AVIT
AARUPADAI VEEDU INSTITUTE OF TECHNOLOGY
VINAYAKA MISSION'S RESEARCH FOUNDATION
Accredited by NAAC Approved by AICTE

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

NAME OF THE LAB – 17SASE02 WIND ENERGY LAB

NAME OF THE LAB – 17SASE02 WIND ENERGY LAB

Prepared By,

Jensie Anita. S

Edited By,

Dr. L. Chitra

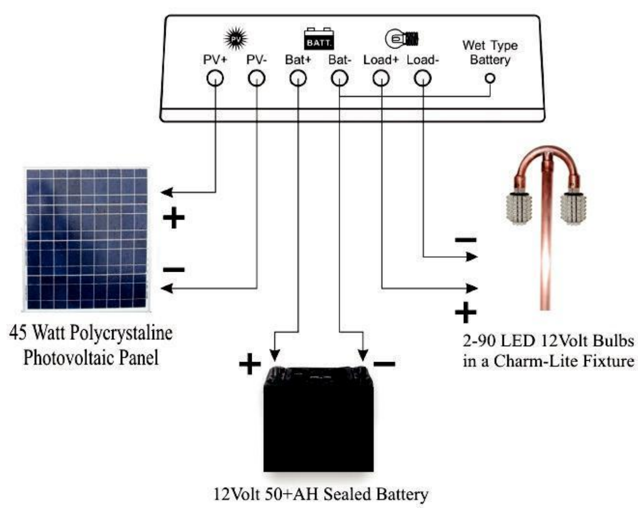
Exp. No.	1	EVALUATION OF THE EFFICIENCY OF THE CHARGE CONTROLLER USED IN THE WIND ENERGY TRAINING SYSTEM
Date		

AIM

To evaluate the efficiency of charge controller used in the Wind Energy Training System.

THEORY

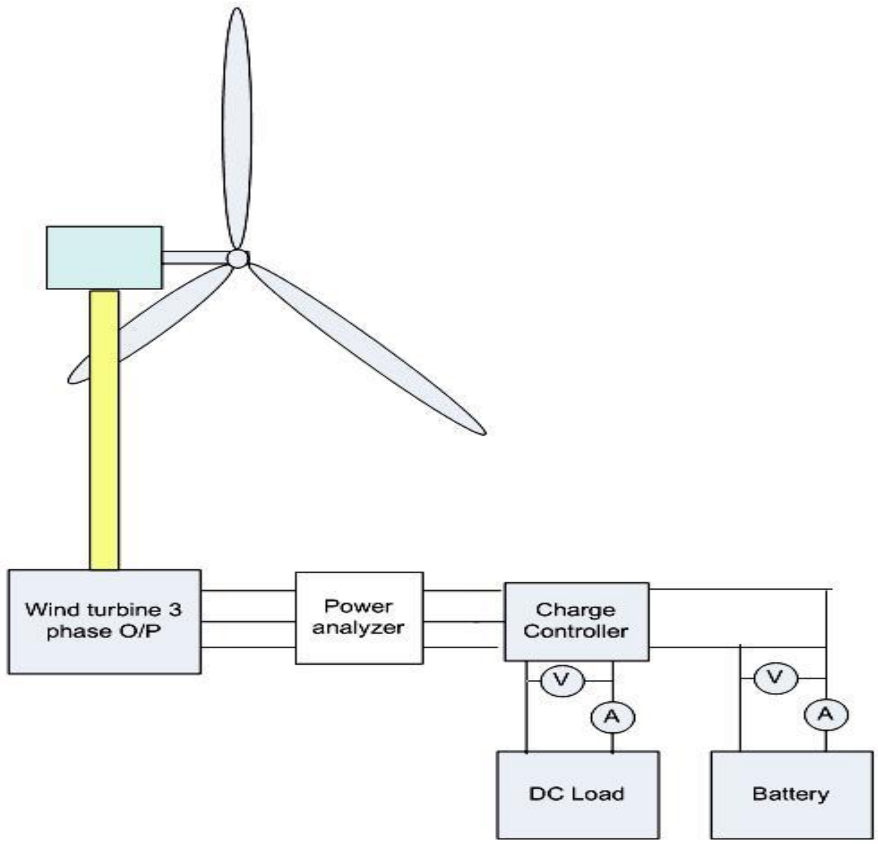
Charge controller is a electronic device which regulates the charging and discharging of battery and control the current and voltage in load. But this device has some efficiency of conversion which is more than 90%. It works on PWM control which open and close the switches at very high frequency. These provide a tapering charge by rapidly switching the full charging current on and off when the battery reaches the fully charged state. The length of the charging current pulse gradually decreases as battery voltage rises, reducing the average current into the battery.



