Design of 1kW Wind Turbine

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Abstract--In this project, stand alone 1 kW wind turbine has been analyzed using RET Screen software in order to design to achieve maximum output power. Blade Design and generator selection are done and implemented. Synchronous 3-phase 1 kW permanent magnet generator has been used. Monthly mean wind speed data for TU (Sittwe) at 10 m above ground level has been analyzed using RET Screen Wind Energy Project Model. The results can determine annual energy production useful for further design of wind farm.

Key words-- maximum output power; RET screen; Project model ; annual energy production.

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I. INTRODUCTION

Nowadays, renewable energies are the best solution to produce clean energy and at the same time to meet the increasing demand of energy remote coastal region. Wind power is considered at the present time as the world's fastest growing energy source and has also become a rapid getting bigger industry. Offshore wind has the ability to deliver a large amount of energy at a price that is relatively cheaper than the other forms of renewable energies.

Wind energy is considered as one of the most important technologies for electricity generation especially when we take into consideration economic and environmental circumstances. Globally, the wind power industry is in an age of substantial growth as a result of advances in technology and is set to expand as the world looks for cleaner and more sustainable ways to generate electricity.

For remote applications, a good site will have average wind speeds of greater than 4 m/sec (9 mph), although sites with significantly lower average wind speeds are acceptable if power requirements are modest or wind is not the exclusive energy source.

In general, wind power systems require more maintenance and will not last as long as comparable PV systems. In deep field applications, it is probably reasonable to expect a service life of between 4 to 10 years out of a top-quality, well-designed, and well-maintained wind turbine, although longer (or shorter) service lives are certainly possible [1].

Design and construction of 1 kW wind turbine project has been doing as a combined research work of four engineering departments. Electronic engineering department has led as focal department of this project, Civil engineering department take responsibilities to design and construct foundation and implementation of tower, Mechanical Engineering Department developed blades and Generator design and selection have made by Electrical Power Engineering Department of TU (Sittwe).

The TU (Sittwe)'s 1kW wind turbine project comprises;

Project Framework

- The promotion of renewable energies to the public sector and to businesses.
- The decline of electricity bills for customers.
- The contribution in the environment preservation.
- The decline of electricity production from fossil fuels.

Project location

- Identification of possible sites for TU (Sittwe)'s 1kW wind turbine project.

Financial Aspect

- Project funding is basically: research funding of TU (Sittwe).

II. METHODOLOGIES

Monthly measurements of wind speed data of TU (Sittwe) for the last 12 months used to analyze the wind energy production. Technical characteristics of 1 kW wind turbine have shown in Table 1. Wind energy results from the movement of air caused by temperature differences in the atmosphere.

Radiations from the sun heats up the air and force it to rise. On the other hand when temperature decreases, a low pressure zone develops. Therefore, wind energy is originally solar energy converted into kinetic energy of moving air. When air mass is flowing through an area (A) with speed (v), the power of that air movement at time (t) is given by:

$$P_{(t)} = \frac{1}{2}\rho A v_{(t)}{}^{3}$$

where (ρ) is the density of air, which is around 1.225 kg/m³ [2].

For air density of 1.225 kg/m3, corresponding to dry air at standard atmospheric pressure at sea level at 15° C. The formula for the power per m^2 in Watts = 0.5 * 1.225 * v^3. The energy (kWh) is the product of power and time:

$$E = P_{(t)}T = \frac{1}{2}\rho A\,\Delta t \sum_{i=1}^{N} v_i^3$$

The energy resulting from wind varies with the cube of the average wind speed. In order to take into consideration wind variations, the energy from an air flow over a time period is made up from the summation of different wind speeds of small time intervals. Often, the average wind speed is measured every hour, thus providing 24 time buckets every day. While the air density is more or less constant, the two parameters to watch out for are the wind-swept area, (A), and the wind speed (v).

