INSTALLATION OF 42 KW SOLAR PHOTOVOLTAICS AND 50 KW WIND TURBINE SYSTEMS

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INTRODUCTION

A solar photovoltaic (PV) system and a wind turbine system are to be utilized to reduce energy use from the electrical grid consumption at West Texas A&M University (WTAMU) through the use of renewable energy. WTAMU's Alternative Energy Institute (AEI) performed the installation of the PV/wind turbine systems.

A 42 kW PV system located at the Palo Duro Research Facility (PDRF) is suitable to offset the energy use of the PDRF since the energy consumed by the facility is primarily during the daytime, with a peak energy use of approximately 225 kW. The expected energy match of 42 kW compared to the typical daily energy consumption of the building (75–80 kW) will have a significant impact on grid energy cost for this office and research space.

A 50 kW wind turbine system located at WTAMU's Nance Ranch produces the energy required by its cattle feedlot operations. It consumed approximately 125,000 kWh of electricity based on data monitored from June 2011 to May 2012. The majority of the energy use at this facility, is consumed on a schedule based upon feeding operations, grinding, mixing, and loading the feed. In addition, there is continual energy used for maintaining proper heat in the feed additives, as well as for the steaming and cracking process for feedstuffs.

KEYWORDS

wind energy, solar energy, wind turbine, tracker array, fixed array

INTERGRATED DESIGN

The PV and wind turbine systems were designed for production of energy and the reduction of energy purchases from the local utility; collection of solar/wind energy raw data; and the assessment of solar/wind energy production in the Panhandle.

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Solar Panels

The PV system is rated at 42 kW, composed of crystalline silicon, and consists of eight fixed panel arrays and two tracker arrays. The PV system connects to the grid through inverters and supports the energy needs of the PDRF.

Tables 1 and 2 show estimated solar radiation (kWh/m^2/day) and projected PV electrical energy production (kWh) of the eight fixed panel arrays and the two tracker arrays, respectively. The estimated output of the PV system was based on PVWATTS version 2. This software is a web-based grid data calculator that uses hourly typical meteorological year weather data and a PV performance model to estimate annual energy production and cost savings for a crystalline silicon PV system.[6] The estimation was based on 0.80 derating from DC converted to AC output and tilt fixed at 30° to 45° from horizontal. It used estimated radiation (kWh/m^2/day) and projected PV electrical energy production (kWh) by month for Amarillo, Texas. This can be easily compared to Canyon which is 17 miles (27 km) to the south of Amarillo.

It can be seen that energy produced with the system set at 35° will be more productive than if the system was set at 30°, 40°, or 45°. Spring and summer months are high solar energy seasons and it is expected that more energy will be produced than the other seasons.

Tracker arrays are designed to follow the sun, so it is expected the energy production to be slightly higher than that of fixed arrays. Based on Tables 1 and 2, it is estimated that the PV system will generate approximately 71,000 kWh/yr. The system will replace electricity at around $0.09/kWh[7] for annual savings of around $6,390/yr. Lifetime of the systems is estimated to be 25 to 30 years, and with increased inflation and energy costs, the savings could be even greater. Since the electricity replaced would have been generated from coal and natural gas plants, the PV will also reduce carbon dioxide emissions by 49.7 metric tons/year. The

TABLE 1. Estimated radiation (kWh/m^2/day) and PV electric energy (kWh) by eight fixed panel arrays.

Mo	30 degree		35 degree		40 degree		45 degree	
	rad	kWh	rad	kWh	rad	kWh	rad	kWh
J	4.83	4,022	5.03	4,190	5.19	4,330	5.32	4,440
F	4.92	3,645	5.04	3,734	5.13	3,799	5.19	3,840
M	6.04	4,797	6.08	4,828	6.09	4,829	6.05	4,800
A	6.56	4,943	6.48	4,878	6.36	4,778	6.20	4,649
M	6.35	4,826	6.19	4,694	5.98	4,537	5.74	4,338
J	6.60	4,683	6.37	4,519	6.11	4,320	5.82	4,097
J	6.69	4,891	6.48	4,719	6.23	4,520	5.94	4,302
A	6.25	4,615	6.14	4,523	5.99	4,407	5.81	4,268
S	6.05	4,425	6.06	4,431	6.03	4,410	5.97	4,362
O	5.92	4,601	6.05	4,710	6.14	4,786	6.20	4,832
N	4.85	3,744	5.03	3,885	5.18	3,998	5.29	4,086
D	4.41	3,674	4.61	3,846	4.78	3,991	4.93	4,109
Year	5.79	52,867	5.80	52,955	5.77	52,705	5.71	52,123

TABLE 2. Estimated radiation (kWh/m^2/day) and PV electric energy (kWh) by two tracker panels.

	30 degree		35 degree		40 degree		45 degree	
Mo	rad	kWh	rad	kWh	rad	kWh	rad	kWh
J	6.53	1,366	6.53	1,366	6.53	1,366	6.53	1,366
F	6.40	1,188	6.40	1,188	6.40	1,188	6.40	1,188
M	7.90	1,592	7.90	1,592	7.90	1,592	7.90	1,592
A	9.00	1,725	9.00	1,725	9.00	1,725	9.00	1,725
M	8.93	1,728	8.93	1,728	8.93	1,728	8.93	1,728
J	9.69	1,764	9.69	1,764	9.69	1,764	9.69	1,764
J	9.55	1,789	9.55	1,789	9.55	1,789	9.55	1,789
A	8.61	1,624	8.61	1,624	8.61	1,624	8.61	1,624
S	7.89	1,462	7.89	1,462	7.89	1,462	7.89	1,462
O	7.90	1,556	7.90	1,556	7.90	1,556	7.90	1,556
N	6.51	1,268	6.51	1,268	6.51	1,268	6.51	1,268
D	6.02	1,259	6.02	1,259	6.02	1,259	6.02	1,259
Year	7.92	18,321	7.92	18,321	7.92	18,321	7.92	18,321

