**Program Name** : **Electrical Engineering Program Group**

**Program Code** : **EE/EP/EU**

**Semester** : **Fifth**

**Course Title** : **Wind Power Technologies (Elective)**

**Course Code** : **22528**

## 1. RATIONALE

Indian energy sector is undergoing a transition with wind power becoming a major energy source in the country with the establishment of large and small wind farms spread all across the country. Wind power plants have become a choice for generating clean and green electricity. Further, with a large number of large and small wind turbine manufacturers, there is a dearth of qualified and trained technologists who can manufacture and maintain the large and small wind turbines. This curriculum is designed in such a way that a technologist will be able to maintain the routine problems of related to large wind power plants and small wind turbines.

## 2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Maintain large wind power plants and small wind turbines.**

## 3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following ***industry oriented*** COs associated with the above mentioned competency:

a. Identify the various types of wind power plants and their auxiliaries.
b. Maintain the normal working of large wind turbines.
c. Optimise the aerodynamic and electric control of large wind power plants.
d. Troubleshoot the common faults of large wind power plants.
e. Maintain the normal working of small wind turbines.
f. Troubleshoot small wind turbines.

## 4. TEACHING AND EXAMINATION SCHEME

| Teaching Scheme | | | Credit (L+T+P) | Examination Scheme | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Theory | | | | | | | Practical | | | | | |
| | | | | Paper Hrs. | ESE | | PA | | Total | | ESE | | PA | | Total | |
| L | T | P | | | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min |
| 3 | - | 2 | 5 | 3 | 70 | 28 | 30* | 00 | 100 | 40 | 25@ | 10 | 25 | 10 | 50 | 20 |

*(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.*

***Legends: L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** - Practical; **C** – Credit, **ESE** - End Semester Examination; **PA** - Progressive Assessment*

