Senior Design
ENG EC 464

To: Professor Pisano

From: Smart Grid ECE Senior Design Team

Team: Power Pooches: 14

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Subject: Second Deliverable Test Report

1.0 Test Summary

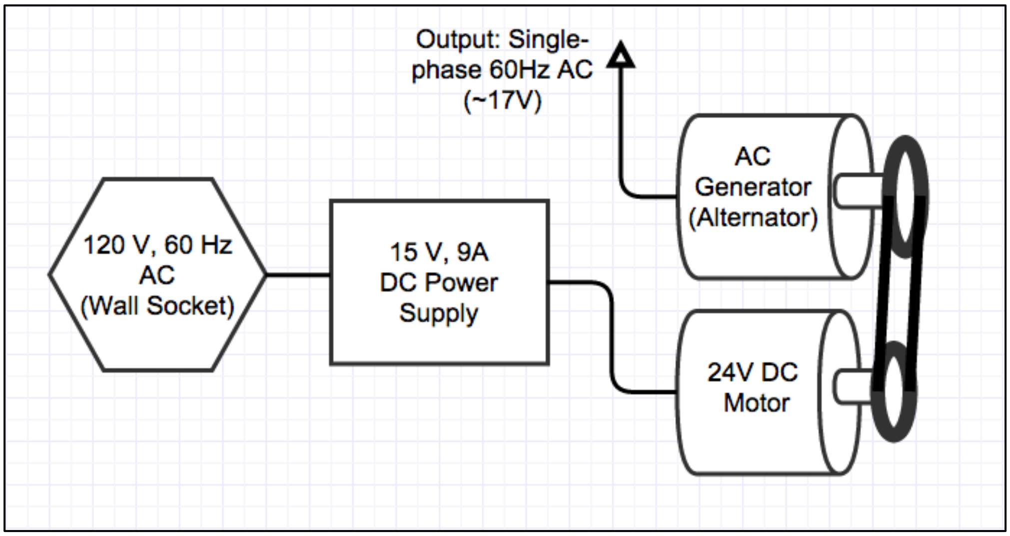
1.1 The overall objective of this Smart Grid Test Facility project is to make an educational tool for engineering students, allowing them to test various circuitry on a small-scale electricity grid. While developments have been made across all aspects of our project (transmission lines, loads, etc.), this testing procedure focuses on two key components of the project.

1.2 This testing procedure focuses on the development of the generation scheme for the power grid. The objective of generation is to create three synchronous sources that generate 60Hz, 12V DC power that propagates throughout the grid. In order to most efficiently and effectively create this system, we are developing the first generation scheme, and then we plan to replicate the scheme twice to create three equivalent generators.

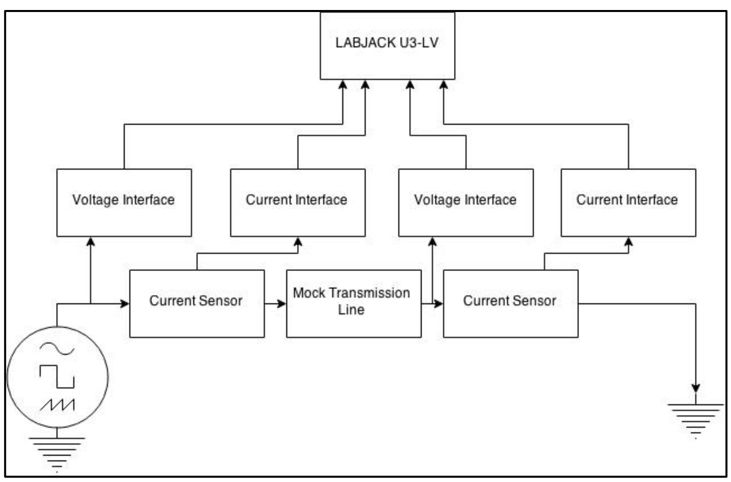
1.3 This testing procedure also demonstrates the progress made on the DAQ. The sensor suite is a system that enables a user to measure current at various points along the grid. The suite interfaces with MATLAB, so users can work on their available lab monitors to observe changes in the power flow within grid.

