Breath Topic 2

Windmill Analysis

For the windmill analysis, I researched the wind patterns of Erie, PA to discover the power generating capabilities of the building. I also performed a cost analysis of the electricity savings versus the initial cost. I also performed a structural analysis of the roof to make sure that the windmill will be able to be placed on the roof. Finally, the schedule impact was looked at. This Breath Assignment deals with electrical power use reduction and circuit redesign as well as a structural strength check. Research of windmills and wind availability, the structural analysis, the electrical load reduction, the cost analysis, schedule impact, and a summary are the key issues to this topic.

Background:

Because clean power has become a more prevalent theme in construction, I have decided to look into one of these systems. Since the building sits less than 8 miles from Lake Erie, there is an abundance of lake effect wind on the building. From the roof of the building, you can actually see the lake and the wind is very noticeable. The idea to generate clean power naturally fell to wind power. Wind power has many pros and cons. It can generate power whenever there is wind but is considered by many to be unsightly and noisy. These windmills will be attached into the power system and will be supplied with a backup battery system so that no power will be wasted. Because the building will be used for engineering and engineering technology purposes, the windmills could then be used as an interactive learning tool. A kiosk will be placed into the main lobby that will allow students and visitors to see the power production and other education information.

Research and Economic Development Center
Erie, Pa
Kristen Eash

Research Intent:

The intent for this analysis is to analyze the pros and cons of placing one or more windmills on the roof of the Research and Economic Development building. Wind patterns and intensity were used to estimate power generated. A specific windmill system was selected and designed for. Cost, schedule impacts, and load impacts were taken into effect. I also looked into vibration and sound proofing the system with respect to the rest of the building.

I would like to be able to use this research to show the owners of the building that this would be a viable alternative to traditional power and that it is cost effective to do so. The key points of my research are as follows:

- Windmill system selection
- Wind analysis of building
- Generating and estimate of power production and building load reduction
- Look into vibration and noise protection
- Calculate the schedule impact
- Check that the building can structurally carry a windmill on the roof and possible ways to beef up the roof if it can't
- Design the electrical system that will connect the windmill to the main power supply.

I expect that the windmills will be possible so long as the structural system does not need to be a lot larger. I believe that with the wind that I experienced while visiting my building, there will be an adequate amount of wind to make this system a cost savings. I will also expect that since has the ability to become an educational area even if it does end up being slightly more expensive to install windmills, they could still be installed.

Research and Economic Development Center
Erie, Pa
Kristen Eash

Wind Study Done 11-2-05

SOLOMAT 510e

PRINT STORED READINGS
TIME INTERVAL 1 HOUR
SITE 1- ERIE, PA (REDC)

RDG	SITE	MEASURE	UNITS
Max	1	12.65	m/s
Min	1	0.00	m/s
Avg	1	2.55	m/s

DATE 11-2-05

The idea behind this study was to get an idea of the wind speeds for Erie, Pa. This was done by taking wind measurements from the top of the building facing towards the lake.

System Secection:

The windmill is an Air 403 industrial wind generator. It will be placed on a 27 foot Air Tower to keep the view of the building clean. For the lobby's kiosk, a Slabb M touch screen kiosk was chosen. The specification for each of these system can be found in Appendix 2 (windmill), 3 (Tower) and 4(kiosk) with a quick recap of the systems listed below.

Air 403 Industrial Wind Generator

- Weight: 14 lbs
- Start Speed: 2.7 m/s
- Output: 400 watts at 12.5 m/s
- Price: $995.00

Tower Kit

- Height: 27 foot
- Price: $140.00
- Anchors: $55.00

Kiosk

- Price: $2,600.00

Power Capacity:

Wind Turbine Power: **(**http://www.awea.org/faq/windpower.html**)**

P = 0.5 x rho x A x Cp x V^3 x Ng x Nb

where:

P = power in watts (746 watts = 1 hp) (1,000 watts = 1 kilowatt)
rho = air density (about 1.225 kg/m^3 at sea level, less higher up)
A = rotor swept area, exposed to the wind (m^2)
Cp = Coefficient of performance (.59 {Betz limit} is the maximum thoretically possible, .35 for a good design)
V = wind speed in meters/sec (20 mph = 9 m/s)
Ng = generator efficiency (50% for car alternator, 80% or possibly more for a permanent magnet generator or grid-connected induction generator)
Nb = gearbox/bearings efficiency (depends, could be as high as 95% if good)

If there is any single equation that the beginning wind enthusiast should memorize, this is it.

