Constant Power Production and Harvesting Using Roof Ventilation Systems

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Abstract

Energy harvesting using horizontal wind turbines is investigated and a performance analysis is done and compared over a period of time using identical rooftop wind turbines. In many buildings, especially high rises, air ventilation systems are operated non-stop with a constant air speed. Real time applications are mainly used with vertical wind turbines, but they have limited efficiency due to wind airflow distribution. Small modifications on wind turbines and ventilator systems can improve the airflow of the vent systems as well as the efficiency of the wind turbine. Using ventilator systems can eliminate weather prediction modelling due to constant airflow and non-stop operation of the ventilator systems. This study shows that even though wind airflow may be stronger at various times during the day, the average power production using a ventilator system is quite large. The ventilator systems can be named a new renewable energy source due to their constant energy production possibilities.

1. Introduction

The need for energy is growing every day. The world's population is growing with a rate of 1.14%, representing a doubling time of 61 years [1][2]. This means the world's population will reach 13 billion in year 2067. This population increase requires more energy usage and production. Some data on energy use per person [3] shows that people are using more energy every year. This means that even if population growth can be stabilized, there will be an increase in energy demand. The world population increase and increase in energy usage per person brings much greater energy demand than previously predicted. Price decreases and globalization created more energy demand and generation as seen in Figure 1. This increase will continue due to more and more people demanding energy.

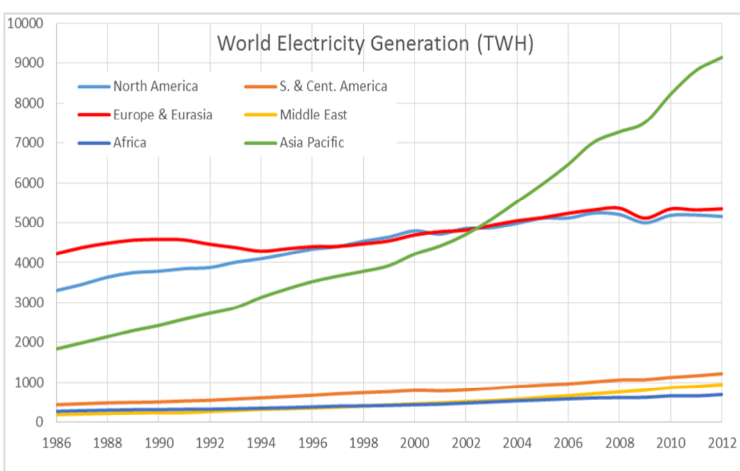

Figure 1. World electricity generation [3].

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Currently, the main source of energy consumption is fossil based (oil, coal and gas) and it is about 80% of the total world consumption by source, as seen in Figure 2. Dependency on oil and annual increase in oil production will cause a peak in oil production in the next few decades and this will be the next big problem. Fossil fuels are finite and take many years to produce. In the last few years, there has been an effort to reduce fossil fuel dependency and increase renewable energy. Countries like the United States, China, Germany, Denmark, etc. are spending more resources on renewable energy and discovering new technologies for energy production and storage. The latest data shows Europe is balancing their energy consumption due to some tough environmental laws and more renewable energy production.

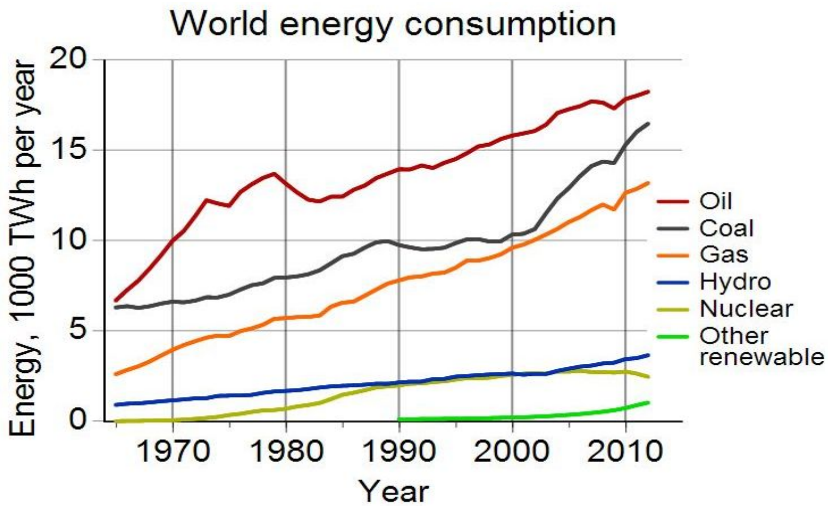

Figure 2. Total world energy consumption by sourse [3].