Experimental Set-up

System layout for this experiment will be same as we discussed before (as shown in following figure) but the measurements will be made at the charge controller output. At this point, DC power is available for battery charging and DC load running. This Power calculation will be done by noting down voltage, current of battery and DC load. This experiment can be done in two ways:

1. Load running with battery only.
2. Load running with battery as well as turbine.



OBSERVATION

a. Load running with battery only

S.No.	Battery Current (A)	Battery voltage (V)	DC load current (A)	DC load voltage (V)
1.				
2.				
3.				

b. Load running with battery as well as turbine.

S.No.	Turbine current (A)	Power factor	Turbine voltage (V)	Battery Current (A)	Battery voltage (V)	DC load current (A)	DC load voltage (V)	Generated power (W)
1.								
2.								
3.								
4.								

Calculations

a. Battery power = battery current*battery voltage

b. Load power = load current*load voltage

c. Turbine power = $\sqrt{3}$*current*voltage*power factor

d. Charge controller efficiency with battery only = (load power/battery power)*100

e. Charge controller efficiency with battery as well as turbine = 100*(battery power + load power)/turbine power

RESULT

Exp. No.	**2**	**EVALUATION OF CUT IN SPEED OF THE WIND TURBINE EXPERIMENTALLY.**
Date		

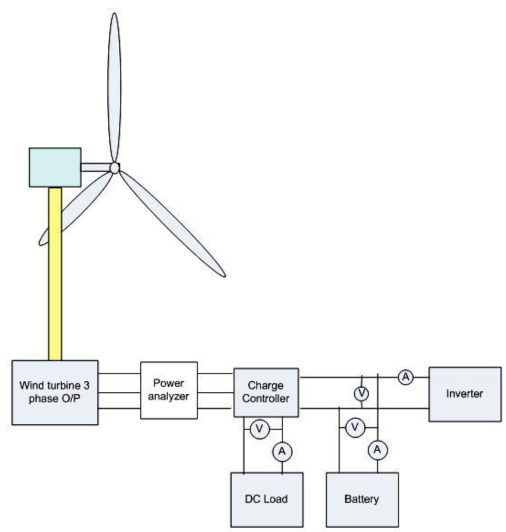
AIM

To evaluate the cut-in speed of wind turbine experimentally.

THEORY

At very low wind speeds, there is insufficient torque exerted by the wind on the turbine blades to make them rotate. However, as the speed increases, the wind turbine will begin to rotate and generate electrical power. The speed at which the turbine first starts to rotate and generate power is called the cut-in speed. It is different with the start-up speed at which turbine starts to rotate, at cut-in speed turbine starts to generate some useful power. It is normally in the range of 3m/s - 4m/s.

CIRCUIT DIAGRAM



PROCEDURE

1. For this experiment, place the anemometer and tachometer at right position and readings will be noted down with these meters at different wind velocities.

2. Note the wind speed and shaft rpm corresponding to starting of turbine shaft rotation and power generation.

3. These wind velocities will be called start-up speed and cut-in speed.

4. Rest of the experimental set-up or system layout will remain the same.

OBSERVATION

S.No	Wind speed (m/s)	Rotational speed (RPM)	Battery Current (A)	Battery voltage (V)	DC load current (A)	DC load voltage (V)	Inverter i/p current (A)	Inverter i/p voltage (V)
1.								
2.								
3.								
4.								
5.								

Calculations

DC power at output of charge controller (DC power) = (DC load voltage*DC load current) + (battery voltage*battery current) OR

DC power at output of charge controller (DC power) = (inverter i/p current*inverter i/p voltage) + (battery voltage*battery current)

Generated power by wind turbine = DC power/charge controller efficiency

RESULTS

Start-up speed and Cut-in speed are found as follows:

Start-up speed = m/s

Cut-in speed = m/s

Exp. No.	3	**EVALUATION OF THE TIP SPEED RATIO (TSR) AT DIFFERENT WIND SPEED**.
Date		

AIM

To evaluate the Tip Speed ratio (TSR) at different wind speeds.

