Winter – 2019 Examinations

Model Answers

Subject & Code: Wind Power Technologies (22528)

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

1 Attempt any FIVE of the following: 10

1 a) State the factors which affect the nature of the wind close to the surface of the earth.

Ans:

Factors Which Affect the Nature of the Wind Close to the Surface of the Earth:

- Horizontal pressure (gradient)
- Rotation of earth (coriolis force)
- Centripetal acceleration
- Frictional forces

1 Mark for each of any two factors = 2 Marks

1 b) State approximate wind power generation in India.

Ans:

Wind Power Generation in India:

Wind power generation is 20,000 MW to 65,000 MW. As of 31 March 2019 the total installed wind power capacity was 36.625 GW, the fourth largest installed wind power capacity in the world.

2 Marks

1 c) List any two advantages of vertical axis WPPs.

Ans:

Advantages of Vertical Axis WPPs:

- They can produce electricity in any wind direction.
- Low production cost as compared to horizontal axis wind turbine.
- Easy construction.
- Low maintenance cost and transportation cost.
- Suitable for areas with extreme weather conditions.
- Variable speed operation.
- Yaw and pitch control mechanism are not needed.

1 Marks for each of any two advantages = 2 Marks

1 d) Name any two aerodynamic controls for WPP.

Ans:

Aerodynamic Control for WPP:

- Pitch control
- Passive stall control
- Active stall control
- Yaw control

1 Marks for each of any two aerodynamic control = 2 Marks

1 e) Identify any two weekly maintenance activities for WPP.

Ans:

Weekly Maintenance Activities:

- Routine checkup, monitoring, periodic reports.
- Blade cleaning.
- Higher voltage equipment maintenance.
- Turbines require periodic lubrication, oil changes.
- Bolt and electrical connections should be checked and tightened if required.
- All rotating equipment need maintenance.
- Machine should be checked for corrosion.

1 Mark for any two maintenance activity = 2 Marks

- Check guy wire for proper tension.

1 f) Give the classification of SWT on any two factors.

Ans:

Classification of SWT:

- **According to axis of rotor**
  1. Horizontal axis wind turbine
  2. Vertical axis wind turbine
- **According to direction**
  1. Up wind
  2. Down wind
- **According to number of blades**
  1. Single blade
  2. Two blades
  3. Three blades
- **According to Speed**
  1. Constant speed
  2. Variable speed
- **According to drive**
  1. Direct Drive
  2. Geared Drive

1 Mark for each of any two base of classification = 2 Marks

1 g) Name any two power electronic components in SWT.

Ans:

Power Electronic Components in SWT:

- Boost converter
- Buck converter
- Buck Boost converter
- Cuk converter
- Voltage Source Inverter
- Current Source Inverter

1 Mark for each of any two power electronic components = 2 Marks

2 Attempt any <u>THREE</u> of the following: 12

2 a) List any four towers related to WPP. Explain any one in brief.

Ans:

List of Towers Related to WPP:

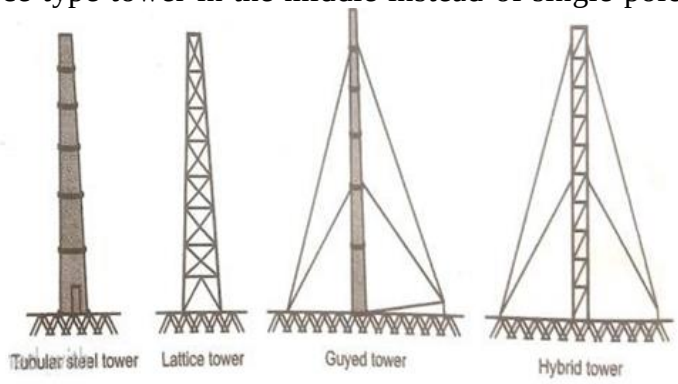
- Tubular Steel / concrete Tower
- Lattice Tower
- Guyed Pole Tower
- Hybrid Tower

2 Marks for list of towers

1. **Tubular steel tower**: Generally used for a large wind turbine and normally manufactured in section of 30-40 meters in length. Complete tower is slightly conical in shape to provide better mechanical stability.

