COST AND BENEFITS OF GRID DEFENDER

Executive Summary

Mr. Dennis Bell and Grid Defender, Inc. have developed and patented an enhancement to commonly-used overhead electrical power lines. By incorporating the ability to raise and lower cross arms and conductors from the ground, construction and maintenance can be performed faster, more safely and at a lower cost compared to current methods. A study by Industrial Engineering students at Montana State University estimates that the Grid Defender apparatus could cut power line construction cost by 14% or $9,123 per mile for a commonly used power line configuration. (This report suggests that savings might be 17% or $11,000 per mile.) One critically important attribute of Grid Defender is its ability to shut off power when the cross arms with conductors are lowered. This feature would serve to protect the public as well as linemen in the case of catastrophic events such as storms or automobile crashes when "live" power lines normally fall to the ground. By hardening the electrical grid, Grid Defender offers the potential for reducing the human suffering and loss of personal property that commonly accompanies catastrophic events.

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Grid Defender Compared to Current Electrical Power Transmission and Distribution

Cost effective and reliable transmission and distribution of electrical power is an on-going requirement as nations expand their use of electricity. In the U.S. much of the current electrical conductors are overhead lines with poles and cross arms that will need replacing in the near future. Because of the aging utility infrastructure of 60 years plus, most utilities are now replacing their lines at a rate of 10% per year. With an average of 25 poles per mile and 130,000,000 poles in the USA alone, this means the replacement of 5,200,000 miles of line or 520,000 miles per year for a net of 13,000,000 poles per year. Additional power lines are needed to move electricity from areas capable of producing "green" energy such as wind, solar and bio-energy to high demand, large population areas such as California and the northeastern U.S. It is appropriate to explore all concepts that offer the opportunity to "harden" existing transmission and distribution lines and build new lines in more cost effective methods. The concept proposed by Grid Defender, Inc. offers both means to conduct electricity more reliably as well to reduce the costs of building, maintaining and replacing service lines. The purpose of this report is to explore the differences in current methods compared the opportunities and possible shortcomings that Grid Defender might embody.

Current Electrical Grid Power System

The majority of today's electrical power comes from centralized power plants fueled by coal, nuclear or hydro. From these plants "transmission" lines (80 to 600 kilovolts) carry electricity to substations that split the power down to smaller transmission lines and "distribution" lines (< 80 kilovolts). The distribution lines then service homes, offices and businesses according to their demand for electricity. For example, a home probably would not need a 3-phase distribution line but a manufacturing plant with large machines would. The distribution lines that feed homes and businesses are usually referred to a "drop" lines.

All three types of conductors – transmission, distribution and drop lines – have traditionally used overhead wires. While many residential subdivisions have incorporated "under ground" service, the heat that comes from moving electricity through conductors has made it not cost effective to bury major amounts of the "electrical grid." Just like electrical motors, laptops, light bulbs, etc. are hot to the touch, wires that conduct electricity dissipate heat. The most cost effective and simple approach to handling this heat is by suspending the conductors in the air. While suspended conductors are very effective, they are also vulnerable to weather and human interaction.

Grid Defender Concept

The inventor of the Grid Defender – Mr. Dennis Bell – as a young man watched power lines collapse from ice, wind and traffic accidents in his home state of Kansas and thought there had to be a way to reduce the loss of power to homes and businesses. At the same time there might be an opportunity to lower the cost of installation and reduce safety concerns inherent to construction crews who build and repair power lines.

Mr. Bell being an inventor with many patents to his credit developed and patented the Grid Defender concept after many years of reflection and observation. His idea was very simple - build the power lines on the ground with a preassembled apparatus and winch them to the top of power poles. (Figure 1) Construction on the ground was much safer and faster than traditional approaches that required linemen to climb poles or ride bucket trucks into the sky. It probably would require less equipment and manpower. He felt that repairs could be conducted much easier and safer if lines could be lowered to the ground. The concept also offered the ability to quickly lower lines before storm events which would preclude replacement of conductors, cross arms and poles after storms. The potential is to return power to customers in a fraction of the time normal to current methods by winching lines back in place after storms. In addition, the costs of replacing lines after a storm including materials and manpower would be greatly reduced. While complete elimination of storm damage to power lines is unlikely, any fractional improvement would bring back service to customers more quickly and reduce the cost of their electricity.

