



# ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY

**AUTONOMOUS INSTITUTION**

Approved by AICTE & Affiliated to Anna University

NBA Accredited for BE (ECE, EEE, MECH) | Accredited by NAAC with A+ Grade

Anjugramam - Kanyakumari Main Road, Palkulam, Variyoor P.O. - 629 401, Kanyakumari District.

## **CAI 335 : SOLAR AND WIND ENERGY SYSTEMS**

### **UNIT 3**

#### **WIND MAPPING ANALYSIS AND CHARACTERISTICS OF WIND**

**Prepared by:**

Mr.Arunpandian.N.

Assistant Professor

Department of Agricultural Engineering

Wind power laws are a set of regulations and policies aimed at promoting the development and integration of wind energy as a renewable resource. These laws help manage the deployment, operation, and grid integration of wind power systems while balancing environmental, economic, and social concerns. The specifics of these laws can vary significantly by country or region, but they generally cover several key areas:

## 1. Policy and Regulatory Framework

Governments play a crucial role in establishing the legislative environment that supports the wind energy industry. These policies often include:

- **Renewable Energy Targets:** Many countries set binding renewable energy targets, which include specific quotas for wind power generation. For example, the European Union has set ambitious targets for renewable energy use, and some individual countries like Denmark and Germany have introduced policies to specifically encourage wind power development.
- **Incentives and Subsidies:** Governments may offer financial incentives such as tax credits, subsidies, or grants to companies involved in wind power projects. In the U.S., the Production Tax Credit (PTC) has been a vital incentive for wind energy development, providing tax benefits for energy produced from qualified wind projects.
- **Feed-in Tariffs (FiTs) and Power Purchase Agreements (PPAs):** These are agreements where the government guarantees a fixed payment rate for wind power producers for a certain period, helping to reduce financial risk and make investments more attractive.
- **Carbon Pricing and Cap-and-Trade Programs:** These mechanisms, such as the EU Emissions Trading System (ETS), help to make fossil fuels less competitive by placing a price on carbon emissions, indirectly encouraging renewable energy development, including wind power.

## 2. Land Use and Zoning Regulations

Since wind turbines need to be located in areas with sufficient wind resources, land use regulations are crucial in determining where wind farms can be built. These include:

- **Site Permitting:** Local, state, or national authorities must grant permits for wind energy projects before construction can begin. The permitting process typically involves environmental assessments to ensure the wind farm does not negatively impact wildlife, ecosystems, or communities.
- **Zoning Laws:** In many regions, specific zoning laws regulate where wind turbines can be installed, often restricting them from certain areas such as residential zones or protected areas (e.g., national parks).
- **Setback Requirements:** These laws require turbines to be placed at a certain distance from homes, roads, and other infrastructure to minimize noise, shadow flicker, and visual impacts on residents.

### 3. Environmental and Wildlife Protection

Wind power laws often address concerns regarding environmental protection and the potential impact on wildlife. These may include:

- **Environmental Impact Assessments (EIA):** Before a wind farm can be approved, an EIA is often required to evaluate the potential impacts on the local ecosystem, including effects on wildlife such as birds and bats. If significant negative impacts are predicted, mitigation measures must be proposed or alternative sites may be selected.
- **Wildlife Conservation Laws:** In some countries, laws may specifically require the protection of wildlife habitats, leading to wind farms being restricted from areas with vulnerable species. For example, wind farms must sometimes avoid migratory bird paths or areas where endangered species live.
- **Noise Regulations:** Wind turbines produce noise, and local laws may limit the amount of noise that can be emitted from a wind farm, particularly in residential areas.

### 4. Grid Integration and Electricity Market Regulations

To integrate wind energy into the electricity grid, specific legal frameworks are required to manage electricity transmission and ensure a reliable energy supply. These laws may include:

- **Grid Access and Priority Dispatch:** In many countries, laws require grid operators to prioritize renewable energy sources like wind power, ensuring that wind farms have guaranteed access to the grid. This can help avoid curtailment, where wind energy production is reduced due to grid congestion.
- **Grid Stability and Storage:** Because wind energy is intermittent, laws may require grid operators to invest in energy storage systems (like batteries) or backup generation to ensure grid stability and reliability when wind power is unavailable.
- **Market Rules for Wind Energy:** Many countries have specific market rules that allow wind energy to participate in electricity markets. For instance, wind power may be given preferential treatment in power auctions, allowing it to compete on equal terms with other forms of energy generation.
- **Transmission Infrastructure Development:** Some laws promote the expansion and modernization of the transmission grid to connect remote wind farms to urban centers or other areas with high energy demand.

