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Determine the Feasibility of Using Isolated Solar/Wind Hybrid Power System to Augment Power at a Signalized Intersection

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DETERMINE THE FEASIBILITY OF USING ISOLATED SOLAR/WIND HYBRID POWER SYSTEM TO AUGMENT POWER AT A SIGNALIZED INTERSECTION

by

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Content

Abstract

An estimation to the monetary profit a solar/wind power system can make when powering a traffic light signal is presented. There are two approaches investigated. One is tracking the price of the equipment and the money it can save to obtain the result. The other approach is to estimate the environmental benefit and then convert it into a monetary value for comparison. A discussion of the results and suggestions on the new solar/wind hybrid power system is presented

Introduction

The traffic light system is a very significant part of daily life. Usually, traffic signals are used to control the flow of traffic and used to prevent traffic accidents. They are used to regulate every driver so that everyone can move smoothly on the road. In 1869, J P Knight invented the first traffic lightand installed it near London's House of Commons (Bellis). After the first traffic light was installed, more traffic lights were applied to control the traffic so that every car could drive orderly. As the number of traffic lights increased, amount of traffic accidents dropped incredibly.

Now with ever more traffic lights applied at cross roads across the world, energy costs have became a problem, since the maintenance of such a great system needs large amounts of energy. Consequently, LED light bulbs have been promoted at many large cities. However, because of the large number of installations, energy usage is still high.

Based on the research of Energy Plus Roadways, which is operated by the University of Nebraska Lincoln, there are 418 signalized traffic intersections in the City of Lincoln, Nebraska. For continuous operation, 92,464 kilowatt-hours are needed to supply all of these traffic lights every month (Lincoln). For comparison, a normal electric clothes drier uses about 1.8-5 kilowatt-hours every month (Estimating Appliance and Home Electronic Energy Use, 2011). There are about 300,000 signalized intersections in the United States and together they consume about 27,739 gigawatt-hours to operate every month. Based on the electricity cost in Lincoln, which is $0.07 per kilowatt-hour, the United States will spend approximetly $55 million per year (Lincoln). Alternatively, those funds may be used to equip traffic signal systems with renewable energy systems.

Almost all of the traffic lights in Lincoln have incadecent light bulbs installed. Although LED (Light Emitting Diode) lights don't create as much heat as normal light bulbs and as such save energy (Tom & Wesley), it is expensive to install it. There are numerous traffic lights need to be powered; as a result, the traffic light signal energy cost approximately 5% of the city's operating budget. Also, to supply this much energy, LES (Lincoln Electrical System) may need to burn tons of coal that will emit tons of GHG.

Applying solar panels and wind turbines to traffic light systems not only saves money, but also it can reduce the GHG (Green House Gases) emissions from electrical companies. From 1990 to 2009, the electric power plants in the United States emitted more carbon dioxide compared to transportation, industry, agriculture, commercial, and residential sectors (EPA, Inventory of U.S. Greenhouse gas emissions and sinks: 1990-2009, 2011). Reducing carbon dioxide emissions from electric power plants by reducing electricity use from traffic signals can help. In Lincoln, Nebraska, applying both wind turbines and solar panels is the best choice to replace local grid electricity. However, installing wind turbines and solar panels at all 418 intersections will be expensive. Therefore, the focus is on how many years it will take to get the payback and how many tons of carbon dioxide can be reduced per year if those technologies are applied on the traffic light signals at all 418 intersections in Lincoln.

Objectives

The main objective for this research is to find out the benefits of installing solar panels and wind turbines on the traffic light system in Lincoln Nebraska. There are two subtopics: economic savings for Public Works and Utilities Department of Lincoln

Nebraska and Carbon dioxide reduction at electricity power plants. In order to get a fair result, the objectives below should be accomplished.

• familiarize how the Roadway Wind/Solar Hybrid Power Generation and Distribution System operates.