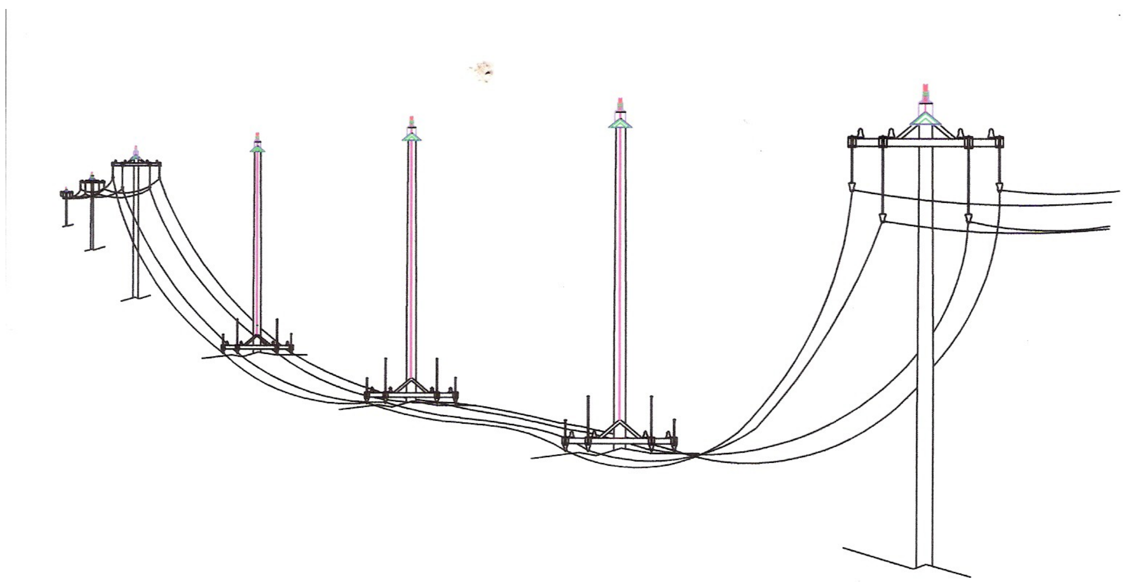

Figure 1. Grid Defender with Lowered Lines.

Current Power Transmission and Distribution

Large transmission lines delivery power across the nation connecting power plants with major substations. These lines require dedicated right of ways and are mostly constructed with tall steel towers and extensive guying for support. While there is a definite opportunity to apply the Grid Defender concept to large transmission lines, this analysis will focus on the more common wooden pole lines that include distribution and drop lines and some smaller transmission lines.

A pole that carries both transmission and distribution lines could have 4 high voltage lines and a neutral line as well as 3 to 4 3-phase distribution conductors. To build such a system, a minimum crew of 3 to 7 linemen would be required along with a bucket truck and pole truck for transporting the poles. At least one other truck would be required to bring spools of wire and cross arm components. A boom truck with an arguer would be needed to bore a hole for each pole. Cross arms, wire insulators and guy wires would be attached to a pole before setting it in the hole. Assembly is done in the field. The poles are lifted into the hole using the boom truck. Guy wires (if necessary) are anchored and tightened to secure the pole in its vertical attitude. Poles are manually tamped in a vertical position. Power conductors are then attached to the cross arms through pulleys for each insulator by a lineman in a bucket truck. As additional poles are installed, conductors are tensioned and fastened permanently to each insulator. All conductors for a pole are attached at the same time before moving to the next pole. Topography, terrain obstacles and man made features such as roads and structures would dictate pole spacing, pole heights and guying. Distribution and drop lines are installed similarly to transmission lines but usually with fewer conductors.

Grid Defender Application to Power Lines

Use of the Grid Defender apparatus differs very little from that of current power pole installations but with the additional benefit of raising and lowering of conductors and any other attachments such as transformers and other add-on cables such as TV and telephone service. One major difference is that it is anticipated that Grid Defender installation will require fewer linemen in the field and much less time per pole. Much of the labor involved will take place in a factory setting prior to field installation. The pole is outfitted with a pulley and Docking Yoke on top of the pole and a winch at a convenient spot near the bottom (just above horseback height). (Figure 2) Pole size would be the same as for traditional configurations. A Docking Arm on the cross arm that matches the Docking Yoke on the pole would plug together much like plugging a power cord into a wall outlet after the Cross Arm Assembly is winched up the pole into its docking position. Any guy wires would be attached above or to the side of the Cross Arm Assembly and tensioned similarly to current methods. The cross arm would be different than most current cross arms in that insulators would be positioned below the cross arm as opposed to above it. To accommodate multiple conductors, small vertical shafts would slide through the cross arm with a stopping head on the top and an insulator on the bottom. This type of shaft and insulator combination would allow conductors and cables to be mounted at various heights on the pole but could allow them to be attached on the ground at a convenient working height. Additional attachments such as TV and telephone cables could be attached at different heights below the cross arm just like conductors. The neutral and a Signal Transmittal Cable would be attached in the same manner. Transformers could be mounted on the top or to the side of the Docking Yoke or on the pole above the Docking Yoke. The poles would be set and guyed the same as with traditional systems but with the winch cable threaded through the top pulley. Once the pole is vertically secured and the winch is attached, the Cross Arm Assembly with conductors and cables attached to the insulators could be winched into place. Depending on the pole spacing, several poles may have their cross arms winched simultaneously in a staged fashion e.g. as the cross arm reaches the yoke on the first pole, the second pole will have its cross arm reach the mid-height position. This would prevent the stretching of conductors or bending of poles. When the Docking Arm settles into the companion Docking Yoke, a switch is opened so that power can flow through the conductors once all poles in a Sector have been finished. This activity is repeated until the entire Sector of poles has been erected.