THEORY

The relationship between the wind speed and the rate of rotation of the rotor is characterized by a non-dimensional factor, known as the tip speed ratio (TSR) or λ. The TSR for wind turbines is the ratio between the tangential speed of the tip of a blade and the actual velocity of the wind, . The tip-speed ratio is related to efficiency, with the maximum wind to electric power conversion efficiency occurring at a specific tip speed ratio for a given turbine under consideration. Higher tip speeds result in higher noise levels and require stronger blades due to large centrifugal forces. Lower tip speeds mean an under-utilization of the wind turbine to generate electricity. Thus it is generally desired to maintain the tip speed ratio at the optimal value to extract the most from the wind.

Tip speed ratio = Tip speed of blade/wind speed

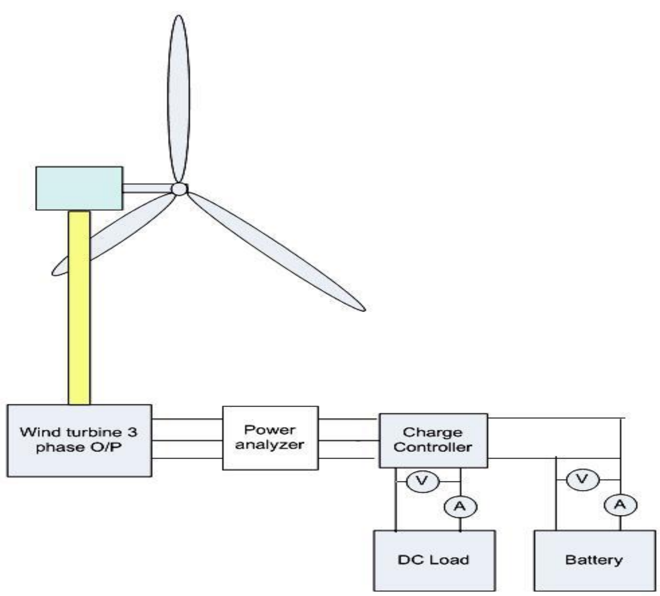
The tip speed of the blade can be calculated as ω times R, where ω is the rotor rotational speed in radians/second, and R is the rotor radius in meters. Therefore we can also write:

$$\lambda = \omega R/v$$

when wind speed is specified in meters/ second.

It should be constant for each wind velocity. Optimum TSR value for three blades wind turbine is 6-7.

CIRCUIT DIAGRAM



PROCEDURE

1. Make the circuit connections as in the diagram.

2. Place the anemometer and tachometer at right position and readings will be noted down with these meters at different wind velocities.

3.Vary the wind speed from cut in to maximum value and note the angular velocity of turbine blade and wind velocities.

4.Rest of the experimental set-up or system layout will remain the same.

OBSERVATIONS

1. Diameter of blades = 1.2m

2. Wind speed and angular velocity:

S.No.	Wind velocity (m/s)	Angular velocity (RPM)	TSR
1.			
2.			
3.			

Calculations

For performing this experiment, wind speed and angular velocity of turbine will be measured and TSR will be calculated by using following formula $\lambda = \omega R/v$

RESULT

TSR value at different wind velocities are as follows:

Exp. No.	**4**	**TURBINE POWER VERSUS WIND SPEED CURVE.**
Date		

AIM

To draw the turbine power versus wind speed curve.

THEORY

Power curve of the wind turbine is the curve between the power output obtained from the wind turbine at different wind speeds. From the power curve one can assess the cut-in-speed, rated-speed, cut-out-speed of the turbine. These parameters are further defined as below.

1) Cut-in speed.

At very low wind speeds, there is insufficient torque exerted by the wind on the turbine blades to make them rotate. However, as the speed increases, the wind turbine will begin to rotate and generate electrical power. The speed at which the turbine first starts to rotate and generate power is called the cut-in speed.

2) Rated speed.

As the wind speed rises above the cut-in speed, the level of electrical output power rises rapidly as shown. However, at a certain wind speed the power output reaches the limit that the electrical generator is capable of. This limit to the generator output is called the rated power output and the wind speed at which it is reached is called the rated output wind speed. At higher wind speeds, the design of the turbine is arranged to limit the power to this maximum level (pitch controlled turbine) or the output power reduces (for a stall controlled turbine).