2.0 Equipment and Setup

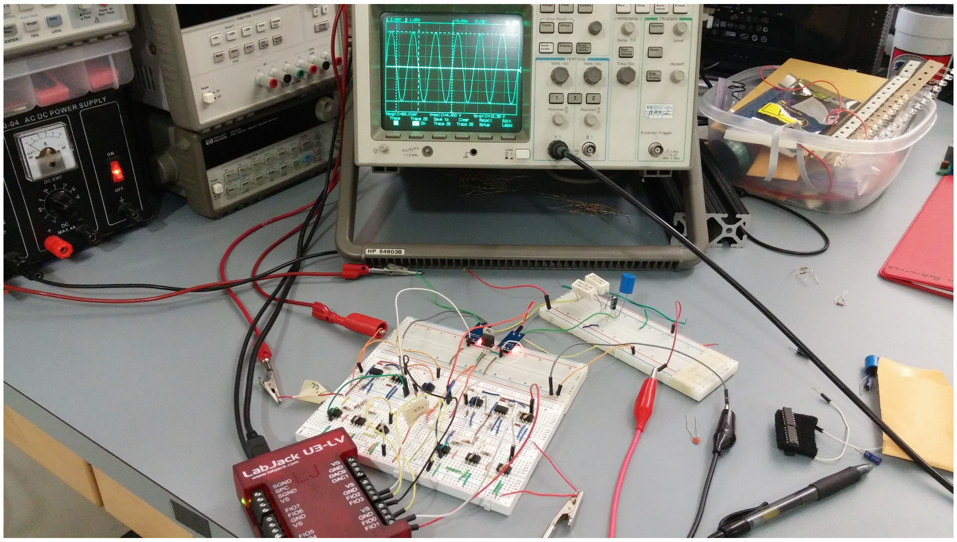
2.1 For the generation portion of the demonstration, the team presented one of the three structurally identical generation points that will power the grid. The setup included the two most essential generation components in our design, a 24V DC motor and a 7 dipole (14 pole) wind turbine alternator (our AC generator), as well as a 15V, 9A DC power supply which was used to power the DC motor. For the initial testing of the alternator, the power transfer was accomplished through a direct-drive configuration (data collected in section 3.1). The efficiency was minimal due to the components/materials used however the measurements obtained proved to be useful in establishing a gear ratio of 2:3 to be used in the final setup. The figure below shows the setup that was demonstrated with pulleys (2:3 ratio) and a 4L V-belt.



2.2 The setup of the sensor suite test bench will be similar to that of the first deliverable test. In this test the LabJack DAQ will be used in conjunction with two current sensing circuits to measure a test signal from an AC/DC power supply available in the lab. The current sensing capabilities of our data acquisition unit were not available during the previous deliverables test, because we had not devised a way to correctly measure the signal without altering its characteristics too much. We will now be using an RLC circuit (in this case a mock 30 km transmission line) to interface to the LabJack.



Experimental Setup



3.0 Measurements & Data

3.1 For testing the generation, we perform a torque test to verify that the frequency of the generation output varies linearly with the voltage supplied at the input. To do this, we track the input voltage at the motor and the corresponding frequency of the AC waveform produced on the windings of the alternator (output voltage signal). After this is concluded, we verify that there is a set nominal voltage that can be supplied to the motor resulting in a 60 Hz or higher frequency of the alternator output power. Varying the input voltage will vary the frequency. Given that this is possible, the frequency of the system can be controlled by voltage modulation.