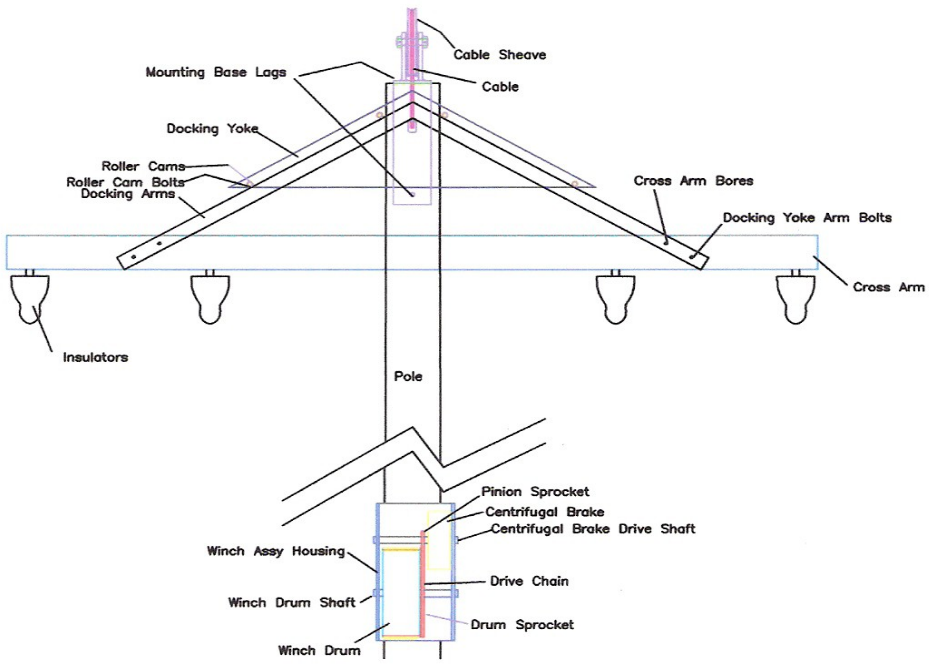

Figure 2. Grid Defender Pole Apparatus

The Grid Defender Signaling System is a key feature of the Grid Defender concept that controls the flow of electricity in conductors within a Sector. (Figure 3) The Signal Transmittal Cable has three small wires (20-gauge – 2 positive and negative) that carries a signal to a Sector Breaker. This Cable is strung across all poles in a Sector, probably attached to the neutral. A Sector can have as many poles as appropriate for the area being serviced. Each Sector is solar powered to a battery to supply DC current for the Signaling System, and each pole has a Signaling Switch. The DC current on the Transmittal Cable that flows through the Signal Switches on all poles in a Sector is always available to send a signal to the Sector Breaker. When a Docking Arm leaves its Docking Yoke, the Signaling Switch on the Docking Arm is closed which connects the Signal Circuit causing the Sector Breaker to trip - instantly cutting off electricity flowing through the conductors, thus preventing deadly electrocution, potential fires and other casualties.

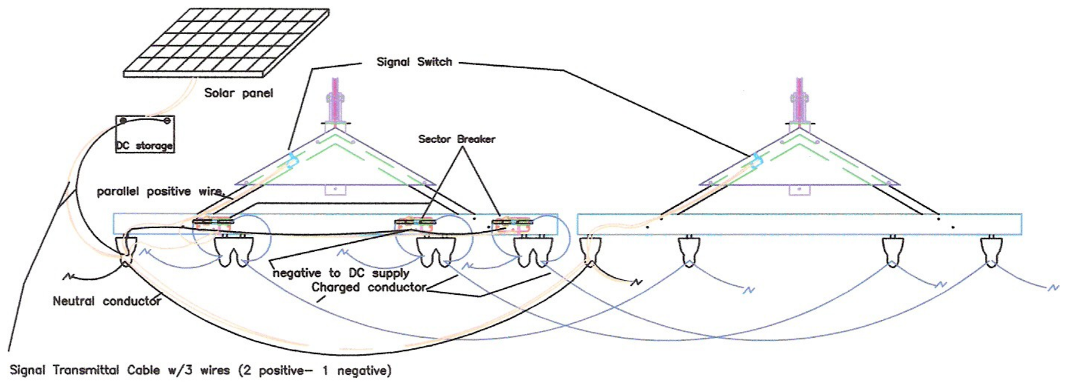

Figure 3. Grid Defender Signaling System

For example, say a pole is hit by a car causing the Docking Arm to come out of its Docking Yoke. The Signaling Switch is closed causing the Sector Breaker to open which cuts off power to all poles in the Sector. Affected conductors are lowered to the ground with no electricity thus rendering them harmless to all unsuspecting passers-by. The power in conductors is instantly stopped when the Docking Arm separates from the Docking Yoke. To repair this situation, a new pole may be needed to replace the one hit by the car. Once the pole is up, the Cross Arm Assembly with conductors can be manually winched back into place along with any other cross arms that came down when the car hit the pole. (Cross Arm Assemblies are released based on a preset mechanical release force and fall to the ground in a slow, predetermined decent rate.) After the Docking Arms have been winched back into their Docking Yokes and the Signal Circuit has been opened, power can be restored by manually resetting the System Sector Breaker.