•compute the costs to install solar panels and wind turbines on all traffic lights system in Lincoln. Also, compute how much money can be saved by running the Roadway Wind/Solar Hybrid Power Generation and Distribution System for a year. (Need to estimate maintenance fee for the equipments)

•compute how much energy (based on kilowatt-hours) can be saved and how much carbon dioxide, nitrogen oxide, and sulfur oxide can be reduced by using the Roadway Wind/Solar Hybrid Power Generation and Distribution System for a year. Convert these savings into monetary value.

Methods

Task #1 – How Roadway Wind/Solar Hybrid Power Generation and Distribution System Works

Literature review will be used for this task. Information will be gathered through internet and research papers which have been reviewed. Some detail part of how the whole system works can be gotten from the thesis advisor. After getting all the information about the wind/solar hybrid power generation and distribution system, it is necessary to rearrange and review all the information. The last step is to get an understanding of the system.

Task #2 – Compute Economic Analysis

For each station, the first thing that needs to be found out is how much it costs to buy solar panels. This information can be gotten from the website named reLI. All information gotten from reLI website is the data about Long Island. Long Island locates at 40.8˚ N latitude and Lincoln locates at 40.8˚N latitude too. Also, Long Island has 3500-4000 Whr/sq in per day solar resource and Lincoln has about 4500-5000 Whr/sq in per day solar resource (Resource Maps, 2012); therefore, they have similar solar resource quntity and reLI website can be used as reference. In order to do research on reLI website, the energy consumption of the traffic lights needs to be found first. According to the report from Traffic Engineering Division Department of Public Works in City of Little Rock in July 1, 2003, a typical traffic intersection which has four traffic lights and each traffic light includes red, yellow, and green incandescent light bulbs use 111kwh per month. Energy consumption should be converted into annual consumption which is 111kwh per month*12 months per year=1,332kwh per year. Then, go to reLI website (http://www.sunshineisfree.org) and choose Suffolk County as a sample county and non-profit facility. For part two, enter 1332kwh, as calculated, in the box and then click the bottom button under it to get the pay back result.

For the wind turbine analysis, the Bergey XL 1.0 wind turbine is used and the price can be gotten from Bergey Wind Power (http://www.bergey.com/price-list). Use the solarestimate.org website to estimate the payback for wind turbine. At that website, go to my wind estimator and enter the zip code as 68504 for Lincoln, Nebraska locates. Click continue. Then, select Lincoln Electric System as your utility and business for the type of building. Choose wind turbine and click continue. Enter 1,332kwh in the blank and click estimate my system. Change the wind turbine size to 1kw and price of installation to $4,595. Also, change the electric rate to $0.07 and then click update my assumption. The result for wind turbine pay back will appear below the blanks.

Then, the cost of installation and maintenance needs to be estimated since different places have different degrees of abrasion. Different brands and versions of solar panels have different abilities to transfer solar energy into electricity and also have different prices. For this research purpose, example of Energy roadway system project run by University of Nebraska Lincoln will be used as a sample since most of the information can be gotten easier. Consequently, there are two types of cost which include equipment cost and maintenance cost. Economic revenue can be gotten from not consuming electricity that was provided by Lincoln Electric System (LES). Except this, selling the extra electricity to the electric company can even make money. The idea result of money saving can be calculated by using the price of electricity which is provided by LES. The Energy Roadway System experiment will be used as a case study. In the short term, of course it is not economically efficient to build a solar panel and a wind turbine. In the long term, it is hard to say. In order to compute whether this new system is economically feasible or not, solar-estimate.org website will be used to calculate the outcome. Solar and wind estimator will be used to get results of how long the pay back can be made.

Task #3 – Computes How Much Carbon Dioxide, Nitrogen Oxide, and Sulfur Oxide Can Be Saved and Their Monetary Value

In order to compute the carbon dioxide, nitrogen oxide, and sulfur oxide that can be saved by using Wind/Solar Hybrid Power Generation and Distribution System, the value of environmental benefits needs to be assessed. Data about the amount of carbon dioxide that can be saved Can be retrieved from websites used in calculating task #2. The offsetted carbon dioxide is converted into a monetary based value. A technical support report from U.S. Department of Energy can be used to determine the value of carbon dioxide. Similarly for nitrogen oxide, a government resource (Khan, 2009) will be used to provide an estimated value of offsetted nitrogen oxide. After finding the value, it can be multiplied by the amount of nitrogen oxide being saved so that the total monetary value will be gotten. The same calculation can be done for sulfur oxide.