As described above, the two main goals are to shift the energy source from oil to more renewable sources and limit consumption by social training, smart technologies, and energy production by demand. The next section will address some of these techniques, with emphasis on energy harvesting and constant energy production which are used in this paper. Section 3 will explain the experiment, and lab construction, the results and conclusion.

2. Energy Harvesting and Prediction

The energy problem can be seen easily by comparing Figures 1 and 2. The world needs energy and this need increases every year due to new markets and an increase in population, but energy sources are finite. One of the important players that can turn the table or ease the problem is renewable energy. Even though the energy problem is addressed by many papers and books [4-7] and peak oil production will be here soon, developed countries were late to increase energy efficiency and conservation, develop renewable energy systems like solar and wind, and find new sources of energy. Some countries like China, Spain, Germany, and Denmark invested in renewable technology and created smart systems for energy efficiency and harvesting. Energy production in some European countries from fossil based sources started declining [3]. All of this shows the importance of an infinite energy source. Are there any resources that are not depleted? The simple answer to this can be found in the definition of renewable energy. Renewable resources such as water, wind and solar power are the main sources of power in renewable energy. These resources are not depleted and can be reused to produce energy over and over again. In theory, these resources can be considered infinite energy sources, but the reality is not that clear, due to the fact that production material of photovoltaic systems and wind turbine systems are finite. Also these systems come with a high construction cost that creates some drawbacks.

The second issue with renewable resources such as water, wind and solar is that they are unpredictable. Determining when there will be a sunny or windy day is difficult to predict. This presents the problem of how much power a renewable energy system will produce at any given day or time. Power demand from industry, commercial and residential users are known and must be accounted for. Due to heavy demand from industry, approximately 25% more power is used between 7AM to 7 PM compared to 7PM to 7AM. Because of this, the unpredictable nature of renewable power production is a drawback. There have been many studies [9-11] regarding power prediction in solar panels and wind turbines, but this area is still open to more studying, due to a number of variables. Creating a model that applies to any wind turbine or solar panel farm is not practical. Modifying a prediction model to fit a new location may require intensive data collection and heavy analysis.

Our answer to these problems is to use roof ventilation systems as a renewable energy source [12-15]. Even though by definition the ventilator systems and air flow produced by these systems are not renewable resources, it could be consider as such because they operate all day long during their operation cycle. Due to this operation cycle, the airflow that is generated by these ventilation systems can be considered as non-depleted resources. The airflow can be considered as a constant wind resource. This constant wind can be a source of constant power production. At any given time, the system produces constant power. The produced power could be a source for smaller ventilation systems or small appliances. Detailed information about the proposed system will be described in the next section.

3. Proposed System

In this section, a description of the research lab, equipment used, and data collection and results will be given.

3.1. SMART Lab

The university has vertical and horizontal ventilation systems for its buildings. Each building has an average of eight vertical and two horizontal ventilation systems. These ventilation systems operate everyday as explained in the previous section. The engineering school has a brand new System Modeling and Renewable Technology (SMART) lab that was funded by the State Energy Conservation Office (SECO) grant number CM1357 [16]. The lab is located on a patio between two buildings shown in Figure 3. The SMART lab is a research, education and outreach lab that develops outreach programs and workshops to promote renewable energy and SMART technology. The SMART Lab is 100% green and uses produced energy from solar panels and wind turbines.

The SMART Lab currently has the following off-grid solar panel and wind turbine system;

- 6750 W Off-Grid Power System
- 3x1520 W Off-Grid Power System
- 2x85 W Off-Grid Power System (Teaching and Research Module)
- 5400 W Wind Turbine System
- 9 x 600 W SunForce Wind Turbine
- 1 HP Data Server
- 1 Dell Server
- 2-desktop and 4-laptop computers
- Real time whether station

3.2. Experiment

The SMART Lab has 9 x 600W SunForce wind turbines. These turbines can be configured as either 12V or 24V and can work standalone as well as in groups of three. Some of the specifications are given in Table 1.

Table 1. Wind turbine specification table [17].