It is outside the scope of this report, but existing technology would allow remote control of the Cross Arm Assemblies. If because of some impending danger – say a significant storm - it is deemed appropriate for power lines to be lowered, a remote signal could be sent to release means that would cause them to lower power lines to the ground or some other safe level. In highly populated areas audible and visual alerts as provided in the patent could accompany the slow decent of the “dead” conductors. These procedures could be a part of a Smart Grid Technology.

In a repair situation, Grid Defender allows linemen to safely lower Cross Arm Assemblies to the ground for repair rather than working on them in the air. This gives linemen more complete control by having power cut off at the pole being addressed and working in a safe environment.

Sources of Costs Information

Mr. Bell and Grid Defender, Inc. solicited the aid of Montana State University Department of Mechanical (ME) and Industrial Engineering (IE) to estimate costs of current power line construction in comparison to similar construction using the Grid

Defender concept. A team of Senior IE students consisting of Michael Bauer, Adam Gereg, and Owen Kelley under the faculty direction of Dr. Durwood Sobeck, Professor, tackled this project for their Engineering Design Capstone Course. The resulting report – *Economic Feasibility of a Novel Distribution Line Protection System* (IE Report) – will serve as a foundational document for the estimation of per pole costs for both current and Grid Defender power line construction costs. (Appendix A) This was a very thorough and well thought-out report and will be used in this analysis with notes where adjustments are needed.

The IE students took a very logical and direct approach at determining costs. For current power line construction, they chose to contact North Western Energy, a major supplier of electricity in Montana, and solicited current bids for construction from them. Recent bid prices are excellent resources to reflect costs in the current market place. Since the Grid Defender apparatus is not presently being manufactured, the students chose to develop a conceptual manufacturing plant to build and assemble the parts for a Grid Defender system. They used standard IE models to estimate plant manufacturing times, solicited material costs from online information and expert testimony, selected manufacturing tools from expert advice, and got land and building costs from local sources. For the installation of Grid Defender apparatus in the field, standard IE models were used for time components and expert advice was solicited from North Western Energy engineers.

<u>Costs for Current Power Line Construction</u>

The IE students calculated an average cost of $3,025 per pole for current construction methods. (Table 1) Of course, this cost is an average and will vary depending on weather and terrain conditions. Key inputs into this cost include the following:

- Linemen to do construction were three (3) at a labor cost of $50 per hour. The training and danger associate with power line construction and repair is reflected in an expensive labor rate.
- Power company warehoused pole components at field offices and based on engineering specifications, linemen take these components to work site. No transportation costs were included except as reflected in the time expended by the linemen. Poles and other components had transportation costs built-in to the price charged by suppliers of these components.
- A complete listing of materials and labor is given in the IE Report (Appendix A).

The students made a very valid point that at an average spacing of 250 feet between poles this current construction method cost estimate expands to $63,897 per mile. Any incremental improvement in per pole cost would have a very large effect on the total cost of power line construction.

Table 1 – Summarized Cost of Current Methods vs. Grid Defender (GD)[1]

Item	Cost of GD for Energy Company	Current Method
Cross Arm Assembly	$434.60	$230.22
Pole	$432.00	$432.00
Shipping GD	$6.22	NA
Conductor	$370.25	$370.25
Framing Pole	$7.00	$500.00
Setting Pole	$780.00	$780.00
Stringing & Tensioning	$229.00	$687.00
Grounding	$26.00	$26.00
Winch Assembly	$308.40	NA
Total	$2,593.47	$3,025.47

Costs for Power Line Construction using Grid Defender

The IE students estimated the cost of constructing a power line similar to the one described above with Grid Defender to be $2,593 per pole which is a savings of $432 per pole (14% under the current costs). They estimated the manufacturing and installation processes as follows:

Manufacturing the Apparatus

Since there were no examples of Grid Defender manufacturing to measure directly, the IE students constructed an analysis model of a manufacturing plant and field installation procedures. They considered three (3) approaches to manufacturing:

Alternative 1. Build and assemble the entire pole and cross arm assembly in a plant. Linemen would only erect the finished pole and string the conductors at the work site.

Alternative 2. Build and assemble the cross arm portion in the plant and attach the pole components but ship cross arm and pole to the work site separately. This alternative would require linemen to attach the cross arm to the pole and string the winch cable at the work site.

Alternative 3. Build and assemble only the cross arm portion and build the pole components in the plant and ship only that kit to the work site. Linemen would supply their own poles and attach winch, top pulley with docking yoke and winch cable at the work site prior to erecting the pole.