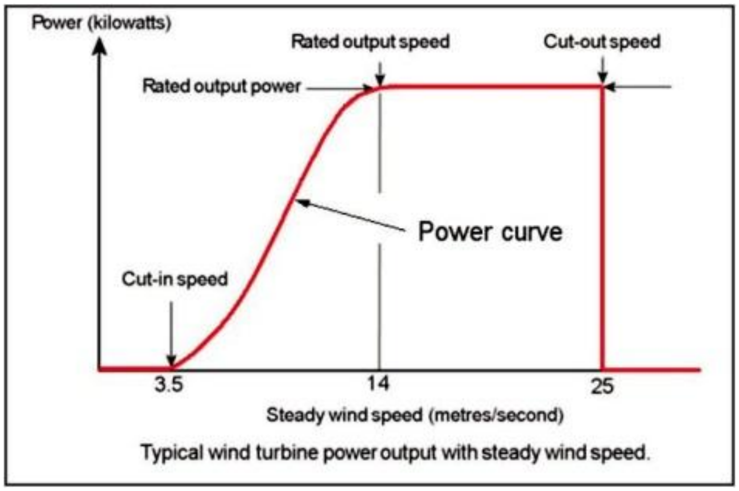
3) Cut-out speed.

As the speed increases above the rated output wind speed, the forces on the turbine structure continue to rise and, at some point, there is a risk of damage to the rotor. As a result, a braking system is employed to bring the rotor to a standstill. This is called the cut-out speed.

The power output of the wind turbine is given by,

$$\mathbf{P = 0.5\ \rho AV3Cp}$$

where, ρ is the air density, A is the turbine swept area, V is the wind speed, Cp is the power coefficient of the wind turbine.



Typical wind turbine power output with steady wind speed.

Experimental Setup

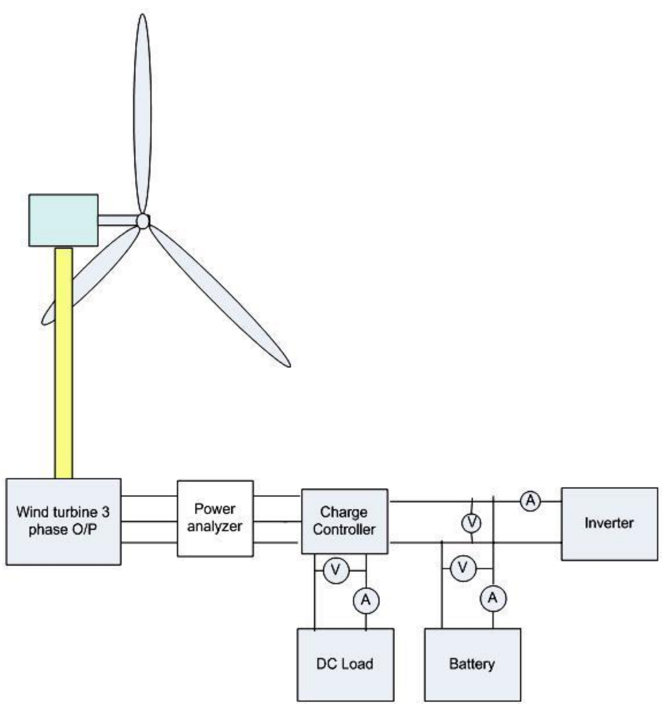
System layout for this experiment will be same as we discussed before (as shown in following figure) but the measurements will be made at charge controller output. At this point, variable frequency AC power of low voltage is available which is converted into DC power with the help of charge controller. Power calculation will be done by noting down voltage, current of battery and DC load. Then power can be calculated by

DC power at output of charge controller (DC power) = (DC load voltage*DC load current) - (battery voltage*battery current)

Generated power by wind turbine = DC power*charge controller efficiency

Power will be calculated at different wind speed and then a curve will be drawn by taking wind speed on x-axis and generated power on y-axis.

CIRCUIT DIAGRAM



OBSERVATION

Efficiency of charge controller =

S.No	Wind speed (m/s)	Battery Current (A)	Battery voltage (V)	DC load current (A)	DC load voltage (V)	Inverter i/p current (A)	Inverter i/p voltage (V)	Wind Power
1.								
2.								
3.								
4.								
5.								
6.								
7.								

