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Electrical Load Management and Maintenance Management for a Hybrid Renewable Energy System in Honduras, Central America

A Capstone Project Report

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1.0 Abstract

There are many benefits to choosing renewable energy power sources for a business, organization, or residence, but what about the downsides. Energy production systems can be delicate, and this fragility is amplified when combining multiple renewable energy sources. This report will feature a school situated on a 2,000-acre working farm 5 km southeast of Catacamas, Honduras. The school's mission is to meet the spiritual, educational, and physical needs of the underprivileged youth of Honduras.

To fulfill its mission, Escuela El Sembrador (EES) needs clean, reliable power. Without it, classrooms go dark; technology is useless, and students cannot complete their homework. EES produces power by utilizing a Hybrid Renewable Energy System (HRES) comprised of a 150 kW hydroelectric generator and a 42.9 kW grid-tie solar system. The HRES is backed up with a 125 kW diesel generator and the national electric grid, Empresa Nacional de Energia Electrica or ENEE. This system is illustrated in Appendix E.

This report will look to identify the impact of recent frequent power generation shutdowns, verify if the hydro-solar combination is the source of these outages, and identify possible solutions to the problem. Along with frequent power shutdowns due to the hydro-solar relationship, equipment and controls on the hydroelectric plant have had a high rate of breakdowns and costly repairs because of lack of maintenance. The maintenance structure for the HRES will be studied to determine the current procedures and strategies for maintenance.

This report will then recommend a maintenance management strategy to ensure that the HRES can continue to support the mission of EES by providing quality electricity, high reliability, improving safety, and limiting the costs of repairs and shutdowns.

2.0 Introduction

Escuela El Sembrador translated "The School of the Sower," is located approximately 4 hours by car northeast of the capital city of Tegucigalpa, Honduras, Central America as seen in Appendix A-C. Situated in a rural agricultural valley, the school provides high-quality education to young students who would not otherwise have the chance to receive this level of schooling. The school shares its 2,000-acre campus with a fully operational farm called Industrias Olanchanas (I/O). The farm side includes one of the largest milk-producing dairies in Honduras and milks cows twice a day. The mission of the farm is to generate income to help support the mission of the school. An I/O dairy production report is included in Appendix J.

EES was founded in 1954 and at that time had no access to an electrical utility. In the late 1960s, a small hydro-electric power generator was installed using a nearby river as its water source. This was sufficient for several years, but the school and farm's electrical needs outgrew the generator. In 1992, a new larger hydroelectric turbine generator was installed that could produce up to 150kW of electricity, as long as the river could supply enough water to spin the turbine.

Honduras has a tropical climate that has two distinct weather seasons. A rainy season from May through October and a dry season from November through April. During the rainy season, rainfall totals can exceed 36 inches, but during the six-month dry season rainfall totals are typically less than 6 inches. Water is plentiful in the rainy season to operate the hydroelectric generator, but during the dry season, water shortages are an issue as the river level decreases.

In January of 2018, a 42.9 kW solar system was installed to supplement the hydroelectric generator. The goal for the photovoltaic (PV) system was to reduce the demand on the hydro and reduce the amount of water that the hydro used. Water usage is reduced because the power produced from the solar system can be subtracted from the amount of power that the hydro-generator needs to produce. Less water is then needed to flow through the turbine. This savings of water allows EES to extend the hydro run time further into the dry season.

Students come from all over the country and from many differing backgrounds. Many students come because they do not have access to high-quality education. There are 91 students that live on campus and 116 that come from local communities. EES provides education from pre-kinder all the way through 11th grade.

3.0 Problem Statement

There are two problems addressed in this report. The first is that power outages at EES have increased since the installation of a 42.9 kW solar grid-tie system in January of 2018. This PV system is a grid-tie system with no battery storage, so it must work alongside a grid forming system, which is the 150 kW hydroelectric power plant shown in Appendix F. During PV surplus events, when "more power is generated by the PV system than is consumed by the grid," the solar system is shutting down the grid forming device, the hydroelectric generator.(Fern, n.d.) When this PV surplus occurs, power is reversed to the hydro-generator, which would normally cause a catastrophic failure because the hydro-generator/alternator would try to become an electric motor spinning in the opposite direction of the hydro-turbine, causing severe damage to both the gearbox and shaft coupler of the hydroelectric power plant.

Fortunately, there is a relay in the hydroelectric generator system for such an occasion. When there is a reverse power situation, the relay opens, trips the main breaker, and does not allow power to reverse back to the generator. However, this shuts down the generator, causing a power outage. Since the PV system is a grid-tie; the inverters detect that the grid has gone down and also shut down production.

The second problem that is addressed in this report is that break downs to the power generating system are more expensive due to untimely or mistargeted maintenance, improper procedures, or lack of parts on hand. The main generating system is the hydro-electric power plant. The cross-flow water turbine and power generator were manufactured in Germany, and so parts are not readily available within the country of Honduras. This makes access to parts expensive and lead times for those parts in excess of up to 10 weeks. Also, written procedures have been forgotten or ignored. In the 25 plus years of service, there have been several operators of the hydroelectric plant. Procedures were passed down by word and example, and each passing gave room for error through miscommunication. By not creating and following written procedures for operating the power system, breakdowns are more frequent and costly.

4.0 Significance

These problems significant because, without high-quality, reliable power, EES's ability to carry out its mission is hampered. The ultimate function of EES is to meet the physical, spiritual, and educational needs of the young men and women of Honduras in order to equip them with the tools necessary to not only change the course of their own life but to transform their families, communities and even their country. At least half of the students that attend EES are unable to afford access to quality education, and in some cases, they do not have access to any type of education. “Poverty is a major obstacle for sustainable development of not only developing countries but also the entire world.” (Kanagawa & Nakata, 2008a) “Poverty is defined as low attainment of social condition, for example, education, health, and nutrition in addition to economic deprivation.”(Kanagawa & Nakata, 2008a) By providing a high-quality education at a cost they can afford, Escuela El Sembrador is giving these youth the step up they need to break the cycle of poverty and create a healthier and stronger nation for generations to come.

This report shows how the electrical power system has been a source of frustration to teachers, students, support staff, I/O employees, and administration at EES. Evidence of this frustration was established by surveying those directly connected to the EES's power system and by examples of specific cases of how the effects of poor power quality have affected the staff and students. The results of the survey show that the power system has frustrated to the point that it is impacting what they need to do daily. See Appendix X for specific examples written by survey respondents.

In the United States, power quality and reliability are so high that it is hardly thought of. It is available 99.95% of the year, but in third world countries, power can still be considered a luxury by a majority of the population in countries like Honduras. ("Average frequency and duration of electric distribution outages vary by states - Today in Energy - U.S. Energy Information Administration (EIA)," n.d.)

Having electricity is a strong influencer in peoples lives. "Access to modern energy like electricity will drastically improve the quality of life of those who do not have it." (Kanagawa & Nakata, 2008b) When electrical power shuts down classrooms go dark, the internet goes down, unsaved work on electronic devices is lost, and technology quits working. The quality of education is decreased. "The purpose of the electrical power system is to deliver high-quality, safe, and reliable electric power to homes, industrial plants, and commercial businesses alike."(Keller & Kroposki, 2010) Escuela el Sembrador needs to increase its power quality and reliability to stay on mission.

This project is also significant because of the financial impact to EES due to break-downs and shutdowns of the HRES at Escuela El Sembrador. The hydroelectric generator is EES's main source of power for two main reasons. First, power is generated by using a renewable resource, water, which is cheap, and the environmental impact is low. Water is diverted from a nearby river, carried through a canal into a 10-acre reservoir for storage and then run down the penstock and through the cross-flow turbine. See Appendix D, F, and G for photos of the reservoir, turbine house, penstock, and hydro turbine electric generator. Once through the turbine, the water is channeled back to the river. The second is that power quality from the hydro-generator is high with small variations to frequency and voltage as shown in the graphs located in Appendix L.

The third reason is that water supplying the hydro is reliable. "Unlike unpredictable and rapidly fluctuating solar and wind power, hydropower has a long seasonal cycle. The water flowing in the rivers and streams change slowly according to seasons of the year."(Bhandari, Lee, Lee, Cho, & Ahn, 2015)

When the hydroelectric generator does break-down due to malfunctioning equipment, repairs are expensive and switching to the diesel generator or hooking up to the national grid is also expensive. The 125 kW Caterpillar diesel generator consumes approximately 6 gallons of diesel per hour. (WorldWide Power Products, LLC fuel consumption chart Appendix I). Current diesel prices are $3.37 per gallon, ("Honduras diesel prices, 10-Jun-2019 | GlobalPetrolPrices.com," n.d.) and so just the fuel running cost is $20.22 per hour or $14,558.40 per month.

When they are connected to the national electric grid (ENEE), neither EES's hydro generator or diesel generator can be running because they do not have synchronization capability. The only power supply they can still function with ENEE is the 42.9 kW solar system. This is because the PV system is a grid-tie system, so it does not care what source forms the grid, it automatically syncs to it.

EES is not a regular customer of ENEE, because EES generates its own electricity most of the time, ENEE charges $0.17 per kWh. They also are charged for reactive power. Their reactive power charges are high because their dairy barn, livestock feed mixers, fluorescent lighting, and irrigation pump motors all have low power factors which means an increase in reactive power.

Power quality from ENEE is poor because of high voltage and frequency swings which damage electrical equipment.

Both of the backup systems are costly when utilized for extended periods of time.

5.0 Literature Review

5.1 Energy access and effects on education and quality of life

Electrification is shown to improve the quality of life. "Access to modern energy like electricity will drastically improve the quality of life."(Kanagawa & Nakata, 2008b) "Education is also widely recognized as one of the most essential components for poverty reduction."(Kanagawa & Nakata, 2008b) Honduras is a developing country with a large percentage of the population below the poverty line.

Mazur shows that "Energy is strongly correlated with diverse indicators of quality of life among the world's nations." (Mazur, 2011) Mazur also says that "analysts agree that increased energy and electricity consumption is essential for improving the wellbeing of people in less developed nations." (Mazur, 2011)

A study on the Energy Return On Investment (EROI) states, "the quality of a unit of energy is essentially the usefulness of that unit of energy to society." (Lambert, Hall, Balogh, Gupta, & Arnold, 2014) They go on to explain that EROI is "one measure for establishing the quality, in this case the net energy available to an organism or society to achieve that organism's or society's various ends." (Lambert et al., 2014)

5.2 Hybrid Renewable Energy system

Hydro and solar can complement each other in tropical climates like Honduras where there is plenty of solar irradiation and where there is a distinct dry season. "PV plants are also a perfect complement to small hydro systems during dry seasons when power production from the hydro plant is low." (Tamrakar, Galipeau, Tonkoski, & Tamrakar, 2015) There are downsides to adding PV to hydro. "A PV-hydro system will exhibit fast frequency dynamics which cannot be handled by the conventional governors of hydro systems, responsible for the primary frequency control of the system. Large frequency deviations at high rate of change of frequency thus may occur in such systems tripping frequency relays and causing unnecessary load shedding." (Tamrakar et al., 2015)

A white paper report from Fronius inverters discusses how to manage energy flow utilizing inverter installed digital outputs to control relays. (Fern, n.d.)

5.3 Maintenance Management

This report discusses the benefits of an Electrical Preventive Maintenance (EPM) program. "An effective EPM program will go a long way to help avoid the extra expense, disruptions and lost profits that can result." (Statement et al., 2019) It goes on to describe key elements to setting up an EPM. "Any maintenance program must include an inventory of the system and then identification of critical loads. That helps you set your priorities. If you have up-to-date one-line diagrams of your electrical distribution system, it will help tremendously and save time. If you do not have current up-to-date one-line diagrams, then it should become a priority to develop them when you contract with the electrical service company." (Statement et al., 2019)

This article describes the facilities role in showing company executives value creation. (Kadzis, 2015) An important aspect presenting changes, especially costly ones, to those who make ultimate decisions.