The amount of nitrogen oxide emitted into the atmosphere when one kilowatt-hour of electricity has been produced is 0.0015 lbs based on the EPA's default value. According to U.S. Department of Energy Facts Program, 0.03 pounds of sulfur dioxide is emitted into atmosphere when creating one kilowatt-hour power by burning coal.

Results

Solar panels can be installed anywhere on the traffic light system. Places to be chosen should have the largest attainable solar energy resource and cannot be easily accessed by the general public. For the wind turbine site, it should be installed at the highest spot so that it can harvest the greatest amount of wind energy and the posibility to be destroyed by humans will be reduced.

Both the solar and wind power generators are connected to the LPMC (Local Power-Management Controller). Within the LPMC, the solar panels are connected to DC/DC

(Direct Current) converter. DC/DC converter can output a usable constant voltage of electricity regardless of the variable input voltage. The input voltage variability is due to different levels of solar radiation and angles between the solar panel and the sun (Rob, Camilo, & Naji, 2004). The DC/DC converter attaches to a battery bank where the energy is be stored.

The wind turbine is first connected with a rectifier, which converts AC (alternating current) that is produced by turbines into DC. The rectifier output terminal is connected to a capacitor bank to stabilize the voltage. AnotherDC/DC converter connects The capacitor bank to the battery bank. Additionally, an inverter is connected with the capacitor bank so that extra electricity produced by the Roadway Wind/Solar Hybrid Power Generation and Distribution System can be sold to the electricity company. Also, electricity can be sent to the traffic light system from the electricity company if necessary. This system helps electric power plants reduce emissions and the Public Works and Utilities Department to save more money. Also, it ensures the normal running of the traffic light system. Figure 1 shows how the Roadway Wind/Solar Hybrid Power Generation and Distribution System is connected.

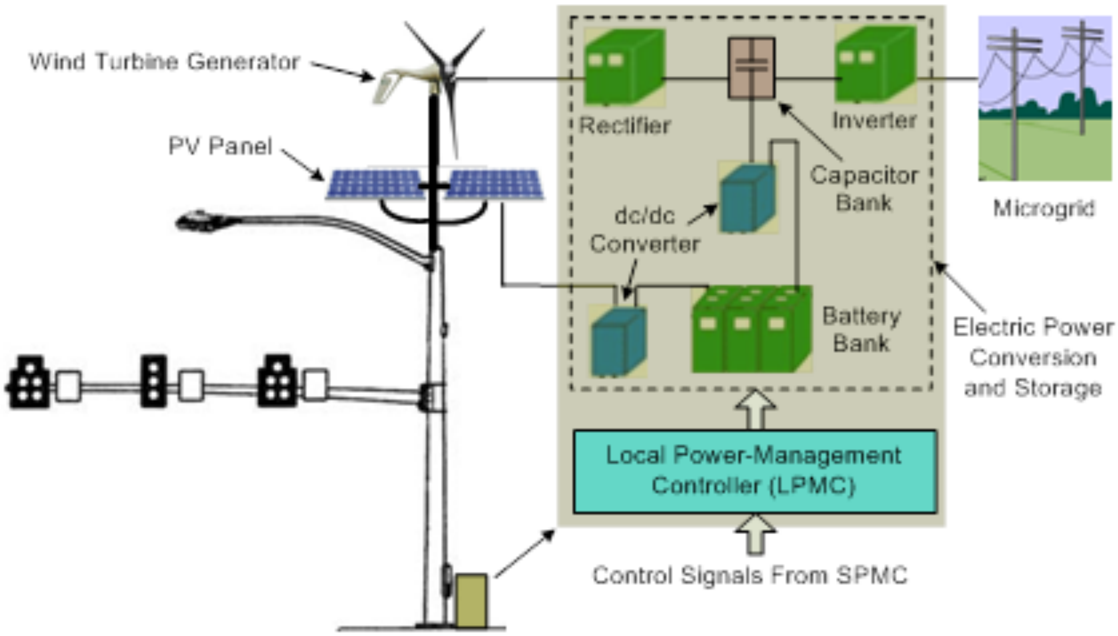

Figure1. The structure of a sample solar/wind hybrid power system for traffic lights. Power produced by wind turbine and solar panel can be stored within the battery or been delivered directly into electric network system in the city. From: http://energyplusroadways.unl.edu/info.php?section=overview