The average wind speed to the building is 11.1 mph (5 m/s) according to the National Weather Service.

Because the windmill produces 400 watts at 28 mph with a rotor radius of 0.57 m, these numbers can be entered into the wind turbine power equation to yield the windmill efficiency and performance (a combination of Cp, Ng, and Nb)

A=.51 m^2

$400=0.5*1.225*0.51*(12.6)^3*$ efficiency
Efficiency=0.64

This means that the power produced using the average wind speed will be:
$P=.5*1.225*0.51*0.64*(5)^3$
P=25 watts

Assuming that the windmill is kept running 24 hours a day (and rounded down to represent the time that the windmill will not be in use due to low wind speeds), a total of 200,000 kWh per year will be produced. This power will be integrated directly into the buildings power supply. Since the building uses power 24 hours a day as well due to the computer usage and lights, this power will be able to be used completely.

Shown on the next page are the 12 locations that the windmills will be placed.

Roof Plan Showing Windmill Locations:

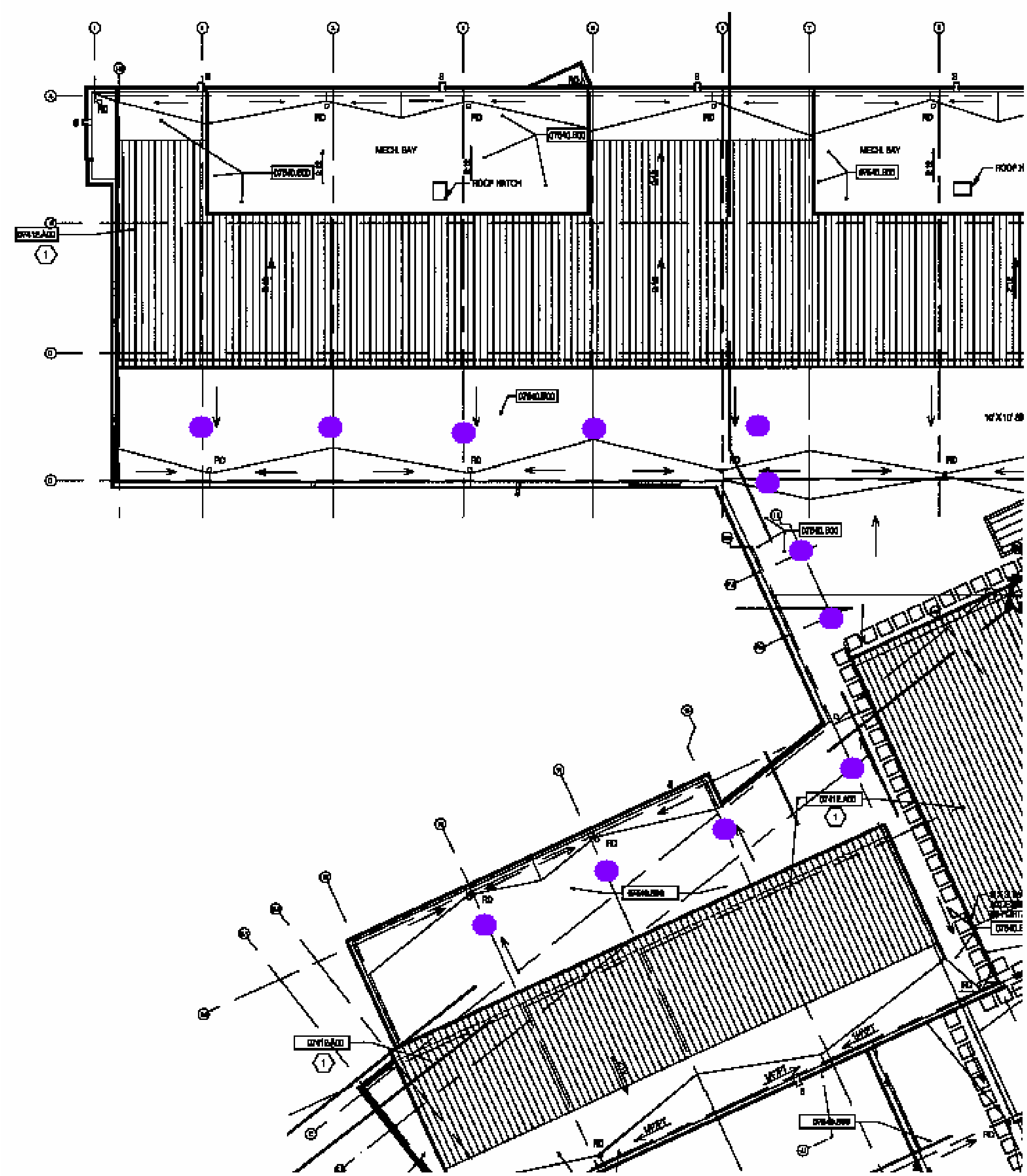


figure 1: windmill locations

Electrical Hookup:

The following information for the electrical system tie-in is sited from the Owner and Operations Manual for the Air 403 by Southwest Windpower.

Grounding/Lightning Protection