The least cost selection from these three alternatives embodies several factors. The labor rates for factory workers (excluding supervisors) was $20 per hour as compared to linemen rates of $50 per hour. Obviously, the danger associated with the linemen's occupation should not exist in the controlled work environment of a factory. Any building of components and assembly that can be accomplished in the safety of a factory is preferred over field applications. In addition, quality and efficiency should be enhanced in the factory environment. For sure, specialized components such as Docking Arms, Docking Yoke, winch, etc. would require a factory setting with proper tools and

[1] Bauer, Michael, et.al. 2011. Economic Feasibility of a Novel Distribution Line Protection System. Final Report. Industrial Engineering Capstone course.

could not be built at a field location. The IE students did not formally consider making all components at the factory and doing all assembly in the field – an alternative that would have been very expensive due to the labor rates of linemen.

The students' selection was alternative three based on cost and flexibility for the linemen. By allowing the linemen to select their own poles, they could adjust pole size to more precisely meet terrain requirements. They found that Alternative 1 was five times more expensive than the other two and Alternative 3 was 9 percent less than Alternative 2. Transportation costs associated with moving fully assembled poles with cross arms made Alternative 1 very expensive. Alternatives 2 and 3 were similar in costs but the flexibility given by Alterative 3 made it their preference.

An additional alternative that was not explored was shipping the cross arm assemblies to the energy company's field warehouse. Just like pole components are being stored for ready application currently, the Grid Defender cross arm and pole components could be stockpiled at these warehouses. It is conceivable that the pole components – top pulley with docking yoke and winch – might be installed at that warehouse with less expensive labor and reduce construction costs even more. In the students' approach comparison, they charged the Grid Defender approach with shipping to the work site. ($6.22 per pole, Table 1) That cost might be lower if shipped to the warehouse instead of the field work site. Shipping poles with the winch, top pulley and docking yoke attached might cause problems of damage during handling and shipping and should be evaluated before establishing this procedure as a common practice.

The students analyzed the costs and projected a selling price for building and assembling at the plant based on several factors:

- Target production capacity was set at 1,800 units (pole assemblies) per day with a two shift operation – 450,000 units per year. At full production a unit was built every 32 seconds. (The target production capacity was recommended by Mr. Bell based on his understanding of potential current market demands from a single manufacturing facility.)
- The plant was analyzed over a seven (7) year period which was assumed to be a reasonable period for depreciation of machinery and tools and included a production rate ramp-up. (1/3 production rate the first year on 1 shift; 2/3 production rate the second year on 1 shift; full production the third year on 1 shift and full production rate on 2 shifts for years 4 through 7)
- Financial assumptions included a 40% income tax rate, MARR (Minimum Acceptable Rate of Return) at 8% and straight line depreciation with no salvage value. Labor was paid at $20 per hour, foremen at $50,000 per year and plant manager at $100,000.

Using Alternative 3 for the 7 year planning period the students arrived at an average cost of $734.62 per unit (pole assembly) and recommended a selling price (f.o.b. plant) of $743 per unit. The plant's capital expense was estimated to be $6.6 million and would yield 21% ROI (Return on Investment) over the 7 year period after taxes. The plant would have a positive annual cash flow after taxes of $57,267 in year 1 that would grow to $3,530,005 in year 7.

As mentioned before, the IE students did very commendable work. Only a few oversights were found such as repair and maintenance for the factory was covered by a one time charge of $200,000 the first year of operations. Typically, repair and maintenance early in a manufacturing facility's life is involved in getting everything working – tools, machinery, plant layout, etc. Later in the plant's life, repair and maintenance involves actual improvement of machinery and repair due to use. The students did not consider repair and maintenance until late in their project and perhaps did not have time to properly consider this expense. If the labor cost for the first year repair and maintenance were continued over the life of the evaluation period (7 years), ROI would drop to 17%.

Another possible oversight was the overhead costs for a second shift. The students did not include the salaries of foremen needed to run the second shift. They may have felt that second shift foremen were not needed but personal experience has proven otherwise. A single plant manager is probably okay. Adding foremen for the second shift would drop ROI to 14%.

Another possible concern is that the plant must be highly automated to achieve the productivity levels targeted i.e. turning out a unit every 32 seconds requires labor and machinery to be performing at top efficiency.

There did appear to be an opportunity to cut material costs by optimizing the cutting of apparatus parts from sheets of metal thus reducing wasted metal. A savings was not calculated but could be quite large.

It should be noted that while creating a manufacturing facility might yield lower costs for the Grid Defender components and an opportunity for a greater profit margins, the manufacturing facility is not unique. Any well-equipped machine shop could build the parts necessary for the Grid Defender system and assemble them ready for sale. Therefore, the $6.6 million of investment could be avoided completely by jobbing out the manufacturing to existing companies. Also, the typical risks of a start-up facility could be avoided.

One possibly major discrepancy concerns the cost of electricity. The IE student's report estimated that each pole assembly would require 1,000 kilowatt hours of electricity. The students came to this estimate by projecting the time and electricity to make the necessary cuts, welds and assembly of the individual parts added together. Based on the proposed plant (45,241 square feet of floor space), estimated electrical usage, production of 900 Grid Defender poles per shift and current industrial electrical rates, electricity will cost $1.59 per shift per sq.ft. or $35.01 per month per sq.ft. (single shift). Personal communication by Mr. Bell has determined with 2 large machine shops (Burris Optics, Inc. [2] and Haake [3]) – very similar in size to the proposed plant – that currently electrical

[2] Personal communication with Mr. John P. McCarty, President of the Board, Burris Optics, Inc., Greeley, CO 80631.

