Senior Design
ENG EC 463

To:	Professor Pisano
From:	Smart Grid ECE Senior Design Team
Team:	Power Pooches: Team 14
Date:	11/13/2014
Subject:	First Deliverable Test Plan

1.0 Test to be Performed

1.1 The overall objective of this Smart Grid Test Facility project is to make an educational tool for engineering students, allowing them to test circuitry (such as loads, clean energy systems) on a small-scale emulation of the power grid.

1.2 The test setup is presented in Figure 1. The test procedure will focus on the Data Acquisition (DAQ), transmission lines, and variable load circuit. A signal generator will supply power to a transmission line, which passes the power onto the resistive load. Meanwhile, the DAQ measures the AC sine wave at various points along the circuit. Although this setup is implemented in a simple form this test will confirm whether our basic arrangement is successful and prove the concepts that will be employed in the final design.

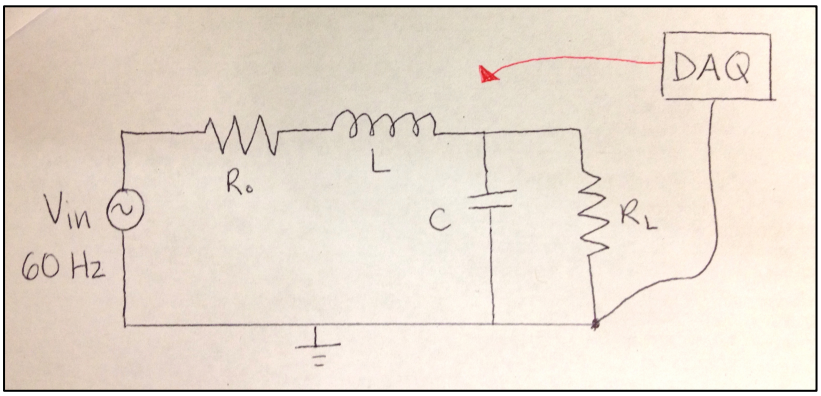


Figure 1: Testing Circuit

1.3 To test the transmission lines, a test signal will be sent through them with an attached load. Comparing the measured output voltage to the calculated output voltage an error calculation will be made. The transmission lines that we have designed model real-grid transmission lines by their resistive, inductive, and capacitive (RLC) characteristics per unit length in miles. The voltage drop that is seen from the source (generator) to load will indicate the validity of our

designs and whether we have successfully created standard transmission lines.

1.4 The variable load will be tested in parallel with the transmission lines. Since the output voltage drop depends on the load, the value of the load is built into the calculation for change in voltage.

1.5 The DAQ was selected because it has a high number of analog inputs for measuring many points along the grid network. Moreover, it can be programmed in MATLAB. This is ideal for studying various components of the test facility, and MATLAB is easily understandable for undergraduate engineering students. The DAQ testing will occur by simply measuring the voltage at two points along the circuit and showing the result on a computer.

2.0 Significance of Deliverable

2.1 This deliverable is essential because it validates the fundamental engineering design of the grid test facility. The final circuit will be far more complex than that seen in Figure 1, but the roots will remain unchanged, with an overall system of generation to transmission to load, with DAQ scoping various points along the network.

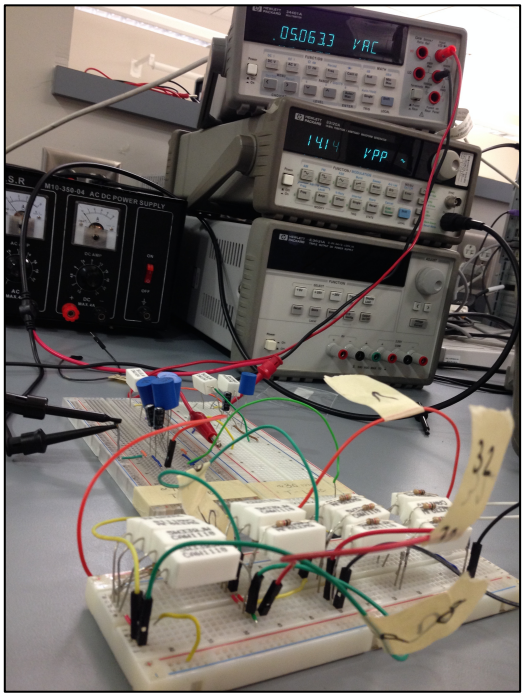
2.2 The transmission lines were designed to model real-grid transmission lines based on RLC characteristics. Testing the transmission lines is significant because we will be able to confirm that the expected voltage drop across the lines is comparable to what actually occurs on the grid.

2.3 Testing the variable resistive load is important because we need to observe how the voltage and current behave in the presence of various loads. We also must ensure that the resistive load circuit is performing properly without skewing results.

2.4 The DAQ testing is important because it serves as the first step toward programming the DAQ to perform more involved computations. At this point, we are simply testing whether we can read the waveform at various points along the circuit. Later, we will build upon this initial testing to provide information such as power factor and phase delay.