5.4 Statistics

To establish the quality and reliability of the United States energy system statistics from the U.S. Energy Information Administration were used. ("Average frequency and duration of electric distribution outages vary by states - Today in Energy - U.S. Energy Information Administration (EIA)," n.d.)

The percent of Honduras that have access to electricity is 87.58%. ("Honduras Energy Situation - energypedia.info," n.d.)

5.5 HRES Optimization

Bhandari describes the characteristics of an HRES. "For isolated and remote places where chances of reaching national grid is minimum because of technical and economic constraints, renewable energy system is considered as an attractive alternative and thus preferred in many regions and countries." (Bhandari et al., 2015) "HRES is largely dependent on its components, thus an accurate modeling of each component of HRES provides tools to better understand the performance and reliability of the system, assisting to optimize HRES."

(Bhandari et al., 2015) Bhandari goes on to define stand-alone systems, "an off-grid system does not have a connection to the main electricity grid." (Bhandari et al., 2015) While EES does have access to the national grid, they do not connect unless they have to.

Another possible solution to the PV surplus problems is the idea of a pumped hydro storage system (PHSS). "Energy storage can be used to mitigate the problems associated with the fluctuating output power of the wind turbines and solar PV arrays due to changing wind speed and solar irradiation intensity." (Salimath, Singh, & Badge, 2018) The integration of "solar generation challenges reliability and stability of the grid in many ways (e.g., reduced system inertia, reduced short circuit capability, reduced voltage control capability, etc.)." (Nobile, Sari, & Schwery, 2018) The idea is to pump water back into the water reservoir during PV surplus situations, thus increasing the run-time of the hydroelectric generator. "PHSS facilities provide large electric energy storage, with low maintenance and operation cost, and high reliability." (Salimath et al., 2018)

6.0 Purpose

The purpose of this study is to first establish a baseline. An accurate energy load profile and assessment of the current, and past strategies for maintenance is needed to determine if change is needed. It is also necessary to establish the accuracy of EES's staff, and students assumed frustration and dissatisfaction regarding energy quality and reliability. If it is not perceived as a problem is it necessary to improve the HRES?

This baseline was determined by performing three studies, an energy analysis of EES, a simple line diagram survey of the power system at EES, and a satisfaction survey of all the staff, students, and employees at EES. This report will describe how each of the studies will be performed include what equipment and techniques will be used.

Once the baseline is established, this information was used to determine what are the appropriate actions that need to be taken. The study looks at optimizing the relationship between solar PV and hydroelectric production. In PV surplus situations, can power be shed off the system so grid shutdown does not occur?

This study also looks at the current maintenance procedures and makes recommendations on managing maintenance with an emphasis on predictive testing to mitigate the effects of power shutdowns and equipment malfunctions.

7.0 Definitions

7.1 HRES- Hybrid Renewable Energy System. It is an energy system that is made of multiple components with at least one being a renewable energy source. In this study, we will look at an HRES that is comprised of hydro, solar, diesel generator back-up, and the ability to connect into the national electric grid.

7.2 EES- Escuela El Sembrador. A not-for-profit school campus situated on a 2,000-acre working farm in rural Honduras Central America. EES owns the 2,000 acres and leases land, equipment, and facilities to I/O. The leasing of these facilities has equated to an average of $200,000 of annual income to EES over the last three years.

7.3 I/O- Industrias Olanchanas- The for-profit working farm that is one of the top three milk producers in Honduras. To date, in 2019 the dairy produces an average of 4,332 liters of milk per day or 1,144 gallons per day. (Production chart in Appendix D)

7.4 ENEE- Empresa Nacional de Energia Electrica (National Electric Power Company)- Government owned electrical power grid of Honduras.

7.6 PV-Photovoltaic-in this report PV and solar panels refer to the same system

7.7 PSM-Power Sight Management Software used for power studies.

7.8 EROI-Energy Return on Investment

7.9 PHSS-Pumped Hydro Storage System.

7.10 CT-Current Transformer. Used to measure current on an electrical wire.

7.11 RCM-Reliability Centered Maintenance

7.12 MMP-Maintenance Management Plan

7.13 NSM-No Scheduled Maintenance

8.0 Assumptions

In this study, it is assumed that all personnel associated with EES have access to EES's HRES power grid. It is also assumed that campus residents pay EES for their electricity. This study also assumes that the main cause for hydro shutdowns is PV surplus situations tripping the hydroelectric generator power reverse relay.

9.0 Scope

This report makes recommendations for hydro-solar optimization and maintenance management, but the execution of the plans is not covered due to time and funds available. Also, this study is specific to EES and its unique equipment, especially the hydroelectric power turbine. Due to time constraints, this project does not address all maintenance issues regarding the electrical utilities of EES.

10.0 Methodology

To establish the baseline perception of the 297 people affected by EES's power system, a survey was administered. The survey instrument utilized was Qaultrics online survey software. Students and personnel were given an internet link to a survey that asked them several questions about power quality and reliability at EES. The questions were rated by the respondents on a scale of one to seven with one being "strongly disagree" and seven being "strongly agree." The results of the survey were quantified by Qualtrics to determine the level of frustration by calculating the mean score of responses. See Appendix P for the survey questions. The questions were translated into Spanish for the survey.

To establish EES's electrical load baseline and investigate how to reduce power shutdowns caused by the hydro-solar relationship, a team traveled to Honduras. They performed an energy analysis, investigated potential causes for hydropower shutdowns, and assessed current maintenance procedures. The two-person team consisted of a facility manager and an electrical and controls expert.

The energy analysis performed utilized a PowerSight PS3000 Power analyzer that recorded multiple characteristics of EES's power over time. These characteristics include voltage, frequency, current, power factor, true power, energy consumption, peak demands, and costs. The analysis site was at the hydroelectric generator turbine house. The CT's and voltage clips were installed at the main breaker that services the entire electrical load of EES. The PowerSight Management software (PSM) analyzed the data and created reports based on that data. (Appendix K)

To optimize the hydro-solar, the investigative team worked at the hydropower plant to investigate options for load shedding PV surplus. The team looked for ways to use outputs from either the Fronius Smart Inverters at the PV arrays or from the controls of the hydro-turbine governor to communicate with a control system to shed PV surplus. The hydro controls are shown in Appendix H. This investigation included studying original control schematics and inverter manuals.

To assess the current maintenance procedures interviews were conducted with personnel and maintenance records studied to determine what is in place. Once this had been established, the team worked to create a maintenance management strategy focused on predictive testing and startup procedure.

11.0 Results

11.1 Energy load profile

The investigative team was able to record four power studies while at EES. The longest study can be seen in Appendix K. What the studies show is the quality of energy produced from the hydroelectric turbine generator is clean and stable. Voltage variation recorded were a maximum of +/- 10 volts. (Appendix L) Maximum frequency variations recorded were + 0.1 Hz and -0.9 Hz. (Appendix L) The power analysis also include a comparison of solar PV production overlayed with the EES load profile. It can be seen in the comparison charts that during a good solar production day there are several times when PV surplus occurs. This happens when EES's load is low enough that PV production is more than the load. The graphs shown in Appendix M are clear examples of this situation. In the graphs, PV surplus occurs in the area where the blue line (PV Production) is above the green line (EES load).

The comparison chart proves that PV surplus conditions occur and cause power shutdowns.

11.2 Student and Personnel Satisfaction with Electrical Power System

A total of 191 surveys were completed through Qualtrics online survey platform. Of the 191 respondents, 150 were students, 33 were EES employees, and 8 were I/O employees. Of the 41 employees of either EES or I/O, 14 marked as living on campus.

Figure 1-Satisfaction Survey Chart-Qualtrics

Soy un:

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Estudiante de EES	150	78.5	78.5	78.5
	Empleado de EES	33	17.3	17.3	95.8
	Empleado de IO	8	4.2	4.2	100.0
	Total	191	100.0	100.0	

Qualtrics calculated the mean response of the participants and each question that was asked. See Appendices R-X for survey results. The closer to seven that their score was, the higher the dissatisfaction. Anything over four indicated dissatisfaction. Figure 2 below, shows that every demographic has some level of dissatisfaction with the power system at EES.

The two groups with the highest dissatisfaction were employees of the farm (I/O) and the students of EES. These low satisfaction scores are reinforced by the responses to the last question of the survey which asked participants to describe a particular situation that poor power quality has affected you at EES. You can read the responses to this in Appendix X but many pertained to the ability of students to perform their school work.

Figure 2-Overall Mean Scores for Satisfaction

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Teacher Rating	16	2.14	6.57	4.6071	1.38652
Resident Rating	14	3.00	7.00	4.5714	1.40468
Overall Rating	169	1.00	6.57	4.0938	1.25580
Student Rating	146	1.00	7.00	5.0788	1.53318
I/O Empl Rating	7	4.00	6.27	5.2338	.81962

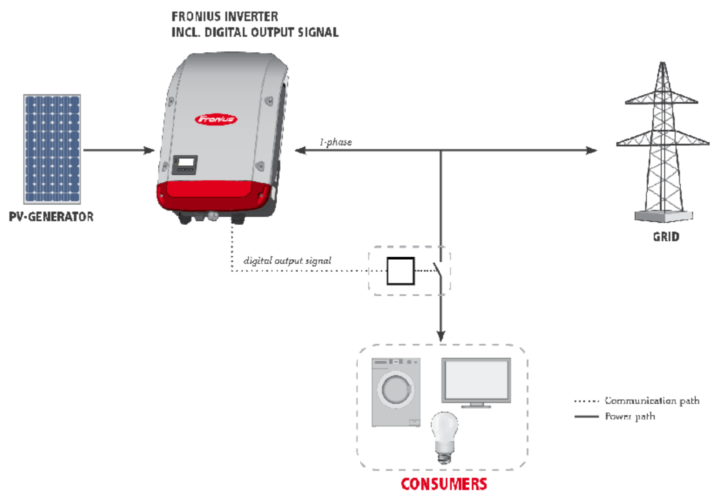
Here are a few examples of the responses. “When we are trying to get our homework done or study for an important class, it shortens our time to get it done.” “When I'm working on the computer and the lights go off I lose the work I'm doing. The lights go off almost every week.” “One time I have experienced losing a big assignment of research because I didn't save my document before the lights went out. It was a lot of information. Also when we don't have lights during school hours, it puts us behind.”

The survey and the responses to question 16 show that power outages have frustrated students and employees to a level that has affected how they perform their duties and ultimately impacting EES's mission negatively.

11.3 Hydro/Solar Relationship

During the investigative study performed in Honduras it was found that the PV surplus can be transferred from the system and therefore eliminating a power reverse shutdown of the hydro. After researching the Fronius Inverters that convert DC power from the solar panels to AC power, it was discovered that the data manager card within the Fronius has four digital outputs that can control a relay based upon user-defined thresholds of power and time. For example, the outputs can be programmed so when the panels produce more than 25 kW of power; the digital outputs send a signal to a relay or contactor to close. This closure energizes a load like an electric motor connected to a water pump. You can then program a time duration for how long the Fronius inverter sends that signal to eliminate short cycling that electric motor.

Figure 3-Control Based on PV-Surplus-www.fronius.com



This can greatly reduce PV surplus power shutdowns because when PV production is high enough to threaten a power reverse situation, a new load comes online (i.e., electric water pump) automatically increasing the load on the grid.

This new load can be in many different forms such as resistive heaters for heating water, electric irrigation pumps, air conditioning, or lighting. The team discussed several of these options and concluded that the best fit for EES would be to install an electric water pump next to the hydroelectric turbine house. In high PV production situations, greater than 25 kW, the water pump would automatically come on and pump water from the discharge of the hydro up to the water reservoir that feeds the hydro. This system would charge the battery, in this case the water reservoir, and extend the run-time of the hydro. A circuit diagram for this proposal is included in Appendix Y.

