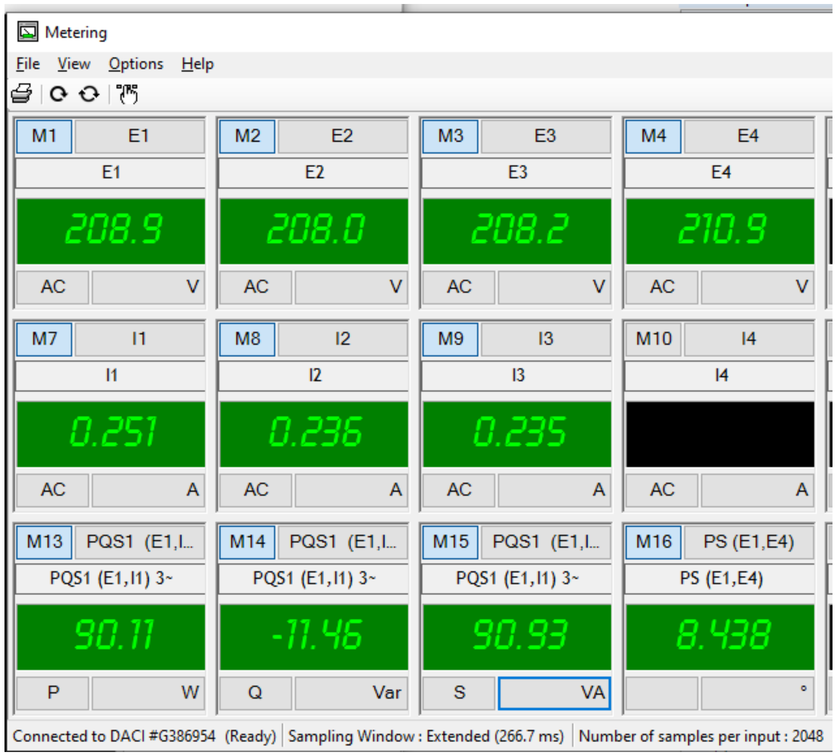
$P_{dynamometer}$ 53.12W, V_{mach} = 218 V