[3] Personal communication with Ms. Bev Haake Roberts, Vice President, Haake Manufacturing Co., De Soto, MO 63020

usage costs $0.15 to $0.19 per month per sq.ft. (single shift). Reducing the kilowatt hour usage for a single pole based on $0.185 per month per sq.ft. versus $35.01 shows that a single pole would need 5.28 kilowatt hours of electricity. Applying this usage gives a ROI of 1,170% as compared to the reported 21%.

If all the above modifications – increased repair and maintenance, added second shift foremen, and reduced electricity usage – were incorporated, after tax ROI would be 1,159% with after tax net cash flows ranging from $3.6 million in year one increasing each year to $24.8 million in year four and continues through year seven. With all the variety of assumptions made in this analysis, it is difficult if not impossible to predict exactly the costs and returns. Since, as mentioned, Grid Defender apparatus does not require a unique manufacturing facility, the way to get a more exact cost would be to request bids from various qualified fabrication shops.

In a time when job creation is very important, at the production level of 1,800 units per day, the factory is projected to employ 144 workers, 12 foremen and a plant manager. Other support personnel such as accounting, secretarial, cleaning and marketing would be needed too. If a new factory were not built, these jobs would still be needed at some other jobber's facility.

Field Installation of Grid Defender Apparatus

Using the recommended sales price, the IE students compared the various parts of the installation process to current methods. Table 1 shows the differences. The cross arm assembly is more expensive for Grid Defender because it is a manufactured component ready for installation as compared to current methods where the parts come un-assembled and must be attached at the work site. The pole cost is no different between the two methods. As mentioned earlier, a shipping cost was charged for Grid Defender that might be less as compared to no extra cost for current methods. The conductors were the same for both methods. Framing of the pole involves assembling the components necessary to complete the pole. The framing costs for current methods were large because the pole and other components came to the work site completely un-assembled. While much of the framing was not dangerous work, the linemen were paid at their higher labor rates rather than at factory rates to attach the cross arm and other components to the pole. The Grid Defender apparatus was mostly assembled and only required the linemen to attach components like the top pulley and docking yoke and winch to the pole. Setting the pole in the hole was estimated to cost the same for both methods. The students estimated that stringing and tensioning the conductors would cost 1/3 as much for the Grid Defender. Their logic was that the conductors would only be handled once compared to twice by current methods and that the work could be accomplished by 2 linemen rather than 3. (There are reliable reports that current methods often require 5 to 7 linemen rather than the 3 projected in this comparison.) Grounding costs were considered to be the same for both methods and since only the Grid Defender required a winch, there was no charge for a winch on the current method. In addition, a bucket truck – an expensive component – may not be needed at all where as with current methods a couple of bucket trucks might be needed. A possible omission by the students is the cost of vehicles used in the installation process such as personnel service truck, boom/auger truck and trailers for poles and conductors. Since costs for current methods come from contractors bidding on power line installation, this type of equipment would be included; the student's inclusion of this equipment is not obvious. If this was an oversight, it would add only a small amount to the final costs and would not significantly affect the conclusions.

Evaluation of IE Students' Findings

As mentioned earlier, the students did a very in-depth study. They performed a sensitivity analysis and found that net present value for manufacturing was highly sensitive to selling price, scrap rate (manufacturing mistakes), energy rate (cost of electricity for the plant), and demand for the product. Net present value was also sensitive to the labor rate but not highly. From personal experience, there are many unforeseen complications that effect the establishment of a manufacturing facility. Risks to investors for a startup manufacturing venture are very real, and in today's money climate where investment capital from traditional lenders is scarce, starting up a new facility should be given a lot of thought and analysis before beginning. The inputs and assumptions used in the analysis are well documented and can be tweaked to reflect an investor's personal situation. A very positive outcome is that existing machine shops can be solicited for bids to build and assemble the Grid Defender components. The students were reasonably conservative in their assumptions; open bidding might produce lower costs for the components than estimated in the study.

As the students identified in their report, the exact time it will take to install poles with the Grid Defender components is unknown until some poles can be erected and time studies performed. Times to erect poles using current technology is well known. It was expected that it would take less elapse time to put up a pole that has its components attached, or mostly attached, than to install one that had to be "built" in the field. Attaching conductors on the ground and not tensioning them in the air will be a new experience for linemen, but should save considerable time. This in combination with one less linemen lead the students to reduce the cost to 1/3 that of current methods. This procedure will not be completely understood until time studies can confirm the student's assumptions.

