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EBU-100

Energy Bank Unit

Test Report

for

DMI Manufacturing, Inc.

by

Wilkes University
School of Science and Engineering
Division of Engineering and Physics

1. **Executive Summary:** This report presents the test setup and results for the DMI Manufacturing, Inc Energy Bank Unit Model 100 – EBU-100. The intent of the test is to investigate the power savings and harmonic filtering described in the product literature. Wilkes University performed the testing independently of the manufacturer.

   The test results will show that with the EBU-100 installed as illustrated in figure 1 will reduce the power measured at the source meter an average of 33%. The test load was variable from 0.4 kW to ¾ kW. When the EBU-100 was switched on the power meter reading reduced to between 0.3 kW to ½ kW respectively with no loss of motor speed or torque.

2. **Test Setup:** The EBU-100 is an energy saving unit. It is intended to be installed in parallel to service meter and all household loads. A typical block diagram installation is given in figure 1.

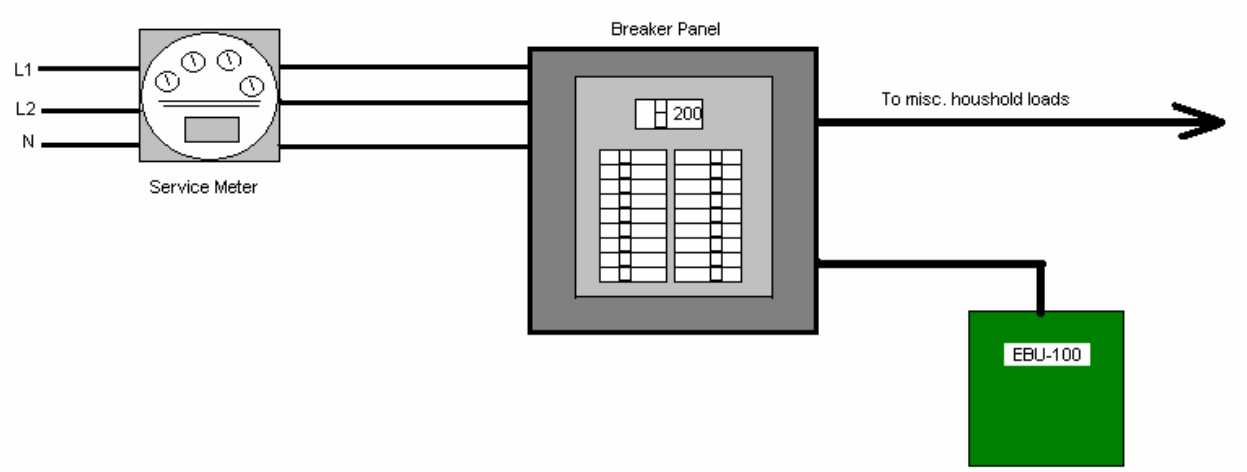

Figure 1 EBU-100 Typical Installation Block Diagram

a. **Input Power:** In order to mimic this installation a 240VAC single phase circuit was developed. It consists of a Buck-Boost Transformer to step the 120 VAC single phase line to 240 VAC. Figure 2 illustrates the transformer connections.

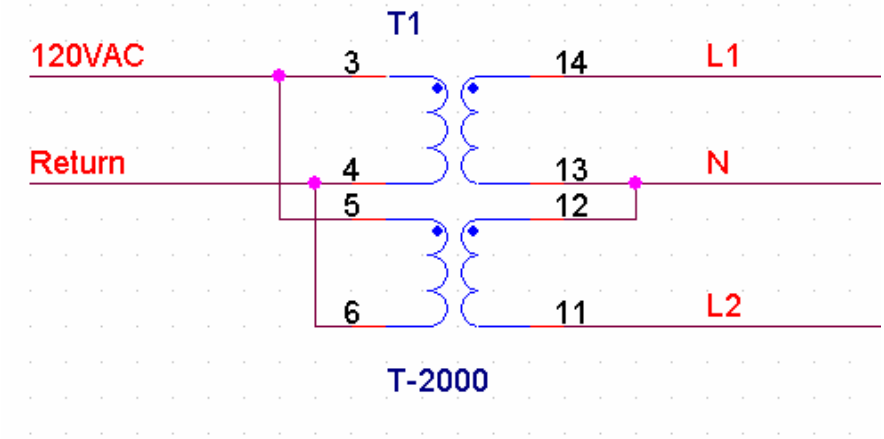

Figure 2 Buck-Boost Transformer

b. **Metering:** The service meter was replicated by using a Hampden AC-Watt Meter ACWM-100 and an AC Volt/Amp Meter ACVA-100. Figure 3 is the schematic diagram for this circuit. All other measurements are made with an Agilent 34401 Digital Multimeter.