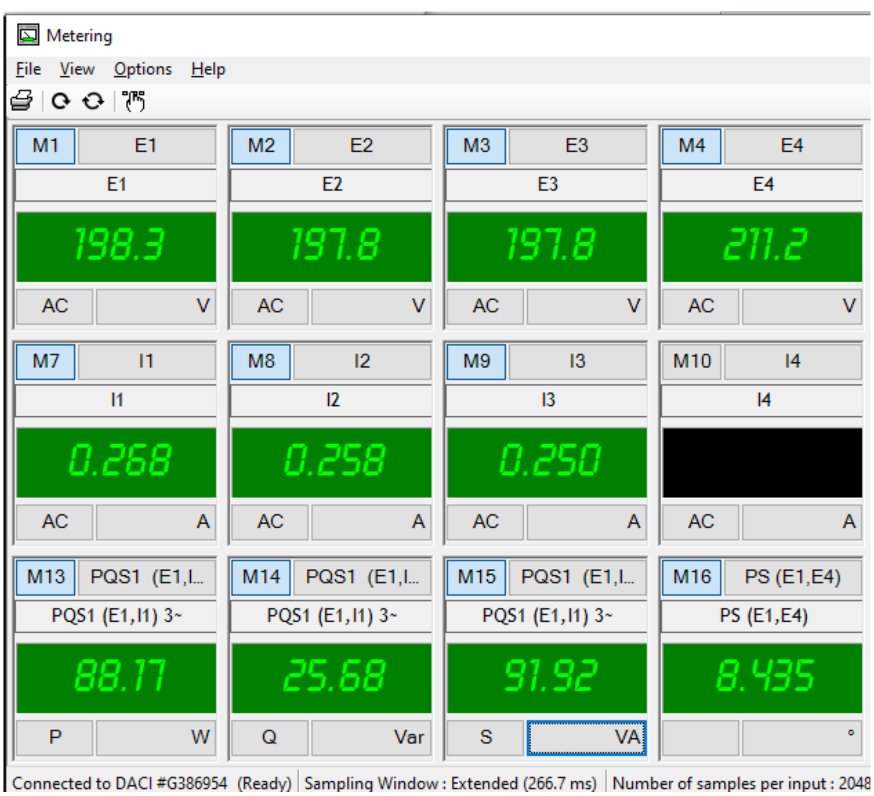
$P_{dynamometer}$ 70W, V_{mach} = 218 V



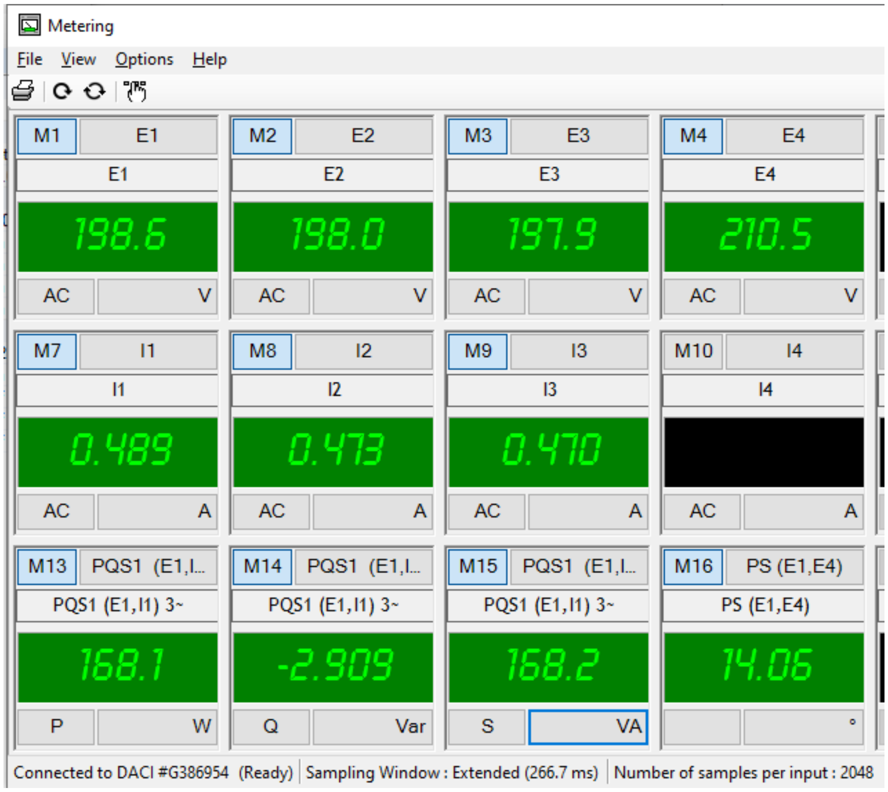
$P_{dynamometer}$ 70W, V_{mach} = 208 V



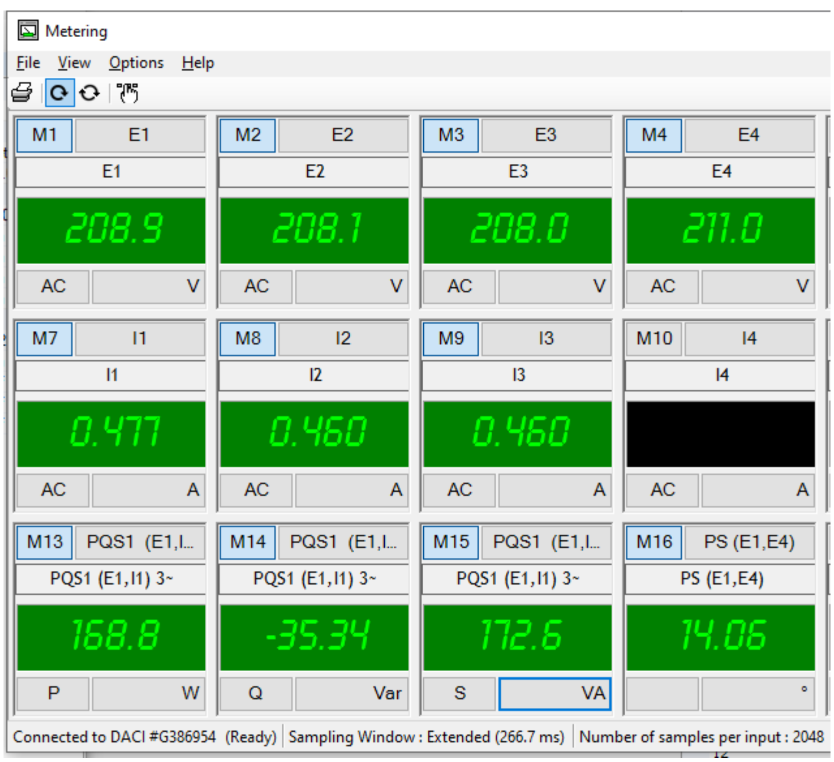
$P_{dynamometer}$ 70W, V_{mach} = 198 V



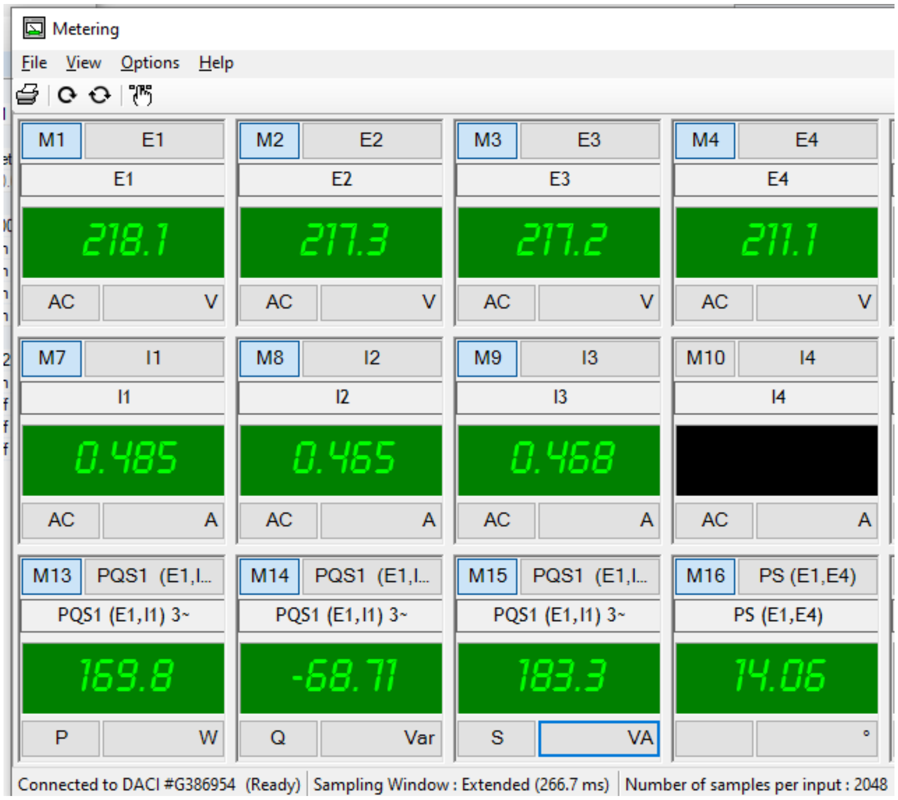
$P_{dynamometer}$ 140W, V_{mach} = 198 V