## 5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

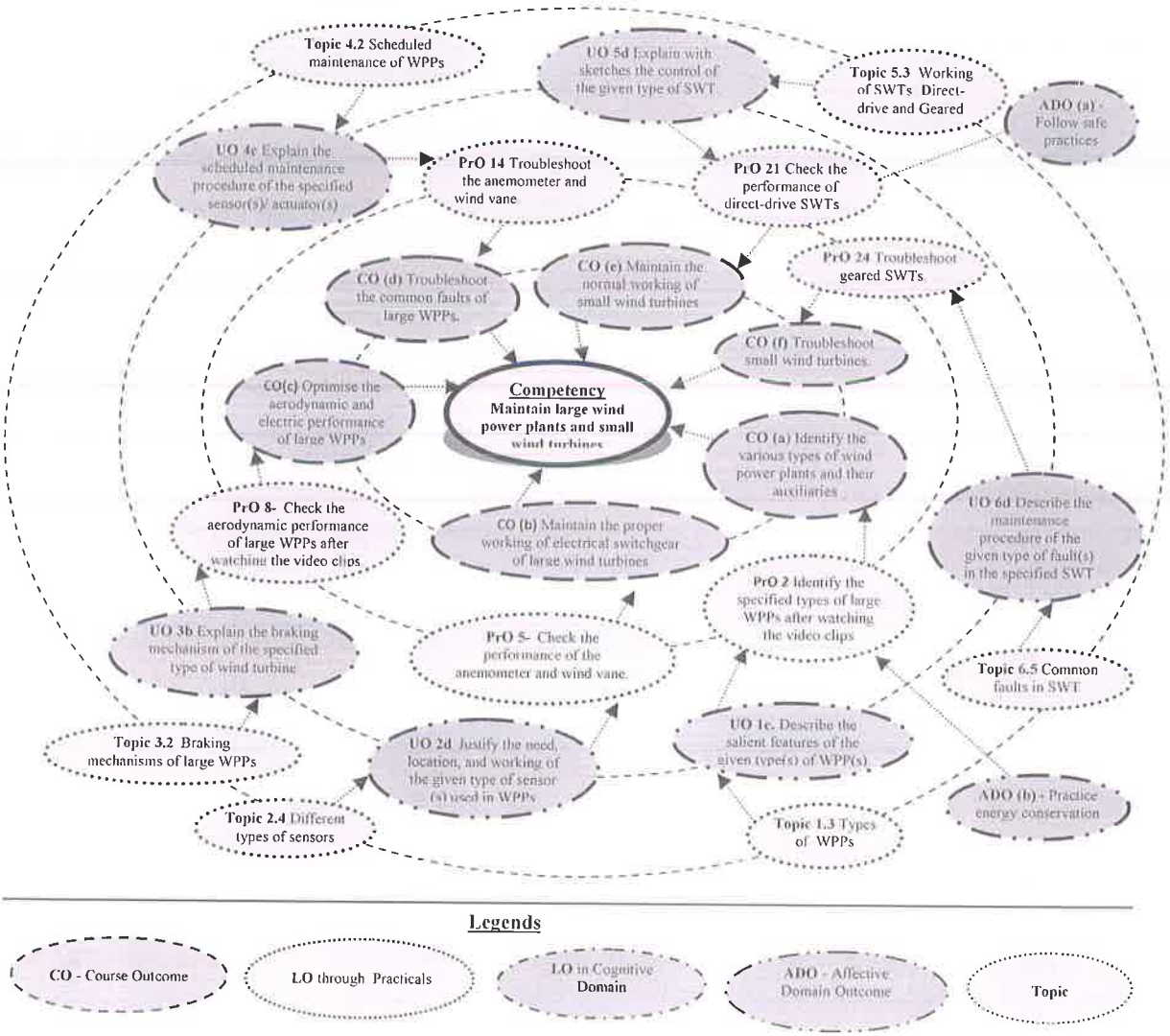


**Figure 1 - Course Map**

## 6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency:

| S. No. | Practical Outcomes (PrOs) | Unit No. | Approx. Hrs. Required |
|---|---|---|---|
| 1 | Identify the specified items of a wind farm after watching the video clip. | I | 02* |
| 2 | Identify the specified types of large WPPs after watching the video clips. | I | 02 |
| 3 | Identify the specified parts inside the nacelle of a large wind power plant after watching the video clips. | II | 02* |
| 4 | Identify the specified parts of the electrical switchyard of a large wind power plant after watching the video clip. | II | 02 |
| 5 | Check the aerodynamic performance of large WPPs after watching | II | 02 |

| S. No. | Practical Outcomes (PrOs) | Unit No. | Approx. Hrs. Required |
|---|---|---|---|
| | the video clips. | | |
| 6 | Check the performance of the temperature and vibration sensor used in 125/150 kW WPPs. | III | 02* |
| 7 | Check the performance of the SCIG | III | 02* |
| 8 | Check the performance of the DFIG | III | 02 |
| 9 | Check the performance of the PMSG | III | 02* |
| 10 | Check the performance of the hydraulic and electric pitch actuator and yaw actuator used in 125/150 kW WPPs. | IV | 02* |
| 11 | Check the performance of the contactless RPM sensors used in WPPs | IV | 02 |
| 12 | Identify the specified parts which require routing maintenance, oiling and greasing, of the large wind power plants after watching the video clips. | IV | 02* |
| 13 | Troubleshoot the anemometer and wind vane | IV | 02* |
| 14 | Check the generator performance of SWTs. | V | 02 |
| 15 | Identify the parts of a direct-drive SWT | V | 02* |
| 16 | Identify the parts of a geared SWT | V | 02* |
| 17 | Dismantle a direct-drive SWT | VI | 02* |
| 18 | Assemble a direct-drive SWT | VI | 02 |
| 19 | Dismantle a geared SWT | VI | 02* |
| 20 | Assemble a geared SWT | VI | 02 |
| 21 | Check the performance of direct-drive SWT | V | 02 |
| 22 | Check the performance of geared SWT | V | 02 |
| 23 | Simulate faults in the small wind turbine trainer | V | 02* |
| 24 | Troubleshoot direct-drive SWT | VI | 02 |
| 25 | Troubleshoot geared SWT | VI | 02 |
| 26 | Interpret the wiring of a SWT electric-electronic control panel | VI | 02 |
| | **Total** | | **52** |