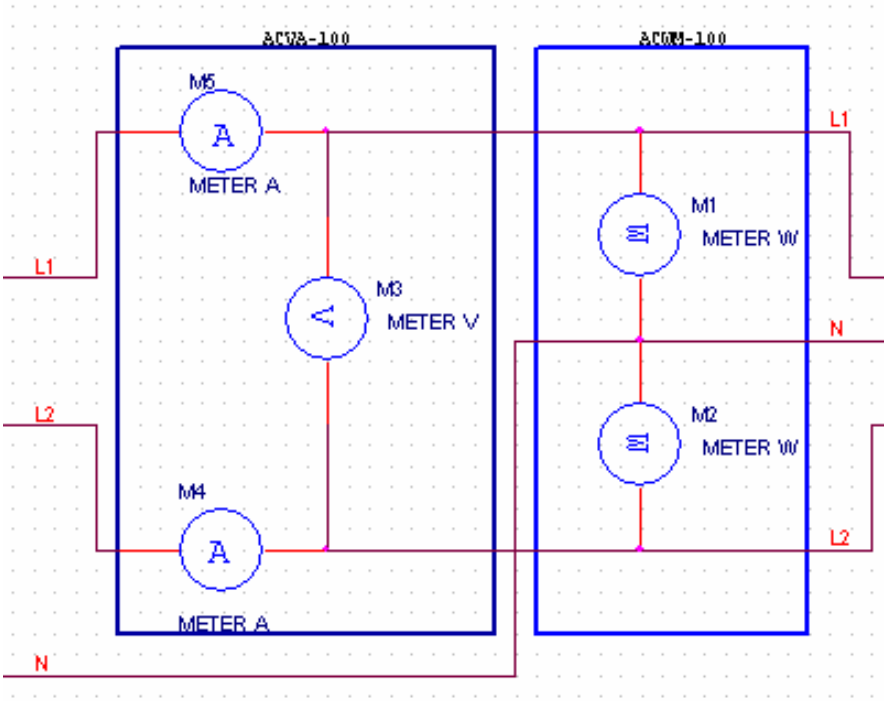

Figure 3 Service Watt Meter

c. **Test Points:** Current shunt resistors were added to provide measurement automation. Two shunts were placed in series on each line input and one shunt is in series before each load. In conjunction with each current shunt, test points for measuring voltage across the input terminals and load terminals were provided. Figure 4 shows the shunts and voltage test points.

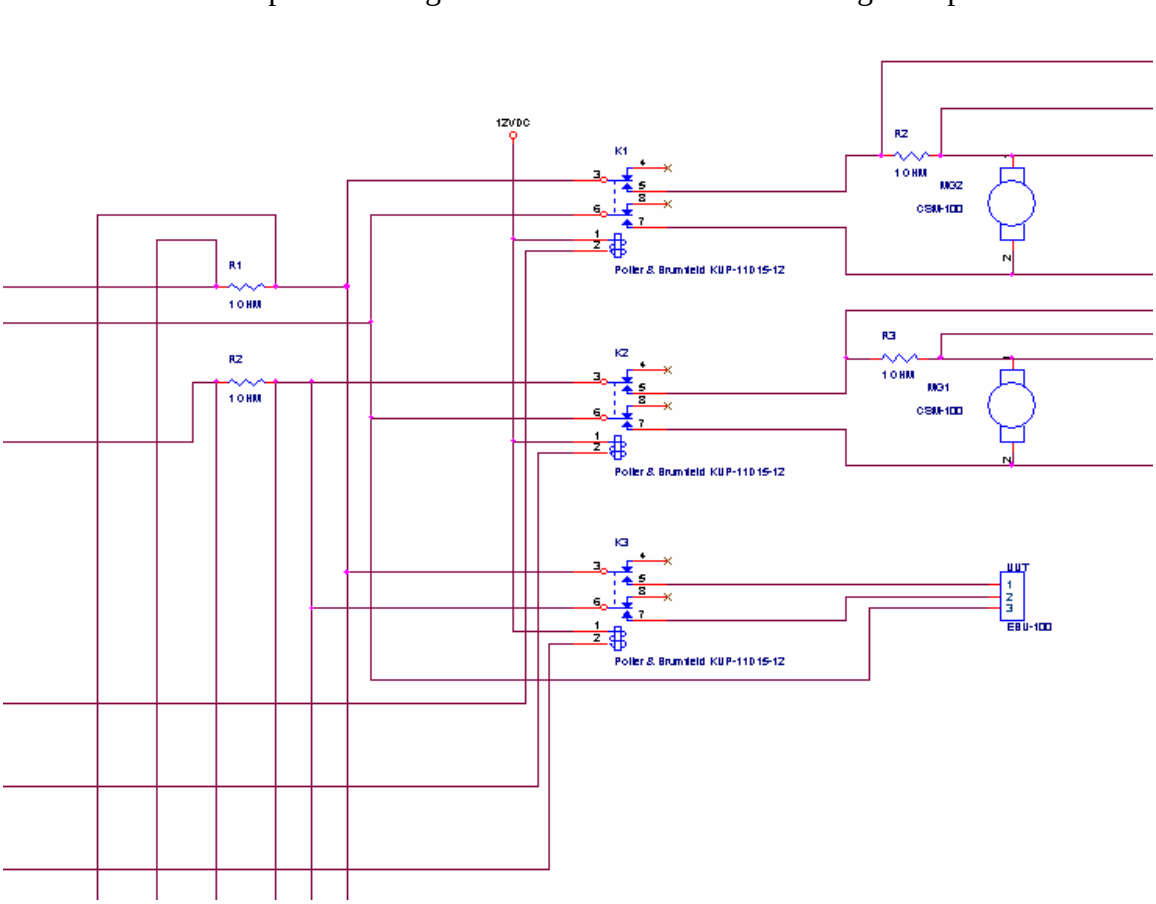

Figure 4 Current Shunts and Voltage Test Points.