Direct-Drive Initial Generation Test			
Trial #	Vin (DC)	Vout (AC)	Frequency (Hz)
1	15	26.2	94.17
2	15	25.98	93.6
3	15	26.15	94.12
4	15	26.36	94.3

3:2 Gear Ratio Final Generation Test			
Trial #	Vin (DC)	Vout (AC)	Frequency (Hz)
1	15	17.35	62.21
2	15	17.1	61.82
3	15	17.24	62.11
4	15	17.46	62.6

Generation Data Summary

Frequency: 60 Hz +/- 5%

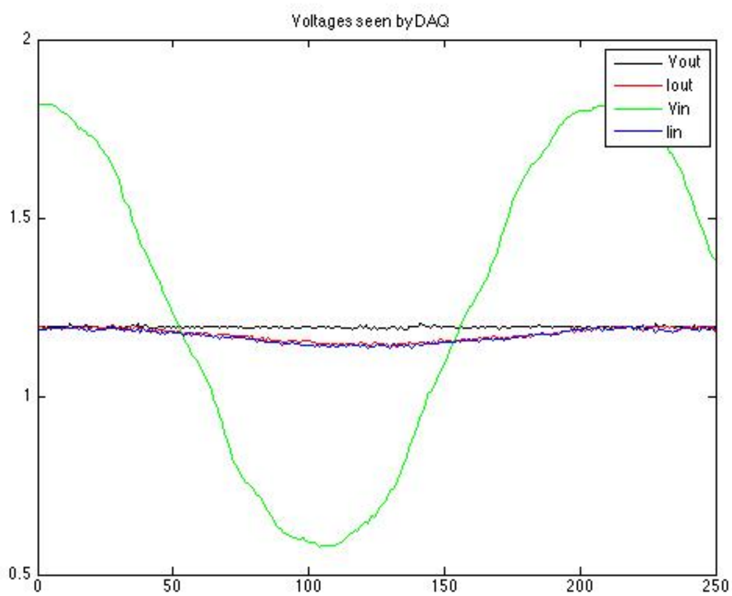
Voltage: 17 V +/- 5%

3.2 For testing the DAQ, the ground of the DAQ should be connected to the ground of the circuit. Then, the other DAQ ports should probe various points throughout the grid network. This can be done by simply connecting a lead from a flexible input output port (FIO) to a part of the circuit and observing the output on a computer via our MATLAB program. For testing purposes, we have attached leads to the outputs of two voltage interface and two current interface circuits attached to our circuit. It should be noted, what might seem like major irregularities in the Vin sine wave is not due to interface design. Instead, it was due to irregularities of the power supply output.