Two components not included in the analysis were the Sector Circuit Breaker and Signal Transmittal Cable. The Circuit Breaker stops the electricity going through the conductors when the circuit is broken at some pole when a cross arm is lowered. Another Montana State University student team from the Mechanical Engineering Department is working with Mr. Bell on a Capstone Project designing this component. Mr. Bell expects this component to cost under $300 per conductor for each Sector. Therefore, the cost per pole will depend on how many poles are in a Sector and how many conductors per pole. At 250 feet between poles, a 10-mile Sector would have 212 poles and for a common 3-conductor pole the Circuit Breakers would add $900 to the Sector or $4.25 per pole. As mentioned earlier, Sectors can have any number of poles. The Signal Transmittal Cable –

a cable with three 20 gauge conductors – sends the signal to the Circuit Breakers to stop the flow of electricity and should be only a minor cost due to its small size.

Until a section of power line can be stalled, the IE students have provided the best information available. Their assumptions and methodology were reasonable. Therefore, it can be concluded that savings of time and cost using the Grid Defender concept are real. With a crew of two linemen instead of three, Grid Defender poles can be expected to be installed in less than half the time of current methods at costs that save 14% over current methods. For the average mile costing $63,897 per mile, the savings translates into $9,123 per mile. Assuming that the manufacturing cost differences found in this report are correct i.e. increased repair and maintenance, added second shift foremen, reduced electricity usage and added Circuit Breaker with cable, the reduced cost of Grid Defender manufacturing could be passed on in the form of a lower price to the end user – power companies – and therefore, the savings per mile could be much greater. These four analysis modifications could cut the estimated breakeven cost by $74.52 per pole. Passing this savings on to a power company would lower the cost to $2,518.95 per pole or a savings of $506.52 per pole versus current methods. This expands to an average savings of $10,698 per mile, a 17% savings.

Other Possible Cost and Time Benefits from the Grid Defender Concept

A number of other possible benefits in addition to initial construction of power lines that was addressed by the IE students are as follows:

Repairing after Damaging Events

As discussed in the car-hits-pole example, power lines are vulnerable to humans as well as nature. This year tornados have caused huge losses of power. While it may be impossible to second guess the occurrence or locations of storms, meteorologists are becoming very accurate. Given the ability to lower power lines along with Grid Defender's Sector Signaling System, much of the danger associated with "live" conductors on the ground can be eliminated. When a cross arm comes down, the power is stopped in that Sector. The cross arms can come down due to un-intentional forces – wind, ice, car crashes, etc. – or intentional forces such as remote lowering of lines as storms approach. The potential of lowering conductors as power companies monitor the build up of ice could possibly protect many poles and lines. The costs and time after a storm might be greatly reduced by winching cross arms up into place instead of completely rebuilding an entire section of power line. The possible reduction of risks to customers and linemen who come into contact with downed lines offers new, elevated safety standards that are currently unavailable. From present understanding of Grid Defender, it is suggested that winching a cross arm back into its docking position might take 2 to 5 minutes with a single lineman and minimal equipment while current methods of complete pole replacement would probably require an hour using an entire crew with multiple machines;. The Grid Defender concept might give power companies a new tool to combat the loss of life and assets. It is possible that this ability to lower conductors and stop power would enhance power company engineers and linemen's unique ingenuity to reduce the impact of catastrophic events.

It should be noted that maintenance and repair of electric power lines are inherently hazardous, and U.S. electric linemen suffer an average rate of 33.4 electrocutions per 100,000 workers each year – more than four times that of electricians, who suffer the second highest rate of electrocutions (8.3 per 100,000 workers).[4] This hazard greatly increases when repairs are conducted under conditions of widespread damage to electrical transmission and distribution systems, such as in the aftermath of a natural disaster like Hurricane Hugo. After this hurricane, in an effort to restore power as quickly as possible, experienced electric company personnel worked shifts of greater than or equal to 24 hours, often in darkness and inclement weather. In addition, to expand the work force, electric company retirees and workers whose job responsibilities normally do not involve work near energized lines volunteered to assist in the power restoration effort. These workers may have been insufficiently familiar with appropriate safety precautions.

Avian Concerns

In recent years, large birds whose wing span can touch multiple conductors have caused some to demand the retrofitting of power lines to protect them. Numerous raptors have been electrocuted. This modification to cross arm design has been very expensive. Grid Defender eliminates this danger to birds by putting conductors below cross arms.

Tampa Electric has a five-year Avian Protection Program to retrofit its electrical infrastructure. The program, which has mostly affected the Polk County area, will continue to be implemented annually. Tampa Electric recently announced that the company has completed a five-year retrofit Avian Protection Program (APP) designed to prevent large birds of prey from coming into contact with electrical infrastructure. The company, the first utility in Florida to establish a program to protect migratory birds, will continue to retrofit high-risk poles as they are identified. During the five-year program, Tampa Electric has retrofitted and/or reconstructed almost 1,200 poles in its service territory, primarily in the Polk County area, at a cost of approximately $800,000.[5]

Retrofitting Existing Power Lines

While cost savings for new power line construction has been discussed, the upgrading of existing lines could be easily facilitated using Grid Defender cross arm apparatus. If existing poles were sound, existing cross arms could be removed on several poles (probably 3 at a time) to lower the conductors to the ground. Then the top pulley and docking arm assembly could be attached to the pole as it stands using a bucket truck. After the winch is attached to the pole and cable connected to the new Grid Defender Cross Arm Assembly, conductors could be attached and hoisted up to the Docking Yoke. While exact time is unknown until tried, it would be expected that this task would take much less time than setting a new pole and framing with current methods. In the states of North Dakota, Nebraska and Oklahoma, there were approximately 2,183 miles of power lines replace each year from 2000 to 2010. Expanding this to the lower 48 states gives