The test points are multiplexed to the DMM through the E1364A relay card.

d. **Load:** Figure 4 also shows the loads as motors. The actual loads were a combination of CSM-100 motors and 700W resistive loads. The CSM-100 is a 115VAC, 5.8A, 1750RPM capacitor start motor. The resistive load can be switched in manually starting at 50W and increasing in 50W increments to 700W maximum. The CSM-100 can also be manually switched off/on. For this test both loads were set to maximum.

e. **Relay Control:** Finally, the line power was switched to two capacitor start motors and the EBU-100 through three relays. The relays are controlled by a transistor amplifier and Digital I/O data acquisition module as shown in Figure 5.

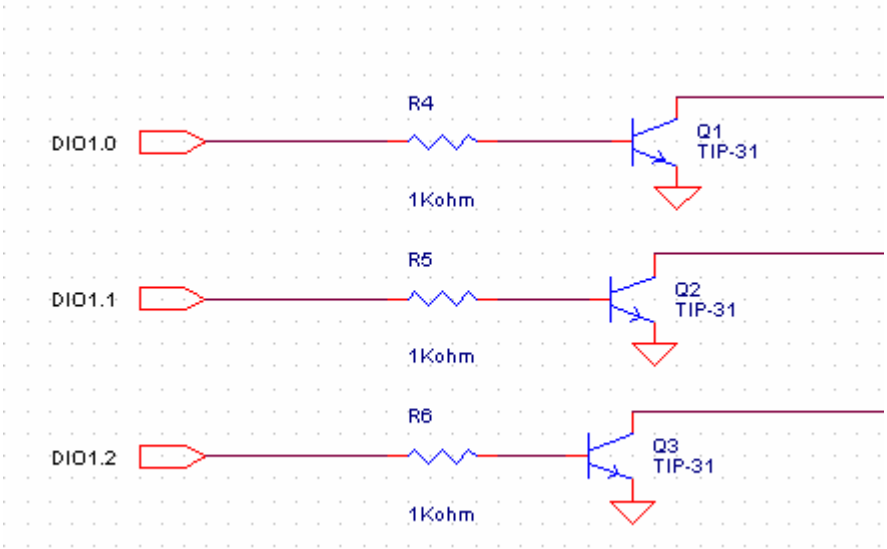

Figure 5 Digital Relay Control

The complete schematic is at the end of this document.

3. **Equipment & Hardware**

The following equipment was used to perform this test:
1- Agilent 34401 Digital Multimeter
1- Agilent E3631A Triple Output DC Power Supply
1- Agilent 75000 9-Slot C-Size VXI Mainframe
1- Agilent E1364A 16-Channel Form-C Relay Card
1- Ametek Model 1723 RPM Meter.
1- National Instruments USB-6008 12 Bit Digital I/O DAQ
2 - Hampden CSM-100 Capacitor Start Single Phase Motor
1- Hampden 2.1KW 3-Phase Resistive Load
1- Hampden AC Watt Meter ACWM-100
1- Hampden AC Volt/Ampere Meter ACVA-100
1- Hampden Transformer T-2000
4- 1 Ohm Resistors
1- National Instruments PCMCIA-GPIB Controller
3 – National Instruments 1 M GPIB Cables
3 – Potter & Brumfield KUP-11D15-12 1/3 HP 125VAC/240VAC 10A Relay
3- TIP31 NPN Transistors
3- 1KOhm 1/4W resistors
1- National Instruments LabVIEW 8.5

4. Power Requirements

Input Voltage: 120 VAC
Input Current: 20 Amps
Input Frequency 60 Hz
Input Phase: Single Phase
Note: A Buck-Boost power transformer (Hampden Model T-2000) is required to boost the voltage from 120 VAC to 240 VAC it also serves to isolate the test from the main power grid.

5. Safety Requirements

When an unsafe condition exists, the Test Conductor shall take whatever action is necessary to prevent injury to personnel and/or equipment damage.

A "STOP" command will be issued if anyone observes any unsafe or potentially unsafe condition. All personnel involved in the operation shall obey the "STOP" command. The operation may be resumed only after the condition has been corrected or the test team determines that no unsafe condition exists.

6. Test Software User Interface:

The test was automated using National Instruments LabVIEW. Figure 6 is a screen shot of the test software graphical user interface (GUI).

Figure 6 Test Program GUI

On the left side of the screen are three toggle switches. These control the relays for the EBU, Load1 and Load2. The meters across the top are for the line input prior to the relays. They display input voltage, input current, input power, L1 and L2 current.