### 5. Ownership and Land Rights

Wind power laws also deal with ownership issues related to land and infrastructure, including:

- **Private vs. Public Land Use:** Whether wind farms can be developed on public lands or private lands is often governed by specific laws. Some countries allow developers to lease land for wind farms, while others may require long-term ownership agreements.
- **Community and Indigenous Rights:** Wind power projects may need to consider the rights of local communities or Indigenous populations who may be affected by the

development. In some regions, specific laws protect the rights of Indigenous groups to give them a say in whether wind projects can be developed on their lands.

## 6. International and Regional Agreements

Since wind energy is a global concern and has a significant role in addressing climate change, international treaties and agreements also influence national wind power policies. These may include:

- **The Paris Agreement:** Under the Paris Agreement on climate change, countries are committed to reducing their carbon emissions. As part of these commitments, many countries have adopted wind energy development as part of their strategy to decarbonize their energy systems.
- **Regional Agreements (e.g., EU Renewable Energy Directive):** Within regions like the European Union, binding laws and directives often set goals for renewable energy penetration, which include specific provisions for wind power.

## 7. Wind Turbine Standards and Safety Regulations

For the safe operation of wind turbines, specific laws and regulations set standards for design, installation, and operation. These may include:

- **Safety Standards:** These laws govern the technical aspects of wind turbine design, ensuring that turbines are built to withstand extreme weather conditions, avoid mechanical failure, and minimize risks to human safety.
- **Decommissioning and End-of-Life Regulations:** Some laws require that wind turbine operators prepare for the eventual decommissioning of wind farms, ensuring the responsible dismantling and disposal of equipment to prevent environmental damage.

## Conclusion

The wind power laws across different regions are designed to create a stable, sustainable, and efficient environment for the development of wind energy. These laws balance the need for renewable energy expansion with considerations for environmental protection, land use, and the economic interests of stakeholders. The legal framework surrounding wind power is constantly evolving as the technology matures, the cost of wind power decreases, and the world continues to address climate change concerns.

Wind velocity and power duration curves are important tools used in wind energy analysis to characterize wind resources, evaluate wind turbine performance, and design wind energy systems. These curves provide valuable insights into the wind speed distribution over time and the corresponding energy production potential of a wind farm or turbine.

## 1. Wind Velocity (or Wind Speed) Duration Curve

### *Definition:*

A **wind velocity duration curve** is a graphical representation that shows the distribution of wind speeds over a specific period (typically one year) at a particular location. It ranks wind speeds from the highest to the lowest and plots them against the percentage of time that each wind speed is exceeded.

This curve is used to assess the variability of wind speed at a given location and provides a better understanding of how often certain wind speeds are experienced. It is essential for evaluating the reliability and consistency of wind resources in a specific area.

### *Construction of Wind Velocity Duration Curve:*

- **Data Collection:** Wind speed data is collected over a specified period (e.g., hourly or daily wind speed data over a year).
- **Sorting:** The recorded wind speeds are sorted in descending order, from the highest to the lowest.
- **Plotting:** The wind speeds are plotted along the x-axis, and the percentage of time each wind speed is exceeded (or the cumulative percentage of time that wind speed or greater occurs) is plotted along the y-axis.

The resulting curve typically slopes downward from left to right, showing that lower wind speeds occur more frequently than higher wind speeds.

### *Interpretation:*

- **High Wind Speeds:** At the left side of the curve, the high wind speeds are plotted. These wind speeds are typically reached only during extreme weather events, such as storms, and may occur for a small percentage of the year.
- **Low Wind Speeds:** At the right side of the curve, lower wind speeds are plotted. These are the most common wind speeds and occur for a larger portion of the year.
- **Intermediate Wind Speeds:** The middle part of the curve represents moderate wind speeds, which are common for many regions and are typically ideal for wind turbine operation.