11.4 Assessment of Maintenance Management

The state of maintenance for the power utility system at EES can be described as reactive. Maintenance tasks are assigned when there are failures. Priority is given to the break-downs or failures that have the most immediate and significant impact on EES. The maintenance department for the electric utility consisted of one individual to oversee and maintain the system. The electrical system includes the generation equipment and the distribution equipment.

There was little to no evidence of maintenance logs or inspection logs. The investigative team found a few notebooks in the turbine house that showed no current records. Relevant information about basic maintenance items such as oil specifications, start-up and shut-down procedures, and safety procedures were not found in the turbine house where it was needed. The team's initial site inspection of the turbine house found two critical items with the water control system for the

Figure 4-Missing Pin on Water Control Shaft

turbine that were simple repairs but had been overlooked and were causing the hydro to use twice as much water as necessary to meet the demand.

Upon further inspection, many spare parts were found in the turbine house but several of them were spares for parts that aren’t used anymore. The team also found many fuses that were being stored in the supply cabinet that had already been burnt out. The state of the supply and tool cabinet did not allow for efficient repairs.

These items were evidence of EES’s reactive state regarding electrical utility maintenance. When operating in a reactive state break downs are commonly complete failures. When equipment is allowed to run to failure the repair costs are much higher. For example, if the bearings on the turbine shaft are not monitored and maintained and allowed to run to failure. The damage will not only be to the bearing and housing but also to the turbine shaft itself. This becomes a serious repair that is very expensive.

12.0 Limitations

A limitation of this project is access to EES. For financial reasons, travel is limited to one trip for conducting studies on the system. Language is also a limiting factor and makes access to data challenging and communicating technical issues difficult. Another major limitation to the study was the amount of time available to do a power analysis. The longest period the team analyzed was 22 hours. They were able to record four total studies with periods of 2.5, 15, 20, and 22 hours.

13.0 Conclusion

One of the purposes of this study was to quantify the effects of power quality at EES. Through the survey and power analysis, it was proven that power shutdowns have negatively impacted the mission of EES. Students and staff are not only frustrated, but are having to adjust how they perform their duties in order to compensate for frequent outages.

One of the biggest contributors to the power shutdowns was found to be the 42.9 kW solar system. The solar PV system was installed to extend the running time of the hydro during the dry season. Unfortunately, the solar system has increased hydro shutdowns due to the volatility of solar. "A PV-hydro system will exhibit fast frequency dynamics which cannot be handled by the conventional governors of hydro systems, responsible for the primary frequency control of the system. Large frequency deviations at a high rate of change of frequency thus may occur in such systems tripping frequency relays and causing unnecessary load shedding." (Tamrakar, Galipeau, Tonkoski, & Tamrakar, 2015) In EES's situation, it also causes reverse power situations that trip the power reverse relay shutting down the system.

As described by Salimath, Singh, and Badge a pumped hydro storage system can be used to "mitigate the problems associated with the fluctuating output of power." (Salimath et al., 2018) This is a good solution for EES because the operating costs for such a system is low due to that fact that it uses energy that was being lost by shutdown solar arrays. It also works well because most of the energy used to pump water is transferred into potential energy that runs the hydroelectric turbine generator. The control mechanism is already in place for this type of system because it is integrated into the Fronius Inverters for the solar arrays. The downside to adding the pumped hydro storage system is that new equipment would need to be purchased. With the new equipment and pumping system, more responsibility would be added to the already thin maintenance department.

Another option is to divert the surplus power produced by the solar panels and use it to power a ten hp motor connected to a water pump that is used for drip irrigation in a nearby field.

The advantage is that the system is already in place and so the only addition would be the control equipment. Another advantage of using the drip irrigation pump is that it is near the hydro-generator. The distance between the hydro and irrigation pump is 500 ft. This shorter distance reduces the amount of wire needed to control the motor.

One of the downsides to using the irrigation pump is that there are times when irrigation is not needed, and so I/O would not want it running. These times include the rainy season, planting time, and harvest.

The last option is to shut down one of the three arrays during peak solar irradiance. This would cut solar production by 1/3 and reduce PV surplus occurrences. The benefit of this option is that there are no additional expenses. The downside is that EES would not receive a payback for the installation and operational costs of that third solar array.

To determine the best option a cost-benefit analysis of the three PV surplus diversion methods described above would need to be calculated to make the best choice.

As with any system, management is the key to success or failure. The pumped hydro storage system appears to be a good solution for frequent shutdowns, but if not managed and understood the danger is that it will be neglected and lost to poor management. This is also true of the hydroelectric turbine generator. Installed in the early 1990s, the system is nearing 30 years old. It has operated well in that time, but the electronic controls have been operating in high heat conditions which can cause failure. EES is at a point where, if they do not invest in their utility infrastructure, they will begin to lose some of the systems they have. The hydro-generator is most susceptible to being lost.

EES needs to shift from a reactive state of maintenance to a proactive state. EES needs to understand the function of the hydro-generator and answer two questions. Why does the hydro exist at EES? It exists to provide high quality, reliable electrical power so that EES can carry out its mission to the best of their ability. The other question they must answer is what happens if they lose it? From a financial standpoint, the hydro-generator offsets approximately $4,500 in electrical usage per month. Without the hydro, EES would have to buy their electricity from ENEE, which is volatile and unreliable.

With this in mind, EES can then begin to build their Maintenance Management Plan (MMP) based on a Reliability Center Maintenance Analysis. The scope of this report does not develop an MMP for El Sembrador, but does introduce the basic techniques for developing one.

An RCM analysis consists of three steps. (Piskorowski, 2019)

1. Develop the Operating Context
    a. What are the equipment issues?
    b. What are the business issues?
    c. What are the organizational issues?
2. Perform Failure Modes and Effects Analysis (FMEA)
3. Decision Analysis

EES needs to anticipate the failures of the system and develop a monitoring system to identify the indicators of those failures. Once identified they must develop a plan to mitigate the effects of those failures. Failures Modes and Effects Analysis (FMEA) is a tool that can be used to develop this. FMEA answer the following seven questions. (Piskorowski, 2019)

1. What are the functions and performance standards of the asset in its operating context?

2. In what ways could it fail to fulfill its functions?
3. What could cause each functional failure?
4. What would happen when each failure occurs?
5. In what ways would each failure matter?
6. What could be done to predict or prevent each failure?
7. What if a suitable proactive task could not be found?

Before the FMEA on the hydro system can be performed, EES must create an asset inventory. What does EES have and how does it interact with other systems. Creating simple system line diagrams showing how the asset interacts with other assets effectively illustrates how each system interacts with other systems. The asset inventory includes identifying, recording, and physically labeling the major components of each asset. Once this completed, they can move on to the FMEA.

Decision analysis is the last step in RCM. Appendix BB illustrates the decision tree used to evaluate what actions need to be taken based upon the FMEA.

Finally, success is dependent on implementation and follow-thru. EES must make the final decision of how high a priority they want to place on their electrical generating equipment. Bringing these systems back up to a reliable state will not be easy or cheap, but neither are the alternatives.

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Appendix

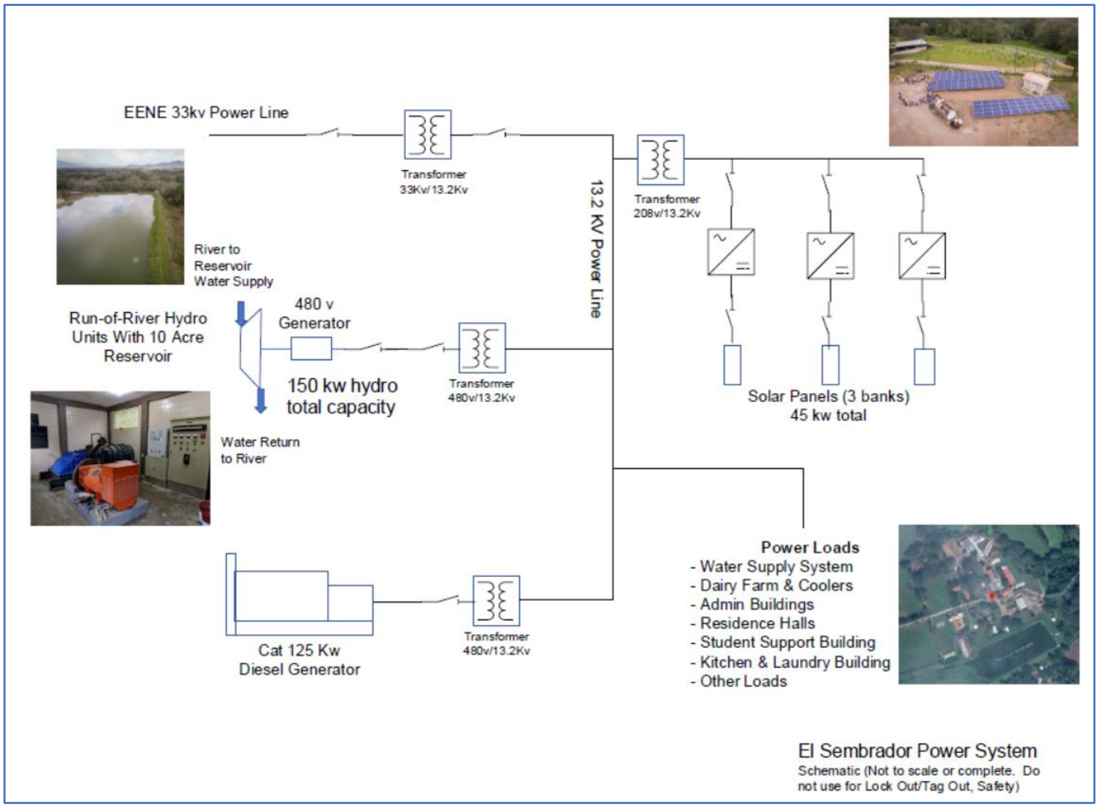
Appendix A-Honduras Position in Central America

Appendix B-Honduras_El Sembrador

Appendix C-Aerial View of El Sembrador

Appendix D-Water Reservoir for Hydro-turbine

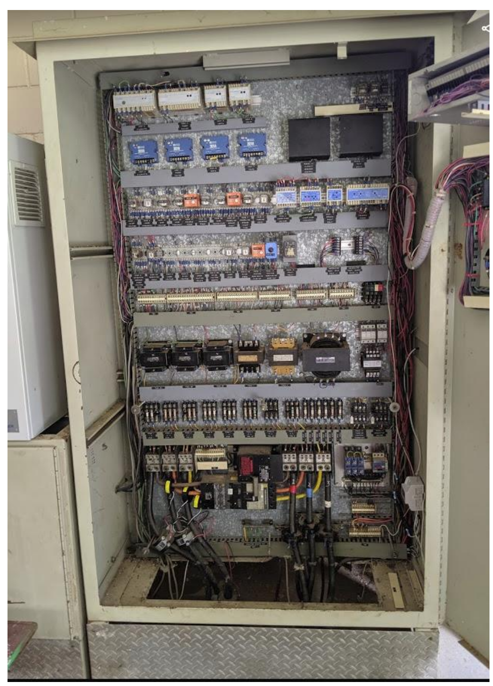
Appendix E-EES Single Line Power Grid



Appendix F-Hydroelectric Turbine Generator_January 2018

Appendix G-Turbine House at base of Reservoir Dike

Appendix H-Control Panel Exterior and Interior



Appendix I-Diesel Generator Fuel Consumption Chart

WORLDWIDE
POWER PRODUCTS, LLC

APPROXIMATE FUEL CONSUMPTION CHART

This chart approximates the fuel consumption of a diesel generator based on the size of the generator and the load at which the generator is operating at. Please note that this table is intended to be used as an estimate of how much fuel a generator uses during operation and is not an exact representation due to various factors that can increase or decrease the amount of fuel consumed.