The next two rows are meters for Load1 and Load2 respectively. They display Load voltage, load current and load power.

The large meter displays the power difference between the input and the loads. Under this meter is a percent kilowatt savings bar.

Table 1 defines the measurements that are made at each test point.

Table 1 Test Program GUI

Test Point	Measurement	E1364 Channel	Scaling Factor	Formula
TP1/TP2	Input Voltage	100/101	1.0	
TP3/TP4	L1 Input Current	112/113	Rs =1.0	VAC/Rs
TP5/TP6	L2 Input Current	114/115	Rs =1.0	VAC/Rs
TP7/TP8	Load1 Voltage	102/103	1.0	
TP9/TP10	Load1 Current	104/105	Rs =1.0	VAC/Rs
TP11/TP12	Load2 Voltage	106/107	1.0	
TP13/TP14	Load2 Current	108/109	Rs =1.0	VAC/Rs

7. **Test Procedure:**

The time required for the Agilent 34401 DMM to scan through all measurements is 10 seconds. The software was set to automatically collect and store each measurement in a comma delimited format text file. The system was programmed to toggle the relays on and off in the following order, Table 2, every 100 seconds.

Table 2 Relay Sequence

State	EBU (K3)	Load1 (K1)	Load2 (K2)
0	0	0	0
1	1	0	0
2	0	1	0
3	1	1	0
4	0	0	1
5	1	0	1
6	0	1	1
7	1	1	1
8	0	0	0

8. **Test Results:**

All data for the plots is contained in table 4 at the end of this report.

The first plot of the data shows the current for Load 1. IL1_In is the current measured at TP3/TP4 and I_Load1 is the current measured at TP9/TP10. Refer to table 2 for system states. The system starts in state 0, all off, transitions states 1, 2 and 3 and ends in state 4. The system will be in each state for approximately 100 seconds.

In state 2, load1 is on and the EBU is off. State 3 shows the EBU on with Load1 on, The IL1_In current dropped 2 amps while the current at the load remained relatively constant.