$P_{dynamometer}$ 140W, V_{mach} = 208 V

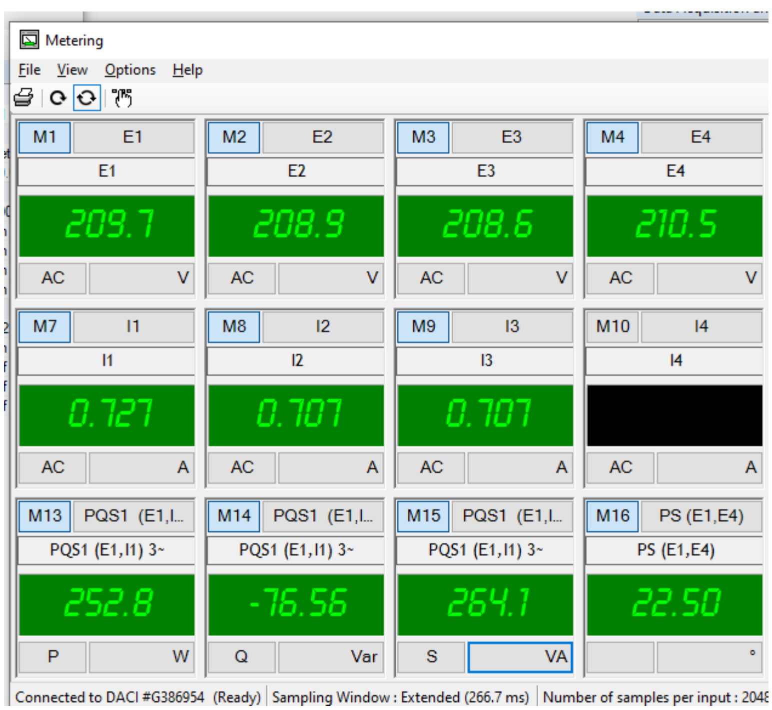


$P_{dynamometer}$ 140W, V_{mach} = 218 V

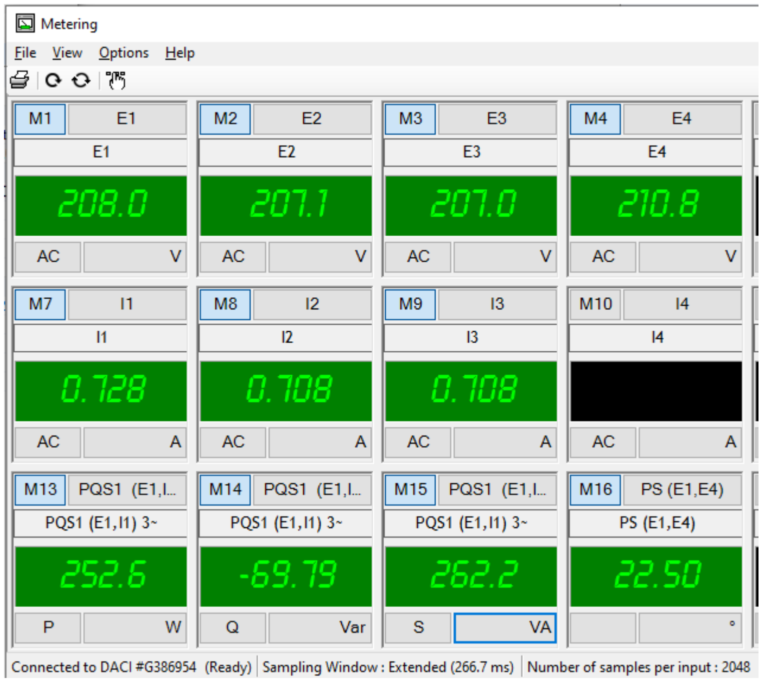


$P_{dynamometer}$ 210W, V_{mach} = 218 V

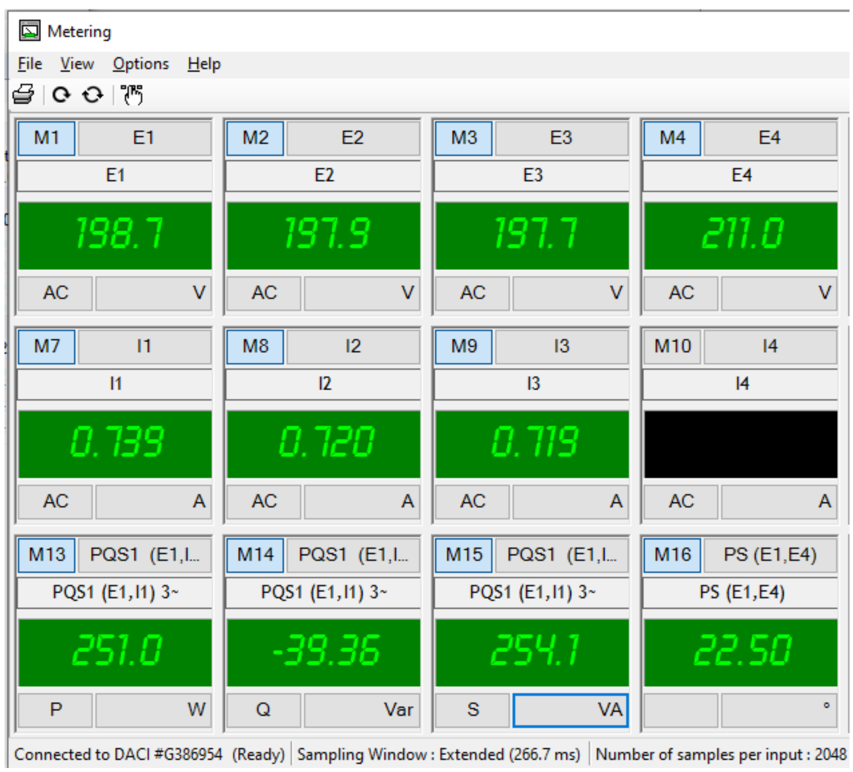
X because we can't turn anymore



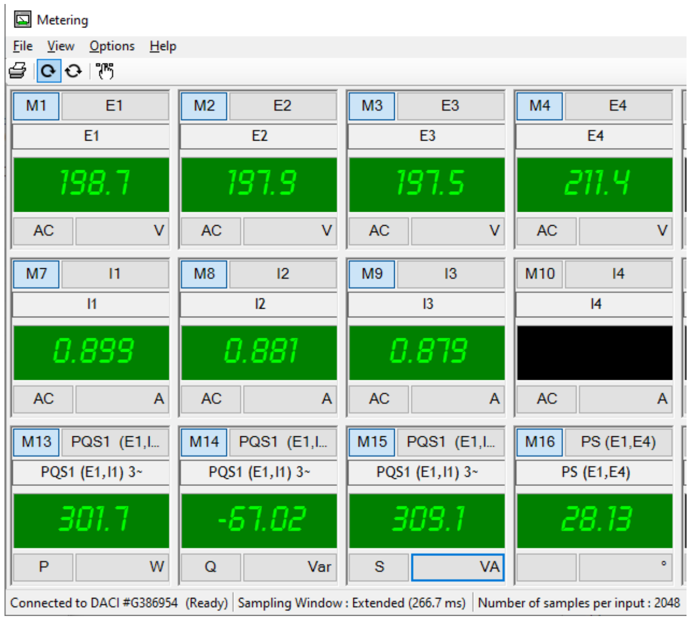
$P_{dynamometer}$ 210W, V_{mach} = 208 V