Generator Size (kW)	1/4 Load (gal/hr)	1/2 Load (gal/hr)	3/4 Load (gal/hr)	Full Load (gal/hr)
20	0.6	0.9	1.3	1.6
30	1.3	1.8	2.4	2.9
40	1.6	2.3	3.2	4.0
60	1.8	2.9	3.8	4.8
75	2.4	3.4	4.6	6.1
100	2.6	4.1	5.8	7.4
125	3.1	5.0	7.1	9.1
135	3.3	5.4	7.6	9.8
150	3.6	5.9	8.4	10.9

Produccion													
	Total Vacas	Total Vacas Entrando	Total Vacas Secas	Promedio AM	Promedio AM por Vaca	Promedio PM	Promedio PM por Vaca	Total Leche por Mes	Promedio Total Diario	Promedio Vaca Grupo A	Promedio Vaquilla Grupo A	Promedio Vaca Grupo B	Promedio Vaca
Enero	258.2	13	18	2199.8	8.5	1850.5	7.2	125,560	4,050	20.2	16.20	12.90	15.7
Febrero	269.9	33	15	2301.3	8.5	1955.0	7.2	119,176	4,256	21.2	15.5	12.6	15.8
Marzo	271.7	17	25	2361.9	8.7	2001.5	7.4	135,267	4,363	21.6	17.2	12.9	16.1
Abril	275.8	24	14	2448.4	8.9	2037.3	7.4	134,571	4,486	22.9	18.0	13.6	16.3
Mayo	282.7	21	16	2453.0	8.7	2049.5	7.2	139,579	4,503	22.0	16.4	12.8	15.9
Junio	284.3	4	1	2425.3	8.5	2008.1	7.1	64,494	4,433	21.3	15.3	12.3	15.6
Julio	0.0	0	0	0.0	0.0	0.0	0.0	-	-	#DIV/0!	#DIV/0!	#DIV/0!	0.0
Agosto	0.0	0	0	0.0	0.0	0.0	0.0	-	-	#DIV/0!	#DIV/0!	#DIV/0!	0.0
Septiembre	0.0	0	0	0.0	0.0	0.0	0.0	-	-	#DIV/0!	#DIV/0!	#DIV/0!	0.0
Octubre	0.0	0	0	0.0	0.0	0.0	0.0	-	-	#DIV/0!	#DIV/0!	#DIV/0!	0.0
Noviembre	0.0	0	0	0.0	0.0	0.0	0.0	-	-	#DIV/0!	#DIV/0!	#DIV/0!	0.0
Diciembre	0.0	0	0	0.0	0.0	0.0	0.0	-	-	#DIV/0!	#DIV/0!	#DIV/0!	0.0
Total Anual		**112**	**89**					**718,647**					
Promedio Mensual	**273.8**	**18.7**	**14.8**	**2365.0**	**8.6**	**1983.7**	**7.3**	**119774.5**	**4348.6**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**15.9**

EES Load_6_15_19_Overnight

Power Study Summary

EES Load_6_15_19_Overnight

Test began at 06.15.19 17:20:00

Test ended at 06.16.19 15:25:50

Measurement	Value	Units
Power Factor, Total, Avg:	0.88	
Power Factor, Total, Max:	0.96	
Power Factor, Total, Min:	0.63	
True Power, Total, Avg:	38.769K	Watts
True Power, Total, Max:	72.243K	Watts
True Power, Total, Min:	7.763K	Watts
VA Power, Total, Avg:	43.674K	VA
VA Power, Total, Max:	78.080K	VA
VA Power, Total, Min:	11.200K	VA
VAR Power, Total, Avg:	19.844K	VAR
Frequency, Avg:	60.1	Hz
Frequency, Max:	61.0	Hz
Frequency, Min:	59.1	Hz
Energy, Total Elapsed:	856.7	KWh
VAH, Total Elapsed:	965.1	KVAh
Energy, estimated per month:	28.301K	KWH
Utility Rate:	0.1700	$/KWH
Cost, Total Elapsed:	145.6	$
Cost, estimated per month:	4.745K	$
Peak Average Demand:	69.581K	Watts
Peak Demand Period, KW:	06/15/19 @ 18:06:40	
Peak Average VA:	74.598K	VA
Peak Demand Period, KVA:	06/15/19 @ 18:06:15	

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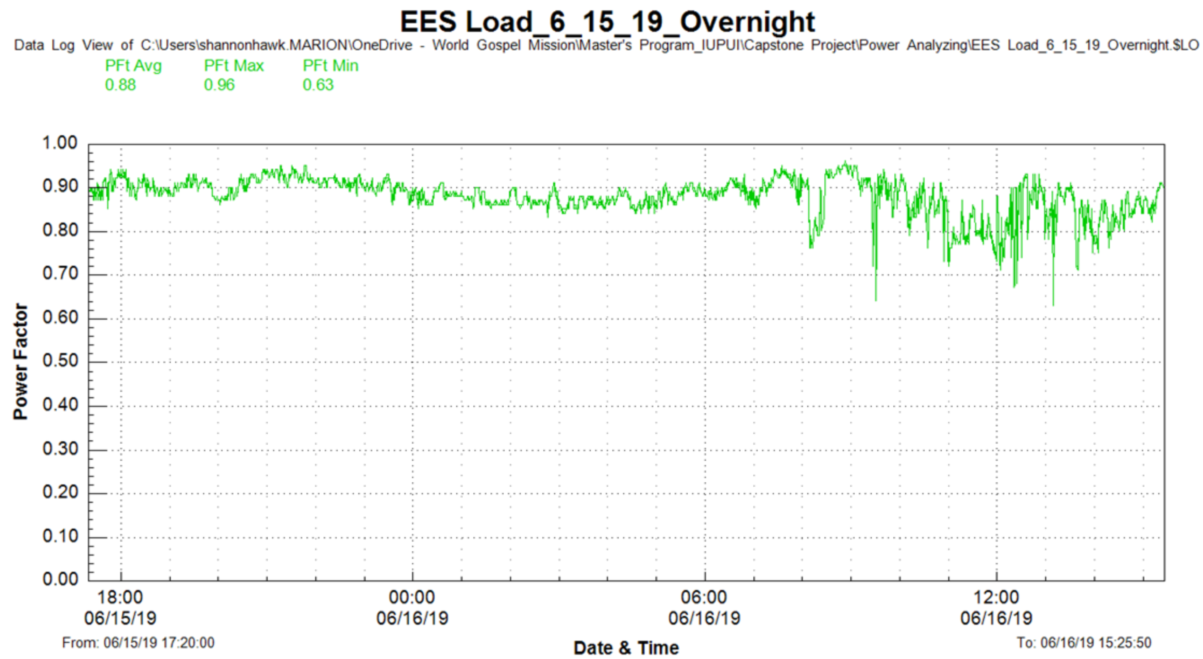
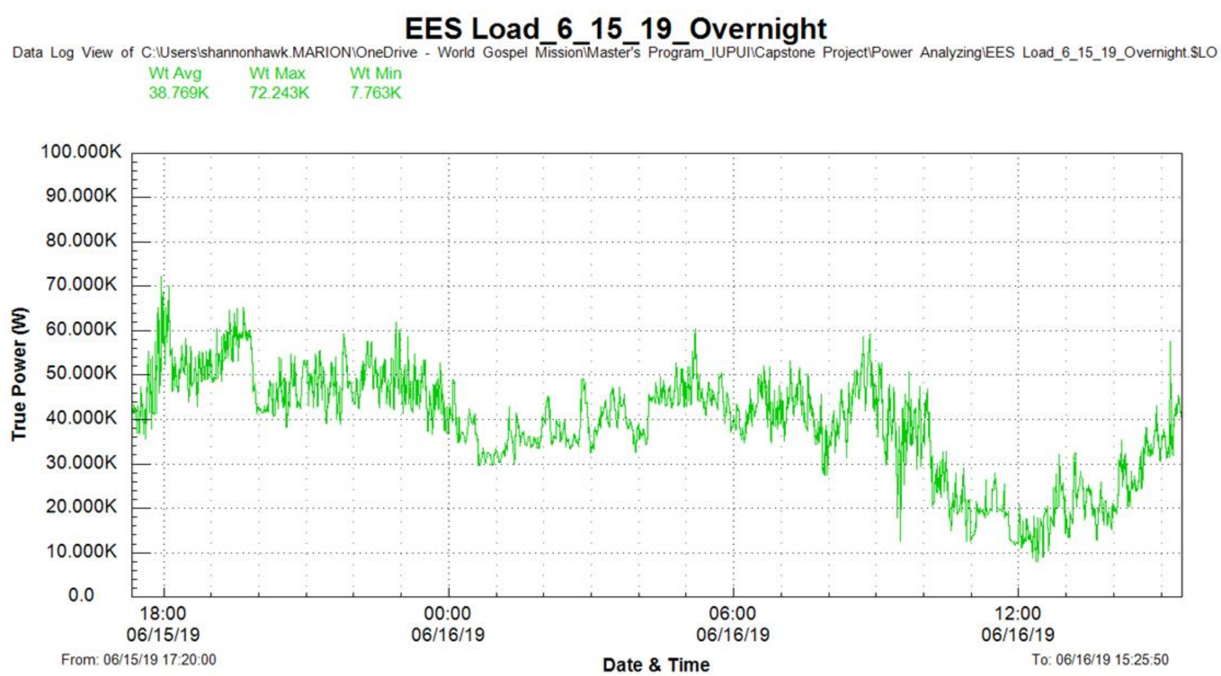
Appendix L-Power Load Summary Graphs_EES_6/15/19

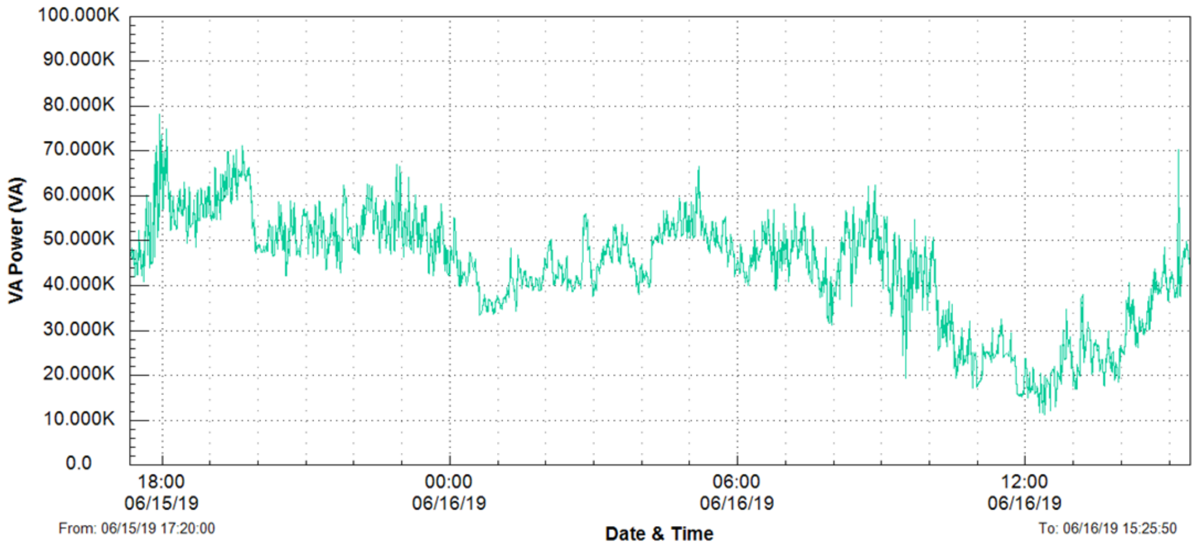




EES Load_6_15_19_Overnight

Data Log View of C:\Users\shannonhawk.MARION\OneDrive - World Gospel Mission\Master's Program_IUPUI\Capstone Project\Power Analyzing\EES Load_6_15_19_Overnight.$LO