Table 1: Technical Characteristics of 1 kW Wind Turbine

TU (Sittwe)'s 1 kW wind turbine project	
Number of rotor blades	3 nos.
Rotor diameter	3 m
Hub height	9 m
Swept area	9 m^2
Cut-in wind speed	Approximately 4.2 ms^{-1}
Rated Speed	15 ms^{-1}

III. Design of 1 kW Wind Turbine

A. Design of Turbine

It is very important to take into account the safety components while design and installing wind turbines. In other words, components of a wind turbine are designed to last for 20 years at least. This implies that they will have to undergo more than 120,000 operating hours, under different weather conditions. During their life time, large or small wind turbines are equipped with a number of safety devices to ensure safe operation.

Wind turbine designers will plan to manufacture a machine that conveys electricity for the minimal expense per kilowatt hour (kWh) of power. The correlation between generator size and rotor size is significant.

The smaller the generator (in terms of rated power output) the less wind is needed to turn it. A substantial wind turbine rotor (catching a lot of wind energy) combined with a small generator will produce electricity at least as it will work in even light winds.

B. Design of Blades

Selecting the right number of blades depends on the cost of the components and the aerodynamic efficiency additional to the system reliability. Mechanical Engineering Department of TU (Sittwe) developed blades with rotor diameters of 3m. Blades are constructed and tested according to the guideline of the research team of DRI (Department of Research and Innovation, Yangon, Myanmar). Hub design has been done as well to connect the rotor blades.

C. Design of Generator

The generator is the component in a wind turbine responsible of converting mechanical energy into electrical energy. The blades transfer the kinetic energy coming from the wind into rotational one using the transmission system; moreover, the generator is the next step in the supply of energy from wind turbines to the load via charging devices and inverter section which are designed by Electronic Engineering Department of TU (Sittwe).

Generator selection has made by Electrical Power Engineering Department of TU (Sittwe). Synchronous type permanent magnet generator has chosen to install 1 kW wind turbine with 400 rpm in order to operate at average cut-in wind speed. 24 V AC 3-phase output has to be rectified, and connected to charging controlled system.

IV. RET screen Software

RETscreen4 program tool was developed by the *'Ministry of Natural Resources of Canada'*. This software is intended to help in order to calculate the wind potential, actual wind energy production of a specific site and other properties. It can be simulated to analyze the preliminary results utilized for 1kW wind turbine of TU (Sittwe)'s project.

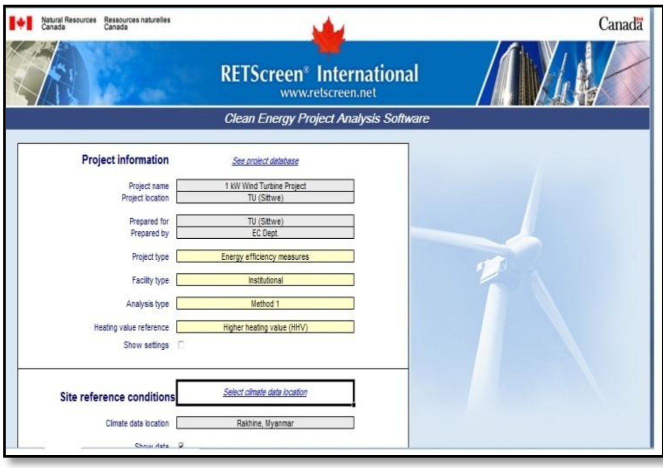
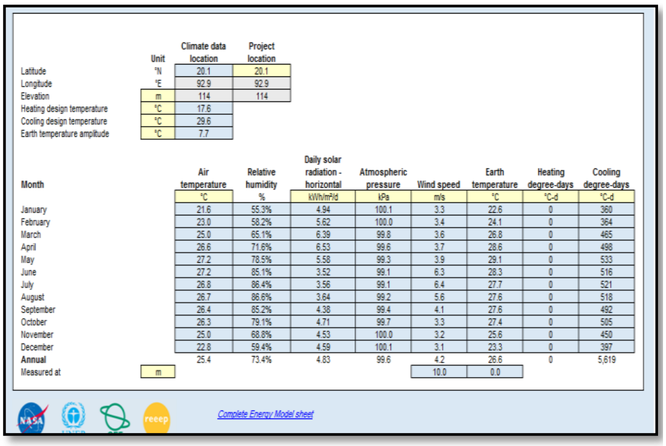