$P_{dynamometer}$ 210W, V_{mach} = 198 V



$P_{dynamometer}$ 250W, V_{mach} = 198 V



$P_{dynamometer}$ 250W, V_{mach} = 208 V

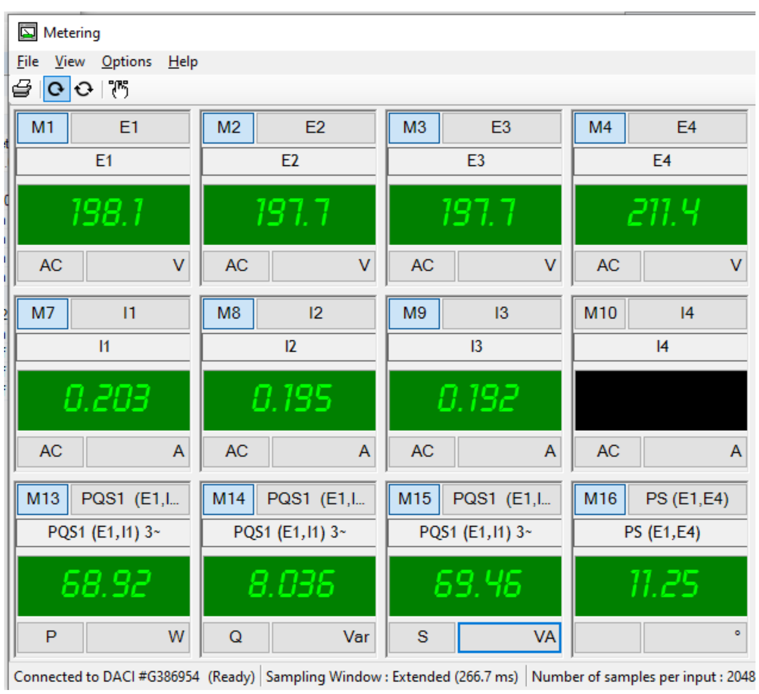
x

$P_{dynamometer}$ 250W, V_{mach} = 218 V

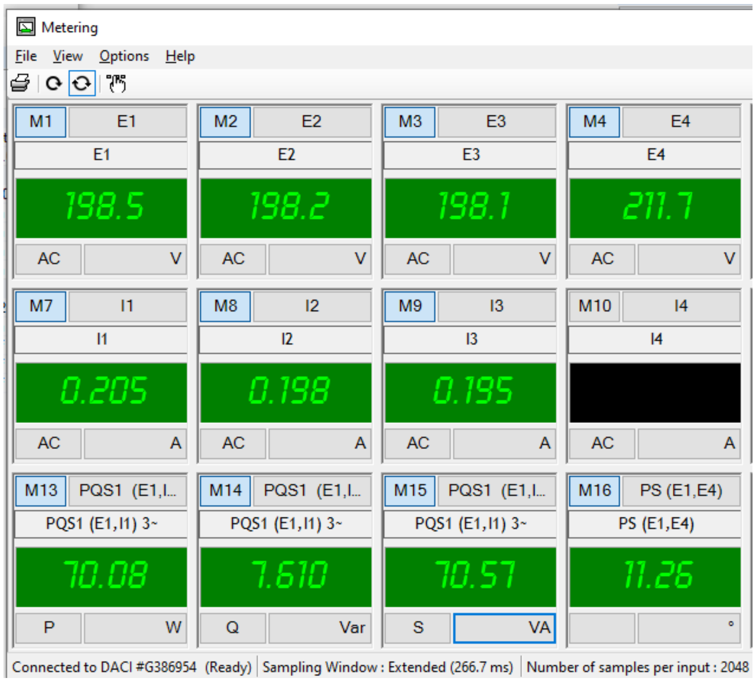
x

2. R_{line} = 120 Ω

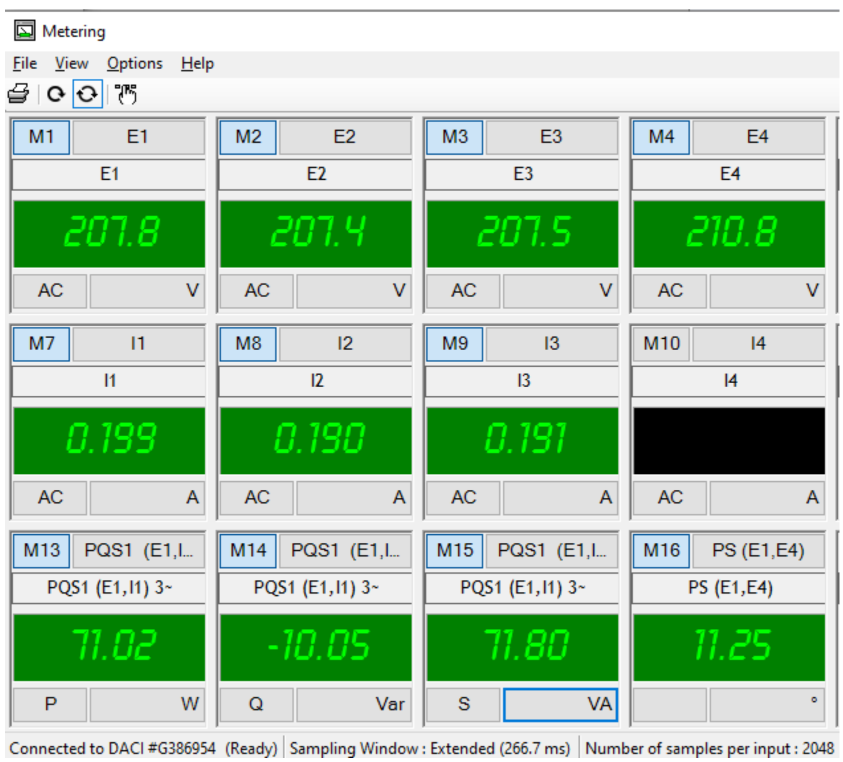
$P_{dynamometer}$ = 0 W, V_{mach} = 198 V



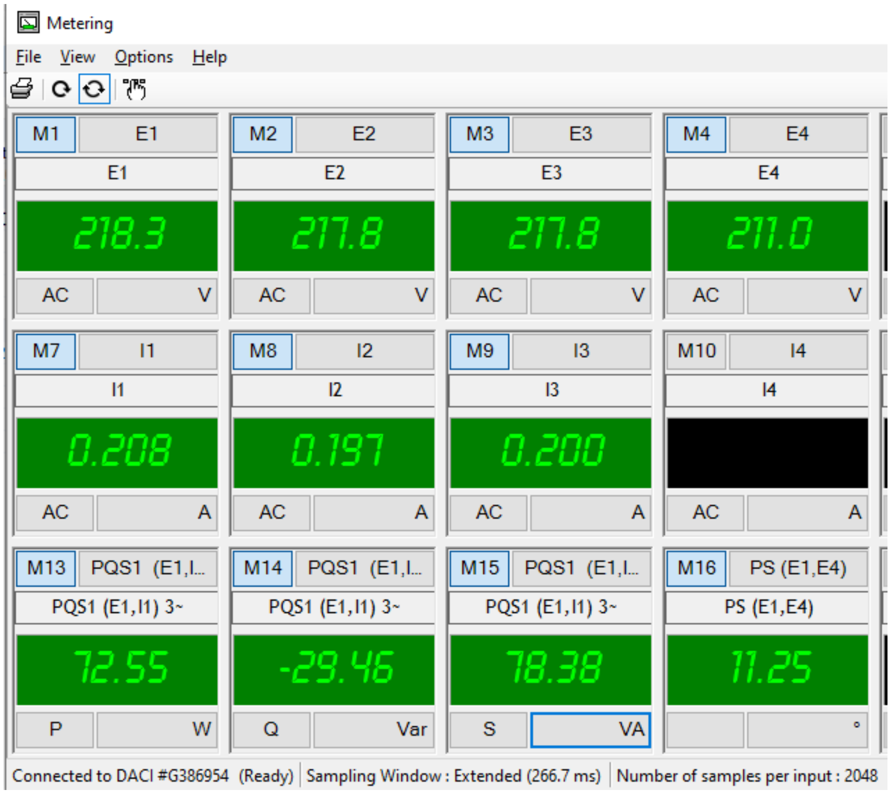
$P_{dynamometer}$ = 53 W, V_{mach} = 198 V



