# DETERMINATION OF POWER GENERATION CAPACITY OF WIND TURBINE

**HARMON EBI OKILO**

**AND**

**ONITA CHUKWUKA LOVEDAY**

Department of Electrical Engineering,
Federal Polytechnic, Ekowe,
Bayelsa State, Nigeria.

## Abstract

The study looked at determination of power generation capacity of wind energy source. Two research questions guided the study. The study was limited to the use of wind as an energy source to generate electricity. The researcher used secondary data to check the power generation capacity of the wind turbine. The data analyses were expressed in percentage to reveal the power difference achieved. The findings of the study revealed that MAPP installation unit had a minimum power output in November at 8%, while its highest output is in the month of April at 56%. That of NEPOOL had a minimum power output in January, November and December at 8%, while its highest power output is at 47% in the month of May. The findings further showed MAPP installation unit in 10 years interval had a minimum power output in Febuary at 12%, while its highest output is in the month of April at 50%. That of NEPOOL in 10 years interval had a minimum power output in Febuary at 13%, while its highest power output is at 53% in the month of May. Finally, it was recommended amongst others that wind data analysis on installation of turbines should be done monthly, annually and five years records to monitor variation across different designs models.

**Keywords:** ***Power Generation and Wind Turbine***

## Introduction

Power generation technology is very essential for economic growth and industrialization in a country. Different renewable natural energy sources have been discovered in the world by countries as a means of supply of electricity and power generation to solve human wants. The society is making effort to avoid excess expenses carried out in purchasing fuels and other materials to sustain power in the environment. Besides this, the constant use of fuels as source of energy generation has influenced the state of the environment negatively by causing excessive environmental pollution. The idea of renewable energy is considered as its process or technology is environmental friendly and creates attractive sites to behold. Some of these renewable energy sources have low cost of running as it relies on nature to function. Some of the common renewable energies are solar, wind, water and so on.

Amongst other renewable sources of power generation, the wind energy has proven to be a reliable source that is been used in the world over for generation of electricity. Wind can be viewed as a free fuel. If all of the wind turbine's output replaces the output of generators that consume the most expensive fuel, then savings are maximized. This simplified point of view is complicated by constraints imposed by integrating the wind resource with the rest of the electricity supply system.

Wind power has value even if forecasts are not accurate. Clearly, the amount of wind energy available at a given time is independent of the forecast. Unexpected wind power can still be used to displace energy that is provided by a load-following unit. However, as wind plants continue to become more economically competitive with conventional energy sources, it is important to correctly assess the capacity value of wind.

A wind turbine is a machine that transforms kinetic power in the wind into electricity. The main parts are rotor and hub, several bearings, gearbox, generator, brakes, control system and a part that balance the electricity. Design of the wind turbine when it comes to rotor and hub can vary, but the most common is that the axis is horizontal. That is, the axis of rotation rotates parallel with the ground with two or three blades. The gearbox task is to speed up the rotation from a low speed to a speed that can operate the generator. Some turbines use special generators that work at a low speed and then do not need a gearbox. Here the focus has been to analyze a general wind turbine with gearbox.

Nearly all wind turbines use induction or synchronous generators that demand a constant or close to constant speed. Because the generator should not be too warm, a cooling system is needed. The generator can be cooled in two ways, either with air or with water. There are two brakes in a wind turbine; one brakes the rotor and the other is placed between the gearbox and generator and is used as an emergency brake or when the wind turbine is being repaired to avoid that the rotor starts spinning. The task of the control system is to put an upper limit on the torque and to maximize the energy production. There is also a small motor that runs a gearwheel so that the nacelle can be turned so that it always is in the wind direction. The nacelle also contains a controller that controls the different parts of the wind turbine (Manwell, McGowan & Rogers, 2002).

The highest efficiency is reached at the designed wind speed. At this wind speed the power output reaches the rated capacity. Therefore the power output of the rotor must be limited to keep the power output close to the rated capacity and thereby reduce the driving forces of the individual rotor blade as well as the load of the whole wind turbine structure. This can be done in three ways: stall regulation, pitch regulation or active stall regulation (Thomas & Lennart, 2002).

Due to the airfoil profile, the air stream conditions at the rotor blade change in a way that the air stream creates turbulence in high wind speed conditions on the side of the rotor blade that is not facing the wind. This effect is called the stall effect (WINDPOWER, 2002). The effect results in a reduction of the aerodynamically forces and of the output of the rotor. In stall regulation, the turbine is designed so that turbulence is created and thereby force and speed is controlled. These systems are most common among old turbines.

A wind resource that cannot be counted on for capacity has a minimal contribution to system reliability. An accurate forecast allows the utility to count wind capacity and reduce costs without violating reliability constraints.

A wind power plant will have more value if it can replace conventional committed capacity, at least for some portion of the year. A generating company that owns significant wind capacity and a slow-start generator, such as coal, will have an incentive to minimize start-ups of the coal plant, because each start-up has a fixed cost. If wind capacity can be counted on as firm for several hours, a potentially expensive thermal plant start-up might be avoided. This is balanced against the need for a reliable generating system.

If we were to avoid starting a conventional generator during a period that sufficient wind capacity is expected, and if the wind capacity did not materialize, system reliability would be compromised.

Wan provides some numerical examples of operational capacity credit, as calculated by the Mid-Continent Area Power Pool (MAPP) and New England Power Pool (NEPOOL) procedures. Each method is applied to one year of wind data (the minimum allowable for each procedure) and ten years (recommended) of wind data.