The windturbine must be properly grounded to protect the electronics if it is to last for long-term usage. This is especially true in lighting areas. The green lead wire provides grounding for the body of the turbine. This wire must be connected to the building's earth ground wire or a ground rod near the base of the tower. For extra protection another wire should connect the tower to the building's ground wire or the grounding rod. The negative wire for the system should also be connected to the building's ground wire by a wire from the negative battery terminal to the building's ground.

Fusing

Because the AIR-403 is capable of producing high amperages, the properly sized fuses and circuit breakers are very important to the protection of the turbines. These fuses should be placed between the stop switch and the positive terminal of the battery (as shown in figure 2 the stop switch wiring).

Recommended Size for Circuit Breakers or Slow-Blow Fuses

• 12-volt model: 50 amps D.C.
• 24-volt model: 30 amps D.C.

Stop Switch

This switch disconnects the battery and then shorts the turbine wires causing the turbine to stop spinning (in high winds the blades will spin slowly). Shorting the turbine will not cause any damage or additional wear to the wind generator.

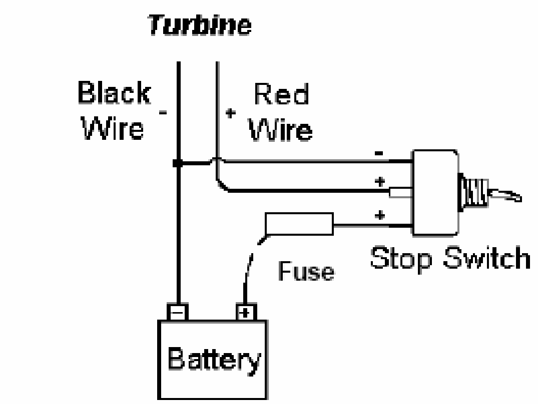


Figure 2 Stop Switch Wiring(http://windenergy.com/AIR_X_Land_Owners_Manual.pdf)