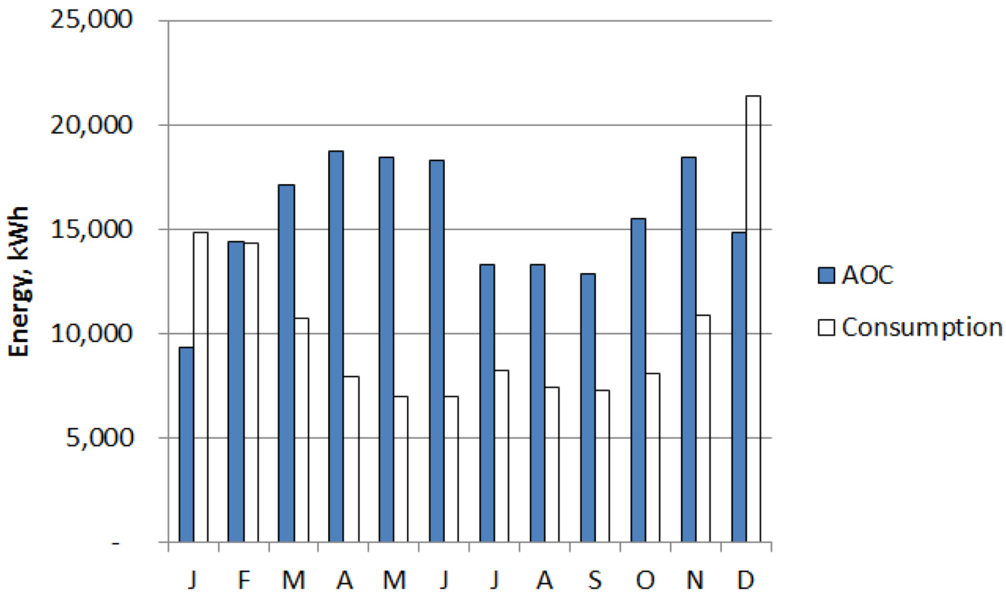
calculation is based on 0.7 kg of CO_2/kWh.[8] Renewable Energy Credits (1 MWh of renewable energy generated in Texas) is worth around 0.0023/kWh,[9] which would an income of $163/yr, and if CO_2 is worth $20/metric ton that would be $1,000/yr for a total estimated value of $7,550/yr.

Wind Turbine

A Seaforth Energy AOC 15/50 kW wind turbine was installed on a 120 ft (37 m) tower at the AEI Wind Test Center (WTC). The energy generated from the wind turbine system will be used to offset the energy required for the feedlot at Nance Ranch. Two years of data were averaged by month and the estimated energy production was calculated from the wind speed histogram and the power curve of the AOC wind turbine. The wind turbine will generate an estimated 184,500 kWh/yr with the high wind speed months being in the spring and the low wind speed month being in January.

Figure 1 shows estimated energy production for the AOC 15/50 wind turbine and the energy consumption from June 2011 to May 2012 for the feedlot at Nance Ranch. According to the figure, the value of energy consumption of the feedlot was $125,000 from June 2011 to May 2012. The feedlot would have to purchase around 12,000 kWh and excess electricity fed back to the grid is about 71,000 kWh. At $0.09/kWh, the average cost of electricity for 2012, it would be worth around $10,170/year based on the electricity displaced by the wind turbine, or 113,000 kWh. Under net billing, excess electricity fed back to the grid is worth the fuel adjustment cost, $0.025/kWh, so the value of electricity, 71,000 kWh, would be $1,775/yr that is corresponding to a total of $11,945/yr. Fuel inflation over the years could increase the value of the electricity produced. Lifetime of the wind turbine system is estimated to be 20 years.

FIGURE 1. Estimated energy production for wind turbine and energy consumption at Nance Ranch.



Using the same estimate of 0.7 kg of CO_2/kWh from natural gas and coal plants, the wind system could reduce carbon dioxide emission by 129 metric tons/year. At a value of $20/ metric ton, that would add another $2,580. Renewable Energy Credits were worth around $0.0023/kWh. If sale of RECs is available, it would add another $420 per year for a total value of around $14,870 per year.

PREPARATION

For the PV/Wind systems, the primary groundwork is preparation for site selection, permits, and equipment preparation. The final locations of the PV and wind turbine systems were decided based on requirements of WTAMU, site size, quality of solar energy, shading, and proximity for interconnection to existing transmission lines. AEI performed a site survey to ensure that no endangered species were found at the construction location.

Site Selection

Site selections for PV systems and wind turbine systems have a significant effect on annual energy production. It is typically worth additional time and effort to choose the best available site, maximize energy production, and maintain the solar panels and the wind turbines systems.

Solar panels

There are four main factors that should be considered for the PV system: site size; quality of solar energy; shading; and proximity for interconnection to existing transmission lines.[10] The first factor is site size and shape. For example, a long and narrow parcel, such as a former railroad right-of-way, would be unsuitably difficult to develop for solar electricity. The larger the site, the larger the potential array and the greater the amount of electricity that can be generated. Quality of solar energy is the second factor. The angle of the sun, the hours of sunlight throughout the year, and the amount and density of cloud cover will impact the amount of solar energy. As a third factor, shading is also significant in solar panel efficiency. If there is tall vegetation nearby the solar panel system, the shadow of vegetation will reduce energy that solar panels produce. Even a partial shadow on a solar panel can reduce its generation capacity to zero. Shading by trees and/or other structures such as hills, even during part of the day, can substantially reduce the energy generation of a solar array. The last factor is proximity for interconnection to existing transmission lines. Sites with close and easy interconnection to the electrical grid are preferable because the cost to connect them to the grid will be much less than sites that are distant, or whose terrain or other factors make them more difficult to connect.

FIGURE 2. Site selection of PV system.