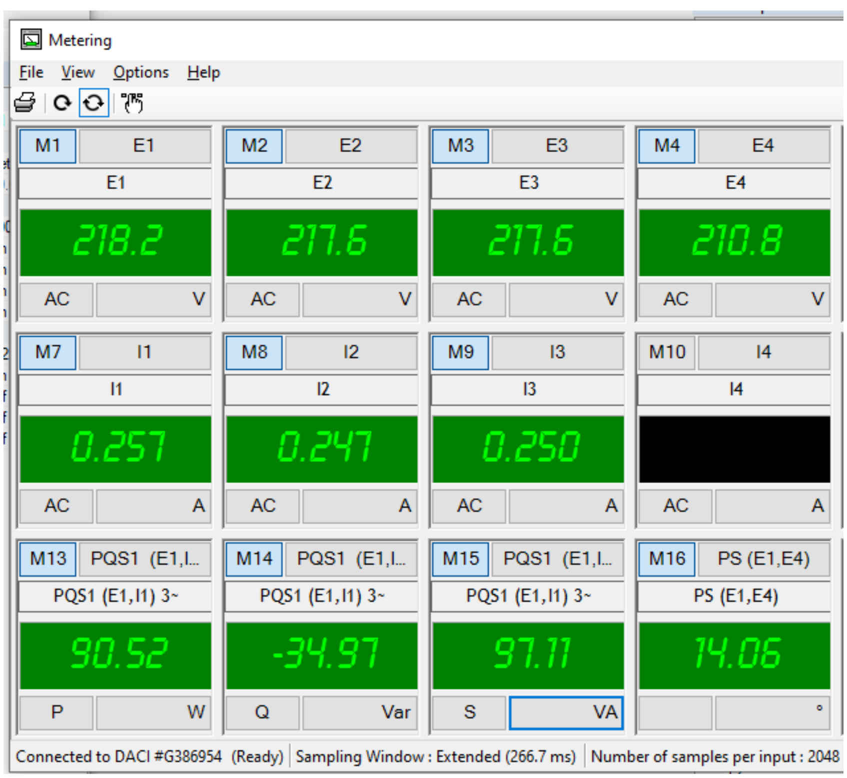
$P_{dynamometer}$ = 53 W, V_{mach} = 208 V



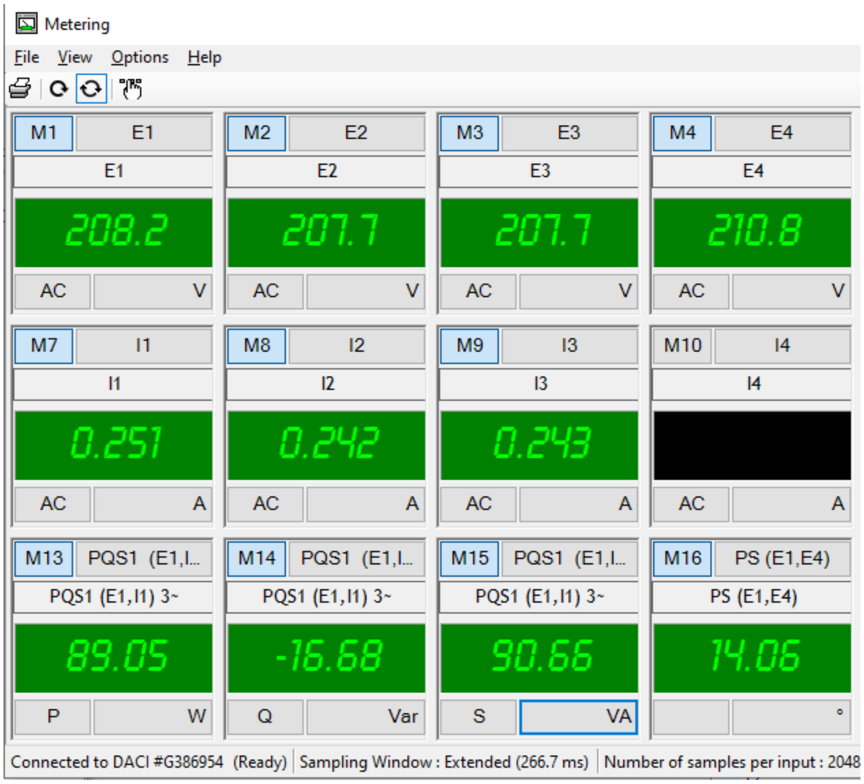
$P_{dynamometer}$ = 53 W, V_{mach} = 218 V



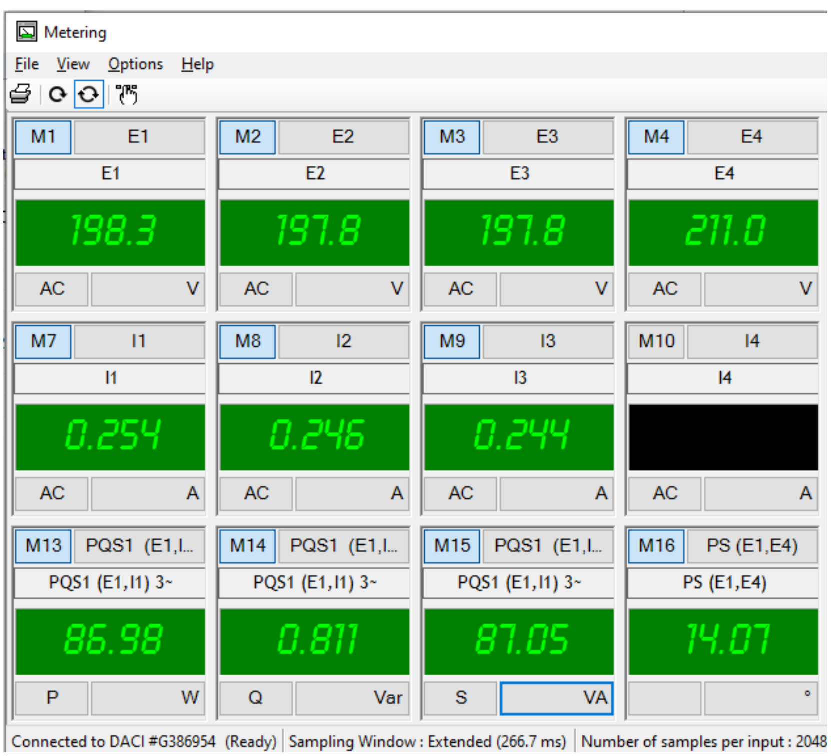
$P_{dynamometer}$ = 70 W, V_{mach} = 218 V



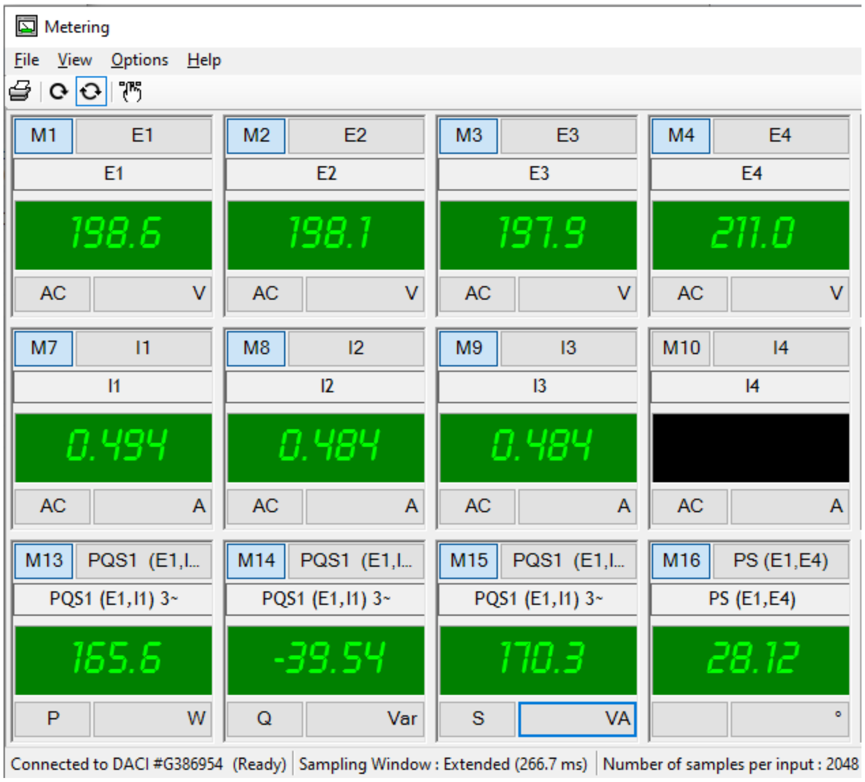
$P_{dynamometer}$ = 70 W, V_{mach} = 208 V