The result from website reLI shows that 105 square feet of solar panel is required to be installed to power up the traffic light system. The installation cost will be $7,856. However, the expected federal rebate is $2,877 and the final cost is $4,979. A 25 year system life is assumed in the analysis. And assuming that the electricity rate will stay at $0.07/kwh (EIA, 2011) for 25 years at Lincoln, Nebraska, the total money saved in 25 years is 1,332*0.07*25=$2,331. Subtracting that amount from the revised total, the PV system costs $2,648.The price of a Bergey XL 1.0 is $4,959. An assumption is made that only one wind turbine is required to power the LED traffic light system. Since this is a government project, there is no federal tax credit. The website assumes a 15 year life of the system. Therefore, the money can be saved within 15 years is 0.07*1,332*15=$1,398.6. Since one turbine will cost $4,979, the wind turbine costs

$4,959-$1,398.6=$3,560.4. The combined cost of the wind and solar is $3,560.4+$2,648=$6,208.4.

In the of UNL project, a Bergey XL 1.0 wind turbine only produced 50kwh per month according to Figure2. The cost of installation is $4,959, but it will only produce 50kwh*12months*15years*$0.07=$630 value in 15 years. It is not economically feasible to install a Bergey XL 1.0 wind turbine at all.

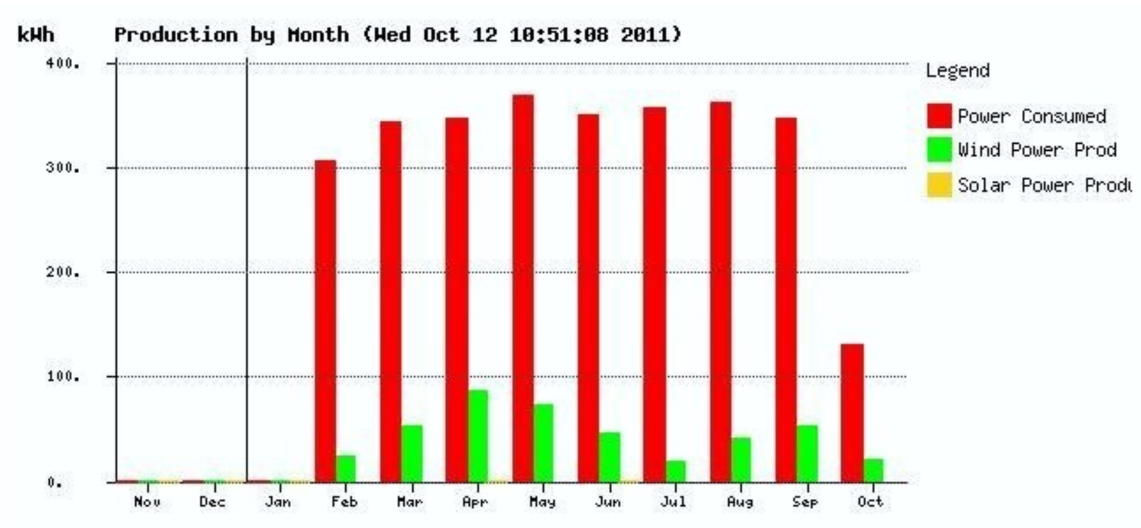

Figure2. Monthly power consumption for a typical traffic intersection and wind power production for a Bergey XL 1.0 wind turbine. Approximately 50 kWh electricity has been produced by wind power. From: http://energyplusroadways.unl.edu/info.php?section=testsite