Specs	Value
Related Speed	12.5 m/s (41 ft/s)
Related Power	600W
Voltage with MPPT	12 or 24V
Rotor diameter	1.31 m (4.3 ft)
Cut-in wind speed	4.5 mph
Survival wind speed	157 mph

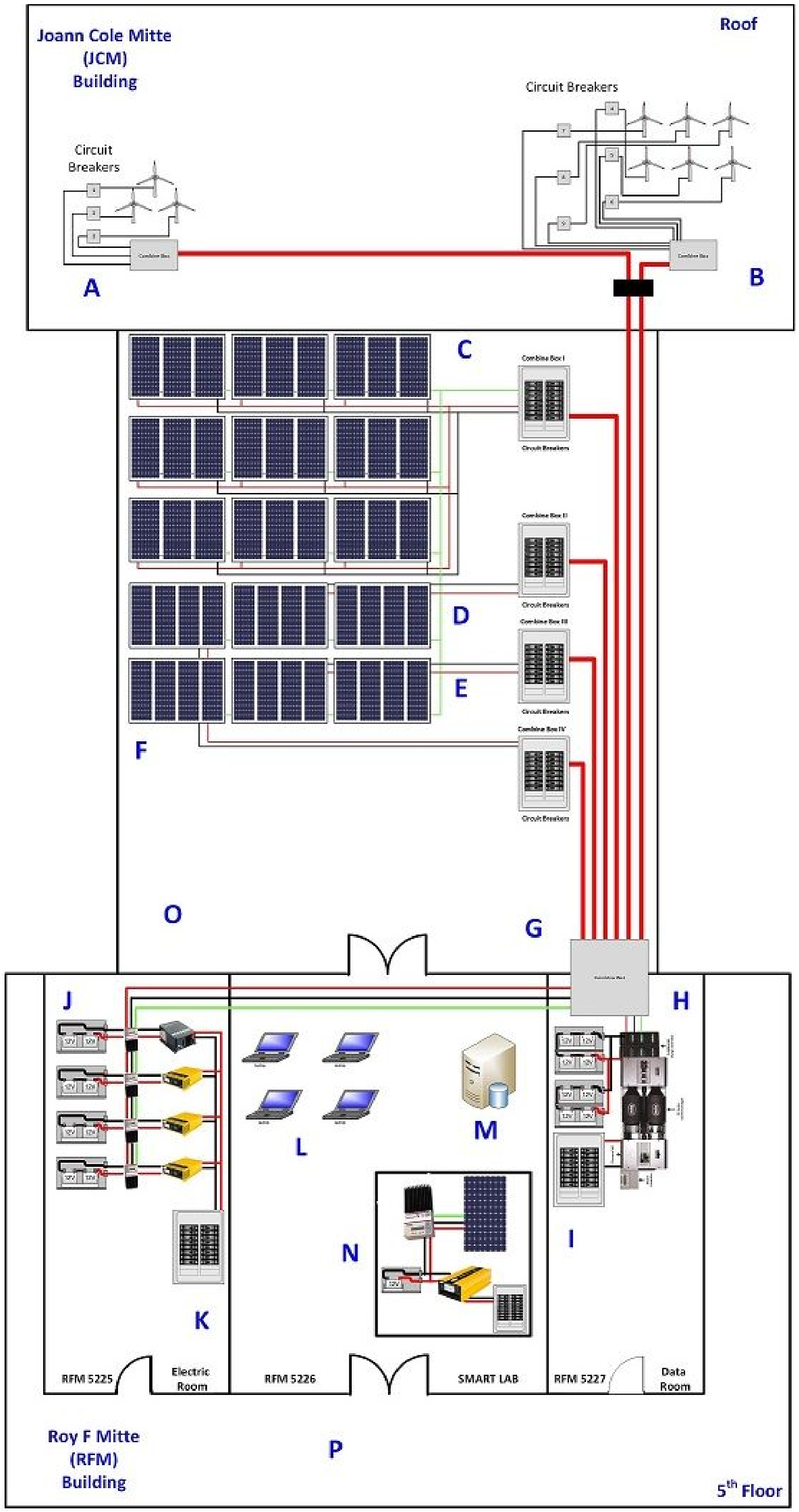

Figure 3. SMART Lab outline.

For this experiment, two SunForce wind turbines are designed to work standalone. Each of the wind turbines power data was captured using data loggers by eGauge[18] over a 2-week period. In addition, an onsite real time weather station is synced with the data loggers to receive weather information for accurate readings. Later, this data is transferred to the data server for analysis. The two wind turbines and weather station used for this experiments are shown in Figures 4.a,4.b and 4.c, respectively.

Figure 4a. Constant wind based system. Figure 4b. Variable wind based system. Figure 4c. Wheather station.