2. **Lattice tower**: It is assembled by different members of steel. All members are bolted or welded together to form complete tower of designed height. Cost is less than tubular tower. Asthetic look is only drawback.
3. **Guyed pole Tower**: This is normally used for small wind turbine plant. Single vertical pole supported by guy wired from different sides. Access to footing area is difficult.
4. **Hybrid tower**: It is used for small wind power plant. It is guyed type tower and thin, tall lattice type tower in the middle instead of single pole.

1 Mark for any one explanation of tower

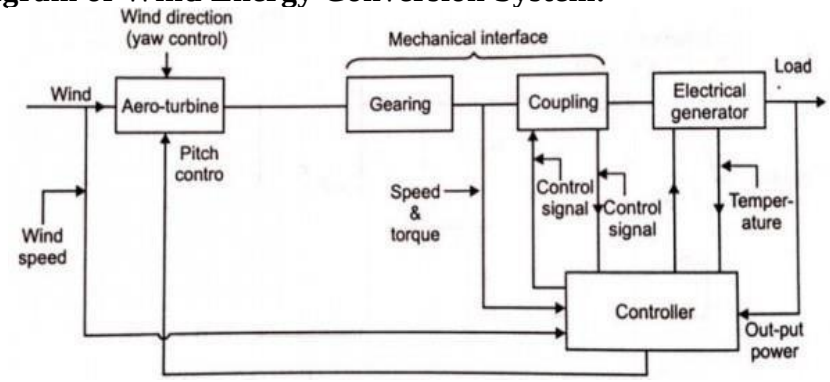


1 Mark for any one sketch

2 b) Draw basic block diagram of wind energy conversion system.

Ans:

Block Diagram of Wind Energy Conversion System:



4 Marks for labeled block diagram

2 Marks for partially labeled block diagram

OR Any Other Equivalent Block Diagram

2 c) List various types of generators used in WPP.

Ans:

Various Types of Generators Used in WPP:

1. Squirrel Cage Induction Generator (SCIG)
2. Wound Rotor Induction Generator (WRIG)
3. Doubly Fed Induction Generator (DFIG)
4. Wound Rotor synchronous Generator (WRSG)
5. Permanent Magnet Synchronous Generator (PMSG)

1 Mark for each type any four type =4 Marks

2 d) Prepare maintenance schedule of various actuators used in large wind power plants.

Ans:

Maintenance Schedule of Various Actuators:

- **Maintenance of Yaw System Actuator:**

The maintenance of Yaw system actuator is done quarterly or yearly. Following maintenance activities are to be performed:

1. Yaw actuator is prone to wear due to its frequent operations and so it is one of the causes of down time, Yaw system has short service life and difficult access for the maintenance.
2. Check and adjust the yaw motor and nacelle bearing.
3. Check the brake pad and change if required.
4. Regular maintenance of yaw bearing.
5. Check the area of oil leak, if any. Select the right type of oil as per operational requirement.
6. Gears in the drivers should be filled with grease and oil.
7. Electric Brake, motor fan, joint-bolts, hydraulic brake, yaw pads should be checked.
8. Check out the rusting, amount of dirt and wear of brake pads.
9. Blades have to be inspected such that there should not be obstruction for right operation.

1 mark for each point Any two points = 2 Marks

- **Maintenance of Pitch System Actuator:**

The maintenance of Pitch system Actuator is done quarterly or yearly. Following maintenance activities are to be performed:

1. Maintenance of tower, blades, rotor, and generator will contribute to proper functioning of the system.
2. Presently feedback control system provides control signal for pitch angle, pitch torque, temperature and data.
3. Real time data allows action for preventive maintenance and optimal performance.
4. Actuators and sensors monitor and give the signal for the area, which needs attention and maintenance.
5. In fault condition, actuators will send signal to the operator to shut down the turbine in controlled condition.
6. Monitor vibration level and if it is more than the limiting condition, then send alarming signal.
7. Monitor change in temperature, pressure and mechanical stresses.

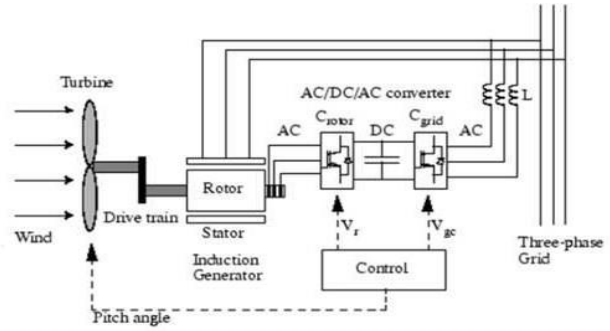
1 mark for each point Any two points = 2 Marks

3 Attempt any THREE of the following: 12

3 a) Draw a block diagram of WPP substation. State function of each block.