VAt Avg	VAt Max	VAt Min
43.674K	78.080K	11.200K



EES Load_6_15_19_Overnight

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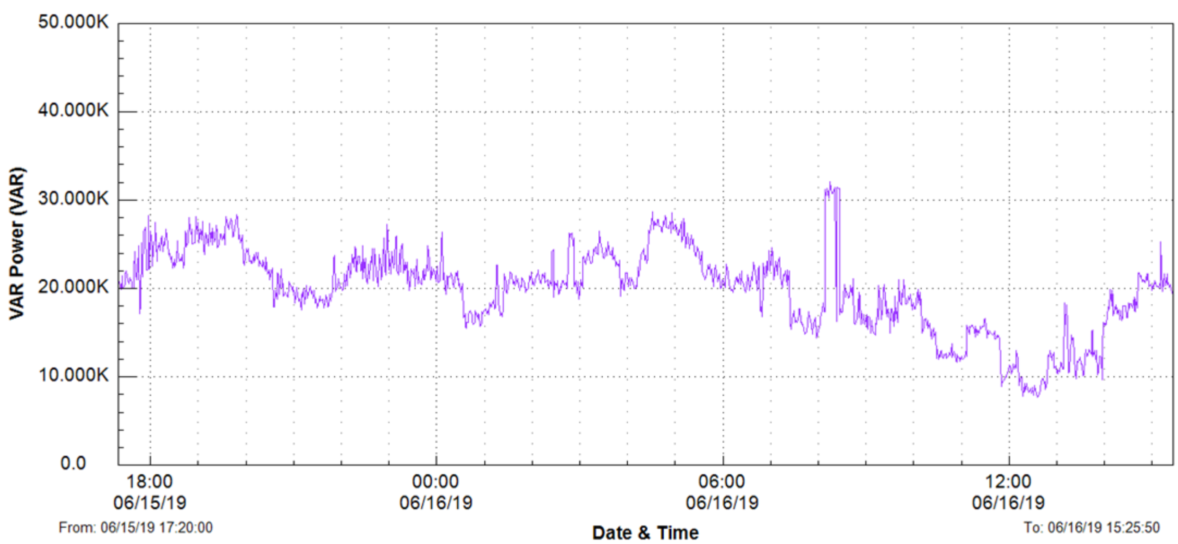
VARt Avg
19.844K



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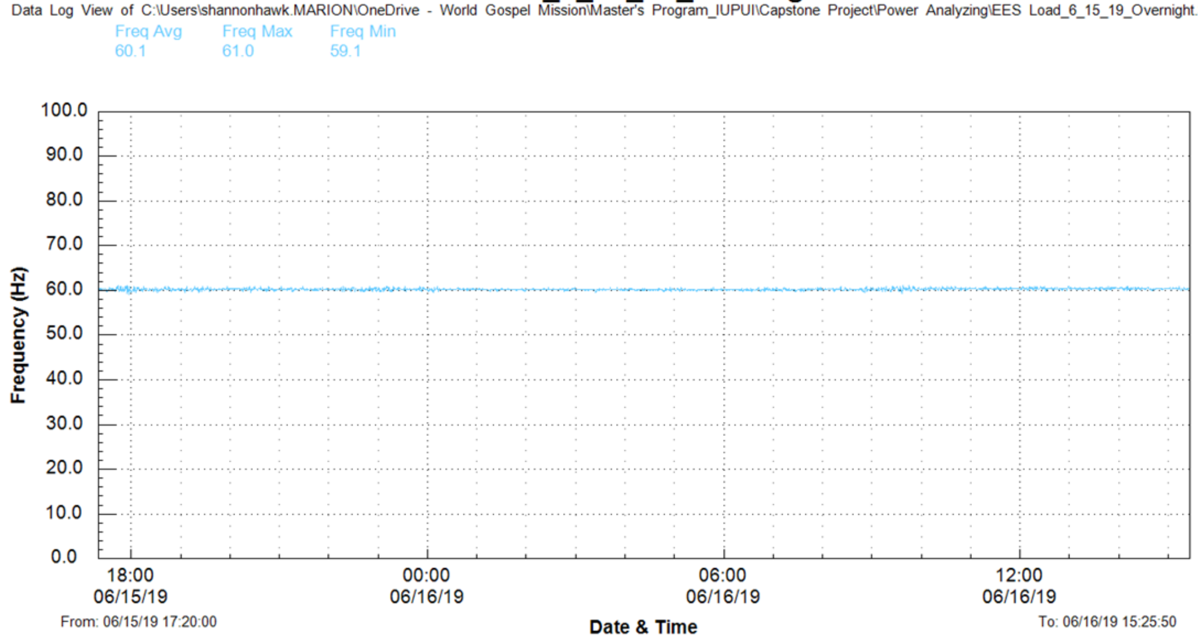

EES Load_6_15_19_Overnight

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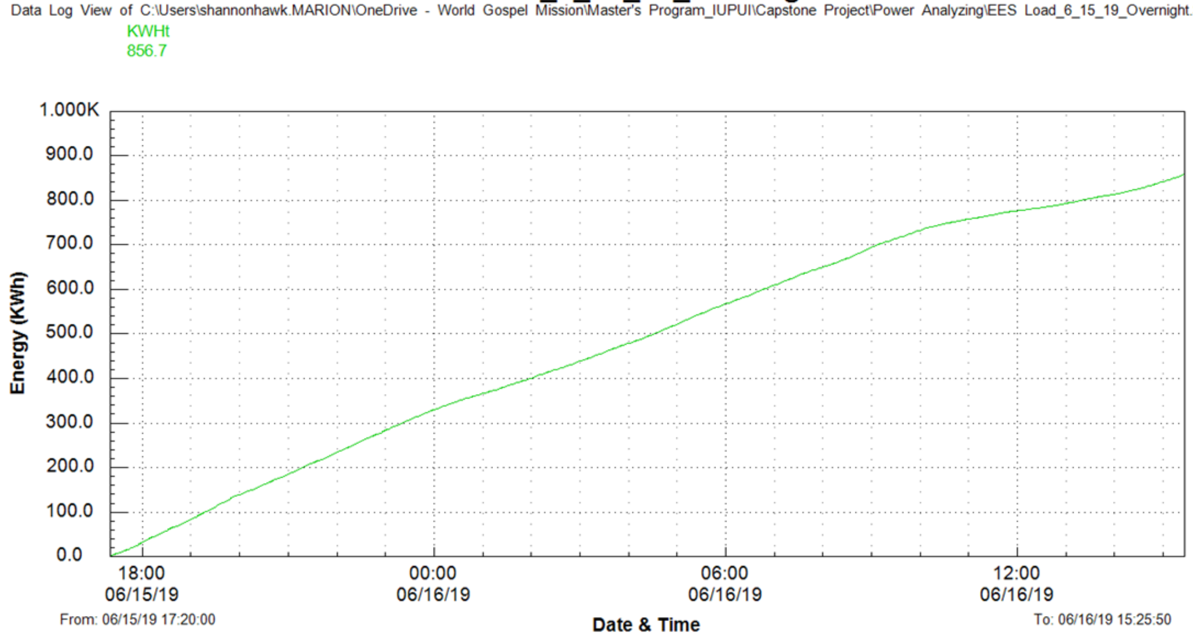

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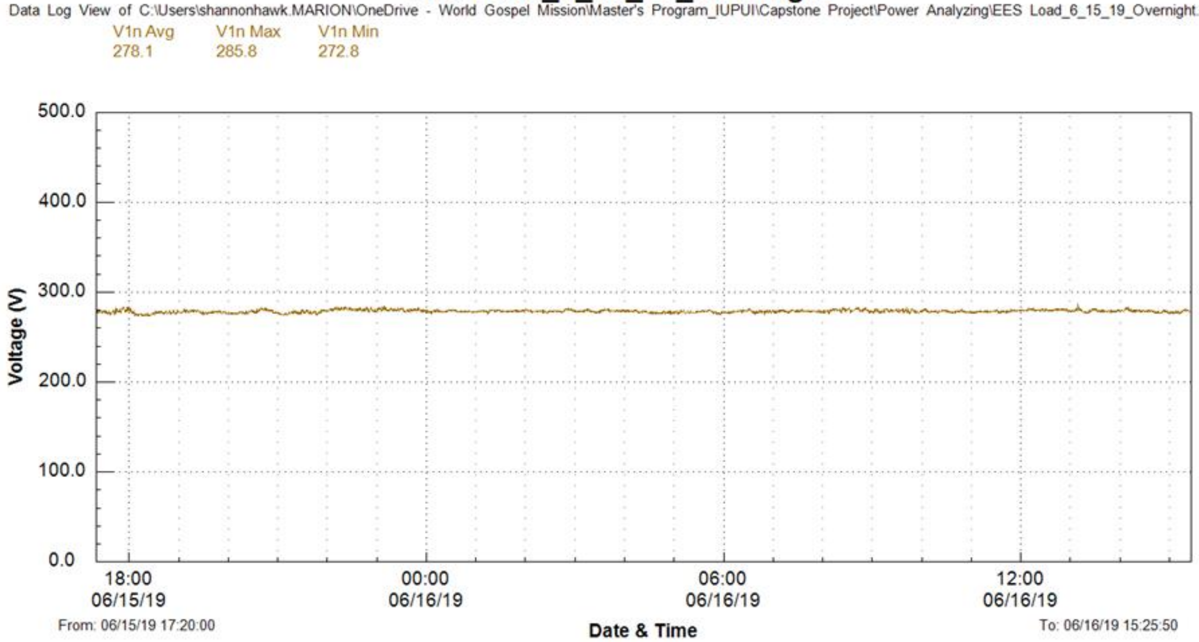
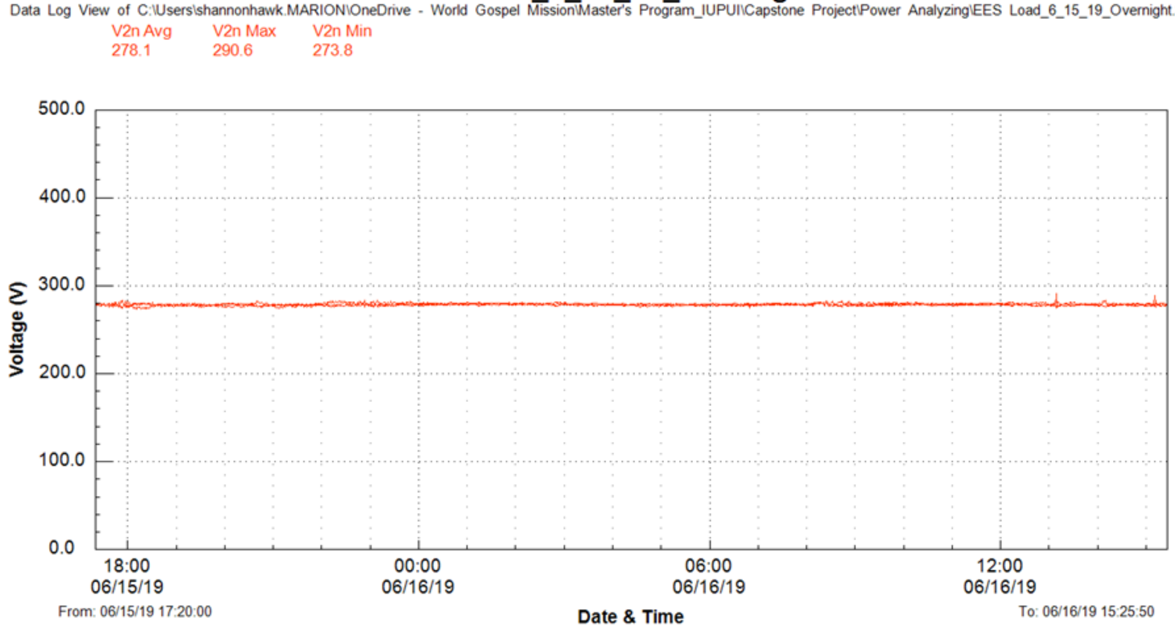
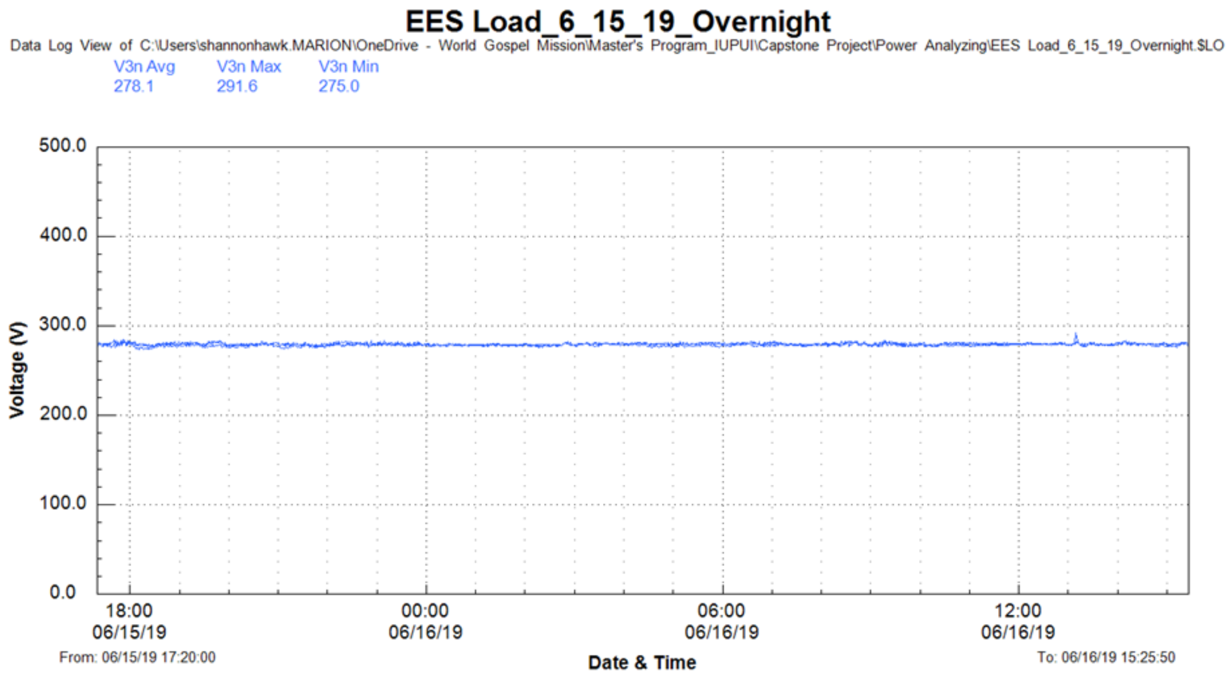