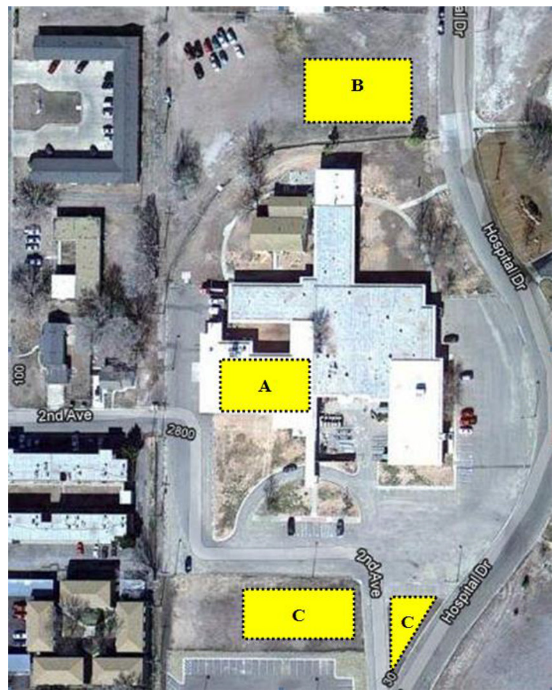


Figure 2 is a Google map which shows three different site choices for PV system installation. Area "A" shown in the figure is the roof of the building of PDRF at WTAMU. Area "B" is a vacant area located on the north side of PDRF. Area "C" is a vacant area located 160 ft (50 m) south of PDRF. There is no shadow on the roof of the building (Site A), meaning that the efficiency of the PV system would be high. The problem is that solar panels are very heavy and that the roof of the building could be damaged by solar panels. Site B is a large space without high buildings around it; however, WTAMU plans to use this area for a new surface parking lot. There are no tall obstructions around Site C, meaning higher energy production efficiency. The close proximity to the building should simplify interconnection to the electricity grid. Based on the four consideration factors, Site C was evaluated as the best site for the PV system. Fixed panel arrays were built on the rectangle portion of Site C, which is a 15,300 ft^2 (1,490 m^2) area, while tracker arrays were built on the triangle portion of Site C, which is 4,125ft^2 (380 m^2).

Wind turbines

There are four main factors that should be considered for wind turbine systems: wind resource characteristics; height and location of obstructions; distance from a utility service point; and maintenance costs.[11] The first factor is wind resource characteristics. With greater wind speed, over time the wind turbine should be at its best efficiency. The second factor is turbine height and location of obstructions. In general, wind turbines should be sited well above trees, buildings, and other obstacles. To make sure that the tower is tall enough, the entire turbine rotor must be at least 30 ft (9 m) above the tallest obstacle within 500 ft (150 m) of the tower. Because trees grow and towers do not, the growth of trees over the lifetime of the wind turbine (typically 20–30 years between major rebuilds) should be considered as well. Distance from a

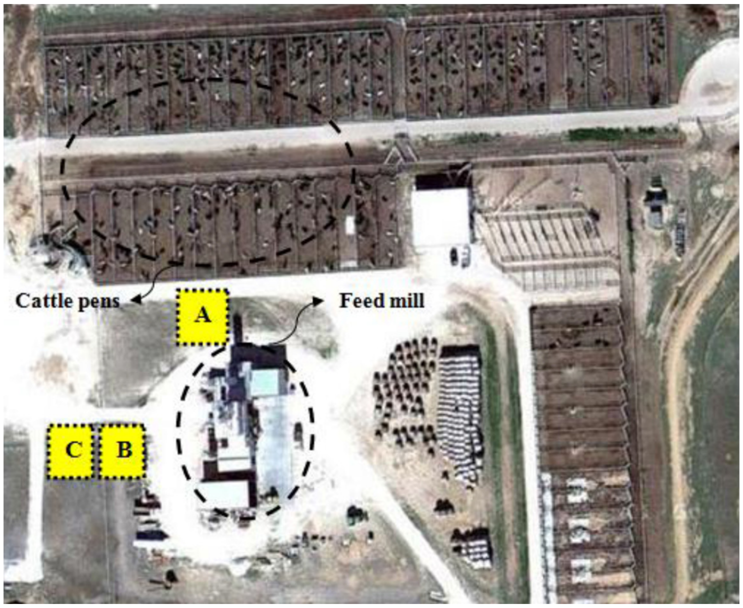


FIGURE 3. Site selection of wind turbine system.

utility service point is the third factor as power loss increases with wire distance. The distance of the cabling will also impact the overall cost of the installation. The last factor is proximity of wind turbines to each other. As wind passes over the blades of a turbine, the turbine seizes a portion of the energy and converts it into mechanical energy. The wind speed will be diminished behind the rotor. It is because of this that wind turbines in a wind farm are placed at least three rotor diameters away from one another in the direction of the wind, so that the reduction in wind speed does not interfere with the operation of the turbines behind it.

Figure 3 is a Google map showing three different site choices for the wind turbine system. They are labeled A, B, and C in the figure. All of the three sites satisfy the four factors. Site A is near to the feedlot so that it does not need a long interconnection to transfer the energy. The main problem is that it is too near to the cattle pens and the cows could be affected by the noise from the wind turbine. Site B is far away from the cattle pens, however, it is too close to the feed mill. Site C is far from the cattle pens and feed mill but requires a little longer wire to transfer the energy. It was determined that Site C is the best area for the wind turbine system.

Permits Preparation

Any federally-funded project in which the construction of new structures takes place is always regulated by governmental agencies. The Endangered Species Act is prominently the biggest obstacle when it comes to developing a project that could potentially harm the well-being of a certain endangered species. Extensive fines could fall upon any construction project which threatens the habitat, nesting areas, or migratory paths of any endangered species.