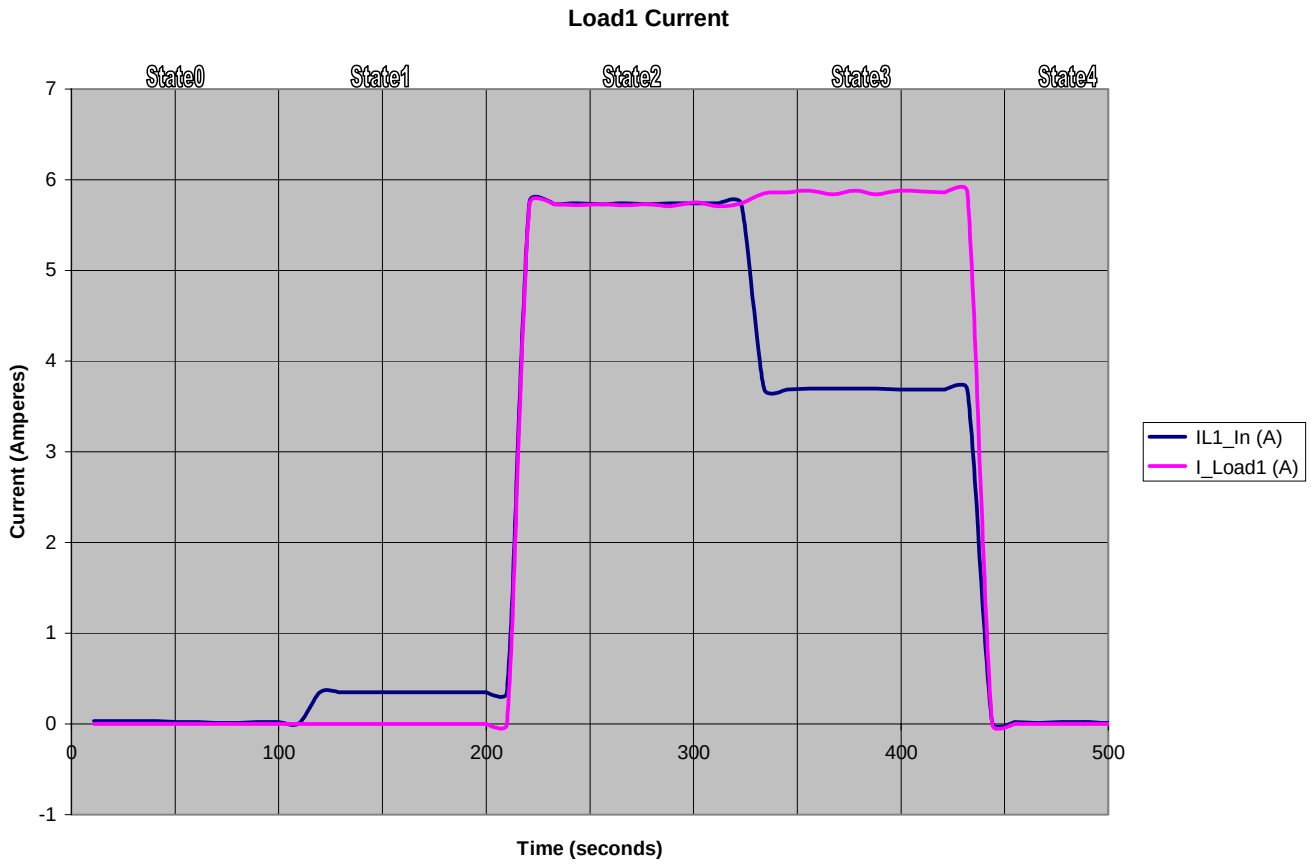

Figure 7 Current for Load 1

The next plot shows the current for Load 2. IL2_In is the current measured at TP5/TP6 and I_Load2 is the current measured at TP13/TP14. The plot starts in state 3, EBU on and Load2 off, transitions states 4 and 5 and ends in state 6. The system will be in each state for approximately 100 seconds.

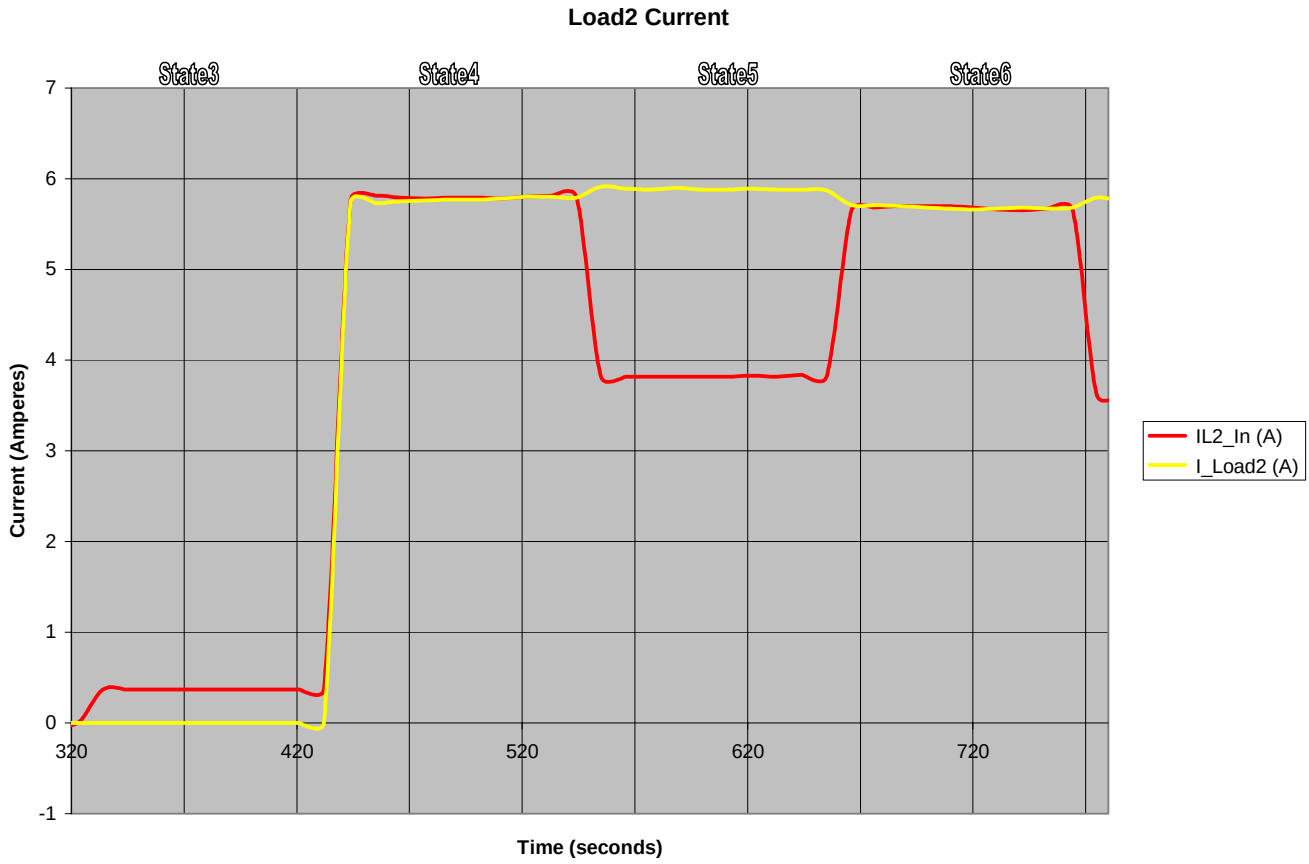

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Figure 8 Current for Load 2

In state 4, Load2 is on and the EBU is off. State 5 shows the EBU on with Load2 on, The IL2_In current dropped 2 amps while the current at the load remained relatively constant.