Calculations

DC power at output of charge controller (DC power) = (DC load voltage*DC load current) + (battery voltage*battery current) OR

DC power at output of charge controller (DC power) = (inverter i/p current*inverter i/p voltage) + (battery voltage*battery current)

Generated power by wind turbine = DC power/charge controller efficiency

RESULT

Exp. No.	5	CURVE BETWEEN TSR AND CO-EFFICIENT OF POWER.
Date		

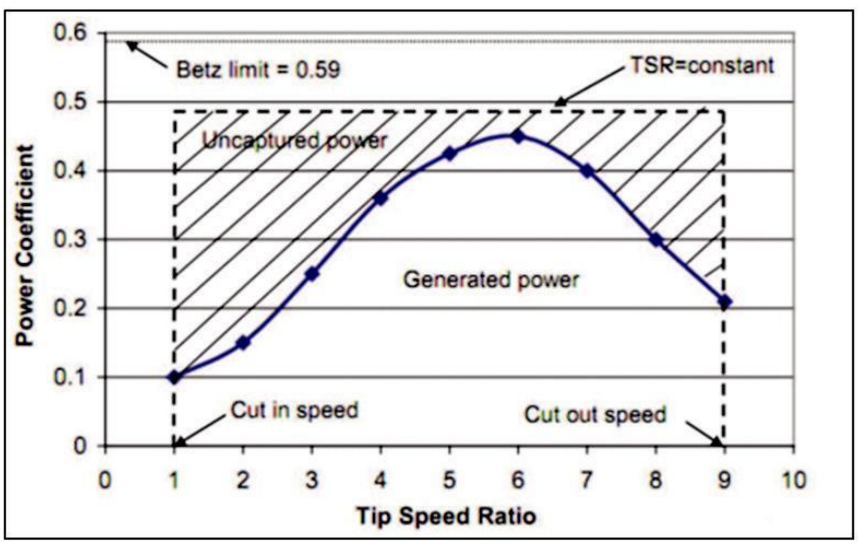
AIM

Draw the curve between TSR and coefficient of power.

THEORY

TSR Vs Cp curve gives the variation of coefficient of power (percentage of the power available in the wind converted into useful electrical power) to the tip speed ratio. This knowledge helps to identify the maximum operating point of the wind turbine to be operated at. The knowledge of tip speed ratio and corresponding Cp is necessary to analize the performance of the wind turbine at any instant of time.

The maximum achievable power coefficient is 59.26 % as per the Betz Limit. In practice however, obtainable values of the power coefficient is less. This value below the theoretical limit is caused by the inefficiencies and losses attributed to different configurations, rotor blades' profiles, finite wings, friction, and turbine designs. Below figure depicts the Betz Limit, ideal constant and actual wind turbine power coefficient as a function of the TSR. As shown, maximum power extraction occurs at the optimal TSR, where the difference between the actual TSR (blue curve) and the line defined by a constant TSR is the lowest. This difference represents the power in the wind that is not captured by the wind turbine. Frictional losses, finite wing size, and turbine design losses account for part of the wind power that is not captured, and are supplemented by the fact that a wind turbine does not operate at the optimal TSR across its operating range of wind speeds.



Experimental Set-up

System layout for this experiment will be same as we discussed before (as shown in following figure) but the measurements will be made at the charge controller output. At this point, DC power is available for battery charging and DC load running. This Power calculation will be done by noting down voltage, current of battery and DC load. Then power can be calculated by

P (electrical) = [(DC load voltage*DC load current) + (battery voltage*battery current)]*charge controller efficiency OR

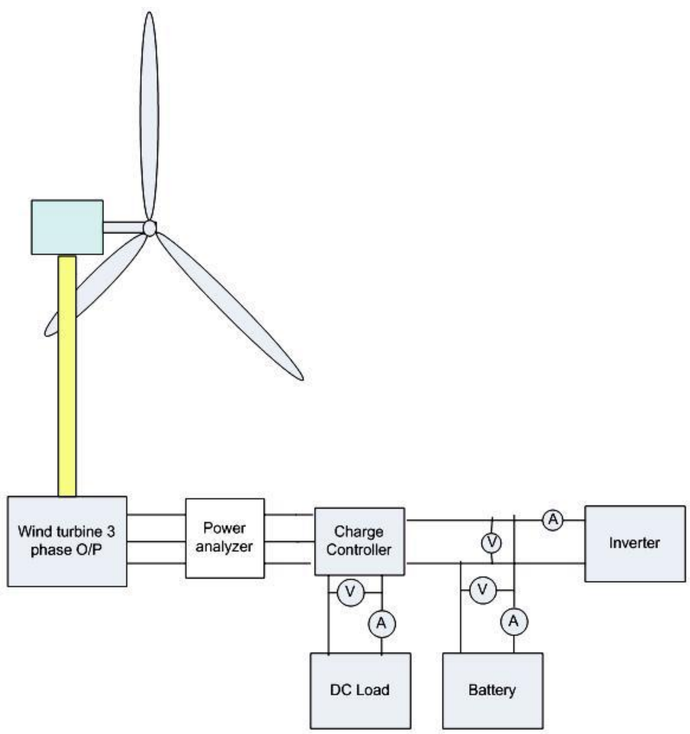
P (electrical) = [(inverter i/p voltage*inverter i/p current) + (battery voltage*battery current)]*charge controller efficiency