Figure 1. The project information

Firstly, project data has to be inputted in the RETscreen4 software, Figure 1 shows the project information and database of the project information have to be extracted using software. Figure 2 shows annual site information. Proposed power analysis using method 2 has been done the parameters of 1 kW wind turbine project, the parameters can be found in Figure 3. Figure 4 shows the power curve data which are customized and the result shown in Figure 5 has been done to achieve the required power no matter how the wind speed increased.



	Unit	Climate data location	Project location
Latitude	°N	20.1	20.1
Longitude	°E	92.9	92.9
Elevation	m	114	114
Heating design temperature	°C	17.6	
Cooling design temperature	°C	29.6	
Earth temperature amplitude	°C	7.7	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		21.6	55.3%	4.94	100.1	3.3	22.6	0	360
February		23.0	58.2%	5.62	100.0	3.4	24.1	0	364
March		25.0	65.1%	6.39	99.8	3.6	26.8	0	465
April		26.6	71.6%	6.53	99.6	3.7	28.6	0	498
May		27.2	78.5%	5.58	99.3	3.9	29.1	0	533
June		27.2	85.1%	3.52	99.1	6.3	28.3	0	516
July		26.8	86.4%	3.56	99.1	6.4	27.7	0	521
August		26.7	86.6%	3.64	99.2	5.6	27.6	0	518
September		26.4	85.2%	4.38	99.4	4.1	27.6	0	492
October		26.3	79.1%	4.71	99.7	3.3	27.4	0	505
November		25.0	68.8%	4.53	100.0	3.2	25.6	0	450
December		22.8	59.4%	4.59	100.1	3.1	23.3	0	397
Annual		25.4	73.4%	4.83	99.6	4.2	26.6	0	5,619
Measured at	m					10.0	0.0		

Complete Energy Model sheet

Figure 2. The annual site information

In doing analysis of the software, the power analysis method (2) has been used because it is more suitable to simulate using input parameters of the system. Input data used are not from the given library, it is customized to achieve required results.

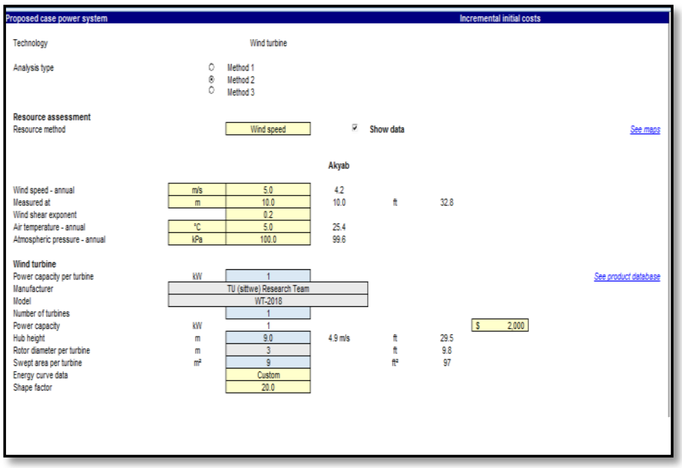
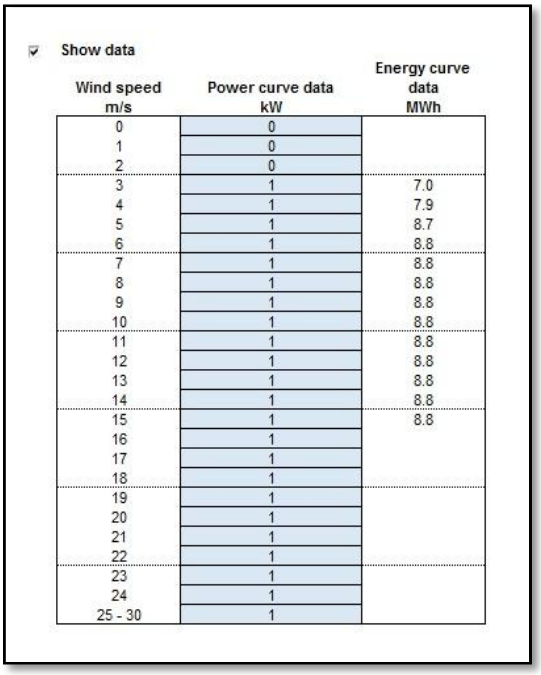