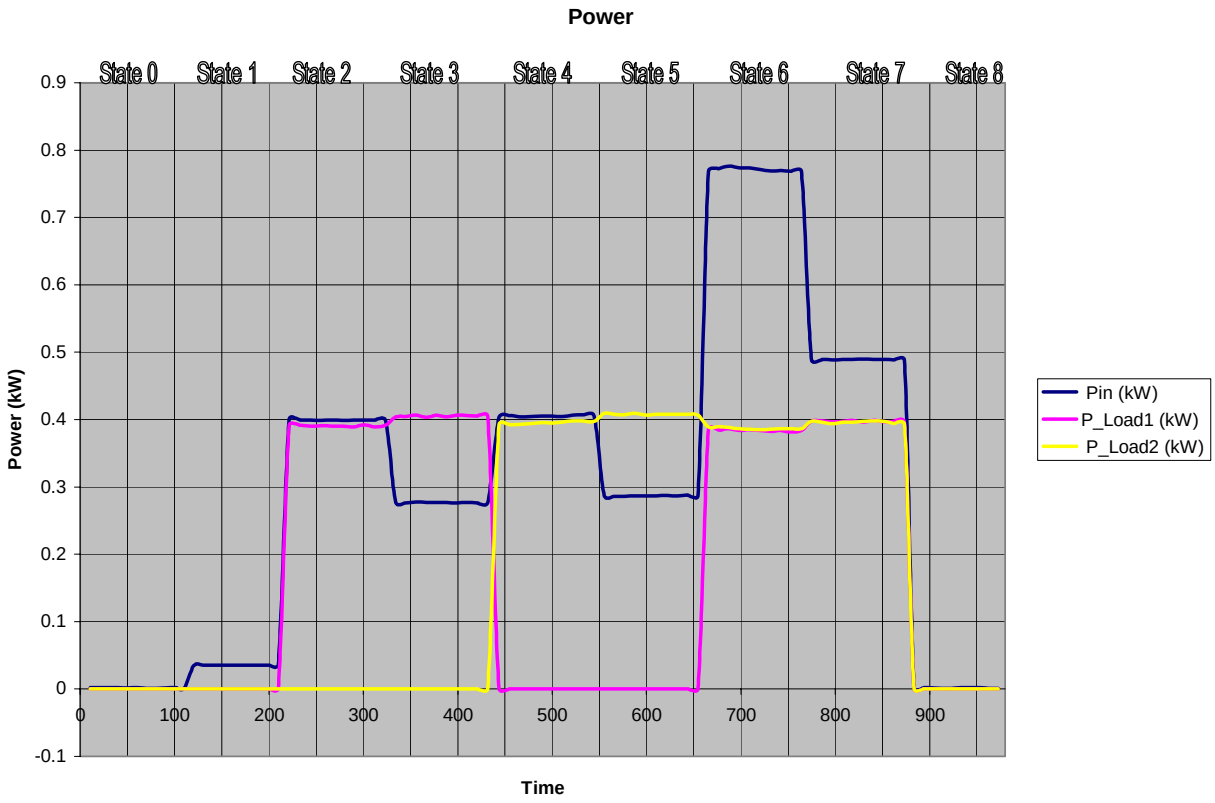

Figure 9 Power

The plot in figure 9 shows the power for both Loads and the input power. The plot is for all states. It should be noted that the EBU is on for states 1, 3, 5, and 7. It should be noted that the power at the loads remains the same.

The difference between the power measured in the previous state (0, 2, 4, and 6) will show the power reduction with the EBU. Table 3 shows the power reductions.

Table 3 Power Reduction

State Change	EBU OFF Power (kW)	EBU ON Power (kW)	Reduction (kW)	%-Reduction
2-3	0.399	0.277	0.123	30.7
4-5	0.405	0.287	0.118	29.2
6-7	0.771	0.489	0.282	36.6

The RPM of the motors were measured manually with the AMETEK RPM meter. The motor speed remained constant at 1595 RPM between state changes.