Multiple AIR Installation

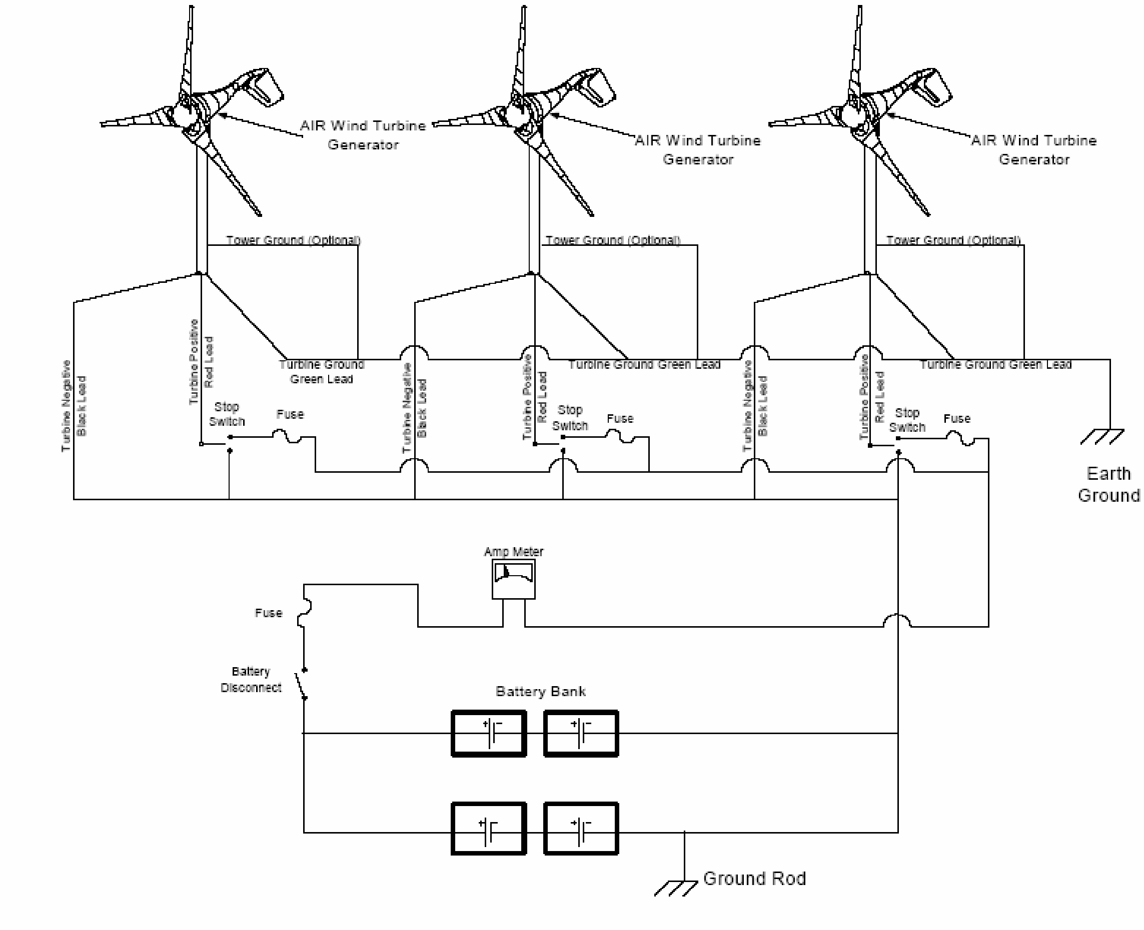


figure 3: windmill wiring diagram (from the http://windenergy.com/AIR_X_Land_Owners_Manual.pdf)

Each Turbine Wired To A Bus Bar

Because for this installation more than two turbines are being wired, they must be connected to a "bus", and then one set of wires will run from the bus to the battery. This way each turbine's internal regulator can be used or it is possible to install an external regulator. For the external regulator use a diversion style regulator that turns excess power into heat for heating a room, water etc. When wiring multiple turbines, it is possible to reduce your wiring costs by using a bus bar system This is shown above in figure 3

To connect the batteries to the main system the power goes through a DC Circuit breaker and then a controller. After this it passes through an inverter which switches it to AC Current. This inverter is estimated to cost roughly $2000. The AC power then goes through an AC Circuit Breaker where it attaches to the main power for the building. This means that when the building pulls power the draw will be from the windmill first and the main power second. It will also mean that when the building's main power supply goes down there will be no backflow from the wind turbine power into the utility lines. It also means that when working on the building it will be necessary to turn off the power from both the turbine and the utility.