***Note***

i. *A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '*' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. *The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:*

| S. No. | Performance Indicators | Weightage in % |
|---|---|---|
| 1 | Selection of suitable components, apparatus/instruments | 20 |
| 2 | Preparation of experimental setup | 10 |
| 3 | Setting and Operation | 10 |
| 4 | Safety measures | 10 |
| 5 | Observations and recordings | 10 |
| 6 | Interpretation of results and calculations | 20 |
| 7 | Answer to sample questions | 10 |
| 8 | Submission of report in time | 10 |
| | **Total** | **100** |

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/a team member.
d. Maintain tools and equipment.
e. Follow ethical Practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organising Level' in 2nd year
- 'Characterising Level' in 3rd year.

## 7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

| S. No. | Equipment Name with Broad Specifications | PrO. S. No. |
|---|---|---|
| 1 | Video programmes of construction and working of large wind power plants. | 1 to 4, 8 |
| 2 | Second hand or new Nacelle of 150 kW to 500 kW wind turbine | 3,12 |
| 3 | Second hand or new 150 to 500 kW Wind turbine gear box | 3,12 |
| 4 | Second hand or new 150 to 500 kW Wind turbine electronic control panel | 4 |
| 5 | Thyristors used in 150 to 500 kW Wind turbine | 4 |
| 6 | Second hand or new 150 to 500 kW Wind turbine power electronic control panel | 4 |
| 7 | 3-Cup type wind anemometer | 13 |
| 8 | Ultra sonic anemometer | 13 |
| 9 | Wind vane | 13 |
| 10 | Vibration sensor used in WPP | 6 |
| 11 | Temperature sensors of Gearbox, electric generator, ambient temperature used in WPP | 6 |
| 12 | RPM sensors of rotor and electric generator used in WPP | 11 |
| 13 | Hydraulic and electric pitch sensor and actuators used in WPP | 10,12 |
| 14 | 3kW to 5 kW direct-drive small wind turbine with permanent magnet electric generator | 14, 17, 18, 23 |
| 15 | 10 kW to 15 kW small wind turbine with gearbox and induction generator | 16,19, 20, 24 |
| 16 | 10 kW to 15 kW small wind turbine electric-electronic control panel. | 24 to 26 |
| 17 | Small wind turbine trainer | 23 |

## 8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

| Unit | Unit Outcomes (UOs) (in cognitive domain) | Topics and Sub-topics |
|---|---|---|
| **Unit – I Wind Energy and Wind Power Plants** | 1a. Describe the India's wind power ranking in (name the year) compared to the world ranking, as well as the ranking between the states in India during the same year using pie chart sketches or bar charts.<br>1b. Explain the specified characteristics of the wind related to wind power generation<br>1c. Describe the salient features of the given type(s) of WPP(s).<br>1d. Explain the need for the specified component of the electric sub-station. | 1.1 Wind power scenario in the world and India<br>1.2 **Characteristics of Wind Energy**: Wind movement, wind profile, roughness, effects of obstacles in wind path.<br>1.3 **Types of Wind Power Plants (WPPs)**: Small and large wind turbines; Horizontal and Vertical axis; Upwind and Downwind, One, Two and Three blades; constant and variable Speed; Geared, Direct-Drive and Semi-Geared (Hybrid) WPPs; WECS, WEGs, WTs, WPPs,<br>1.4 **WPP Tower Types**: Lattice; tubular: steel, concrete, hybrid, ladders, cables.<br>1.5 **WPP substation:** Switchgear, transformers, inside layouts of Electric electronic panels at block level. |
| **Unit– II Construction and Working of Large Wind Power Plants** | 2a. Explain the given terms related to wind power.<br>2b. Describe the function(s) of the specified WPP component(s).<br>2c. Explain with sketches the specified principle of the rotation of the wind turbine rotor.<br>2d. Justify the need, location, and working of the given type of sensor (s) used in WPPs.<br>2e. Explain the need and working of the given type of actuator(s) used in WPPs. | 2.1 **Wind Turbine Terminologies:** Cut-in, cut-out and survival wind speeds, Threshold wind speeds, rated power, nominal power, Wind Power Curve,<br>2.2 **Major parts and Functions of WPP:** Rotor blades, hub, nacelle, tower, electric sub-station, nacelle layouts of Geared, Direct-Drive and Semi-Geared WPPs, Main shaft, gearbox, electric generator, electronic control panels<br>2.3 **Rotation principles**: Drag and Lift principle, thrust and torque of wind turbine rotor.<br>2.4 **Different types of Sensors**: Anemometer, wind vane, rpm sensors of main shaft and generator, temperature sensors of nacelle, gearbox and generator; cable untwisting and vibration sensors<br>2.5 **Different types of Actuators**: Electric and hydraulic pitching and yawing mechanisms, cable untwisting and braking mechanisms |
| **Unit– III Aerodynamic Control, Electric Generators and Grid Connection** | 3a. Distinguish the specified type of aerodynamic control also using the wind power curve.<br>3b. Explain with sketches the braking mechanism of the specified type of wind turbine.<br>3c. Explain with sketches the | 3.1 Aerodynamic Control of WPPs: Stall, Pitch and Active Stall.<br>3.2 Braking mechanisms of large WPPs.<br>3.3 **Electric Generator Types**: Working of Squirrel-Cage rotor Induction Generator (SCIG), Wound-Rotor Induction Generator (WRIG), Doubly-Fed Induction Generator (DFIG), wound rotor and permanent magnet synchronous generators. |