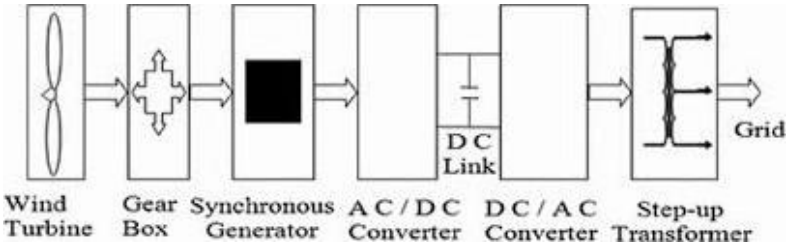
Ans:

Block Diagram of WPP Substation:



2 Marks for block diagram

OR

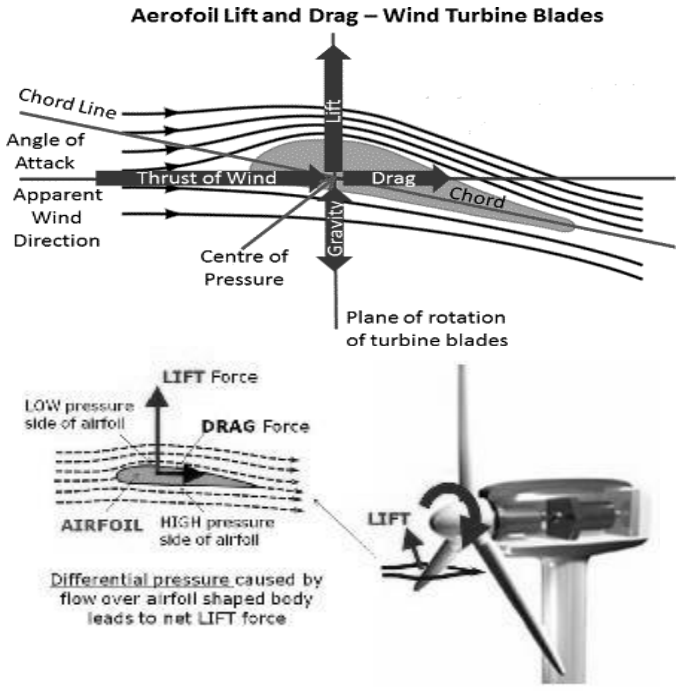


2 Marks for function of blocks

- **Wind Turbine** : Converts wind power to rotational mechanical energy
- **Gear Box**: Transfer low speed to high.
- **Generator:** Converts rotational mechanical energy to electrical energy.
- **Converter**: Converts AC to DC and vice-versa of correct frequency.
- **Transformer:** Step up the voltage to grid level.

3 b) Explain lift & drag wind energy conversion principle.

Ans:



2 Marks for labeled diagram

Two primary aerodynamic forces work in wind turbine rotors are:-

1) Lift which acts perpendicular to the direction of wind flow and
2) Drag acts parallel to wind flow.

To increase wind turbine blade efficiency, rotor blades need to have an aerodynamics profile to create lift and rotate the turbine. Curved aero foil type blade offer better performance and higher rotational speed and make them ideal for power generation.

2 Marks for explanation

3 c) Explain working of doubly fed induction generator.

Ans:

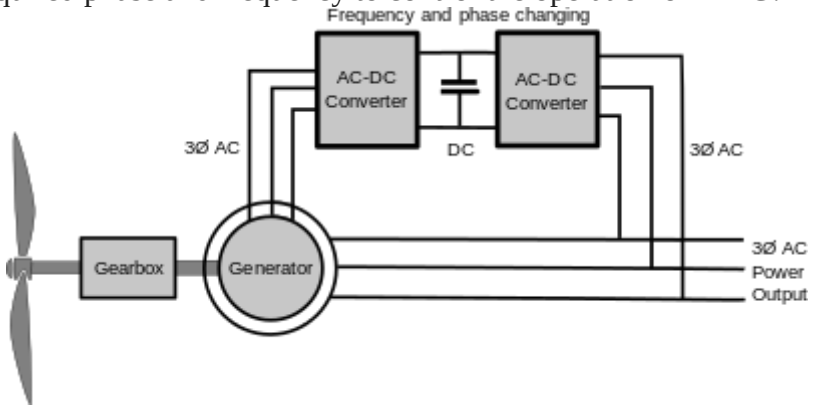
Working of Doubly Fed Induction Generator:

Doubly fed induction generators are Slip-ring induction motors operated as generators

having additional features which allow them to run at speeds slightly above or below synchronous speed. This is useful for large variable speed wind turbines, because wind speed can change suddenly. When a gust of wind hits a wind turbine, the blades try to speed up, but a synchronous generator is locked to the speed of the power grid and cannot speed up. So large forces are developed in the hub, gearbox, and generator as the power grid pushes back. This causes wear and damage to the mechanism. If the turbine is allowed to speed up immediately when hit by a wind gust, the stresses are lower as the power from the wind gust is still being converted to useful electricity.

2 Marks for working

For DFIG, input mechanical power is provided by wind turbine to the shaft. The stator is connected to grid. The control is provided from rotor-side. The rotor winding is connected to grid or stator through back-to-back converter. The back-to-back converter essentially consists of two converters connected back-to-back. One is Grid-side-converter (GSC) and other is Rotor-side-converter (RSC). The GSC converts 3ϕ AC power into DC and charges the coupling or DC link capacitor between the converters. The GSC controls the DC link voltage and also the terminal voltage at the point of common coupling (PCC), i.e stator voltage. The RSC converts the DC power into AC power of required phase and frequency to control the operation of DFIG.



2 Marks for labelled block diagram

3 d) Name any four main parts of SWT. Give function of each part.

Ans:

Parts of SWT:

1. **Rotor** - It includes blades for converting wind energy to low speed rotational energy.
2. **Gear box** – It converts low speed rotational energy to high speed.
3. **Generator**: It includes electric generator, electronic control, gear-box for converting low speed incoming rotation to high speed rotation suitable for generation of electrical energy.
4. **Tower**: It supports the assembly. It includes tower and yaw mechanics.
5. **Other Equipment**: Control equipment, electric cables, hub, tale vane, sensors, anemometer to implement control.

1 Mark for each part's name and function
Any four part = 4 Marks

4 Attempt any THREE of the following: 12

4 a) Related to WPP define following wind speeds

i) Cut in

ii) Cut out
iii) Survival
iv) Threshold

Ans:

i) Cut-in wind speed: This is the minimum wind speed at which the turbine blades overcome friction and begin to rotate.

ii) Cut out speed: This is the speed at which the turbine blades are brought to rest to avoid damage from high wind.

iii) Survival speed: It is the maximum speed of wind, above which wind turbines will be damaged, and speed up to which turbine are designed to work safely.

iv) Threshold wind speed: It is range of speed between cut in and cut out speed. By operating in this range, it is ensured that available energy is above the minimum threshold and structural health is maintained.

1 Mark for each definition = 4 Marks

4 b) Describe the general maintenance issues of the horizontal axis WPPs.

Ans:

General Maintenance Issues of Horizontal Axis WPPs:

1. Gearbox failure.
2. Misalignment between generator and gearbox.
3. Problems related to lubrication.
4. Variation among the components by manufacturer, configuration and operating environment of such items such as generators, power converters, gear box.
5. General routine maintenance related about tower, storage devices, wiring, charging gear oil, brake pads, filters, bearings, sensors, actuators.
6. Bearing failure issue.

1 Mark for each issue Any four issues = 4 Marks

4 c) Describe with sketch Lattice tubular type & hydraulic towers for SWT.