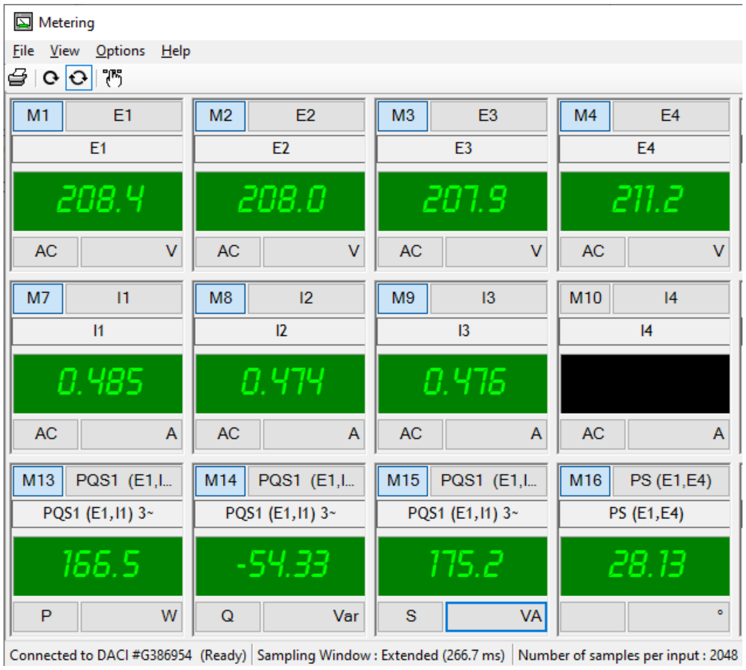
$P_{dynamometer}$ = 70 W, V_{mach} = 198 V



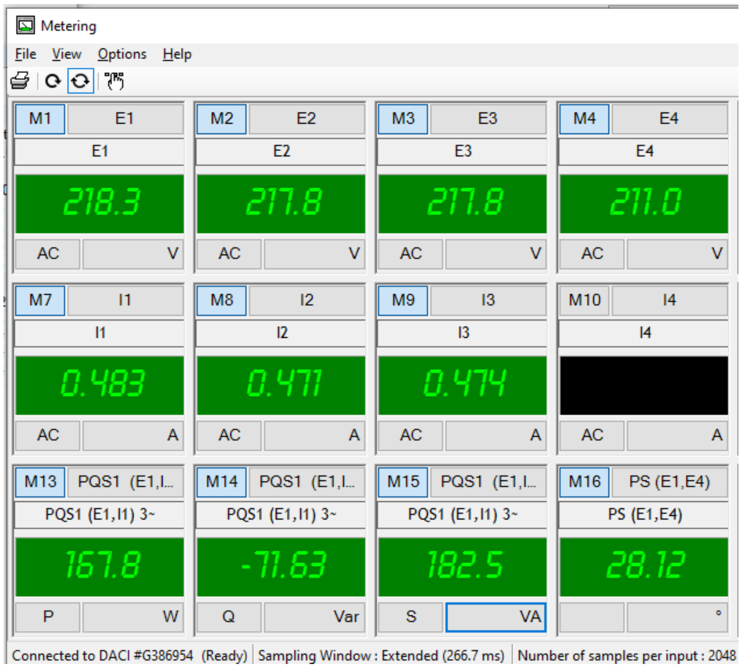
$P_{dynamometer}$ = 140 W, V_{mach} = 198 V