In order to prevent any sanctions, fines, or obstruction to the development of a project, it is imperative to ensure that all construction is performed in accordance with state and federal regulations. In the particular scenario of this solar/wind energy project it is not necessary to have a permit because it is not considered a business activity.

The Texas Parks & Wildlife Department provides information on naturally-occurring and potentially-occurring species per county. In the particular case of the facilities located in or near Canyon, Texas, a list of rare, threatened, and endangered species is provided. Among the species found in the database are Baird's Sparrow, Western Burrowing Owl, Ferruginous Hawk, Black-tailed prairie dog, Palo Duro mouse and others.[12]

Additionally, the Texas Natural Diversity Database (TXNDD) provides site-specific data on the endangered species, their habitat, natural communities, and other significant feature. When installing a wind turbine at any location in the United States, migration patterns should be taken into consideration due to the potential risk of affecting migratory patterns of a certain species. Furthermore, the TXNDD database does not have a method for mapping migratory paths, although Randall County is considered a major migratory route.

After reviewing all potential impacts on the wildlife and species living in the project site, the Wildlife Habitat Assessment Program Review provides a review of all relevant assessments, including the information from the two sources mentioned above.[13]

Although the information from the two sources above presents county-specific data, it does not necessarily represent occurrence of a species in a certain location. In other words, a species could be occurring in an area even though the database provides information denying the occurrence of such species. The only legitimate procedure to accept or reject the existence of a species occurring in an area is an in-site assessment performed by a certified biologist. For Randall County, the database has not mapped records for lesser prairie chickens although they are known to occur in the Panhandle region. Burrowing owls have also been documented in the area.

In order to proceed with the technical operations in the project, the Alternative Energy Institute surveyed the test site to ensure that no endangered species were found in the area. The results confirmed that there were no endangered species such as burrowing owls, black footed ferrets, bald eagles, or any others in the area. Furthermore, the test site is being monitored to ensure that no rare, threatened, or endangered species are harmed whatsoever by the wind energy project.

Materials and Equipment Preparation

Solar panels

Currently, the two most common types of PV modules sold are crystalline silicon (monocrystalline and multi-crystalline, also called polycrystalline) and thin film (amorphous-silicon and cadmium-telluride). Crystalline silicon modules were selected for this project because of the following advantages. First, module efficiency of crystalline silicon modules is higher than thin film. Second, the multi-crystalline modules have been demonstrated to last over 30 years and warranties of up to 20 years are offered. Last, crystalline modules are easy to find in the market and they are more powerful per area than thin film modules.

Wind turbine

For a wind turbine system, because the warranty is usually limited, selecting a high quality wind turbine is very important. The AOC 15/50 Wind Turbine was selected because it is durable, lightweight, and proven. It is also one of very few turbines that fit the size class needed for this project. For more than 20 years, the AOC 15/50 Wind Turbine system design has been installed in Canada, the United States, the Caribbean, Europe, Russia, and India.

INSTALLATION

For the PV system, the process of installation is comprised of building the foundation, frame, and panels. For the wind turbine system, construction includes the foundation, tower, and wind turbine. The following describes the installation of the PV/Wind turbine systems in detail.

Tracker Arrays

Foundation and frame

First, all of the rails were bolted onto the frame. Starting with the two outside sections, three-piece cow catchers were bolted to the end of the rails and then the middle section was placed on top and bolted as shown in Figure 4. Second, the ⅜-16×1 (10 mm diameter, 25 mm length) carriage bolts were torqued to 22 ft-lb (30 N-m) to hold the cow catcher together. On the bottom of the frame, the ends of the rails were set 53⅛″ from the inside of the e-beam (shown in Figure 5) and then all rail bolts were torqued to 26 ft-lb (35 N-m).

Third, the frame assembly was lifted from the bottom side. The frame was set on the cylinder and the four U-bolts were bolted loosely onto the cylinder. Then the frame was centered on the cylinder 19¼″ (49 cm) between the e-beam and the end of the cylinder. Finally, the frame was tilted up and connected to the hydraulic cylinder.

FIGURE 4. Cow catchers bolted to the frame.

FIGURE 5. Set the rails.

Loading panels

In order to install the panels, the hydraulic cylinder was first disconnected to control the frame tilt. Then the frame was tilted down and the disconnected cylinder was hung free. The closest side of the frame and the mast were strapped with a 4″ (10 cm) spacer between the mast and the frame.

Once the frame is secure, the bottom cow catcher (A1 shown in Figure 6) was pulled out and the panels (A2, see Figure 6) were loaded with all wires facing towards the east side of tracker. As the panels are placed on the rails loosely, the washers and nuts were added to the carriage bolts (A3, see Figure 6). One row (four panels) was loaded at a time, using self tapping screws, tying the row of panels together 4 inches from the top. The edge of the panel was positioned to stick by the end rail evenly. The top set of bolts and washers were always left loose so there was room for the next layer of panels to fit. Three rows were installed and then the cow catcher carriage bolts and the first two rows of carriage bolts were torqued to 26 ft-lb (35 N-m).

FIGURE 6. Panels installed facing east side of tracker.

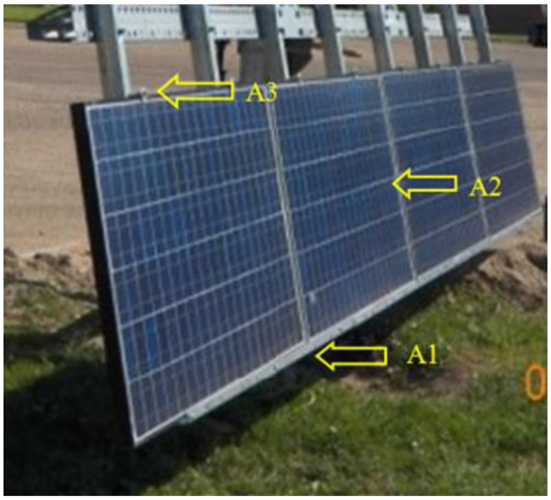


FIGURE 7. Complete panel installations.