3.0 Procedure I: Equipment and Setup

3.1 The overall setup should correspond with the one denoted in Figure 1. A waveform generator connects directly to the transmission line, which has a resistor, inductor, and capacitor in series, along with a load in parallel with the capacitor. Figures 2 and 3 show what this arrangement may look like.



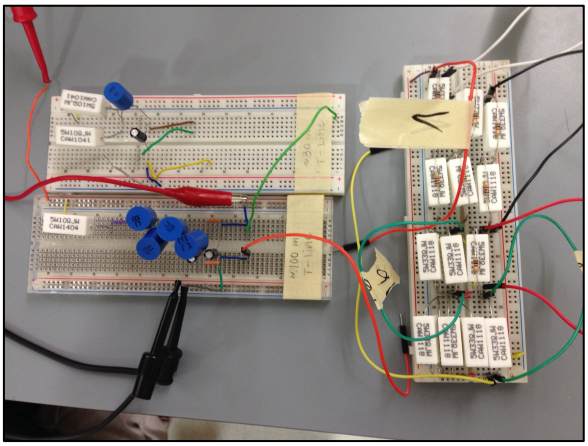


Figure 2, Figure 3

3.2 The DAQ shares ground with the circuit and is used to probe points throughout the circuit. For testing the DAQ, the waveform generator should be set for an output of 60 Hz 0-2.4V (thus, 1.2V DC offset, 2.4V_{pp}). For testing the transmission lines, no DC offset is needed and various voltages may be used in order to test (within the range of the waveform generator).

4.0 Procedure II: Data Collection

4.1 For testing transmission lines (and thus the variable load), data can be collected using a multimeter to measure AC voltage. Table 1 below shows the variety of arrangements used to test the transmission lines. The voltmeter should read the voltage across the resistive load.

Table 1: Transmission Line Testing

TL Characteristics				Setup					
TL Length	R (Ω)	L (mH)	C (μF)	Load (Ω)	Re(Z)	Im(Z)	Total Impedance (Ω)	Input Voltage (V)	Input Frequency (Hz)
30	5	33	1	64	68.99909039	12.416872	70.10744029	6.636	60
30	5	33	1	192	196.9972712	12.36861601	197.3851755	6.636	60
100	10	130	2	64	73.9963617	48.96174403	88.72831523	6.636	60
100	10	130	2	192	201.9890851	48.86523208	207.8157872	6.636	60

4.2 For testing the DAQ, the ground of the DAQ should be connected to the ground of the circuit (See Figure 1). Then, the other DAQ port should probe various points throughout the grid network. This can be done by simply connecting the red lead to a part of the circuit, running the DAQ script, and observing the MATLAB output.

5.0 Criteria for Success

5.1 For the transmission lines, success is measured in terms of the percent error between expected output voltage and measured output voltage. Data from a previous test is provided in Table 2. By the nature of these calculations the resistive load operation can also be verified.

Table 2: Transmission Line Testing

TL Characteristics				Setup						Output Voltage		
TL Length	R (Ω)	L (mH)	C (μF)	Load (Ω)	Re(Z)	Im(Z)	Total Impedance (Ω)	Input Voltage (V)	Input Frequency (Hz)	Calculated (V)	Measured (V)	% Error
30	5	33	1	64	68.9990904	12.416872	70.10744029	7.0710678	60	5.8462621	2.4	-58.9481
30	5	33	1	128	132.998181	12.392744	133.5743096	7.0710678	60	6.4005977	3.59	-43.9115
100	10	130	2	64	73.9963617	48.961744	88.72831523	5	60	2.8065298	1.22	-56.5299
100	10	130	2	128	137.992723	48.9134881	146.4053313	5	60	3.5951055	1.96	-45.4814
100	10	130	2	300	309.982945	48.7838001	313.7981607	5	60	4.2854717	3.03	-29.296
100	10	130	2	600	609.965891	48.5576003	611.8956028	5	60	4.6152439	3.79	-17.8808
100	10	130	2	850	859.951679	48.3691004	861.3108962	5	60	4.7221183	4.09	-13.3863
100	10	130	2	1000	1009.94315	48.2560004	1011.095352	5	60	4.7618149	4.2	-11.7983
100	10	130	2	10000	10009.4315	41.4700043	10009.51742	5	60	4.9751146	4.96	-0.3038

5.2 The errors seen in Table 2 are a result of several conditions. First, the waveform generator has an internal resistance of 50 Ω, which introduces a new element that was not part of the calculations for expected output voltage. For such small loads that we connect to the generator, the impacts of this resistance become clear. As we increase the load resistance, it is clear that this problem is reduced. Additionally, the breadboard of the load circuit has a small internal resistance that was also not accounted for in the output voltage calculation (although this value is negligible relative to the remainder of the circuit).

5.3 The criteria for success for the DAQ is a continuous signal readout from the LabJack. Noisy signals will require filtering that is currently unavailable and therefore must be re-read. Since the objective for the DAQ testing is to confirm that it can read AC signals at points along the circuit, the test is deemed successful if readings are visible and sensible; this means that they match the known input values. The readings should not be noisy, and should show logical phase shifts between voltage and current, indicating inductive or capacitive loading. As more complex functionality is built into the DAQ, testing will be more quantitative, including measurements such as phase angle and power factor.