## Purpose of the Study

The aim of the study is the determination of power generation capacity of wind turbines. Specifically, the study sought:

1. The percentage capacity of installation of MAPP and NEPOOL development model.
2. Hypothetical wind plant operational capacity credit using 10-year actual load and wind data.

## Research Questions

The following research questions guided the study:

1. What is the percentage capacity of installation of MAPP and NEPOOL development model?
2. What is the hypothetical wind plant operational capacity credit using 10-year actual load and wind data?

## Scope of the Work

The work is limited to the operational capacity of installation data of Mid-Continent Area Power Pool (MAPP) and New England Power Pool (NEPOOL) procedures. The data were collected across one year and ten years specifically.

## Methodology

Survey design methodology was adopted to see wind data analyzed over one and ten years respectively. A total of fifteen wind turbines were analyzed across each unit. Monthly records of data collection were reported according to observation of the wind direction and readings. Simple percentage was used to analyze the data across the months (January to December).

## Data Analysis

### Research Question 1

What is the percentage capacity of installation of MAPP and NEPOOL development model?

**Table 1:** Percentage capacity of installation of MAPP and NEPOOL development model across the year

| Percentages \ months | Jan. | Feb. | Mar. | April | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MAPP** | 17% | 13% | 15% | 56% | 47% | 41% | 17% | 29% | 51% | 28% | 8% | 10% |
| **NEPOOL** | 8% | 9% | 15% | 39% | 47% | 43% | 18% | 27% | 35% | 21% | 8% | 8% |
| **Percentage difference** | 9% | 4% | 0% | 17% | 0% | 2% | 1% | 2% | 16% | 7% | 0% | 2% |

Table I of research question 1 showed that MAPP installation unit had a minimum power output in November at 8%, while its highest output is in the month of April at 56%. That of NEPOOL had a minimum power output in January, November and December at 8%, while its highest power output is at 47% in the month of May. There was the same level of power output achieved in the months of March, May, June, August, November and December at 0%, 0%, 2%, 2%, 0% and 2%. The maximum power difference was obtained in the month of April at 17% difference level.

### Research Question 2

What is the hypothetical wind plant operational capacity credit using 10-year actual load and wind data?

**Table 1:** Hypothetical wind plant operational capacity credit using 10-year actual load and wind data

| Percentages \ months | Jan. | Feb. | Mar. | April | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MAPP** | 19% | 12% | 23% | 50% | 49% | 44% | 28% | 34% | 41% | 20% | 14% | 17% |
| **NEPOOL** | 18% | 13% | 17% | 46% | 53% | 51% | 29% | 35% | 35% | 27% | 15% | 26% |
| **Percentage difference** | 1% | 1% | 6% | 4% | 4% | 6% | 1% | 1% | 6% | 7% | 1% | 9% |

Table 2 of research question 2 revealed that MAPP installation unit had a minimum power output in February at 12%, while its highest output is in the month of April at 50%. That of NEPOOL had a minimum power output in February at 13%, while its highest power output is at 53% in the month of May. The maximum power difference was obtained in the month of December at 17% difference level.

## Discussion of Results

The research work looks at the power generation capacity of wind turbines. The result obtained from the study showed that MAPP installation of wind turbine unit had a minimum power output in November at 8%, while its highest output is in the month of April at 56%. That of NEPOOL had a minimum power output in January, November and December at 8%, while its highest power output is at 47% in the month of May. This revealed that annual wind report made on MAPP and NEPOOL wind level was high at April and May respectively. This also yielded high power production at that month. Nice (2000) stated that the simplest benefit of an accurate wind forecast is that wind-generated energy can be planned for and used by the utility so the utility avoids the need to consume fuel to produce electricity.

Further, research question 2 revealed that MAPP installation unit had a minimum power output in February at 12%, while its highest output is in the month of April at 50%. That of NEPOOL had a minimum power output in February at 13%, while its highest power output is at 53% in the month of May. This is showed that maximum power output was obtained in the months of May and April on NEPOOL and MAPP respectively. This further implies that there would be a maximum power output obtained using the wind turbine in the months of May and April on an interval of 10 years actual wind full load. Michael (2002) states that the data can be used to predict the feature of wind direction for turbines.

## Conclusion

In all, the power production capacity of wind turbine is a function of wind speed and availability within the year. On the inflow of high wind supply, power supply system also rises in the same magnitude. On assessment of MAPP and NAPOOL, it is evident that at one year, data indicate minimum power output in November and maximum power out in April due to availability of wind. Further, on analysis of 10 years data, it is evident that minimum power output was indicated in February and maximum power output was shown in April.

## Recommendations

Based on the findings of the study, it would be recommended that:

1. Manufacturers of wind turbine should observe wind data in installation of wind turbines using different locations.
2. On location of highest point of wind movement in a specific month, maximum power storage system should be put in place to contain enough electricity to be distributed in months were wind power is weak.
3. Wind data analysis on installation of turbines should be done monthly, annually and five years records to monitor variation across different designs models.

## References

Manwell, J.F., McGowan J.G.& Rogers, A.L. (2002). *Wind Energy Explained*, Wiley & Sons, West Sussex, UK.

Michael, R. M. (2002). *Modeling Utility-Scale Wind Power Plants*.National Renewable Energy
Laboratory 1617 Cole Boulevard Golden, Colorado 80401-3393.

Nice, F. (2000). Operational Results from a Physical Power Prediction Model. *European Wind Energy Conference Proceedings.* March 1–5.

Thomas A. & Lennart S. (2002). An overview of wind energy-status 2002, Renewable and sustainable energy reviews 6, 67-128.

WINDPOWER (2002) Wind with Miller, *www.windpower.org/en/kids/index.htm*.