FIGURE 8. The frame of fixed array panels.

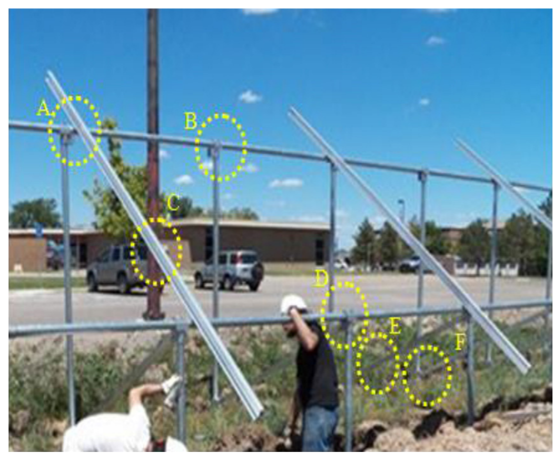


FIGURE 9. Six parts of fixed frame.

The final panels were added in pairs, completing each column and allowing the washer and nut between them to be added. All three remaining columns of panels were repeated and rows were screwed together to bond them for grounding.

The edges of the panel were made to extend past the end rail equally on each side and then all remaining carriage bolts were tightened to 26 ft-lb (35 N-m). The second tracker then had its panels installed using the same method. The trackers, with the installed panels, are shown in Figure 7. The tracker panels were installed in groups of 20 panels measuring 188 in by 260 in (4.78 m by 6.60 m).

Fixed panel arrays

Foundation and Frame

The frame of fixed array panels shown in Figure 8 consists of six main parts that are marked A to F in the figure. The details of the six main parts are also shown in Figure 9.

In Figures 8 and 9, A is the rail bracket attaching the rail to horizontal pipes by one U-bolt, three hex head bolts and five flange nuts; B is the rear cap covering the back horizontal pipe and vertical pipes by two U-bolts sized for pipe and four flange nuts, and four set screws; C is the solar mount rail supporting the PV modules to the pipes; D is the front cap covering the front horizontal and vertical pipes, anchoring the upper end of the north–south braces by two U-bolts and a cross-brace bolt sized for pipe, five flange nuts, and four set screws; E is the cross brace providing the north-south and east-west diagonal bracing; and F is the slider attaching the lower end of the north-south cross braces to rear legs by one cross-brace bolt sized for pipe, one flange nut, and two set screws.

The pipes were concreted together using a continuous ditch. It is firmer than the proposed plan. A total of 76 yd^3 (58 m^3) of concrete was used for the 2 ft (60 cm) deep concrete footing.

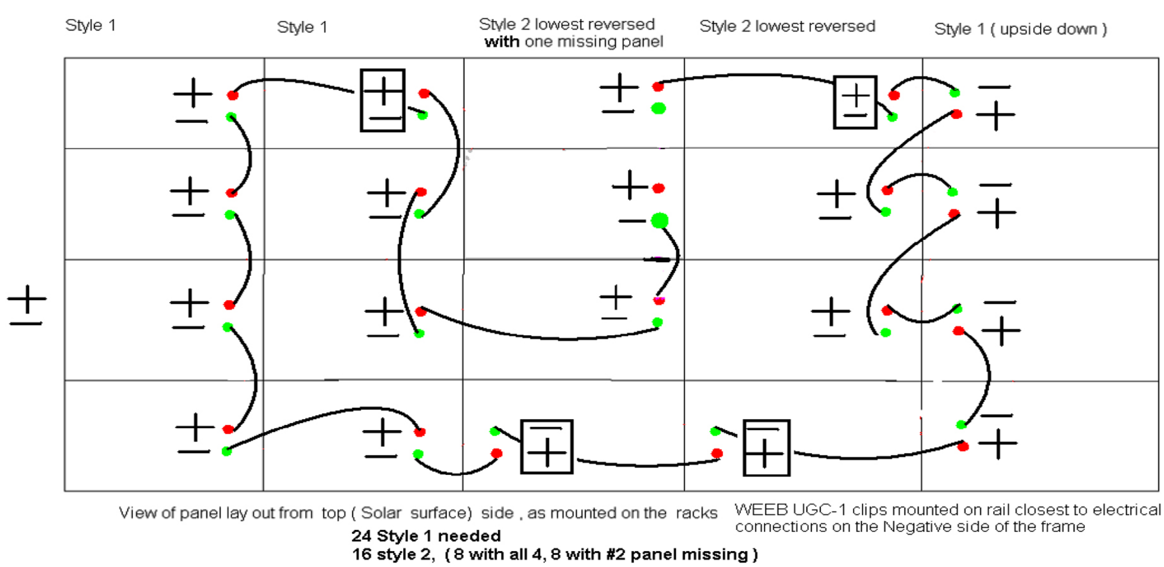
Solar panel assembly

Four panels were connected together to make a section. First, the positive pole and negative pole of the panel were connected together. This protects the workers from accidental electric shock while working with the panels before they are grounded. The panel was transported to assembly frame and the first panel was aligned to marks on the wood supports. The ground Washer Equipment, Electrical Bond (WEEB), also called a Universal Ground Connector (UGC), is used to make a firm ground connection and act as a spacer for the panels as they are assembled. Panels were spaced by UGC. The rail was then added to the panel rear and adjusted to panel holes. Clips and bolt/nut combinations were added loosely at each clip. Panel clips and back bolts were torqued to specifications.

Loading panels

Four panels were connected together to form one column. There are two styles of columns, style one and style two (see Figure 10). Each fixed panel array has five sections, three of style one and two of style two. The wiring plan is shown in Figure 10. The wiring plan was a simple series of connecting each panel in a "head to tail" fashion and still had the leftover positive and negative ends close to the expected inverter location.

FIGURE 10. Wiring plan.