3.3. RESULTS

During the 14-day experiment period, the captured data from eGauge [18] and weather station is averaged. This data is shown in Table 2 and Figure 5. The Figure 4.a data shows the experiment data where a ventilation system is used as a constant wind source. On the other hand, the Figure 4.b data in Table 2 shows the wind pattern and power production of the wind turbine that is shown in Figure 4.b.

Table 2. Power comparasion of two wind turbines.

Day	**Figure 4.a**		**Figure 4.b**	
	Wind speed (mph)	**Power (W)**	**Wind speed (mph)**	**Power (W)**
1	18	285	4	10
2	18	285	9	88
3	18	285	4	12
4	18	285	23	365
5	18	285	21	320
6	18	285	14	218
7	18	285	12	207
8	18	285	8	84
9	18	285	6	73
10	18	285	7	78
11	18	285	8	84
12	18	285	10	104
13	18	285	12	207
14	18	285	10	104

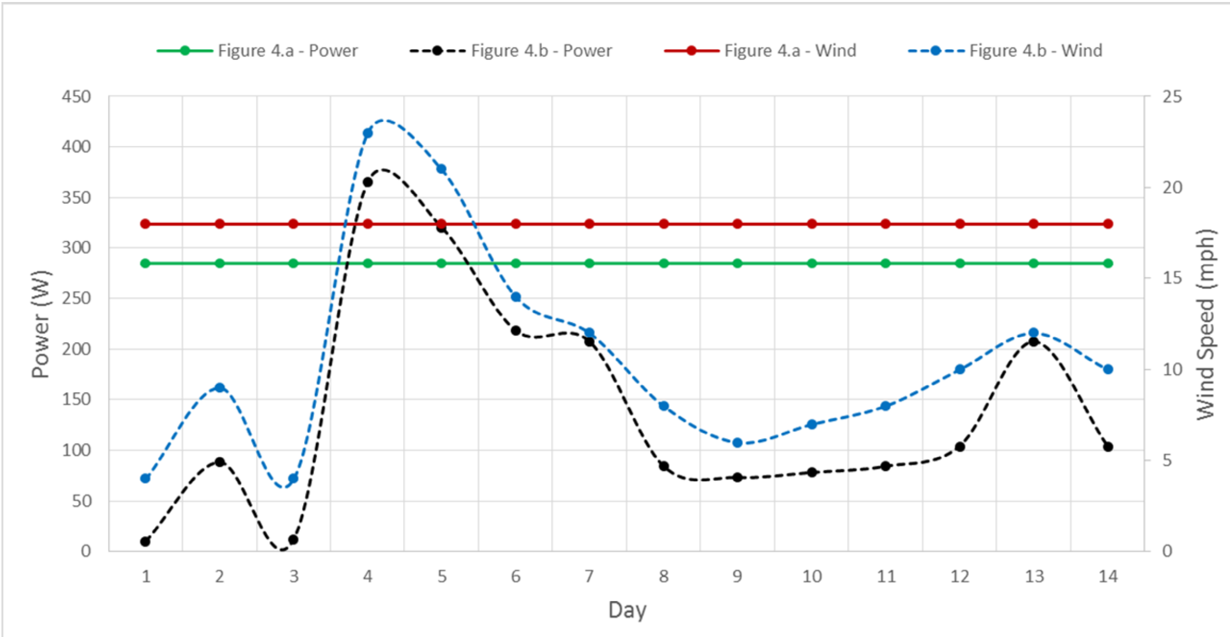

Figure 5. Power comparison of two wind turbines.

The data shows that the wind turbine that uses the ventilation system produces constant power. On the other hand, the wind turbine that uses wind as a power source has uneven power production due to an unpredictable wind pattern. Using the system described in Figure 4.a can make it easy to install an optimized system by getting the right size of wind turbine, battery and inverter system. This will reduce the overall system cost and optimize the power production.

4. Conclusion

This paper presents an energy harvesting method using roof ventilation systems. Constant speed airflow is used as a power source for the wind turbine to produce constant power. This method eliminates power prediction modeling and supplies the desired power to customer. A second wind turbine is used for comparison purposes. Using air ventilation systems as a renewable resource cannot be the solution to all energy problems, but it can easily be implemented on many buildings due to low construction cost. Future work will include an enclosure around the wind turbines, a more efficient airflow ventilator design, as well as various amounts and styles of wind turbines blades, it will also utilize vertical ventilation systems and will use them together with horizontal systems to create a small rooftop power grid system for university buildings.

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