Table 4 Test Result Data

Time	EBU	Load1	Load2	Vin (V)	IL1_In (A)	IL2_In (A)	Pin (kW)	V_Load1 (V)	I_Load1 (A)	P_Load1 (kW)	V_Load2 (V)	I_Load2 (A)	P_Load2 (kW)
11	0	0	0	248.08	0.03	0.00	0.002	0.00	0.00	0.000	0.00	0.00	0.000
21	0	0	0	247.96	0.03	0.00	0.002	0.00	0.00	0.000	0.00	0.00	0.000
31	0	0	0	247.77	0.03	0.00	0.002	0.00	0.00	0.000	0.00	0.00	0.000
41	0	0	0	247.81	0.03	0.00	0.002	0.00	0.00	0.000	0.00	0.00	0.000
51	0	0	0	247.67	0.02	0.00	0.002	0.00	0.00	0.000	0.00	0.00	0.000
61	0	0	0	247.48	0.02	0.00	0.002	0.00	0.00	0.000	0.00	0.00	0.000
70	0	0	0	247.53	0.01	0.01	0.001	0.00	0.00	0.000	0.00	0.00	0.000
80	0	0	0	247.51	0.01	0.00	0.001	0.00	0.00	0.000	0.00	0.00	0.000
90	0	0	0	247.54	0.02	0.00	0.001	0.00	0.00	0.000	0.00	0.00	0.000
100	0	0	0	247.27	0.02	0.00	0.002	0.00	0.00	0.000	0.00	0.00	0.000
110	0	0	0	247.33	0.01	0.01	0.001	0.00	0.00	0.000	0.00	0.00	0.000
120	1	0	0	249.33	0.35	0.37	0.035	0.00	0.00	0.000	0.00	0.00	0.000
130	1	0	0	249.39	0.35	0.37	0.035	0.00	0.00	0.000	0.00	0.00	0.000
140	1	0	0	249.45	0.35	0.37	0.035	0.00	0.00	0.000	0.00	0.00	0.000
150	1	0	0	249.62	0.35	0.37	0.035	0.00	0.00	0.000	0.00	0.00	0.000
160	1	0	0	249.61	0.35	0.37	0.035	0.00	0.00	0.000	0.00	0.00	0.000
170	1	0	0	249.65	0.35	0.37	0.035	0.00	0.00	0.000	0.00	0.00	0.000
180	1	0	0	249.70	0.35	0.37	0.035	0.00	0.00	0.000	0.00	0.00	0.000
190	1	0	0	249.90	0.35	0.37	0.035	0.00	0.00	0.000	0.00	0.00	0.000
200	1	0	0	249.76	0.35	0.37	0.035	0.00	0.00	0.000	0.00	0.00	0.000
210	1	0	0	249.55	0.35	0.37	0.035	0.00	0.00	0.000	0.00	0.00	0.000
221	0	1	0	241.16	5.76	0.00	0.401	118.27	5.74	0.392	0.00	0.00	0.000
233	0	1	0	241.11	5.73	0.00	0.399	118.21	5.73	0.391	0.00	0.00	0.000
244	0	1	0	240.80	5.74	0.00	0.399	118.13	5.72	0.390	0.00	0.00	0.000
255	0	1	0	240.98	5.73	0.00	0.399	118.16	5.73	0.391	0.00	0.00	0.000
267	0	1	0	241.11	5.74	0.00	0.400	118.21	5.72	0.390	0.00	0.00	0.000
278	0	1	0	240.98	5.73	0.00	0.399	118.14	5.73	0.391	0.00	0.00	0.000
289	0	1	0	241.00	5.74	0.00	0.399	118.12	5.71	0.389	0.00	0.00	0.000
301	0	1	0	240.94	5.74	0.00	0.399	118.28	5.75	0.392	0.00	0.00	0.000
312	0	1	0	241.13	5.74	0.00	0.399	118.13	5.71	0.389	0.00	0.00	0.000
323	0	1	0	241.03	5.73	0.00	0.399	118.28	5.74	0.392	0.00	0.00	0.000
334	1	1	0	243.42	3.70	0.37	0.277	119.56	5.85	0.404	0.00	0.00	0.000
345	1	1	0	243.59	3.69	0.37	0.276	119.57	5.86	0.405	0.00	0.00	0.000
356	1	1	0	243.55	3.70	0.37	0.277	119.77	5.88	0.406	0.00	0.00	0.000
367	1	1	0	243.50	3.70	0.37	0.277	119.65	5.84	0.404	0.00	0.00	0.000
378	1	1	0	243.75	3.70	0.37	0.277	119.72	5.88	0.407	0.00	0.00	0.000
388	1	1	0	243.66	3.70	0.37	0.277	119.62	5.84	0.404	0.00	0.00	0.000
399	1	1	0	243.56	3.69	0.37	0.276	119.70	5.88	0.406	0.00	0.00	0.000
410	1	1	0	243.60	3.69	0.37	0.277	119.74	5.87	0.406	0.00	0.00	0.000
421	1	1	0	243.54	3.69	0.37	0.276	119.71	5.86	0.405	0.00	0.00	0.000
432	1	1	0	243.59	3.69	0.37	0.276	119.66	5.87	0.405	0.00	0.00	0.000
444	0	0	1	241.49	0.02	5.77	0.404	0.00	0.00	0.000	118.45	5.75	0.393
455	0	0	1	241.33	0.02	5.81	0.406	0.00	0.00	0.000	118.46	5.73	0.392
466	0	0	1	241.19	0.01	5.79	0.404	0.00	0.00	0.000	118.42	5.75	0.393
477	0	0	1	241.24	0.02	5.78	0.404	0.00	0.00	0.000	118.56	5.76	0.394
488	0	0	1	241.44	0.02	5.79	0.405	0.00	0.00	0.000	118.67	5.77	0.395
500	0	0	1	241.72	0.01	5.79	0.405	0.00	0.00	0.000	118.57	5.77	0.395
511	0	0	1	241.74	0.02	5.78	0.405	0.00	0.00	0.000	118.67	5.78	0.396