Wind speed will be measured with the help of anemometer which is placed just behind the turbine. Power in wind flow can be measured by following formula

$$\mathbf{P\ (wind) = \rho * A * V3/2}$$

Power will be calculated at different wind speed and then coefficient of performance will also be evaluated at different wind speed.

CIRCUIT DIAGRAM



OBSERVATION

Efficiency of charge controller =

S.No	Wind speed (m/s)	Angular Velocity (w)	Battery Current (A)	Battery voltage (V)	DC load current (A)	DC load voltage (V)	Inverter i/p current (A)	Inverter i/p voltage (V)	Wind Power
1.									
2.									
3.									
4.									
5.									
6.									
7.									

Calculations

DC power at output of charge controller (DC power) = (DC load voltage*DC load current) + (battery voltage*battery current) OR

DC power at output of charge controller (DC power) = (inverter i/p current*inverter i/p voltage) + (battery voltage*battery current)

Generated power by wind turbine = DC power/charge controller efficiency Coefficient of performance = Generated power*100/Wind power TSR will be calculated by using following formula $\lambda = \omega R/v$

RESULT

Exp No	6	Draw the power curve of turbine with respect to the rotational speed of rotor at fix wind speeds
Date		

AIM:

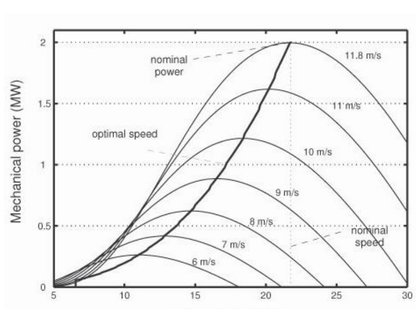
Draw the power curve of turbine with respect to the rotational speed of rotor at fix wind speeds.

THEORY:

A power versus rpm relation is found for the generator, and referred to the low- speed side of the gearbox by dividing the generator speed by the gearbox speed-up ratio. This relation is superimposed on a series of plots (for a range of wind speeds) for rotor power vs. rotor rpm. Every point where a generator line crosses a rotor line defines a pair of power and wind speed points on the power curve. These points also define the operating speed of the rotor.

Experimental set-up

Experimental set-up will remain the same as in previous experiments. Power at the output of generator which is variable frequency AC power and rotor RPM will be measured continuously. This power will be measured at the output of charge controller. This procedure will be repeated for different wind speeds.



Observations

Observation will be made in correspondence to fix wind speeds. It means during the measurements of power and RPM wind speed will not be changed

S. No.	Wind speed (m/s)	Angular velocity Ω	Battery Current (A)	Battery voltage (V)	DC load current (A)	DC load voltage (V)	Inverter i/p current (A)	Inverter i/p voltage (V)	Wind power

Calculations

DC power at output of charge controller (DC power) = (DC load voltage*DC load current) + (battery voltage*battery current)

OR

DC power at output of charge controller (DC power) = (inverter i/p current*inverter i/p voltage) + (battery voltage*battery current)

Generated power by wind turbine = DC power*charge controller efficiency

Result

Thus the power curve of turbine with respect to the rotational speed of rotor at fix wind speeds is plotted.

Note: Battery current will be used with negative sign if battery supplies the power to the load.

Exp No	7	Demonstrate the power analysis at turbine output (for high wind speeds).
Date		

AIM:

Demonstrate the power analysis at turbine output (for high wind speeds).