$P_{dynamometer}$ = 140 W, V_{mach} = 208 V



$P_{dynamometer}$ = 140 W, V_{mach} = 218 V



$P_{dynamometer}$ = 160 W, V_{mach} = 218 V

x

$P_{dynamometer}$ = 200 W, V_{mach} = 208 V

x

$P_{dynamometer}$ = 210 W, V_{mach} = 218 V

X

$P_{dynamometer}$ = 280 W, V_{mach} = 198 V

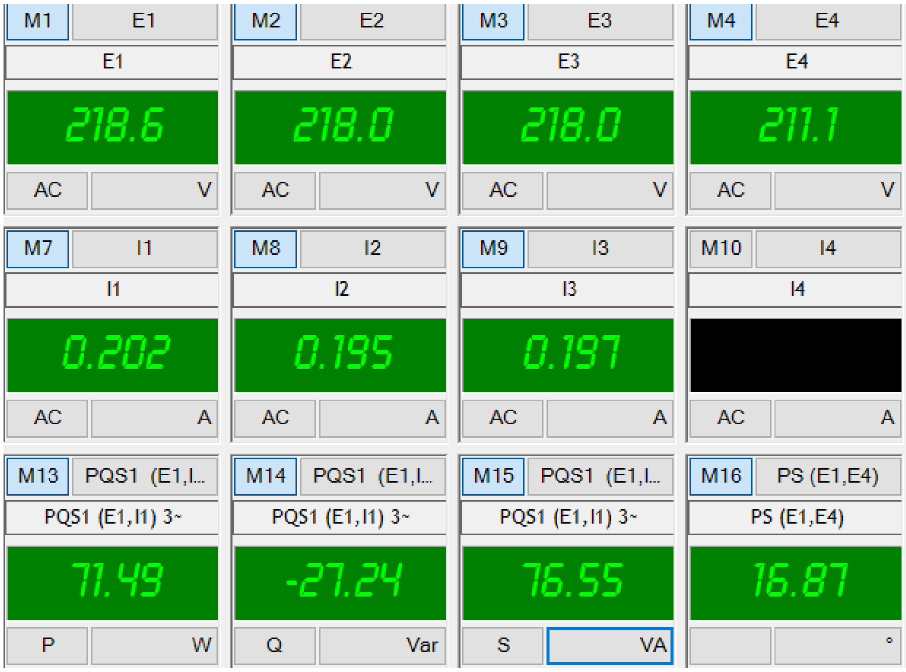
x

3. R_{line} = 180 Ω

$P_{dynamometer}$ = 53 W, V_{mach} = 198 V

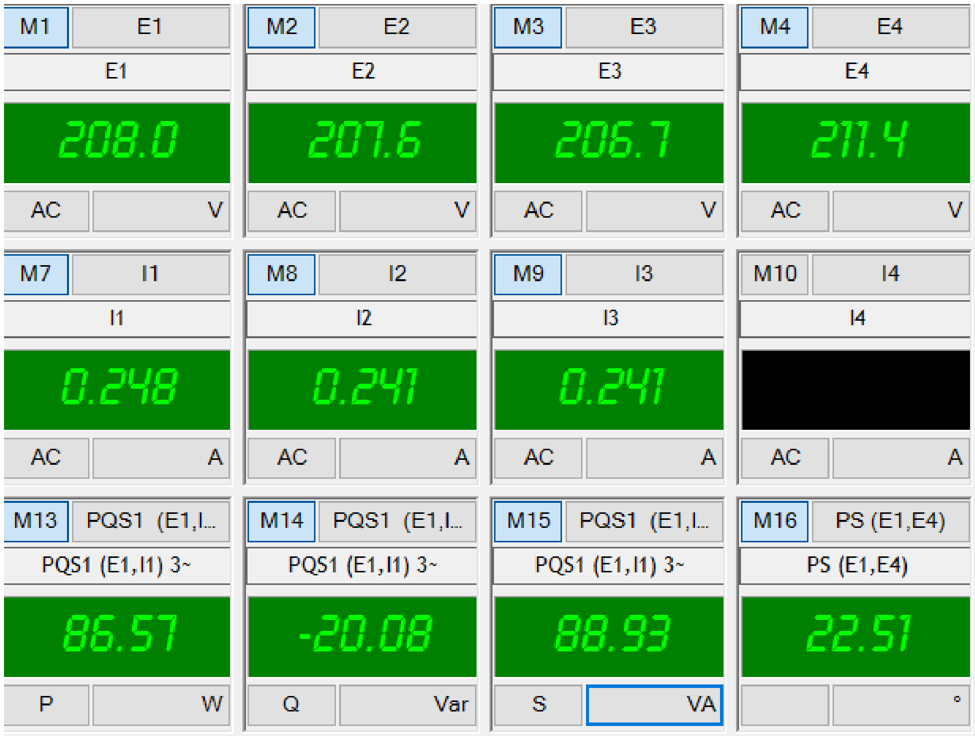
$P_{dynamometer}$ = 53 W, V_{mach} = 208 V

$P_{dynamometer} = 53\ W$, $V_{mach} = 218\ V$



$P_{dynamometer} = 70\ W$, $V_{mach} = 198\ V$

$P_{dynamometer} = 70$ W, $V_{mach} = 208$ V

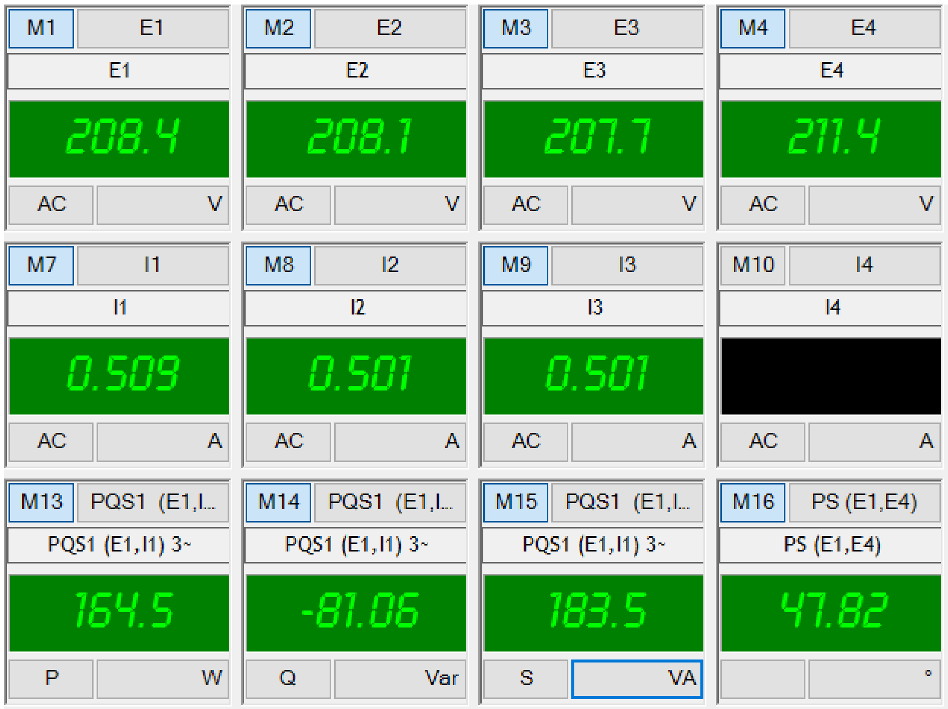


$P_{dynamometer} = 70$ W, $V_{mach} = 218$ V

$P_{dynamometer}$ = 140 W, V_{mach} = 218V

x

$P_{dynamometer}$ = 140 W, V_{mach} = 208 V



$P_{dynamometer}$ = 140 W, V_{mach} = 198 V

$P_{dynamometer}$ = 150 W, V_{mach} = 198 V

x

$P_{dynamometer}$ = 150 W, V_{mach} = 208 V

x

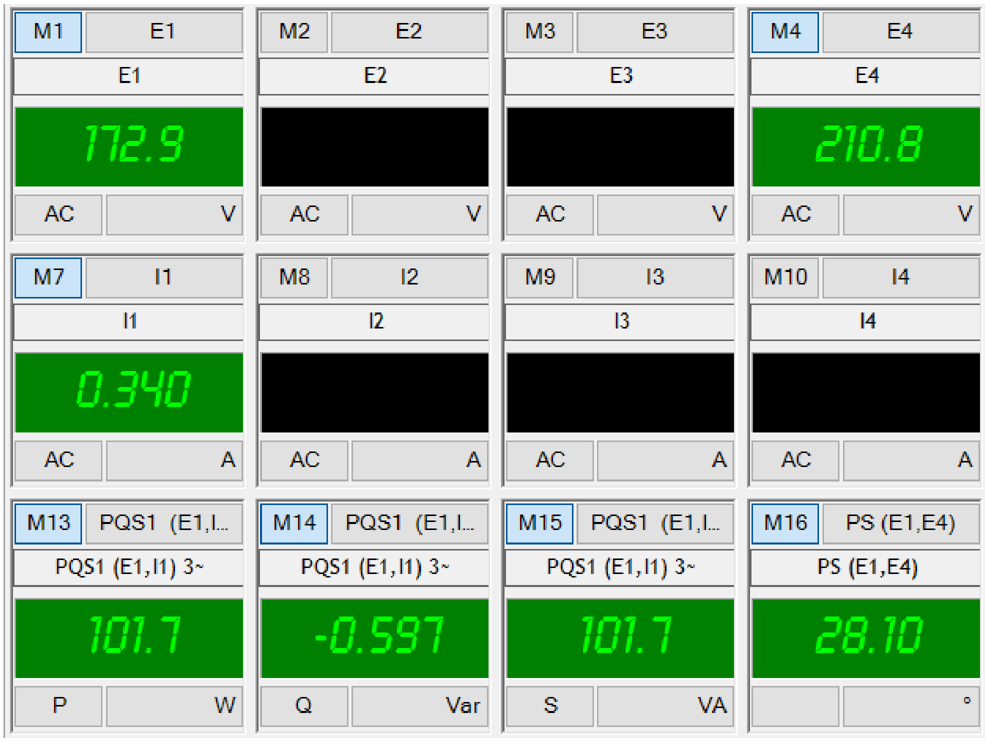
$P_{dynamometer}$ = 150 W, V_{mach} = 218 V