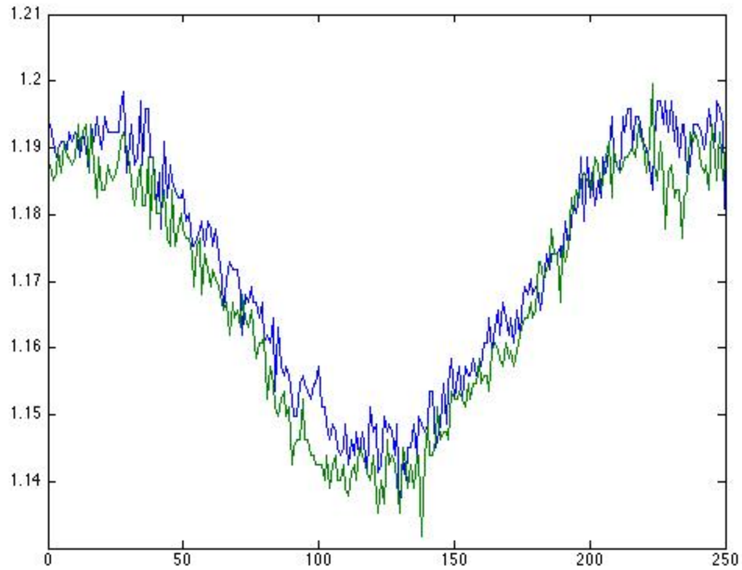
Sample MATLAB Output

Output waveforms of

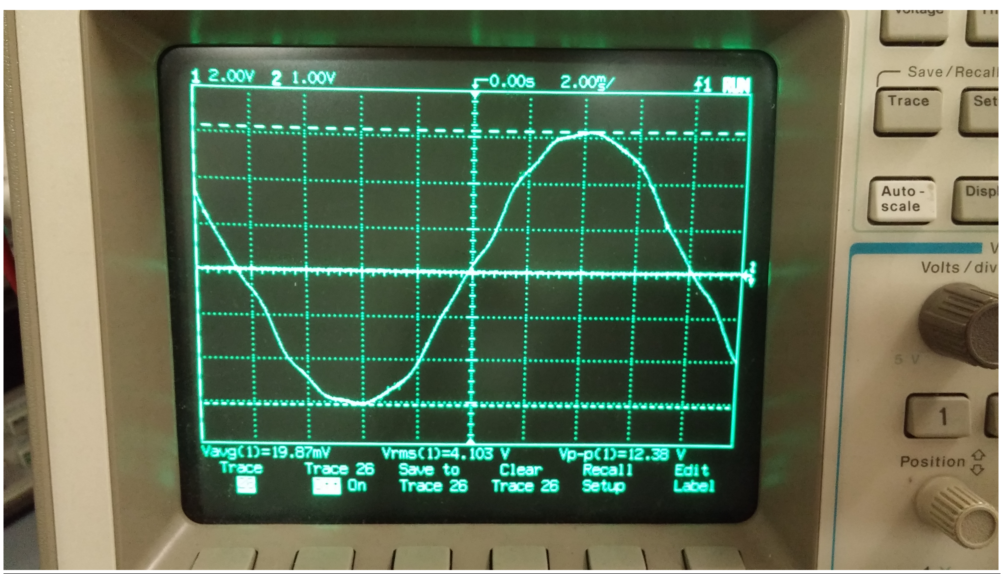
current and voltage interfaces into the DAQ.



Separated Current Values



Power Supply Output



4.0 Data Analysis and Criteria for Success

4.1 The success criteria for the generation demonstration revolved around the frequency of the power generated. It is crucial that we are able to generate power at 60Hz (+/- 5%) given the set of concrete requirements for our deliverables and we wanted to demonstrate this aspect of our progress. Secondly, we wanted to replicate the voltage achieved during initial testing.

This is also a rather crucial aspect due to the transformers that need to be wound in order to achieve the 12V as per our requirements.

4.2 The criteria for success with the data acquisition system are as follows:

4.2.1 By Design, there must be a wave form read by the current interface circuits that is centered around 1.2V +/- .05 V due to part precision. This is median voltage that will give the best resolution for the DAQ.

4.2.2 The phase between current and voltage is being read from the interface circuits. This can be used to calculate power factor for power flow in the system.

4.2.3 The input and output power factor will be read so that the power flow of the system can be characterized through the system. This is necessary for the ultimate functioning of the DAQ within the final system.

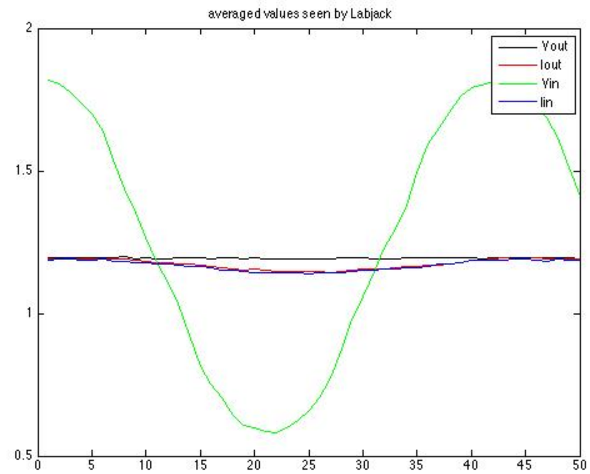
4.2.4 Current sensors show a value within 5% of one another (on the same line).