The inverter is planned to be placed near the center column of each string of panels, high up near the upper most row of panels. This will protect it from direct exposure to the weather and make the connection to the DC disconnect manageable without adding splices to the original panel wires.

The plan called for the preassembly of the columns in order to simplify the production work. When workers became adept at making one style of panels they could replicate it until all the required columns were completed. The second style was unusual in that the lowest panel was reversed to allow easier connection to the next columns of panels. This also maintained the upper three panels in each column in the same configuration as the style one column. Grounding lugs were located on one rail of each column—the rail that was always closest to the negative connection of the most panels. This made for the shortest average distance between the electrical connections on each panel and the rail that would provide the panel equipment ground.

This wiring plan was utilized only for the fixed array solar panels. Panel columns were put on the frame and then secured by U-bolts. When mounting rails be sure to center them on the horizontal pipes, leaving about 20 percent overhang on north and south sides. Mounted fixed panel arrays are shown in Figure 11. Eight fixed panel arrays were built with four different tilt angles: two at the northwest were 32°; two at the northeast were 34°; two at the southeast were 33°; and two at the southeast were 35°. The finished PV system, consisting of eight fixed panel arrays and two tracker arrays, is shown in Figure 12.

FIGURE 11. Installed fixed panel arrays.

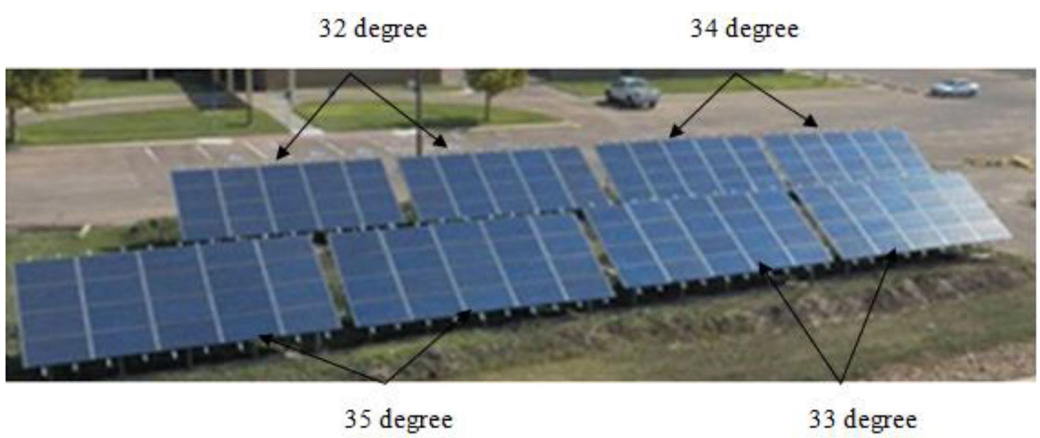
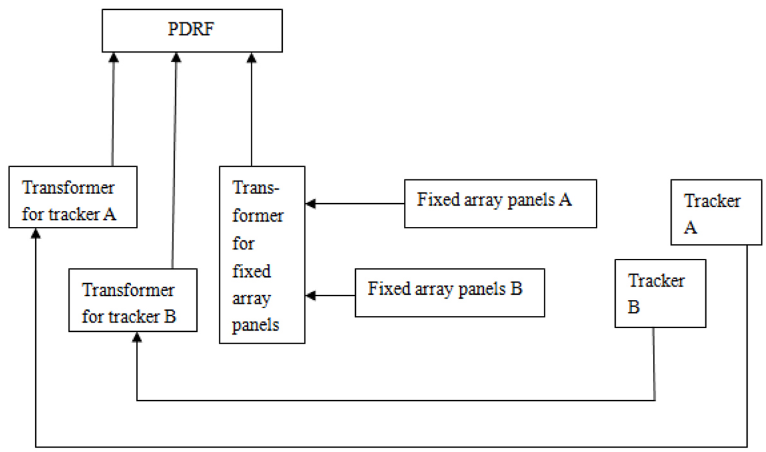


FIGURE 12. Installed entire PV system.

PV system electrical connection

Figure 13 shows the interconnection layout for the PV system. For the fixed panel arrays, each inverter and DC disconnect switch will be mounted on the back of the arrays. The planned location is the highest point of the center column in order to reduce energy loss on the DC side. For the tracker arrays, the inverter and DC disconnect switch will be hung on the bracket directly mounted on the upper mast.

FIGURE 13. Interconnection layout for the PV system.



The energy produced by the eight fixed panel arrays will be combined through a three phase transformer while the energy that is produced by the two tracker arrays will be sent through separate transformers. All energy will be transferred to the main 480 volt, three phase connection point inside the PDRF, and controlled by a single disconnect switch there. The normal interconnections between the 480 volt, three phase main power, and the usual circuits throughout the PDRF will be used to distribute the solar power to loads inside the building.

Wind Turbine

The wind turbine system was installed on a 120 foot (37 m) tower. The proposed area for the tower was 24 feet by 24 feet (7.3 m by 7.3 m) at Nance Ranch feedlot.