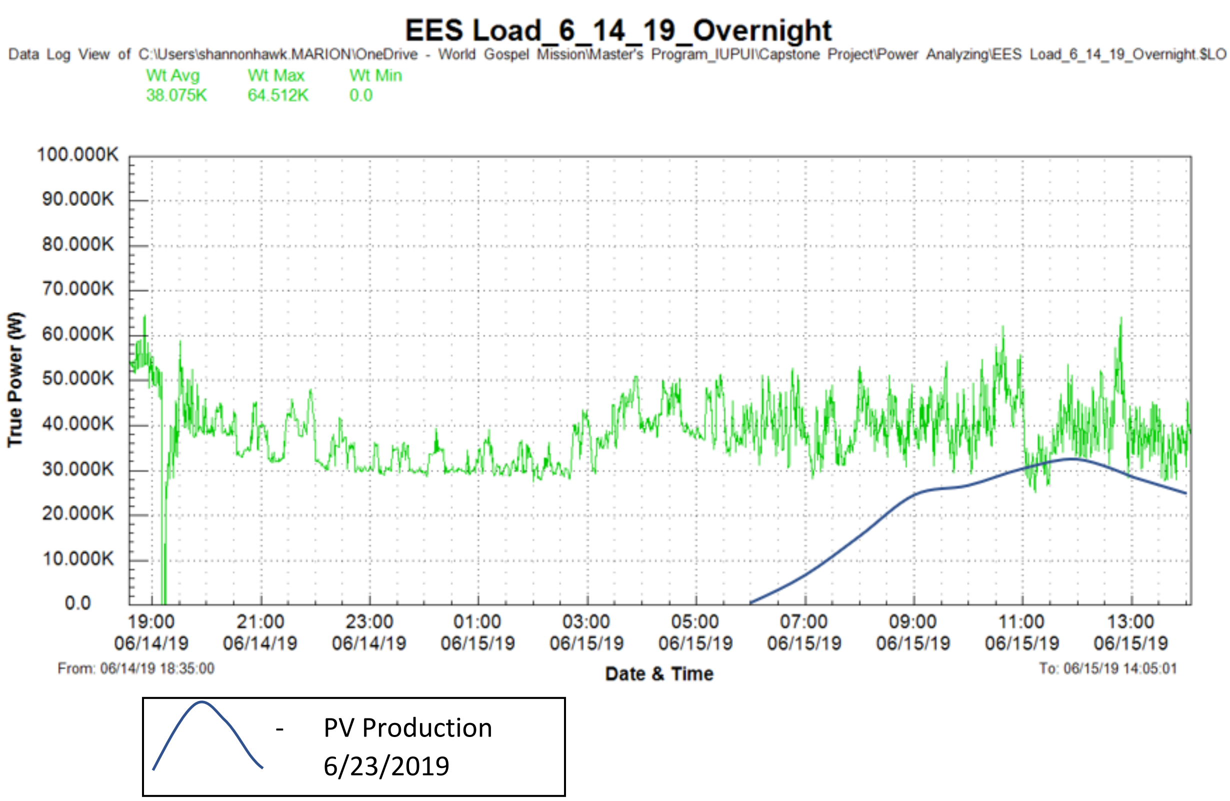
EES Load_6_15_19_Overnight

Data Log View of C:\Users\shannonhawk.MARION\OneDrive - World Gospel Mission\Master's Program_IUPUI\Capstone Project\Power Analyzing\EES Load_6_15_19_Overnight.$LO

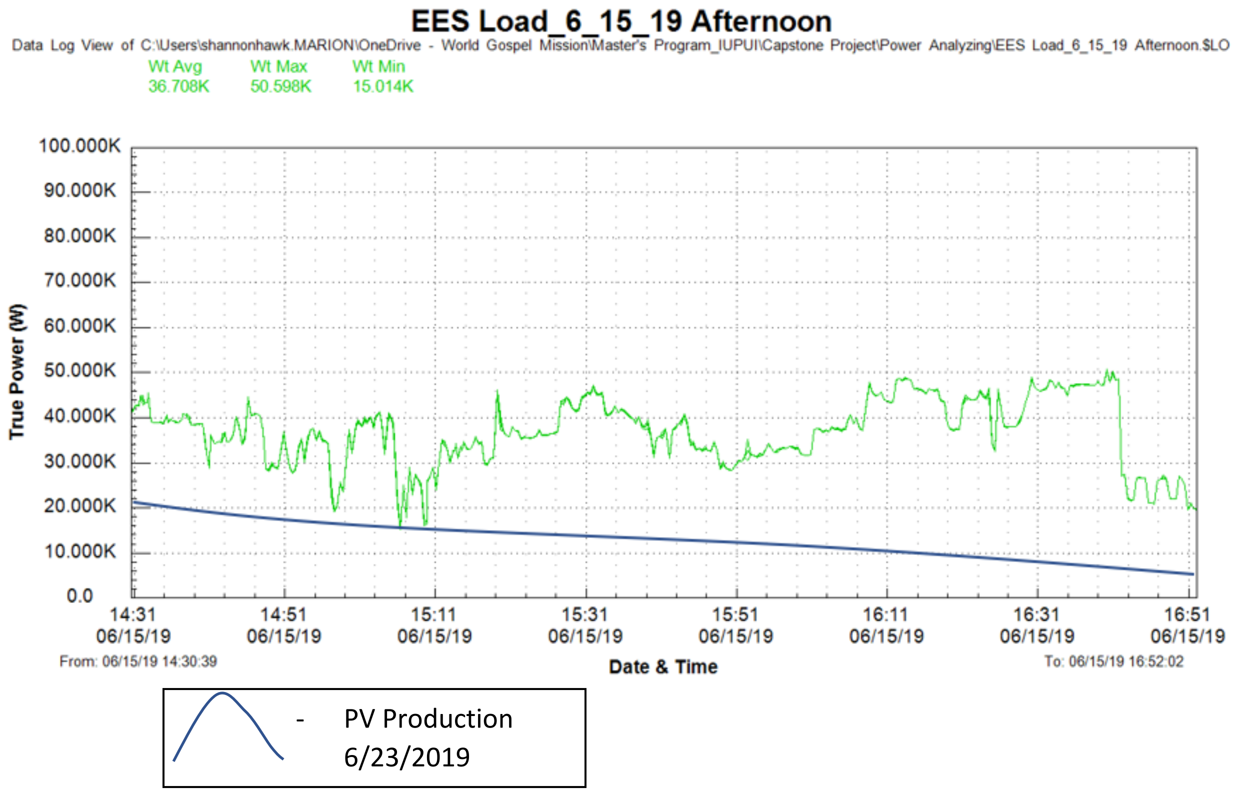




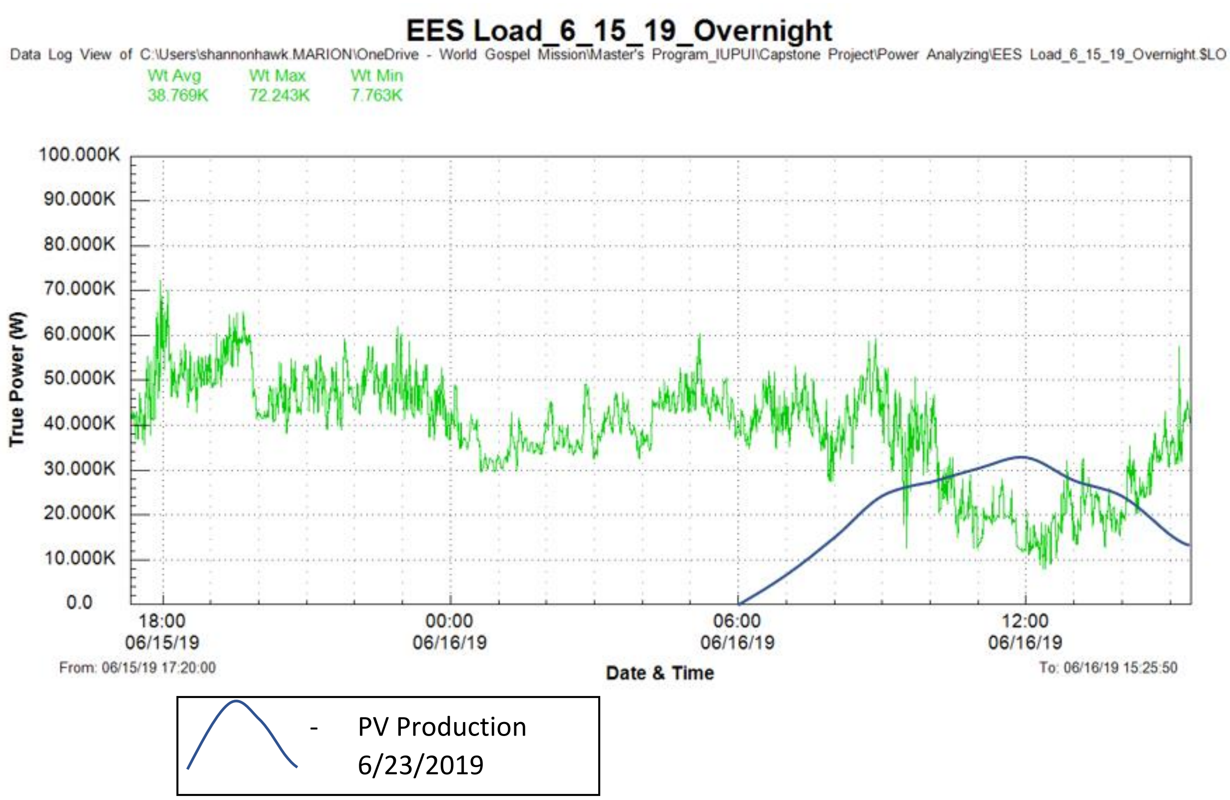
Appendix M-EES Load and PV Production Comparison



Appendix N-EES Load and PV Production Comparison



Appendix O-EES Load and PV Production Comparison



Our lives are impacted by electricity every day. It helps perform our daily routines such as providing light to a dark room, powering a fan motor to keep us cool, powering tools to help us work, and many others. But when the power is off how does it affect us and what we do. Please take a few minutes to answer the following questions regarding electrical power at Escuela El Sembrador and how it impacts you. Thank you for your time.