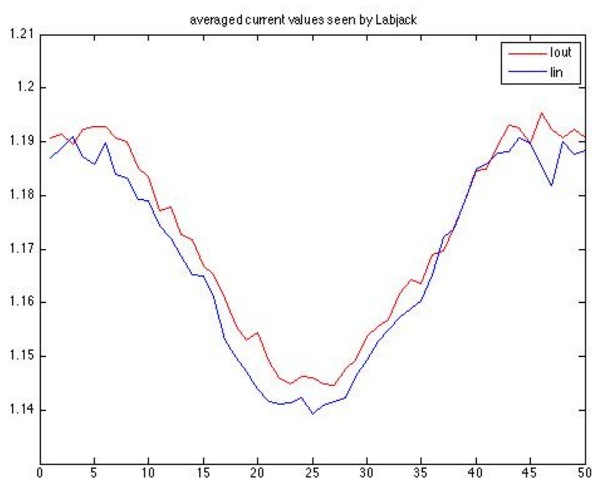
5.0 Conclusions

5.1 The data obtained from the initial test provided a guideline to perform a linear approximation for the desired output voltage and frequency of the alternator. The purpose of engineering the 3:2 gear ratio was to derive 60Hz at the generator output from a higher value of 90Hz when employing direct contact between the motor and alternator shafts (1:1 ratio). After observing the customer's 60Hz standard in our final generation test, it verifies that, given the existing pulley ratio, our generation unit has the rotational speed to yield 60Hz when provided a DC input voltage of at least 15V. We can ultimately meet the 5% tolerance specification for both voltage and frequency in the project. The voltage will be modulated by the feedback loop as the encoder monitors the frequency of the system. Single-phase step-down transformers may now be added to the grid for our 12V design requirement. Given an AC output voltage of 17V, a 1.42:1 primary to secondary winding ratio would net 12V. The results further confirm that our new 24-28V DC power supply has the capacity to power our generation scheme. Overall, the test verified the functionality of one out of three possible generation units to be delivered to the customer. It proves that the introduction of two more identical generating schemes can part of an integrated 60Hz system.

5.2 Based on the graphs in part 4, the design of the current sensor is sound with a median value of about 1.17 volts, which is within precision parameters. In addition when connected to the same current, the sensors each outputted similar waveforms with otherwise negligible deviations (< 10 mV) due to noise; with the amount of noise due to go down since the final interface is a PCB fabrication instead of a breadboard circuit.

However looking at the separated current values provided above, one might come to the conclusion that the circuit is too noisy to be useful. This is not the case, as we are looking for the general behavior of the signal, which in turn means average values may be used. When averaged with a 1:5 resolution (i.e. 1 new data point = average of 5 old data points), we get the following: (note that a phase difference can be seen between Vin and Iin in the first graph)





Using this process, if we were to increase the sampling size from 1 to multiple wavelengths of the signal in the future, these results can then be used to calculate phase and power factor to a good degree of precision by averaging the results of each wavelength.

However, just by visual inspection we can see a phase difference between Vin and Iin with minimums at index 22 and index 25 of the averaged values respectively. Since the original sampling frequency was 12500 Hz for each input (MATLAB code divides the Labjack sampling frequency 50 KHz by number of inputs, in this case 4), and the results were then averaged with a 5:1 ratio, we can find the phase with the following equations. $\Delta t = (5 / 12500) * \Delta x$ with Δt = difference in real time and Δx = difference in indexes. In this case $\Delta t = (5/12500) * 3 = 1.2 * 10^{-3}$ seconds. Which converted into a phase difference between 60 Hz signals is equivalent to 7.2 * 10 ^ -2 wavelengths or .4524 radians / 25.92 degrees. This is turn means a power factor of .899 for the input.