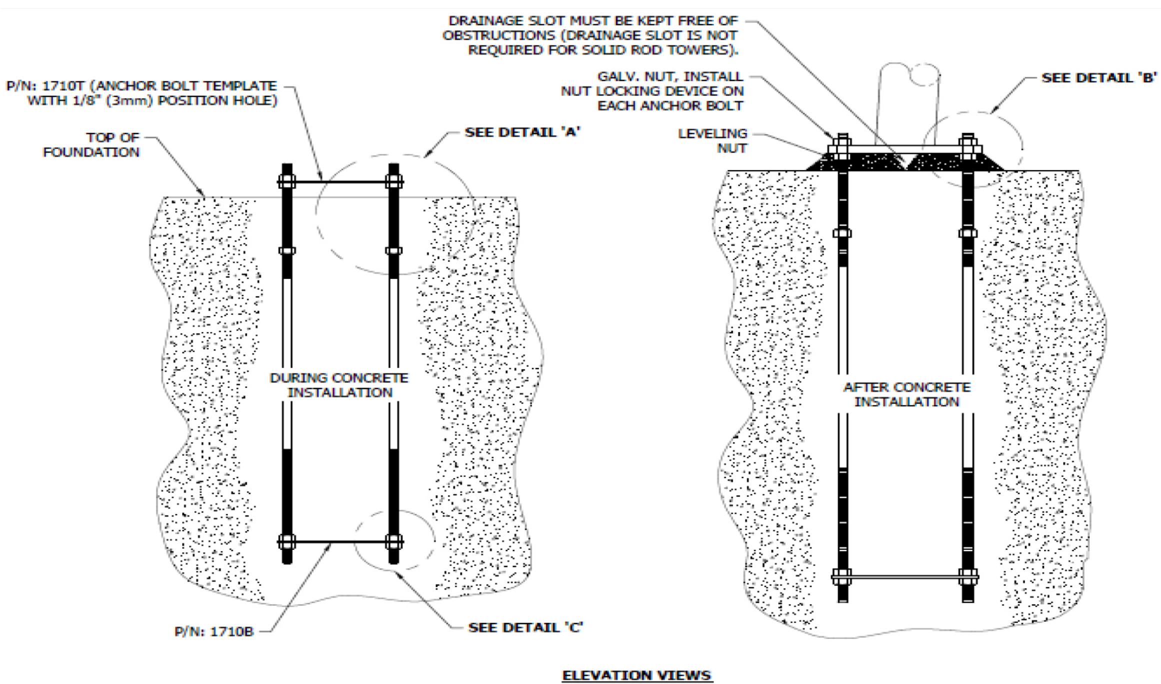
Foundation

The foundation of the tower was a large mat-type foundation with three one-meter diameter rebar cages for the legs. The three rebar cages form an equilateral triangle when properly positioned. There were two layers of rebar connected together inside the mat foundation. Three rib frames were created by connecting ten 70 inch (1.78 m) long bolts and placed into the three rebar cages. The three rib frames were leveled. A bolt placement fixture was connected to the top of the three rib frames as shown in Figure 14.

The three rebar cages and ribs were positioned to have 6 ft (1.8 m) deep concrete at each tower leg. The concrete strength of the mat was 3000 psi (21 MPa) while the tower legs were 5000 psi (35 MPa). The elevation views after the concrete was poured are shown in Figure 15. After concrete, earth was packed into the area between the tower leg pads. A total of 50.7 yd^3 (38.8 m^3) of concrete was used for the foundation.

FIGURE 14. Bolt placement fixture with triangulated frame.

FIGURE 15. After concrete elevation views.



Tower

The lattice tower consists of six sections. Each section is 20 ft (6.2 m) long and the total height is 120 ft (37 m). The tower is properly sized when the wind speed is best suited for the wind turbine production, neither too low to reduce the energy production nor too high to cause mechanical damage. The obstacles around the proposed site were 96 ft (30 m) or less in height. When the wind flows over an obstacle like a building or a tree, the wind is slowed down and turbulent air is created. If a wind turbine is located in this zone of turbulence, the result will be poor energy production and increased mechanical wear and tear on the turbine. Tower costs increase with greater height. If the tower consists of five lattice sections the total height would be 100 ft (31 m). This height would be too low for optimal energy production. If the tower consists of seven sections, the total height would be 140 ft (43 m). While this would provide greater energy production, it would be cost prohibitive. Therefore, 120 ft (37 m) was determined to be the optimal tower height. This allows the turbine to be placed 30 ft (9 m) above any obstacle.

Wind turbine

The wind turbine is configured with three blades. Each blade is 49 ft (15 m) long and weighs 308 lb (140 kg). For the turbine installation, two blades were connected to the drivetrain before lifting. The drivetrain with two blades connected was lifted in place using nylon slings. Nylon slings were used because metal slings could possibly damage the drivetrain. A blade cap screw was threaded into each blade mounting hole to ensure the threads were clean and undamaged. The blade was positioned against the hub flange with the concave side of the blade toward the turbine. The turbine and two blades were firmly connected to the top of the tower section and additional lift for the last blade followed. Oval-shaped special blade mounting washers were used on the blade bolts. They are designed specifically to ensure the proper baseline blade pitch. These inserts would place the bolt properly in the hub so that the blade could only fit in a single fixed pitch position. Figure 16 shows the finished wind turbine.

FIGURE 16. Finished wind turbine.