Ans:

Lattice Tubular Tower for SWT:

Lattice Tubular Tower

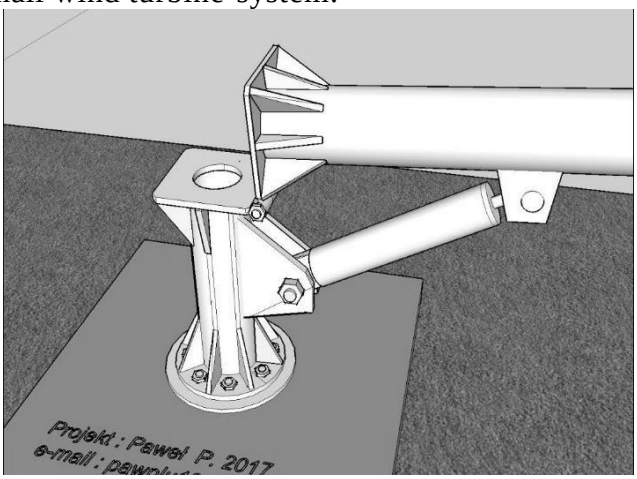
Generally used for a large wind turbine and normally manufactured in section of 30-40 meters in length. Complete tower is slightly conical in shape to provide better mechanical stability.

Hydraulic tower:

1 Mark for each sketch and 1 Mark for description

Hydraulic lifting tower is very popular tower solution for small wind turbine system, especially for the not easy maintenance.. After the first tower installation, it will do not need the crane or lifting equipment for the lay down and erecting process. The tower and turbine can be lay down by the hydraulic system within 5 or 15 minutes for the maintenance, repair. The hydraulic system can be powered by the state grid or mobile power station. It is the lowest maintenance cost solution for the small wind turbine system.

1 Mark for ketch and 1 Mark for description



4 d) Recommend with justification the generators used in SWT.

Ans:

1. Fixed Speed Induction Generator:

This is squirrel cage induction generator for fixed speed.

This is 1) reliable 2) self-starting 3) easy to adjust 4) have low maintenance.

2. Permanent Magnet Synchronous Generator:

This is synchronous generator for variable speed.

This is 1) eliminate field copper loss 2) high power density 3) low rotor inertia 4) high efficiency 5) optimizes use of given grid capacities 6) Better cooling performance 7) Reduced noise level of moving parts.

2 Marks for name and 2 Marks for justification

4 e) List any four mechanical and electrical faults in SWT.

Ans:

Mechanical Faults in SWT:

1. Bearing and gearbox issue
2. Blade design , manufacturing, installation issue
3. Mechanical break down
4. Hydraulic failure
5. Nacelle fire
6. Turbine collapse
7. Axial stress
8. Yaw motor events
9. Foundation damage
10. Extreme weather conditions
11. Insufficient oil drain
12. Fatigue, high stress on shaft and gearbox

2 Marks for any 4 mechanical faults

13. Improper handling during construction
14. Structural deformation

Electrical Faults in SWT:

1. Generator failure
2. Electrical breakdown of generator, transformer ,CB
3. Lightning strikes
4. Power converter failure
5. Grid failure
6. Wind turbine electric system failure
7. Excessive vibration, voltage imbalance, inadequate insulation.
8. Transient shaft voltage, wrong selection of cables
9. Damage of rotor, stator
10. Improper grounding
11. Poor design, material failure, power regulator failure
12. Torque reversal due occasional connecting and disconnecting generator to grid

2 Marks for any 4 electrical faults

5 Attempt any TWO of the following: 12

5 a) Identify the sensors for the following :

i) Wind speed
ii) RPM of generator shaft
iii) Temperature in generator
iv) Cable untwisting
v) Vibration
vi) Wind direction

1 Mark for each sensor = 6 Marks

Ans:

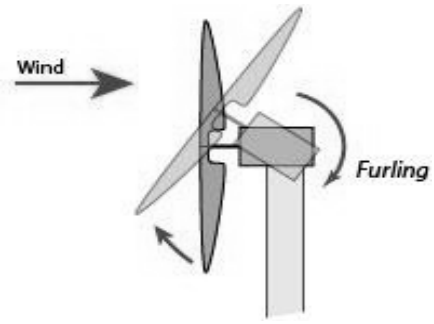
i) **Wind Speed :** Anemometer.
ii) **RPM of Generator Shaft:** Accelerometers.
iii) **Temperature in Generator:** Thermistor, thermocouple, RTD.
iv) **Cable Untwisting :** Cable Twisting sensor.
v) **Vibration :** Accelerometer, piezoelectric.
vi) Wind direction: Wind vane.

5 b) Recommend & explain with neat sketch a suitable braking mechanism for the large WPP.