DEMOGRAPHICS
Position
Teacher, School Administrator, School Support Staff,

1. I am an:
   a. EES Student (Answer "Overall Impact" and "Student"
      i. Grade _____
         1. Years at EES
   b. EES Employee
      - Teacher (Answer "**Overall Impact**", "**Teacher**")
      - School Administration (Answer "**Overall Impact**", "**Teacher**")
      - EES Administration (Answer "**Overall Impact**", "**Support Staff**")
      - Support staff (Answer "**Overall Impact**", "**Support Staff**")
      - Counselor (Answer "**Overall Impact**", "**Teacher**")
         - Total years working at EES _______
         - I live
            - On Campus ___ (Also answer "resident")
            - Off Campus____
   c. I/O Employee (Answer ""I/O employee")
      1. Total Years working at I/O_______
         i. I live
            1. On Campus ___ (Also answer "resident")
            2. Off Campus____

Please rate the extent to which you agree with each statement regarding poor power quality at EES. Poor power quality includes voltage spikes, reliability, and outages.

SD/SA
OVERALL IMPACT

1. Poor power quality significantly impacts the mission of EES.
2. ~~Poor power quality reduces my ability to perform my duties at EES.~~
3. Poor power quality frustrates me
4. I am less motivated to perform my duties when the power is out.
5. Poor power quality impedes my ability to be effective at EES.
6. Poor power quality affects the reputation of EES.
7. Poor power quality affects relationships with others (community partners, ministry partners, friends or vendors that EES does business with)
8. Power outages affect my sense of security.
9. ~~Power Quality is better in Catacamas compared to EES~~
10. ~~Power is cheaper in Catacamas than EES~~

TEACHER SPECIFIC

11. Poor power quality makes it difficult to follow my lesson plans
12. Because of poor power quality I do not plan to utilize technology that is available at school
13. I am as effective as a teacher without power as I am with power (***Reverse code in data)
14. ~~Students are not impacted by power outages.~~
15. Learning is negatively influenced by poor power quality.
16. Students are regularly frustrated by poor power quality.
17. Poor power quality results in students losing work on their devices.
18. Student motivation is negatively affected by poor power quality.
19. Poor power quality impacts students' ability to work on homework at night.

Support Staff (maintenance, cook staff, housekeeping/cleaning)

20. Inconsistent power causes me to change how I perform my duties
21. ~~Poor power quality causes me to be less productive~~
22. Poor power quality gets in the way of special events (i.e., services, weddings, conferences and other programming)
23. Poor power quality costs EES extra money.

RESIDENTS

24. I pay too much for the electrical power that I receive.
25. Power outages significantly disrupt my personal and/or family life.
26. I have to buy equipment to protect my personal electronic equipment from poor power quality.
27. Power at EES is a good value. (***Reverse code in data)

Students

28. I worry about losing my work on my electronic device because of poor power quality
29. My educational experience would be better if power quality was better

I/O Employee

30. Inconsistent power causes me to change how I perform my duties
31. Poor power quality significantly impacts I/O ability to do business
32. Poor power quality can lead to spoilage of our product (milk, meat, or grain)
33. I am less motivated to perform my duties when the power is out
34. Poor power quality affects the reputation of I/O
35. Poor power quality affects relationships with others (community partners or vendors that I/O does business with)
36. Poor power quality impedes our ability to make timely repairs to our equipment in the mechanic shop
37. Poor power quality frustrates me
38. Power outages affect the security of our business
39. Poor power quality negatively impacts our milking schedule
40. Poor power quality impacts our hog production

(Everyone)
Please describe any other specific instances that poor power quality has affected you at EES____________

Appendix Q-Online Survey Platform Example

Por favor, responda a cada declaración sobre la mala calidad de la energía eléctrica en EES. La mala calidad de la energía incluye picos de voltaje, fiabilidad y cortes de energía eléctrica. Califique su respuesta desde muy en desacuerdo a muy de acuerdo.

	muy en desacuerdo	desacuerdo	algo en desacuerdo	Ni de acuerdo ni en desacuerdo	parcialmente de acuerdo	de acuerdo	Totalmente de acuerdo
La mala calidad de la energía eléctrica afecta significativamente la misión de EES	○	○	○	○	○	●	○
La mala calidad de la energía eléctrica me frustra.	○	○	○	○	●	○	○
Estoy menos motivado para realizar mis tareas cuando no hay electricidad.	○	○	○	○	○	●	○
La mala calidad de energía eléctrica impide mi efectividad en EES.	○	○	○	○	○	●	○
La mala calidad de la energía eléctrica afecta la reputación de EES.	○	○	○	○	●	○	○

Appendix R-Overall Mean Scores for Satisfaction

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Teacher Rating	16	2.14	6.57	4.6071	1.38652
Resident Rating	14	3.00	7.00	4.5714	1.40468
Overall Rating	169	1.00	6.57	4.0938	1.25580
Student Rating	146	1.00	7.00	5.0788	1.53318
I/O Empl Rating	7	4.00	6.27	5.2338	.81962

Appendix S-"Overall Satisfaction" Scores

Items for Overall Satisfaction Scale

Item Statistics

Question - English	Question - Spanish	Mean	Std. Deviation	N
Poor power quality significantly impacts the mission of EES.	Overall - La mala calidad de la energía eléctrica afecta significativamente la misión de EES	4.53	1.816	169
Poor power quality frustrates me.	Overall - La mala calidad de la energía eléctrica me frustra.	4.42	1.938	169
I am less motivated to perform my duties when the power is out.	Overall - Estoy menos motivado para realizar mis tareas cuando no hay electricidad.	4.48	2.079	169
Poor power quality impedes my ability to be effective at EES.	Overall - La mala calidad de energía eléctrica impide mi efectividad en EES.	3.77	1.842	169
Poor power quality affects the reputation of EES.	Overall - La mala calidad de la energía eléctrica afecta la reputación de EES.	4.01	1.924	169
Poor power quality affects relationships with others (community partners, ministry partners, friends or vendors that EES does business with)	Overall - La mala calidad de la energía eléctrica afecta las relaciones con los demás (socios de la comunidad, socios del ministerio, amigos o proveedores con los que EES hace negocios).	3.91	1.909	169
Power outages affect my sense of security.	Overall - Cortes de energía eléctrica afectan mi sentido de seguridad.	3.54	1.732	169

Appendix T-Teacher Satisfaction Scores

Teacher Satisfaction Scale

Item Statistics

Question - English	Question - Spanish	Mean	Std. Deviation	N
Poor power quality makes it difficult to follow my lesson plans	Teachers - La mala calidad de la energía eléctrica hace que sea difícil seguir mi curriculum educativo.	4.25	1.880	16
Because of poor power quality I do not plan to utilize technology that is available at school	Teachers - Debido a la mala calidad de la energía eléctrica no planeo utilizar la tecnología que está disponible en la escuela	4.63	2.029	16
I am as effective as a teacher without power as I am with power	Teachers - Soy tan eficaz como maestro sin energía eléctrica como lo soy con energía eléctrica	5.56	1.590	16
Learning is negatively influenced by poor power quality.	Teachers - El aprendizaje está influenciado negativamente por la mala calidad de la energía eléctrica.	3.50	1.751	16
Students are regularly frustrated by poor power quality.	Teachers - Los estudiantes se sienten regularmente frustrados por la mala calidad de la energía eléctrica.	5.00	1.789	16
Poor power quality results in students losing work on their devices.	Teachers - La mala calidad de la energía eléctrica hace que los estudiantes pierdan trabajos guardados en sus dispositivos.	4.88	2.125	16
Student motivation is negatively affected by poor power quality.	Teachers - La motivación de los estudiantes se ve afectada por la mala calidad de la energía eléctrica.	4.44	1.861	16
Poor power quality impacts students' ability to work on homework at night.	Teachers - La mala calidad de la energía eléctrica afecta la capacidad de los estudiantes para trabajar en la tarea por la noche.	5.56	1.711	16

Appendix U-I/O Employee Satisfaction Scores

I/O Employee Satisfaction

Item Statistics

Question - English	Question - Spanish	Mean	Std. Deviation	N
Inconsistent power causes me to change how I perform my duties	IO Employees - La energía eléctrica inconsistente me hace cambiar la forma en que realizo mis labores	5.57	.976	7
Poor power quality significantly impacts I/O ability to do business	IO Employees - La mala calidad de la energía eléctrica afecta significativamente la capacidad de I / O para hacer negocios	5.29	1.604	7
Poor power quality can lead to spoilage of our product (milk, meat, or grain)	IO Employees - La mala calidad de la energía eléctrica puede provocar el deterioro de nuestro producto (leche, carne o grano)	6.00	1.528	7
I am less motivated to perform my duties when the power is out	IO Employees - Estoy menos motivado para realizar mis tareas cuando no hay electricidad	3.71	1.890	7
Poor power quality affects the reputation of I/O	IO Employees - La mala calidad de la energía eléctrica afecta la reputación de EES	4.43	2.070	7
Poor power quality affects relationships with others (community partners or vendors that I/O does business with)	IO Employees - La mala calidad de la energía eléctrica afecta las relaciones con los demás (socios comunitarios o proveedores con los que I / O hace negocios)	4.00	1.633	7
Poor power quality impedes our ability to make timely repairs to our equipment in the mechanic shop	IO Employees - La mala calidad de la energía eléctrica impide nuestra capacidad para realizar reparaciones oportunas de nuestros equipos en el taller mecánico	6.00	1.000	7
Poor power quality frustrates me	IO Employees - La mala calidad de la energía eléctrica me frustra	5.43	1.512	7
Power outages affect the security of our business	IO Employees - Los cortes de energía afectan la seguridad de nuestro negocio.	6.00	1.155	7
Poor power quality negatively impacts our milking schedule	IO Employees - La mala calidad de la energía eléctrica afecta negativamente nuestro horario de ordeño	5.00	2.380	7
Poor power quality impacts our hog production	IO Employees - La mala calidad de la energía eléctrica afecta nuestra producción de cerdos	6.14	1.215	7

Appendix V-Resident Satisfaction Scores

Resident Satisfaction — **Item Statistics**

Question - English	Question - Spanish	Mean	Std. Deviation	N
I pay too much for the electrical power that I receive.	Residents - Pago demasiado por la energía eléctrica que recibo.	3.57	1.828	14
Power outages significantly disrupt my personal and/or family life.	Residents - Los cortes de energía perturban significativamente mi vida personal y / o familiar.	4.93	1.385	14
I have to buy equipment to protect my personal electronic equipment from poor power quality.	Residents - Tengo que comprar equipos para proteger mis equipos electrónicos personales por la mala calidad de la energía eléctrica.	5.21	1.968	14
Power at EES is a good value.	Residents - La energía eléctrica en EES es un buen valor.	5.29	1.899	14