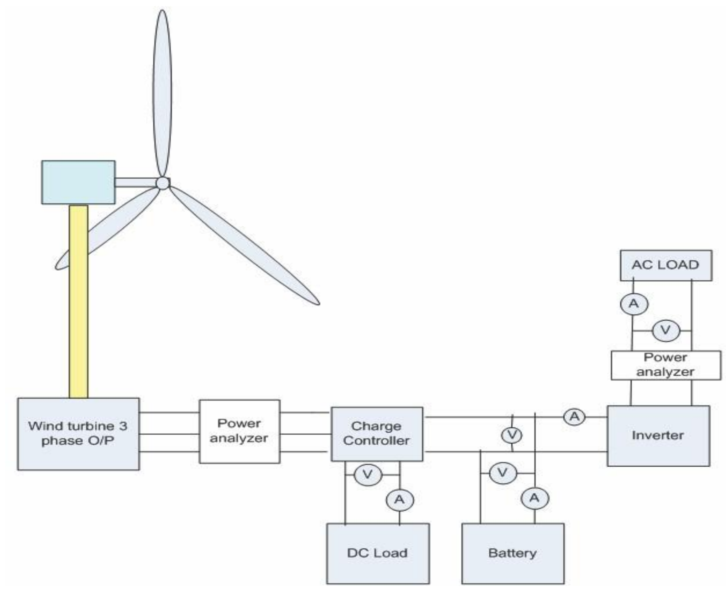
THEORY:

The quality of the power like active power, reactive power, frequency etc available at the turbine power output is variable with time as wind speed is changed with time.

These parameters can be observed from the power analyser unit at different wind speed. The fluctuating AC from the turbine power output is converted to the DC and back to AC to have a steady power which is ready to be supplied to the electric load.

Experimental set-up

Experimental set-up will remain the same as in previous experiments. All measurements will be made at turbine output (which is 3 phase). These measurements will be in correspondence to change in wind speed and change in load. Voltage, current, frequency, active power and reactive power are the main parameters which will be measured.



Observations

Following are the main parameters for measurements:

Set A: Parameters with changing wind speed

S. No.	AC voltage	AC current	Power factor (cosΦ)	Frequency (Hz)	Active power (W)	Reactive Power (VAr)	Wind speed (m/s)
1							
2							
3							
4							
5							
6							

Set B: Parameters with changing load value

S. No.	AC voltage	AC current	Power factor (cosΦ)	Frequency (Hz)	Active power (W)	Reactive Power (VAr)	Wind speed (m/s)

Calculations

Active power = $\sqrt{3}*V*A*Cos\Phi$

Reactive power = $\sqrt{3}*V*A*Sin\Phi$

Result

Show the active power, reactive power and frequency at different wind speeds and different load values. It can also be shown in graphical form by taking the wind speed on x-axis and active and reactive power on left and right y-axis. Similarly, load value on x-axis and active and reactive power on left and right y-axis.

Exp No	8	Demonstrate the power analysis at different branches of wind turbine energy system (at high frequency) with AC load only.
Date		

AIM:

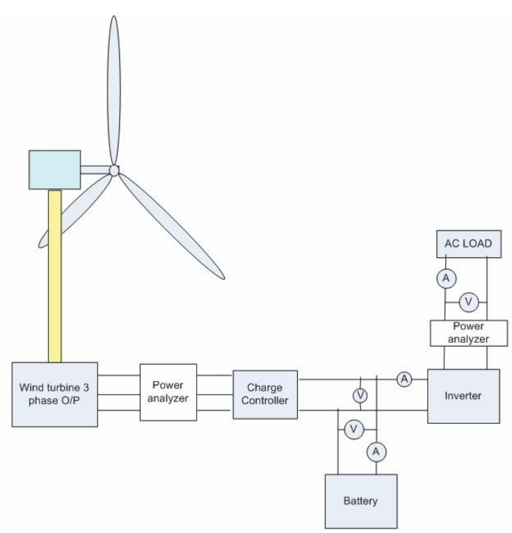
Demonstrate the power analysis at different branches of wind turbine energy system (at high frequency) with AC load only.

THEORY:

The amount and quality of the power like active power; reactive power can be measured in different branches of system. These parameters can be observed with the help of power analyser unit and different voltmeter and ammeter at different wind speeds. The fluctuating AC from the turbine power output is converted to the DC and back to AC to have a steady power which is ready to be supplied to the electric load.

EXPERIMENTAL SET-UP

Experimental set-up will remain the same as in previous experiments In this experiment, all meters starting from turbine output, battery voltage current, inverter input and inverter output will be in the circuit and all these readings will be noted down. All these measurements will be taken with change in wind speed and change in load. Voltage, current, frequency, active power and reactive power are the main parameters which will be measured.