522	0	0	1	242.03	0.02	5.80	0.406	0.00	0.00	0.000	118.82	5.80	0.398
533	0	0	1	241.97	0.02	5.81	0.407	0.00	0.00	0.000	118.87	5.80	0.398
544	0	0	1	241.91	0.01	5.80	0.405	0.00	0.00	0.000	118.76	5.79	0.397
555	1	0	1	244.52	0.35	3.82	0.287	0.00	0.00	0.000	119.95	5.91	0.409
566	1	0	1	244.54	0.35	3.82	0.286	0.00	0.00	0.000	119.93	5.89	0.408
577	1	0	1	244.40	0.35	3.82	0.286	0.00	0.00	0.000	119.94	5.88	0.407
589	1	0	1	244.71	0.35	3.82	0.287	0.00	0.00	0.000	120.05	5.90	0.409
599	1	0	1	244.77	0.35	3.82	0.287	0.00	0.00	0.000	119.93	5.88	0.407
610	1	0	1	244.59	0.35	3.82	0.287	0.00	0.00	0.000	120.00	5.88	0.408
622	1	0	1	244.72	0.35	3.83	0.287	0.00	0.00	0.000	120.04	5.89	0.408
633	1	0	1	244.74	0.35	3.82	0.287	0.00	0.00	0.000	120.04	5.88	0.408
644	1	0	1	244.72	0.35	3.84	0.288	0.00	0.00	0.000	120.01	5.88	0.408
655	1	0	1	244.57	0.35	3.82	0.287	0.00	0.00	0.000	119.84	5.87	0.406
666	0	1	1	235.57	5.66	5.65	0.769	117.79	5.68	0.386	118.10	5.71	0.389
676	0	1	1	235.91	5.66	5.68	0.773	117.81	5.65	0.384	118.06	5.71	0.389
688	0	1	1	235.93	5.70	5.70	0.776	117.75	5.68	0.386	118.05	5.70	0.389
699	0	1	1	235.82	5.66	5.70	0.773	117.68	5.65	0.384	117.98	5.68	0.387
710	0	1	1	235.58	5.68	5.70	0.773	117.64	5.67	0.385	117.95	5.67	0.386
720	0	1	1	235.54	5.66	5.68	0.771	117.55	5.65	0.384	117.88	5.66	0.385
731	0	1	1	235.56	5.65	5.66	0.769	117.55	5.64	0.383	117.84	5.67	0.386
742	0	1	1	235.46	5.67	5.65	0.770	117.53	5.66	0.384	117.92	5.68	0.387
753	0	1	1	235.62	5.63	5.67	0.768	117.55	5.63	0.382	117.91	5.67	0.386
764	0	1	1	235.05	5.67	5.66	0.769	117.54	5.66	0.384	117.87	5.68	0.386
775	1	1	1	237.81	3.51	3.61	0.489	119.06	5.78	0.397	118.99	5.79	0.398
786	1	1	1	238.19	3.51	3.61	0.489	119.06	5.79	0.398	118.99	5.76	0.396
797	1	1	1	237.82	3.50	3.61	0.488	119.00	5.78	0.397	118.82	5.75	0.394
808	1	1	1	237.95	3.51	3.61	0.489	119.00	5.78	0.397	118.97	5.76	0.396
819	1	1	1	238.03	3.51	3.62	0.489	119.08	5.80	0.398	118.91	5.77	0.396
829	1	1	1	238.02	3.51	3.62	0.490	119.02	5.76	0.396	118.94	5.79	0.397
840	1	1	1	238.21	3.50	3.61	0.489	119.07	5.80	0.399	118.99	5.79	0.398
851	1	1	1	238.06	3.51	3.61	0.489	118.95	5.78	0.397	119.01	5.78	0.397
862	1	1	1	237.85	3.50	3.61	0.488	119.01	5.78	0.397	118.80	5.75	0.394
873	1	1	1	237.83	3.50	3.61	0.488	118.85	5.78	0.396	118.84	5.74	0.394
884	0	0	0	247.66	0.01	0.00	0.001	0.00	0.00	0.000	0.00	0.00	0.000
894	0	0	0	247.72	0.03	0.00	0.002	0.00	0.00	0.000	0.00	0.00	0.000
904	0	0	0	247.63	0.01	0.00	0.001	0.00	0.00	0.000	0.00	0.00	0.000
913	0	0	0	247.81	0.01	0.00	0.001	0.00	0.00	0.000	0.00	0.00	0.000
923	0	0	0	247.63	0.01	0.00	0.001	0.00	0.00	0.000	0.00	0.00	0.000
933	0	0	0	247.52	0.02	0.00	0.002	0.00	0.00	0.000	0.00	0.00	0.000
943	0	0	0	247.54	0.02	0.00	0.002	0.00	0.00	0.000	0.00	0.00	0.000
953	0	0	0	247.62	0.02	0.00	0.002	0.00	0.00	0.000	0.00	0.00	0.000
963	0	0	0	247.73	0.01	0.00	0.001	0.00	0.00	0.000	0.00	0.00	0.000
973	0	0	0	247.71	0.01	0.00	0.001	0.00	0.00	0.000	0.00	0.00	0.000