Ans:

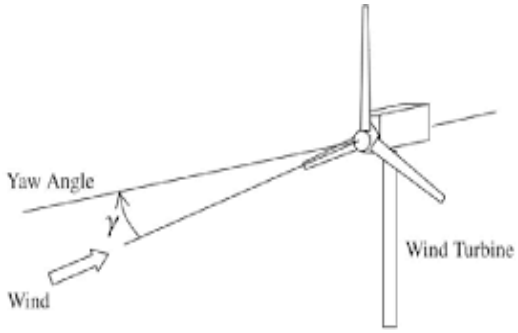
Braking Mechanism For The Large WPP:

1. **Furling Mechanism:**



Furling allows the whole set of blades to change its position and blades turned away from wind, if wind speed is beyond safety limit. It decreases the angle of attack.

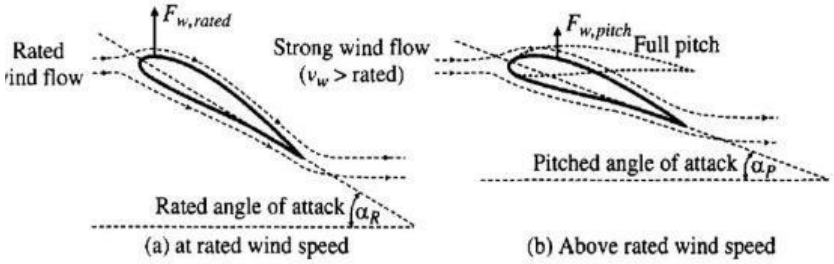
2. Yawing Mechanism:



3 Marks for sketch and 3 Marks for explanation (Any one type)

It is used for the precise positioning of the nacelle in the wind. Yaw system allows optimum position of the nacelle in the high wind speed conditions. For the large WPP it is monitored by computer and electronic control where as small wind turbine uses tail vane for positioning purpose.

3. Pitch Control Mechanism:



It allows the rotor blades angle of attack to be measured, monitored and controlled.
Pitch control used for adjustment of blade angle.
1. To harness optimum power from wind
2. To protect turbine in case of high wind speed.

5 c) Identify & explain any two difficulties faced while connecting WPP to the power grid.

Ans:

Difficulties Faced while Connecting WPP to Power Grid:

There are several technical issues associated with grid connected systems like power quality issues, power and voltage fluctuations, storage, protection issues, harmonics and frequency fluctuations.

1. Short Circuit Power Control:

An electric fault in power system can be defined as short circuit in the system. Short circuit power is one of the indicator of capacity of WPP production which can be connected to the grid. Usual practice is that the installed capacity of WPP should be about 10% of short circuit power. If the short circuit power is high then voltage variation at connection point is low and vice a versa.

During and after fault in the system, behavior of WPP is different than conventional plants. Which use synchronous generator. If the large number of WPPs are tripped due to fault, the negative effect of fault are magnified. This will affect the transmission capacities in the areas with significant of wind power.

3 Mark for each difficulty Any two = 6 Marks

2. **Reactive Power Control:**
   Reactive power is exchange of wind stored in capacitive and inductive components of power system. Each WPP should behave like a other conventional plants. The exchange of reactive power is zero. WPP with reactive power control capacity have pf within ± 095 over entire operating range of WPP. WPP are connected at weak points in the network and reactive power losses are considerable and are not able to provide contribution in reactive power balance.
3. **Harmonics:**
   Harmonics are current or voltage with frequency that are integer multiplies of fundamental power frequency. Electrical appliances and generators all produce harmonics and large volumes, can cause interference that results in number of power quality problems.
4. **Voltage fluctuations:**
   Inverter are generally configured to operate in grid 'voltage-following' mode and to disconnect DG when the grid voltage moves outside set parameters. This is both to help ensure they contribute suitable power quality as well as help to protect against unintentional islanding. Where there are large of DG systems on particular feeder, their automatic disconnection due grid voltage being out of range can be problematic because other generators on network will suddenly have to provide additional power.
5. **Power factor correction:**
   Because of poor power factor line losses increases and voltage regulation more difficult. Inverters configured to be voltage following have unity power factor, while inverters are in voltage regulating mode provide current that is out of phase with grid voltage and so provide power factor correction.

6 Attempt any TWO of the following: 12

6 a) Explain scheduled maintenance of Stall Pitch, Active Pitch controlled of WPP.