x

4. Part II: R_{line} = 180 Ω

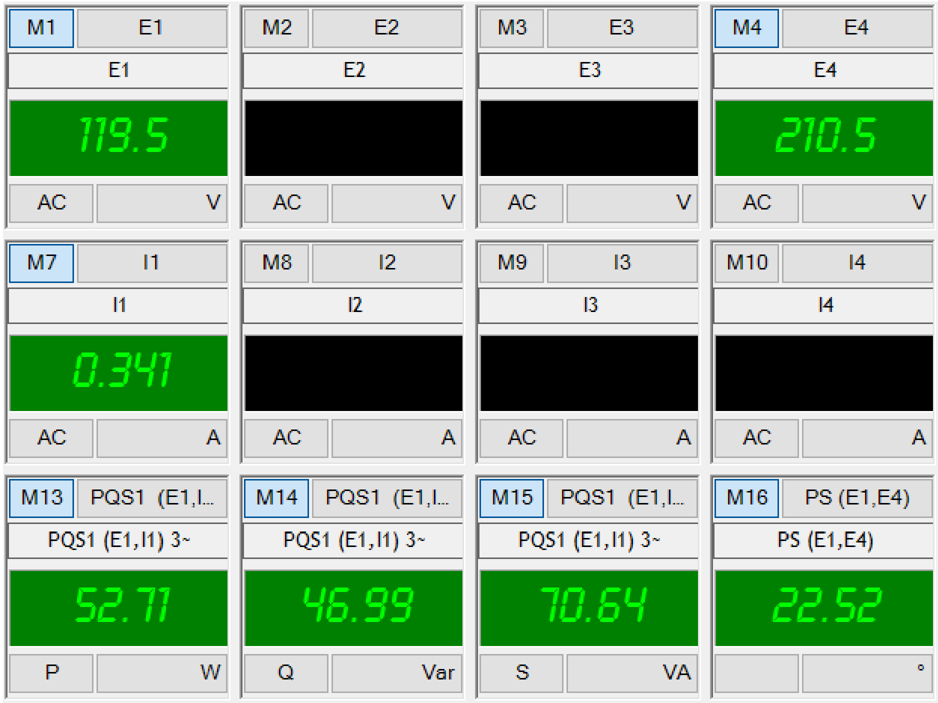
R = 0 Ω, X = 0 Ω

R = 300 Ω, X = 0 Ω

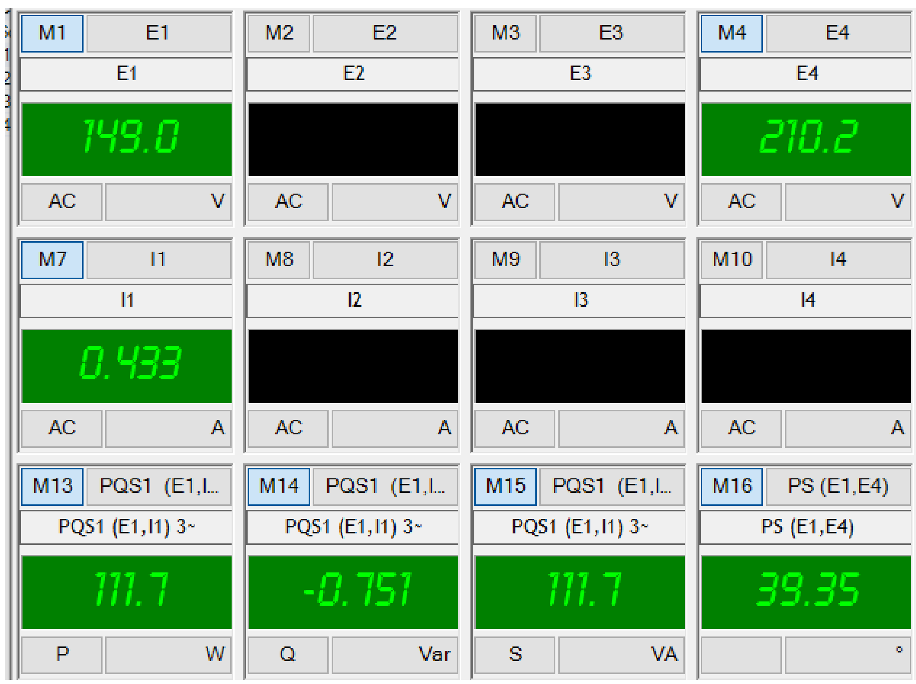


R = 0 Ω, X = 300 Ω

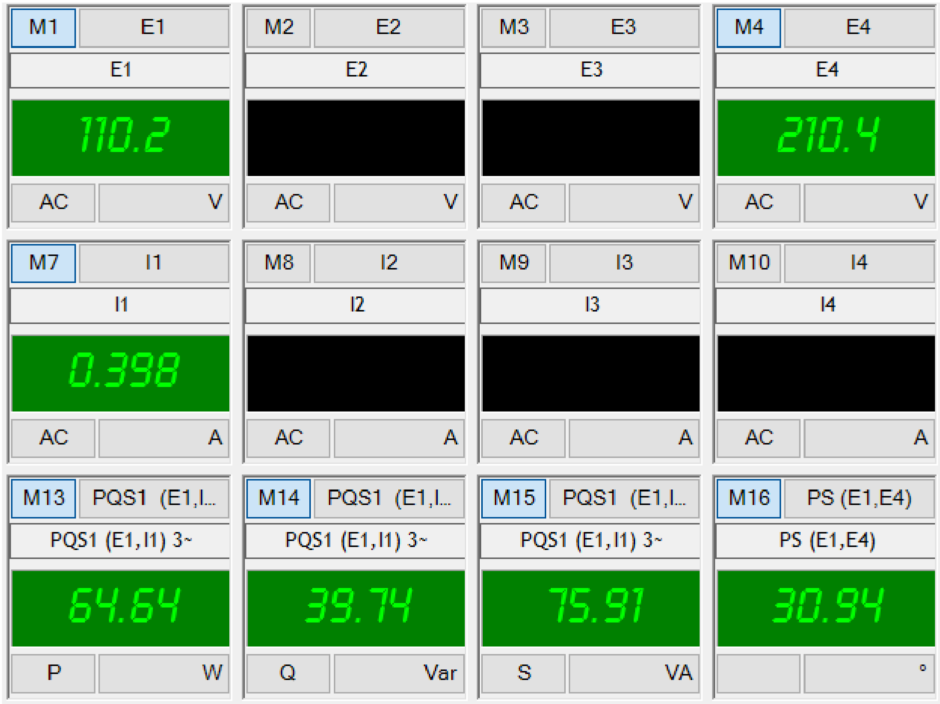
R = 300 Ω, X = 300 Ω



R = 200 Ω, X = 0 Ω



R = 200 Ω, X = 300 Ω



R = 171 Ω, X = 0 Ω