Wind and solar energy are considered clean energyand there are some environmental values of this energy. According to the Regional Electricity Emission Factors Final Report, the average emissions rate for electricity is 1.64 pounds CO_2 per kilowatt-hour. Since both solar panel and wind turbine have been installed, twice energy will be produced, which is1,332kwh*2*20years = 53,280kwh annually. This means1.64 pounds/kwh*53,280kwh = 87,379.2 pounds of carbon dioxide will be saved in 20 years. Converting into tons, that is 43.69 tons of carbon dioxide. According to the document from U.S. Department of Energy, one ton of carbon will cost $50 when considering the climate change impacts. So, $50*43.69 tons=$2,184. This will lower the cost from $6,208.4 to $4,024.4.

The solar/wind hybrid system will also save nitrogen oxide emittions into the atmosphere. The environmental price for nitrogen oxide is from $432 to $4,441 per metric ton in 2007. $2,400 per metric ton is used as an average monetary value. As mentioned in earlier, 0.0015 lbs nitrogen oxide is generated when producing one kilowatt-hour of electricity. Therefor, 0.0015 lbs/kwh*53,280 kwh =79.92 lbs, which is also equal to 0.036 mt. Then, 0.036 mt*$2400/mt=$86.4 will be saved within 20 years.

The monetary value for sulfur dioxide is $8,542/mt in 2007 measured by DOE (Department of Energy). The calculations are 0.03 pounds/kwh *53,280 kwh =1,598.4 pounds of sulfur dioxide can be saved during 20 years. 1,598.4 pounds equal to 0.725 mt. So, the total monetary value is 0.725 mt*$8,542/mt=$6,192. With sulfur dioxide and nitrogen oxide, there is $6,192+$86.4=$6,278.4 savings. Finally, $6278.4-$4024.4=$2,254 profit for the system.

Discussion

The results show there is no economic benefit to install the solar/wind hybrid power system at traffic intersection to power the traffic lights. But there are environmental reasons to promote this system. As we can see in the results, there is a cost of $6,208.4.

Cities and municipalities do not have the funds to install such systems at every traffic intersection. However, after installing the solar/wind hybrid power system, all energy produced is free and clean. There are almost no emissions, like carbon dioxide, nitrogen oxide, and sulfur dioxide. If left to pollute, these will cause environmental problems and money is needed to solve the problems. This can be prevented.

For example, global warming is caused by rising concentrations of greenhouse gases in the atmosphere. Carbon dioxide, as one of the greenhouse gases, has been emitted by human activities. Nitrogen oxide is created when electricity has been generated, and it can cause problems in human breathing (Health, 2012). Therefore, it is necessary to reduce emission of nitrogen oxide so that the medical costs can reduce. Sulfur dioxide is one of the main components to acid rain. Acid rain can erode buildings, cause damage to human skin, and destroy habitats. But by applying the solar/wind power system wolrd-wide, the emissions of carbon dioxide, nitrogen oxide, and sulfur dioxide can be reduced

It is obvious that the value of environment is hard to estimate. Although there will be environmental monetary benefits, those benefits cannot be converted into currency, and the profit is distributed globally. So, it is difficult for investors to receive monetary benefits after they installed the solar/wind hybrid system.

Consequently, it is not suggested to install the solar/wind power system to power the traffic lights when economic benefits alone areconsidered. But, if the city decides to consider environment benefits, it is suggested to install the solar/wind power system.

Suggestions

After doing research on the solar/wind power system, it was found that one of the biggest problems that stop customers fropm purchasing such systems is the payback period. There are four ways to decrease the payback period. First of all, decrease the costs on wind turbine and solar panels. This requires technological development and competition between different companies. Secondly, increase government tax credits and increase the rebate rates when buying wind turbine and solar panels. Third of all, increase the life period for the wind turbine and solar panels so that they can last longer and create more lifetime energy. Lastly, apply the solar/wind hybrid system at places that have high electricity rates such as Hawaii, New York, and California. Although promoting this power system is difficult now, there is an increasing trend of installing renewable energy.

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