The reading from the ammeter will then be collected and the output will be able to be read from the Kiosk. The Kiosk will also read the rotor speed from the monitoring wire of the windmill

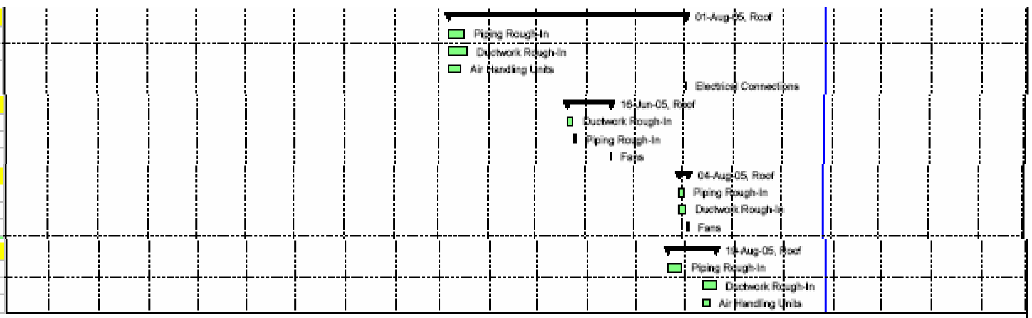
Cost:

With the cost of power in Erie being around 9.6 ¢/kWh a total of $18,800 is saved per windmill. This is amazing due to the fact that on average the windmill will cost around $1,500 including the installation per windmill. This will yield a total of $225,600 per year saving in electrical costs

There will also be other costs for this system to work. The kiosk will cost $2,600 including the stand, touch screen monitor, hard drive, shipping and tax. The new electrical system for the building will cost roughly $6,000 for the wiring and new controls. The battery backup will also run roughly $3,000 for a mid sized backup system. This ran the initial cost of the system up to just under $30,000. This however will be earned back by the end of the first year's power production.

Schedule:

Because the windmills will go on the roof and the roof gets done very early. There will be no schedule change. The length of time for the installation of the windmills does not affect the overall CPM schedule. This also includes the time for running the wires, since there are only two wires run from the windmill. One is the power output wire that gets connected to the building's power system. The other is the monitoring wire that will go to the kiosk and records the RPM of the windmill and computes the windmill power output. Both of these wires sets will run through an existing conduit. You can see how the roof schedule is very open by looking at excerpts of the schedule below



Roof		104	07-Mar-05	01-Aug-05
A1	Piping Rough-In	8	07-Mar-05	16-Mar-05
A1	Ductwork Rough-In	10	07-Mar-05	18-Mar-05
A1	Air Handling Units	6	07-Mar-05	14-Mar-05
A1	Electrical Connections	1	01-Aug-05	01-Aug-05
Roof		19	20-May-05	16-Jun-05
A1	Ductwork Rough-In	2	20-May-05	23-May-05
A1	Piping Rough-In	2	24-May-05	25-May-05
A1	Fans	1	16-Jun-05	16-Jun-05
Roof		5	29-Jul-05	04-Aug-05
A1	Piping Rough-In	2	29-Jul-05	01-Aug-05
A1	Ductwork Rough-In	3	29-Jul-05	02-Aug-05
A1	Fans	2	03-Aug-05	04-Aug-05
Roof		22	21-Jul-05	19-Aug-05
A1	Piping Rough-In	7	21-Jul-05	29-Jul-05
A1	Ductwork Rough-In	6	12-Aug-05	19-Aug-05
A2	Air Handling Units	2	12-Aug-05	15-Aug-05

Noise:

Many wind turbines relied on their aero-elastic blade design for protection in high winds, causing loud flutter noise in winds above 35 mph (16 m/s). AIR-430's circuit monitors the wind speed and electronically slows the blades as it reaches its rated output preventing it from going into flutter. This results in a much quieter wind turbine. The tower will also sit on isolators so that no vibrations will travel through the structure of the building causing noise inside the building.

Structural:

All of the Windmills will sit directly on a joist or a column. With the weight of the windmill being only 15lbs and the tower structure weighing roughly 30lbs, the total load due to each windmill will be only 45 lbs dead. There is also a torsion load and moment due to the movement of the windmill due to the wind. This will also be very minimal. Each joist or column will hold only one windmill. As shown in the skylight analysis, the roof truss system can support far greater loads than is on it due to it's large over design for safety factors. This means that the small load that the windmill causes will not affect the structural system. A picture of showing where the windmills will sit on the structural system is shown below.