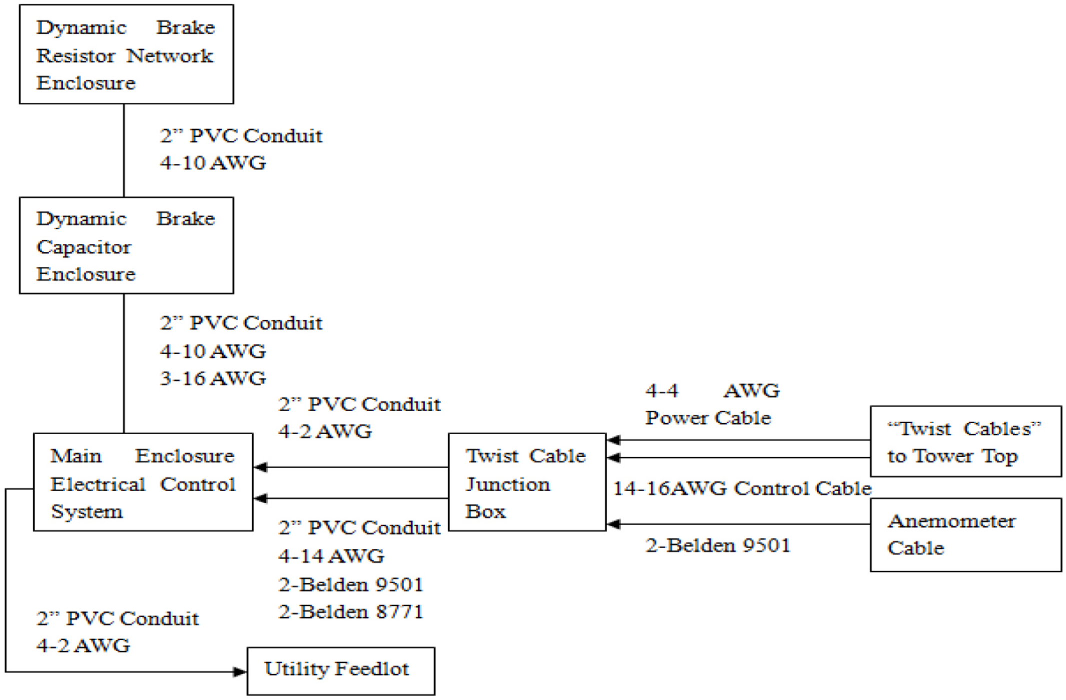
Electrical installation

The primary electrical connections for the wind turbine system consist of three sections: generator junction box; tower junction box; and control box. The generator box is on the side of the drivetrain. The power and control cables were connected at generator junction box terminals and then lowered to the tower junction box (see Figure 17), which is mounted about 10 ft (3 m) high above the foundation.

The control and power cables were connected to the tower junction box. They were long enough to

FIGURE 17. Tower junction box.

FIGURE 18. Interconnection layout for the wind turbine system.



reach from the tower top to about 1 ft (0.31 m) from the ground and then looped back up to the tower junction box. It is critical to have a sufficient loop at the bottom because when wind turbine rotates around the hub, the cables will twist. When the cables become too twisted, they must manually be disconnected and untwisted. Two anemometers were mounted at a distance of 28 ft (8.5 m) below the top flanges of the tower. One is the primary control sensor and the other one is used for redundancy. These two anemometer signal cables were also connected to the tower junction box. The cables from the tower are combined in the tower junction box and then run to the control room.

The control room was placed beside the tower. The white shed to the left of the tower in Figure 16 is the control room. The electrical connections in the control room are the main control panel, dynamic brake capacitor panel, and dynamic brake resistor panel. Figure 18 shows the interconnection layout for the control panels. For example, the dynamic brake resistor panel and dynamic brake capacitor panel were connected using 4-10 AWG cable in 2 in (50 mm) seal tight conduit. The electrical wires were from the control box to the tower base, and all wires between the control box, dynamic brake capacitor box, and dynamic brake resistor box were run in seal tight conduit and terminated in the control box.

RISK MANAGEMENT

Primary risk refers to the problems that may affect the continued operation and maintenance (O&M) of the systems. It is expected that O&M for the wind turbine will require more effort than O&M for the PV array.

PV System

AEI operated a 2 kW PV array from1991 until 2009. One module was replaced due to a lighting strike and the inverter had to be repaired twice. When the inverter requires a repair, it represents a major expense because the inverter must be shipped back to the manufacturer.

Lightning strikes pose a high risk for the PV array. A direct strike or spike coming over the grid could damage the control system. Lighting is capricious, and there is always the possibility of damaging the PV array, inverter, and controls. This will not be a problem during implementation but might be a problem in long term O&M.

Another problem with PV system O&M is regular cleaning. Cleaning a solar panel is not just cosmetic. A panel needs to be cleaned for it to operate at its rated capacity. Snow, pollen, bird droppings, dirt, and dust can build up on the surface of panels, and this will reduce the panel's energy-producing capacity. PV systems need to be cleaned regularly with at least two cleanings a year.

Wind System

Maintaining a wind turbine system is a complex undertaking. A wind turbine system may have more than 1,000 mechanical and electrical parts, and a typical wind project is located far from the manufacturer. AEI and USDA have over 25 years experience maintaining three AOC wind turbines, which ensures the proper assessment of maintenance issues and the performance of major repairs, if necessary. The main concern is that any major repair will require the use of a crane or a man-lift. At least two events, requiring a crane, are estimated to occur over the 20 year life cycle of the turbine. Additionally, AEI and USDA have ample experience with maintaining and repairing control systems.

Extreme winds from thunderstorms and tornadoes pose a threat to the wind turbine. In 30 years of operation, AEI has recorded several direct strikes from lightning on a wind turbine plus several technical difficulties with controllers and inverters due to spikes coming in from the utility grid. Accumulations of bugs, oil, and ice on the blades reduce power. Regular cleaning of the blades is a maintenance requirement.

The primary environmental issues are the presence of birds, bats, and excessive noise, among others. The wind turbine is taller than the feedlot and is located within 500 ft (150 m) of an occupied house for WTAMU students. Students and staff at the feedlot will be surveyed with respect to noise and the visual effects of the wind turbine in comparison to normal operation of the feed mill. Records will be kept in case any wildlife is affected by the wind turbine.

CONCLUSION

A 42 kW PV system is installed with eight fixed panel arrays and two tracker arrays located at the PDRF, WTAMU while a 50 kW wind turbine system is installed at the AEI WTC. The PV/Wind system project was started in 2010 and finished in 2012. The two systems reduce energy consumption from the local utility and demonstrate how these systems impact the energy use of two different office/feedlot operations.

Both PV and wind turbine systems will be compared for electrical energy production (by time of the year), value of energy produced, and operation and maintenance requirements. It is expected that the summer season is generally low on wind generation capacity but high for solar energy, thus, even though the two systems are not at the exact same location, they are close enough to be analyzed for combined energy production (wind/PV system) by hour and day. This data will be available to the public. This will be useful information for potential users of distributed renewable energy systems in the Texas Panhandle area.

NOTES

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