[4] Center For Disease Control (CDC) - Weekly Report 10-27-89 Morbidity/Mortality weekly report 38(42); 718-725

[5] Tampa Electric Company is the principal subsidiary of TECO Energy, Inc. (NYSE: TE)

104,784 miles per year or 2,410,032 poles at 23 poles per mile.[6] While it is not known how many of these poles could be retrofitted and how many replaced, the replacement savings using Grid Defender might be $1 billion per year or more.

Adding Other Cables and Conductors

One of two approaches could be used to attach additional cables and conductors: The cross arms could be lowered to the ground for ease of connection thus stopping power within the Sector or bucket trucks could be used to add to existing conductors and cables without cutting off power. Either way, cross arms could have extra holes bored to accept additional shafts with insulators.

Other Possible Improvements

There are many possible ancillary benefits for use of the Grid Defender concept. During catastrophic events such as storms the loss of power over a long period of time magnifies the actual storm damage. We use electrical power to fuel everything from our home utilities to appliances to the machines used in factories. Food spoils in refrigerators without electricity. Chickens die without power to cool and feed them. Milk cows must be slaughtered when they can't be milked. Crops can be completely lost. Even our hospitals need power restored as soon as possible to relieve backup supplies. Electricity is critical to our financial infrastructure. The military backup system needs power restored as soon as possible. Insurance premiums increase as loss claims rise above expectations. (Conversely, premiums could come down when the electrical grid becomes more hardened.) While much communication is done with cellular service, cell phones must be recharged. In short, when we loose electrical power our country is not prepared to function for any great length of time. As a country, we have chosen to create power in centralized locations and send it out through a grid instead of each family or other entity making their own electrical power; therefore, power needs to be restored as soon as possible. Grid Defender could bring more security to the power grid.

Electrical power outages, surges and spikes bring about more than $150 billion in annual damages to the U.S. economy. Every year, an estimated $104 billion to $164 billion gets expended due to power interruptions, while another $15 billion to $24 billion is lost on account of poor power quality such as voltage fluctuations, power surges and spikes. Specifically, industrial and digital business firms suffer losses amounting to $45 billion annually. Some industries, such as manufacturing, can lose as much as $6.45 million per hour of downtime.[7] The benefits of investments made in necessary power backup arrangements far outweigh the shocking costs related to irreparable damages and irretrievable loss of revenues caused by downtime.

Some other damaging spinoffs from destroyed power lines include wildfires and cleanup and repair issues. When "live' conductors fall to the ground they often cause sparks that result in fires and add more costs to other damages. Wildfire and a myriad of other collateral damages are a result of downed power lines. Cleanup of the broken poles and

[6] http://www.nfs.unl.edu/CommunityForestry/TreeCare/alma&orleans.pdf

[7] Energy Data & Statistics, U.S. Energy Information Administration, 1000 Independence Ave., SW Washington, DC 20585

stretched conductors add costs to catastrophic events. Wooden poles and cross arms are treated (often with creosote) to prevent decay and insects; their disposal after being broken require special handling – an added burden to waste handling facilities. Metal components – brackets, bolts and conductors - can be recycled but must be removed from the poles and delivered to recycling points. Disposal of toxic treated poles costs about $300 per pole and recycling of metal towers cost about $2,300 each.

While the Grid Defender concept cannot assure that these types of losses will not occur, it has the potential to lessen their impact. Savings from hardening the grid are difficult if not impossible to calculate without understanding each individual situation, but it is very apparent that potential savings do exist.

A very real benefit of the Grid Defender approach is the jobs created to construct new power lines and retrofit existing lines. Since much of the work would be in a factory setting, jobs would be performed in a much safer environment than with current methods. Much of the materials come from renewable natural resources – trees. Using more trees benefits the total environment by removing older trees giving room for younger trees that replace carbon dioxide with oxygen more rapidly than declining trees. In addition the carbon emitted from equipment used to construct power lines would be reduced since Grid Defender is more time efficient than current methods.

Conclusion

Grid Defender, Inc. provides a new novel way of hardening the electrical grid. By having the ability to raise and lower power lines, utility companies are afforded a safer work environment. In addition, by using Grid Defender's Sector Signaling System electricity is shutoff when power lines come down whether intentionally or unintentionally. IE students from Montana State University have modeled the startup of a factory to build Grid Defender apparatus and the installation in the field and compared Grid Defender to current methods of power line construction. They found that the Grid Defender approach saves over $400 for each pole or over $9,000 per mile as compared to current power line construction methods. This report's analysis suggests that a savings of $11,000 per mile might be more accurate. Based on these findings, it appears that Grid Defender can save money and time in the handling of power lines during initial construction and repairing after catastrophic events. More importantly is the reduction of safety hazards for both power company linemen and the general public.