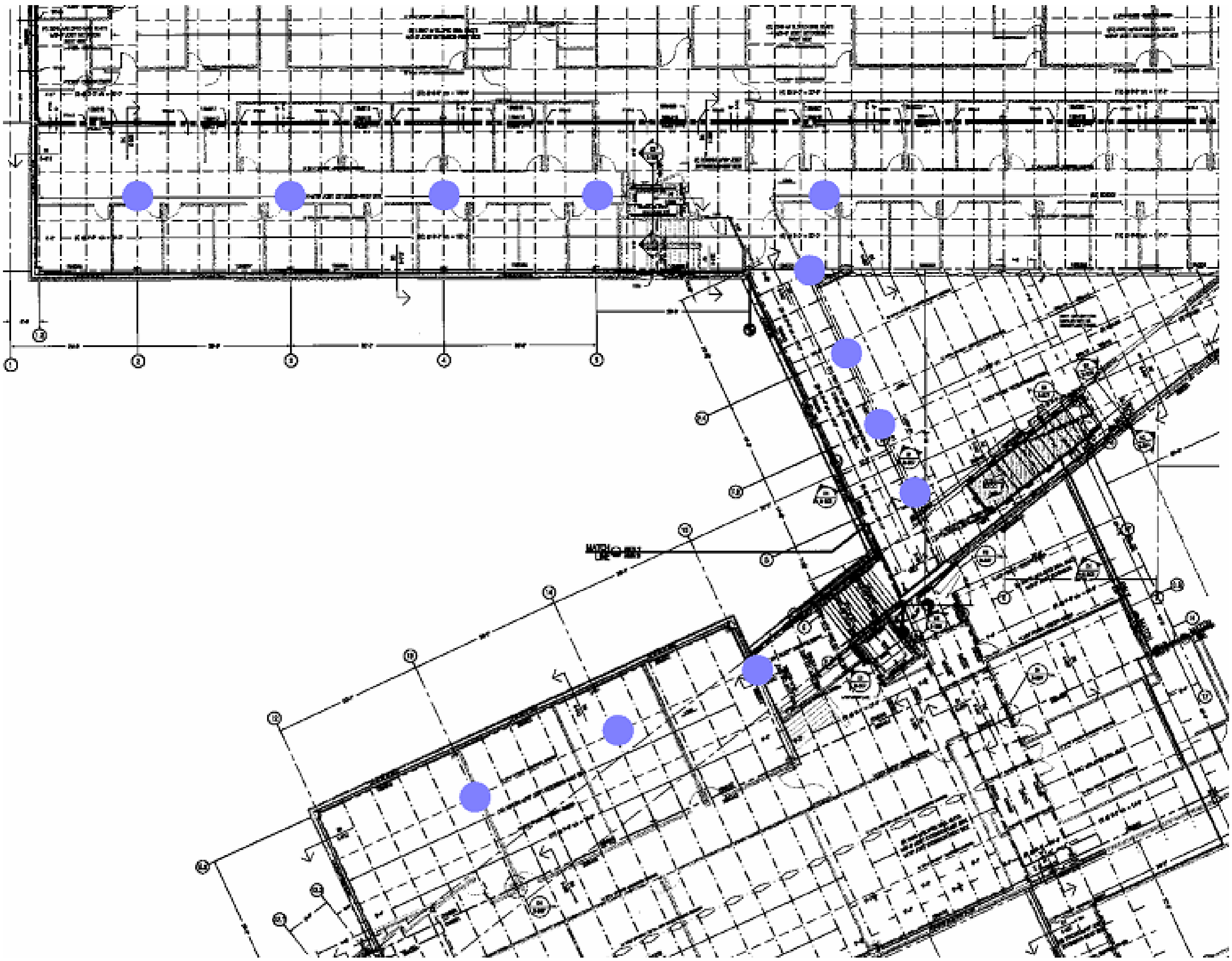


figure 4: windmill location on roof structural plan showing support.

Conclusion:

I recommend that the windmills get installed onto the roof of the REDC building. Although there is a high initial cost, the building should be able to save enough in energy that the windmills will pay for themselves by the end of the first year with extra monies saved. The schedule changes also are unimportant because of where the system sits and the schedule for roof construction. There should be no concern for structural issues or vibrations.

The other important thing to remember about this, is that the windmill is expected to be used for educational purposes. That alone would have justified the added cost and schedule demands associated with installing this system.