| Unit | Unit Outcomes (UOs) (in cognitive domain) | Topics and Sub-topics |
|---|---|---|
| | working of the given type of electric generator used in large WPPs.<br>3d. Explain the impact of the specified problem when connecting the WPP to the grid. | 3.4 Electric grid connection of WPPs: Local Impacts and system wide impact |
| **Unit– IV Maintenance of Large Wind Power Plants** | 4a. Explain the procedure of preventive maintenance of the given WPP component.<br>4b. Describe the general maintenance issues of the specified type of WPP(s)<br>4c. Explain the scheduled maintenance procedure of the specified sensor(s)/ actuator(s).<br>4d. Explain the procedure of the unscheduled maintenance of the specified WPP component(s). | 4.1 **General maintenance of WPPs:** preventive maintenance schedule of actuators such as yaw control, pitch control, braking mechanisms and sensors; oiling and greasing; electric and electronic equipment related; tower related; minor repairs, some tips,<br>4.2 **Scheduled Maintenance:** of Stall and Pitch and Active Pitch controlled WPPs<br>4.3 **Unscheduled maintenance**: operational factors, design faults, wear and tear of components, spurious trip, Major repairs.<br>4.4 Software related, warranty and insurance related issues |
| **Unit– V Construction and Working Small Wind Turbines** | 5a. Distinguish the features of the given types of small wind turbines.<br>5b. Describe with sketches the functions of the given part(s) of the specified SWT.<br>5c. Explain with sketches the blade rotation of the given type of SWT.<br>5d. Explain with sketches the control of the given type of SWT.<br>5e. Describe with sketches the features towers of the given type(s) of SWT.<br>5f. Explain with sketches the working of the given type of electric generator used in SWT. | 5.1 **Types and working of different type of small wind turbines (SWT):** Classification: Horizontal and Vertical axis, Upwind and Downwind, One, Two and Three blades; Constant and Variable Speed; Direct-Drive and Geared; braking of SWTs<br>5.2 **Parts of SWTs:** Rotor, generator, gearbox, tower, electric control panel, tale vane, anemometer, wind vane, temperature and rpm sensors.<br>5.3 **Working SWTs:** Direct-drive and Geared.<br>5.4 **Electrical generators in SWTs**: permanent magnet synchronous generators, induction generators<br>5.5 **SWT towers:** Lattice tubular type, hydraulic towers, ladders, cables. |
| **Unit-VI Maintenance of Small Wind Turbines** | 6a. Describe the installation of the specified SWT.<br>6b. Identify the power electronic device(s) in the given SWT with justification | 6.1 Small wind turbine assembly.<br>6.2 Installation of different types of small wind turbines (SWT): tubular and lattice types.<br>6.3 **SWT Routine maintenance:** Tips; Preventive maintenance schedule of braking mechanisms, sensors; oiling and |

| Unit | Unit Outcomes (UOs) (in cognitive domain) | Topics and Sub-topics |
|---|---|---|
| | 6c. Describe the function of the given type of power electronic converter in the specified type of SWT<br>6d. Describe the maintenance procedure of the given type of fault(s) in the specified SWT. | greasing related; electric and electronic equipment related; tower related; software related, minor repairs<br>6.4 Power electronic devices and converters in different types of SWTs: thyristors, power transistors<br>6.5 Common mechanical faults in SWTs<br>6.6 Common electrical faults in s SWTs |