The duration curve helps in understanding the **wind resource availability** and whether a location is suitable for a wind farm. Locations with high wind speeds at frequent intervals are ideal for large-scale wind turbine deployment, while areas with more variable or weaker winds may need additional infrastructure (like energy storage) or specific turbine technologies to make them viable.

## 2. Power Duration Curve

### *Definition:*

A **power duration curve** is similar to the wind velocity duration curve, but instead of showing wind speeds, it shows the available **power output** of a wind turbine (or wind farm) over time. This curve ranks the power produced by the wind turbine from the highest to the lowest and plots it against the percentage of time the power is exceeded.

### *Construction of Power Duration Curve:*

- **Wind Speed to Power Conversion:** The wind speed data is used to calculate the power output of a wind turbine at each wind speed. This is done by using the **power curve** of the wind turbine, which represents the relationship between wind speed and power output.
  - The power curve of a wind turbine shows how much electrical power a turbine generates at different wind speeds. Typically, power output increases with wind speed up to a certain point (called the rated wind speed), beyond which the power output remains constant (at the rated power) despite increases in wind speed.
- **Sorting Power Values:** After calculating the power output for each wind speed, the power values are sorted in descending order from the highest to the lowest.
- **Plotting:** The sorted power values are plotted on the x-axis, while the cumulative percentage of time that each power output level is exceeded is plotted on the y-axis.

### *Interpretation:*

- **High Power Output:** On the left side of the curve, you see the highest power output, which occurs during periods of high wind speeds. These periods are typically short-lived and represent the times when the wind turbine is producing its maximum output.
- **Low Power Output:** On the right side, you see the lower power outputs, which occur more frequently when the wind speeds are low or below the cut-in speed of the wind turbine. These low wind speeds typically result in minimal or zero power production.
- **Intermediate Power Output:** The middle part of the curve represents the times when the turbine is generating power at a moderate level. This corresponds to wind speeds within the operational range of the turbine.

### *Key Aspects:*

- **Capacity Factor:** The area under the power duration curve provides an estimate of the **capacity factor** of the wind farm, which is the ratio of the actual output of a wind turbine to its maximum possible output. A higher capacity factor indicates that a wind turbine is producing power at or near its rated capacity for a larger percentage of time.
- **Wind Energy Variability:** The power duration curve helps to visualize how often a wind farm or turbine operates at various power levels, showing how much energy is available in different wind conditions.

## Relationship Between Wind Velocity and Power Duration Curves

The **wind velocity duration curve** and the **power duration curve** are closely linked because the power output of a wind turbine is directly related to the wind speed. Wind turbines typically operate within a specific range of wind speeds, and the power output at each wind speed follows the turbine's power curve.

1. **Wind Velocity Curve:** Gives information about how often certain wind speeds occur.
2. **Power Duration Curve:** Provides the corresponding power output based on those wind speeds.

By knowing the wind velocity distribution (duration curve) and the turbine's power curve, it is possible to predict how much power will be produced at different times, helping to:

- Estimate the energy production of a wind farm.
- Analyze the economic viability of wind energy projects.
- Determine the need for grid integration solutions (e.g., storage) to smooth out power generation variability.

## Applications of Wind Velocity and Power Duration Curves

- **Site Selection:** These curves help determine the best locations for wind farms by comparing the wind resources of various regions. Sites with high wind speeds for significant periods will have higher energy production potential.
- **Designing Wind Farms:** Wind resource assessments using these curves guide the design of wind farms, including the number and type of turbines needed to meet energy production goals.
- **Energy Management:** Power duration curves allow energy planners and grid operators to understand the intermittency of wind power and plan for backup power sources or storage systems.
- **Economic Analysis:** By understanding how much power will be produced at different times, operators can assess the financial feasibility of wind projects based on potential revenues and costs.

## Conclusion

In summary, wind velocity and power duration curves are critical tools in wind energy analysis, helping to assess the availability of wind resources and the power production potential of wind turbines. These curves provide essential data for the planning, design, and operation of wind farms, allowing stakeholders to make informed decisions regarding turbine selection, energy storage, and grid integration.