Figure 3. The power analysis using method 2



Show data

Wind speed m/s	Power curve data kW	Energy curve data MWh
0	0	
1	0	
2	0	
3	1	7.0
4	1	7.9
5	1	8.7
6	1	8.8
7	1	8.8
8	1	8.8
9	1	8.8
10	1	8.8
11	1	8.8
12	1	8.8
13	1	8.8
14	1	8.8
15	1	8.8
16	1	
17	1	
18	1	
19	1	
20	1	
21	1	
22	1	
23	1	
24	1	
25 - 30	1	

Figure 4. The power curve data

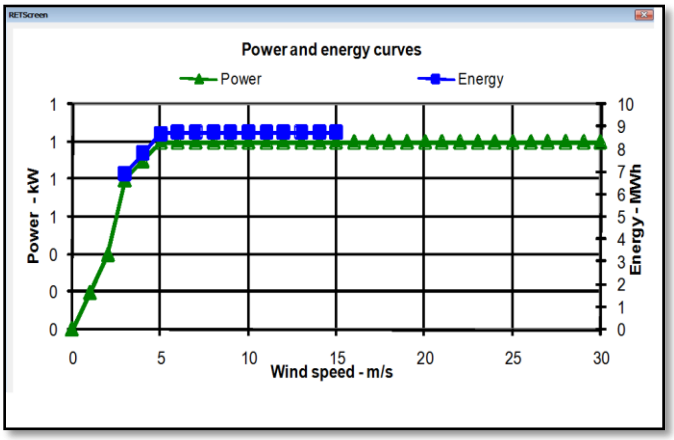


Figure 5. The power versus energy curve

Actually, the parameters used in the power curve data are not the integer '1s', the numbers are rounded off of the software to display in Table of Figure (4). In order to satisfy the system requirements, the controller designs for the charging system and inverter section have to be done by Research Team of Electronic Engineering Department. Annual energy production useful for further design of wind farm has not been described.

V. CONCLUSION

Many countries around the world are focused on renewable energies and are trying to make the best out of the nature and environment without causing any harm. In Myanmar, wind and solar energies based research projects are encouraged to promote the usage of renewable energies. Many researches have to make collaborate with technical partners and try to extend our projects to the international level so as to benefit from other countries experiences and knowledge in this field. The use of RET screen software is highly recommended in order to make the right decision and to have enough proves that the project location or electricity productions are more accurate to real system.

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Author's Profile

Kyaw Soe Lwin has received his B.E. degree in Electronic Engineering (in 2002), M.E. degree in Electronic Engineering (in 2004) from Yangon Technological University and Ph.D. degree in Electronic Engineering (in 2009) from Mandalay Technological University. He is dedicated to teaching field from the last 16 years. He has supervised 25 M.E students, guided 5 Ph.D. students and 50 under graduate students. His research areas are power electronics, electronic circuit design (including VHDL) and RF and Microwave Circuit Design. At present he is working as Professor and Head of Electronic Engineering Dept. at Technological University (Sittwe), Rakhine State, Myanmar.