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'.*

## 9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

| Unit No. | Unit Title | Teaching Hours | Distribution of Theory Marks | | | |
|---|---|---|---|---|---|---|
| | | | R Level | U Level | A Level | Total Marks |
| I | Wind Energy and Wind Power Plants | 04 | 02 | 02 | 04 | 08 |
| II | Construction and Working of Large Wind Power Plants | 08 | 02 | 04 | 06 | 12 |
| III | Aerodynamic Control, Electric Generators and Grid Connection | 10 | 02 | 06 | 08 | 16 |
| IV | Maintenance of Large Wind Power Plants | 08 | 02 | 04 | 06 | 12 |
| V | Construction and Working Small Wind Turbines | 10 | 02 | 04 | 08 | 14 |
| VI | Maintenance of Small Wind Turbines | 08 | 02 | 02 | 04 | 08 |
| **Total** | | **48** | **12** | **22** | **36** | **70** |

***Legends:** R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
***Note**: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

## 10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a. Prepare journal of practicals.
b. Undertake micro-projects.

## 11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a. Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.

b. ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c. About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d. With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
a. Guide student(s) in undertaking micro-projects.

## 12. SUGGESTED MICRO-PROJECTS

***Only one micro-project*** is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a. Case study of any large wind power plant.
b. Study of gearboxes used in large WPPs.
c. Study of electric generators used in large WPPs
d. Study of towers used large WPPs
e. Study of electric switchyards used in large WPPs.
f. Comparative study of SWTs.
g. Comparative study of towers used in SWTs

## 13. SUGGESTED LEARNING RESOURCES

| S. No. | Title of Book | Author | Publication |
|---|---|---|---|
| 1 | Wind Power Technology | Earnest, Joshua | PHI Learning, New Delhi, 2015, ISBN: 978-8120351660 |
| 2 | Wind Turbines | Hau, Erich | Springer-Verlag, Berlin Heidelberg, Germany, 2013, ISBN: 978-3-642-27150-2 |
| 3 | Wind Power Plants and Project Development | Earnest, Joshua | PHI Learning, New Delhi, 2015, ISBN: 978-8120351271 |
| 4 | Wind Energy Basics | Gipe, Paul | Chelsea Green Publishing Co;2009, ISBN: 978-1603580304 |
| 5 | Wind Electrical Systems | Bhadra, S.N., Kastha, D., Banerjee, S. | Oxford University Press, New Delhi 2013, ISBN: 9780195670936 |
| 6 | Wind Energy | Siraj Ahmed | PHI Learning, New Delhi, 2015 ISBN: 978-8120351639 |

## 14. SOFTWARE/LEARNING WEBSITES

a. https://www.youtube.com/watch?v=FSB8_pb88P8
b. https://www.youtube.com/watch?v=P9SyZvHrJvc
c. https://www.youtube.com/watch?v=A-k2YGrpATo
d. https://www.youtube.com/watch?v=qSWm_nprfqE
e. https://www.youtube.com/watch?v=LNXTm7aHvWc
f. https://www.youtube.com/watch?v=x3AfhSHAcqg
g. https://www.youtube.com/watch?v=vN5Fdv_OKd0
h. https://www.youtube.com/watch?v=hXcgvKpDyzs
i. https://www.youtube.com/watch?v=c5sG1cMhSNw
j. https://www.youtube.com/watch?v=45Xh7FKS9nM (small wind turbine)
k. https://www.youtube.com/watch?v=j_fViOJbJLk (small wind turbine)
l. http://mnre.gov.in/file-manager/grid-wind/guideline-wind.pdf


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