Ans:

Scheduled Maintenance of Stall Pitch:

In scheduled maintenance of stall pitch, following maintenance activities are performed quarterly or yearly basis:

1. Grease the cable, which pulls the blade tip.
2. Check the movement of blade tip and angle.
3. Check the carbon rod, which turns the blade.
4. Grease blade tip bearing.

1 Mark each (any three points) = 3 Marks

Scheduled Maintenance of Active Pitch Control:

In scheduled maintenance of Active pitch following maintenance activities to be perform to be perform quarterly or yearly basis:

1. Check oil level of pitch drive, grease slew ring and slew pinion
2. Check the limit switches for perfect angles of blade pitching.
3. Check encoder, calibration of blades.
4. Check the connections of battery. In case of power failure, batteries will ensure the

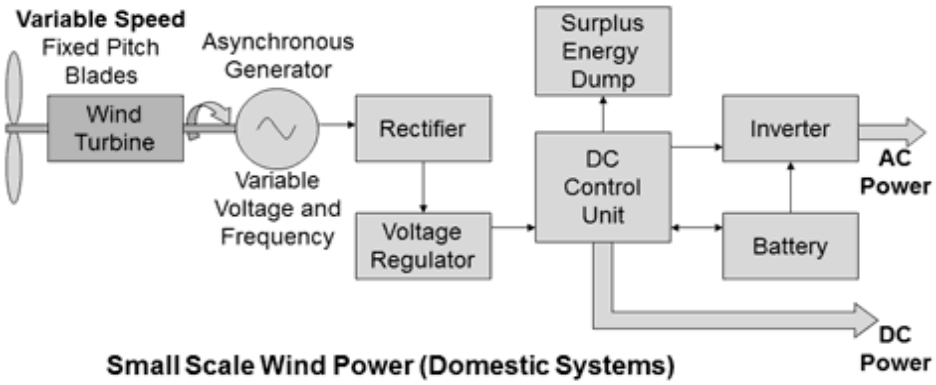
1 Mark each (any three points) = 3 Marks

movement of blade to safe position.

6 b) Explain with neat sketch working of direct drive SWT. Give any two advantages of it over geared type SWT.

Ans:

Direct Drive SWT:



Small Scale Wind Power (Domestic Systems)

2 Marks for labeled sketch

This plant has no gear box. Turbine blades are very light weight made up of stiff carbon fibre material. Blades are flat shaped. Due to this shape, lift increases.
Pitch controller helps blades from high wind forces. Wind power rotates blades and hence turbine rotor rotates. Rotor rotates generator. It is permanent magnet synchronous generator. It converts mechanical power into electrical power. Diameter of rotor of generator is such that it converts much more power when turning slowly. Wind speed direction data is received from sensors and accordingly yaw drive turns nacelle to face maximum wind. With the use of pitch control, the blade angle is adjusted as per wind speed. Rectifier converts AC to DC. And DC load is fed from this DC supply. Inverter convers DC to AC and connected to grid.

2 Marks for working

Advantages:

1. It has high power to weight ratio
2. Plant is efficient
3. Cooling needed is less
4. More reliable
5. Better performance
6. Light weight
7. Less maintenance

2 Marks for any two advantages

6 c) Prepare preventive maintenance schedule for SWT related to i) Oiling and greasing ii) Electronic equipment iii) Towers

Ans:

Preventive maintenance schedule for SWT:

I. Oiling and greasing:

1) Checking geared motor oil, greasing, lubrication and maintenance of drive train.
2) Changing oil, belts, bearing lubrication.
3) Regular maintenance includes gearbox oil changes and it protects components from wear.

2 Marks for any two points

4) Oil used for wind turbine should resist water contamination.
5) Oiling and greasing at regular intervals will provide gear and bearing protection.
6) Condition monitoring has to be performed to overcome the challenges like rust corrosion foam formation, water contamination, filterability etc.

II. Preventive maintenance schedule Electronic equipment

1) Every 12 months, visual check of the bus capacitor and power equipment should be made, looking for possible defective areas.
2) Every 12 months checking of harmonic filter, EMC filter etc.
3) Every 6 months converter, UPS operation should be checked.

2 Marks for any two points

III. Preventive maintenance schedule for Towers

1) Visual check out for concrete base foundation, its clearance, ladder and life line fastening.
2) Visual check out for tower cleaning, joint bolt between foundation and tower
3) Every 6 months inspection for loop condition, safety norms, tower surface.

2 Marks for any two points