Appendix W-Student Satisfaction Scores

Student Satisfaction — **Item Statistics**

Question - English	Question - Spanish	Mean	Std. Deviation	N
I worry about losing my work on my electronic device because of poor power quality	Students - Me preocupa perder mi trabajo guardado en mi dispositivo electrónico debido a la mala calidad de la energía eléctrica	5.39	1.991	146
My educational experience would be better if power quality was better	Students - Mi experiencia educativa sería superior si la calidad de la energía eléctrica fuera mejor	4.77	1.730	146

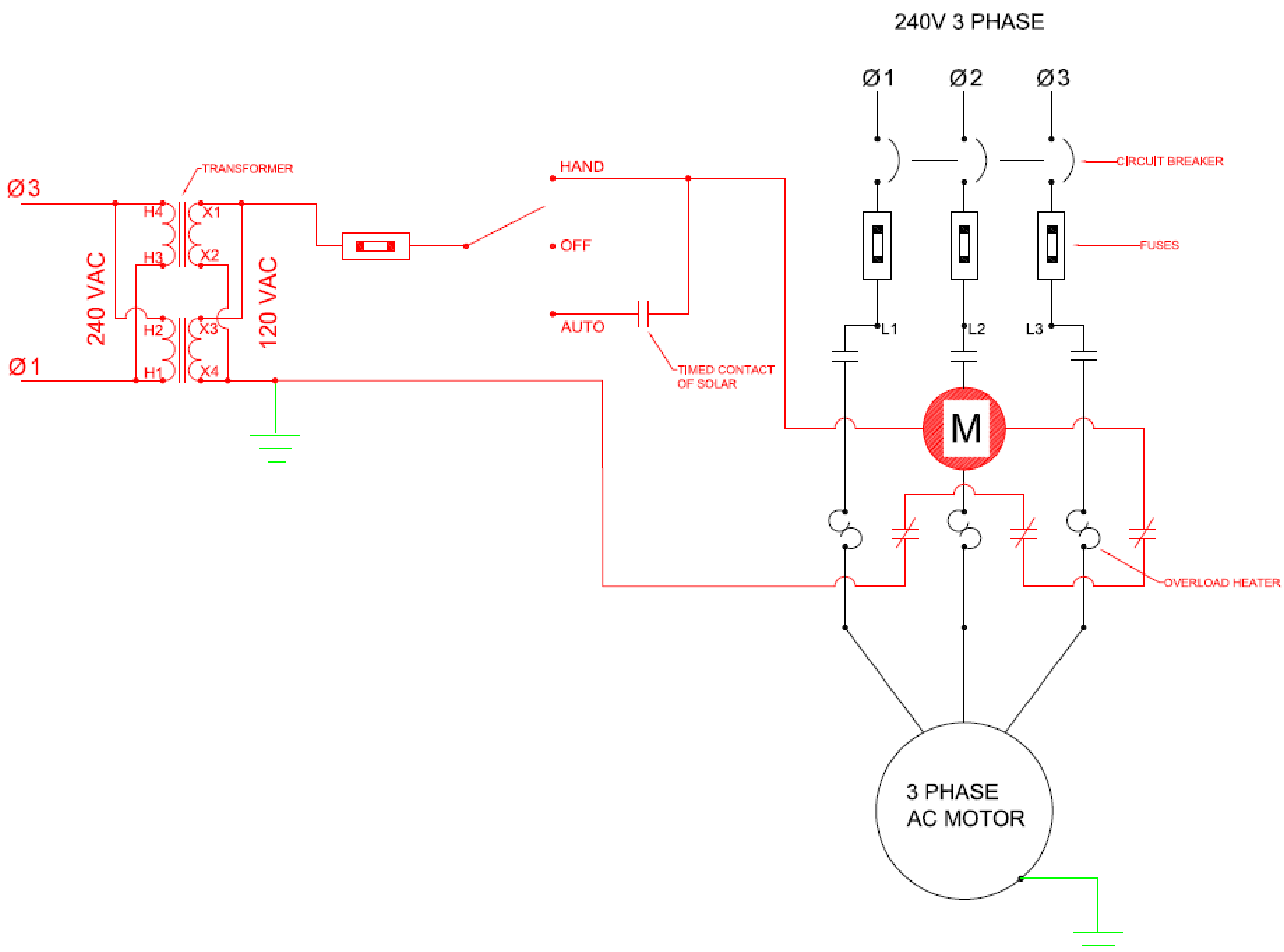
Appendix X-Responses to Survey Question 16

Below are survey response to the question, "Please describe any other specific instances that poor power quality has affected you at EES."
Use of the computer lab
Use of Communication equipment
When using the computer lab and when presenting a video.
It affects using my computer because it shuts off before I'm finished.
When I'm trying to download a document or information, and suddenly the electricity fails before I'm finished.
Without electricity we lose e-mails or are unable to send information to others. We can't complete the work we need to get done. It slows us down when we have to depend on it.
When a student needs to present a report projected on the wall. The project is postponed for another time.
I just want to say many times the hydro generator nor the barn generator are ready when the lights fail.
In assignments in the computer lab when we need to use the computers.
In expositions, computer lab assignments and print documents
It affects when we are presenting an assignment that uses power point.
When we are in the computer lab, watching TV or playing at night on the basketball court.
It affects us getting our homework done, it's hot in our dorm rooms and uncomfortable in the dark. We have to bathe frequently now in the heat.
When we are trying to get our homework done or study for an important class, it shortens our time to get it done.
Without electricity I'm not able to wash my clothes at night because I can't see.
When I'm doing my homework and the lights go off, I lose everything.
It affects when we are doing an activity that requires electricity or when we want to relax and watch a movie at Ethan's house or when we are doing homework and lose everything.
I am unable to complete the activities I have planned in the classrom, also unable to conduct speech classes.
When I'm doing my homework and the lights go out I lose all my work.
At the time when I want to show a video in the classroom, many times the lights are off.
When I'm trying to study at night or send my homework.
When we need to do assignments in the computer lab and the lights go out it puts us behind. It also is very warm without the fans.
When we are doing expositions or computer class, being without lights affects us.
When we have homework that requires research or when we have to do an exposition.
When I'm in the middle of taking a shower or when I'm doing my homework, without lights I have to try to find another time to get it done.
In science lab when the lights go up and down it is not good for the microscopes and other equipment. Also in the computer lab I lose information that I have researched.
When I'm working on the computer and the lights go off I lose the work I'm doing. The lights go off almost every week.
When I'm preparing for my class or when I'm in the middle of a presentation.
At times when the lights go out and the student is unable to finish his homework it causes a lot of stress on the student.
To be able to study at night.
In my studies and in the classroom.
It affects us when we have quizes and exams to study for in the evening and even sometimes in the morniing the lights aren't on so we can finish our work.
One time I have experienced losing a big assignment of research because I didn't save my document before the lights went out. I t was a lot of information. Also when we don't have lights during school hours, it puts us behind.
When it's the time to iron our uniforms and we don't have lights, we aren't able to present ourselves well.
When I'm working on my homework, ironing or washing my clothes.
When we have homeowrk that we need to use the computer for.
Sometimes we can't finish our assignments in computer lab because there is no electricity.

We cann't finish our assignments in the computer lab when the lights go on and off.
When we need to use the computer for homework and the lights are off, it puts us behind.
When we have free time at night and want to play but we can't because we don't have lights.
When we are in the computer lab and suddenly the lights go out and we haven't had a chance to save the information.
It affects our appliances in our home.
It is difficult to be good students and get our homework done when we don't have lights at night.
The time to ring the bell at night should change.
Unable to use the fans in the classroom. The students get very hot.
At times machines and appliances burn out because of the irregularity of the lights.
It affects our studies.
It affects the water and other things.
Its good because when the lights go out they connect to the hydro for only the residents.
I have fallen because I couldn't see where I was going.
Nothing. I believe in every institution I things that affect the mission, but this precisely doesn't.
I can say in the area of information, sometimes when the lights go, the gmail accounts remain open.
When we are showing a poswer point and the lights are going up and down, it affects the presentation alot.
In the exposition or investigation in the lab or with research.
It could be better in order to beable to complete our assignments in the lab.
It affects us alot when we are doing an exposition or power point presentation.
In my house the lights go out more frequent than other houses because the transformer is bad.
When we need to use the projector and the lights go out we are not able to finish what we need to do.
It bothers not only the students but employees also. It affects equipment such as computers, printers, fotocopy machines, etc.
As residence when the lights go out we are not able to finish our work or carry out our responsibilities as we should.
In information assignments.
If we are working on something special we aren't able to finish it.
We are not able to finish our homework
Nothing
Security is at risk because of thievery
When there aren't lights in the morning it's difficult to get done what you need to do because you can't see.
Computer lab class because we have lost a lot of work becauswe of no lights.
When we are presenting and the lights go out, it affects us alot.
When we are doing a presentationn and the lights go out before we are finished or we lose assignments that we have been working on.
Sometimes I'm not able to do a good job with my homework for lack of electricity.
I can't say because I don't live at the school.
Sometimes we lose information because we weren't able to save our document bvefore the lights go out.
Only when I'm working on something in the computer lab.
If I'm studying and the lights go down, I'm not able to complete my work.
I'm not able to iron my uniform.
It affects us at various events like soccer games, social events, etc. in order to make the best of these events without delays.
IDuring our study time we lose a lot of time if the lights go out.
During study hourts at night. It affgects the activities of the students.
It affects the residential from the study time to the need to complete our responsibilities.
Sometimes we aren't able to get our homework done and our teachers don't believe us that it was becaouse we didn't have lights.

I enjoy my time here at the farm. I understand the ligfhts is a problem.
It affects us when we are to prepare an exposition and not able to because of no lights and our teacher doesn't believe us.
When we have a lot of homework and the lake is low, the lights go off. That doesn't give a good presentation for the school.
It affects us somewhat because we are not able to study at night nor iron. Sometimes we lose a lot of information on the computer.
It affects during study hours and relaxing time before bed time.
I was not able to finish my biography because the lights went out.
The lights should be better.
It's good
I don't have electricity in my home but El Sembrador does a lot.
One day I was doing my homework and I lost everything.
The Electricity needs to be better.
I was doing nmy homework and the lights went out, I wasn't able to complete it for 3 days.
One time I was looking for information and the lights went out and I wasn't able to finish it until the next day.
This doesn't make sense to us
We are working on our computer about a related to electricity and the lights go out and we lose everything.
When the lights go out I worry about getting my homework done.
It's hard to get our homework done when the lights go out.
For example, a projector was burned out in 7th grade because of the low voltage.
For me the electricity is not a problem but for the people that live there, they can not have some appliances, etc for fear of them being burned up.
We don't understand the technical terms so don't know what they are saying.
I was working on my Social Studies homework and the lights were out for 1 day.
A projector burned out and we were not able to do our presentation
One time I was doing my homework and the lights went out and I lost everythihg.
Homework and the lights went out.
I was playing soccer and the lights went out.
A week ago I was watching a movie and the lights went out.
I was working on my math homework and the lights went out for 2 days.
In my work when the lights go out it makes it more difficult to control the students and for the students to get their homework done.
In the clinic when we need electrical equipment to take care of people.
None
Classes, plans, teaching.

Appendix Y-PV Surplus Shedding Circuitry



PV SURPLUS SHEDDING CIRCUITRY

Appendix Z-Disorganization of Tool Parts Cabinet-Turbine House

Appendix AA-RCM Information and Decision Worksheet

RCM INFORMATION WORKSHEET

Item:	N°	Complied by	Date	Sheet
Component	Ref.	Reviewed by	Date	of

FUNCTION		FUNCTIONAL FAILURE		FUNCTIONAL MODE *(Cause of failure)*		FAILURE EFFECT *(What Happens when it fails)*	

RCM DECSION WORKSHEET

Item	N°	Complied by	Date	Sheet
Component	Ref.	Reviewed by	Date	of

Information reference			Consequence evaluation				H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	Default tasks			Proposed Task	Vu	Can be done by	
F	FF	FM	H	S	E	O				H4	H5	S4				

Appendix BB-Decision Worksheet