Observations

Following are the main parameters for measurements:

Set A: Parameters with changing wind speed

S.No.	AC voltage (L-L)	AC current (L-L)	Power factor	Battery voltage (V)	Battery current (A)	Inverter i/p current(A)	Inverter i/p voltage (V)	Inverter o/p voltage (V)	Inverter o/p Current (A)	Inverter o/p power factor	Wind speed (m/s)
1											
2											
3											
4											
5											
6											

Set B: Parameters with changing load value

S.No.	AC voltage (L-L)	AC current (L-L)	Power factor	Battery voltage (V)	Battery current (A)	Inverter i/p current(A)	Inverter i/p voltage (V)	Inverter o/p voltage (V)	Inverter o/p Current (A)	Inverter o/p power factor	Load (W)
1											
2											
3											
4											
5											
6											

Calculations

Generated Active power = $\sqrt{3}$*V*A*CosΦ

Power consumed (or supplied) by battery = battery voltage*battery current

Power consumed at inverter input = voltage*current at inverter input

Power output for Ac load = V*A*CosΦ

Charge controller efficiency = [(battery power + power at Inverter input)/generated active power]*100
Inverter efficiency = power at output of inverter/ power at inverter input

Result

Show the active power in different branches of system at different wind speeds and different load values. It can also be shown in graphical form by taking the wind speed on x-axis and different active power on y-axis. Similarly, load value on x-axis and different active power on y-axis.

Note : Battery current will be used with negative sign if battery supplies the power to the load.

Exp No	9	Demonstrate the power analysis at different branches of wind turbine energy system (at high frequency) with DC load only.
Date		

AIM:

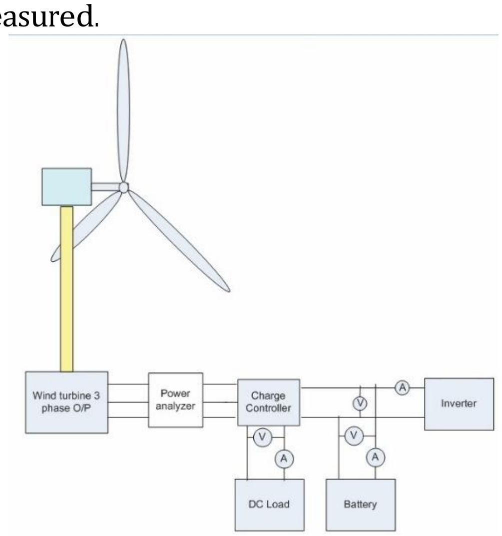
Demonstrate the power analysis at different branches of wind turbine energy system (at high frequency) with DC load only.

THEORY:

The amount and quality of the power like active power; reactive power can be measured at input of charge controller and DC power in different branches of system. These parameters can be observed with the help of power analyser unit and different voltmeter and ammeter at different wind speeds. The fluctuating AC from the turbine power output is converted to the DC and this can be used to run the DC load..

EXPERIMENTAL SET-UP

Experimental set-up will remain the same as in previous experiments.In this experiment, all meters starting from turbine output, battery voltage current and charge controller output will be in the circuit and all these readings will be noted down. All these measurements will be taken with change in wind speed and change in load. Voltage, current and power are the main parameters which will be measured.



Observations

Following are the main parameters for measurements:

Set A: Parameters with changing wind speed

S.No.	AC voltage (L-L)	AC current (L-L)	Power factor	Battery voltage (V)	Battery current (A)	DC voltage (V)	DC Current (A)	Wind speed (m/s)
1								
2								
3								
4								
5								
6								

Set B: Parameters with changing load value

S.No.	AC voltage (L-L)	AC current (L-L)	Power factor	Battery voltage (V)	Battery current (A)	DC voltage (V)	DC Current (A)	Wind speed (m/s)
1								
2								
3								
4								
5								
6								

Calculations

Generated Active power = $\sqrt{3} * V * A * \cos\Phi$

Power consumed (or supplied) by battery = battery voltage*battery current

Power consumed by DC load = voltage*current value of DC load

Charge controller efficiency = (battery power + DC load power)/generated active power

Result

Show the active power in different branches of system at different wind speeds and different load values. It can also be shown in graphical form by taking the wind speed on x-axis and different active power on y-axis. Similarly, load value on x-axis and different active power on y-axis.

Note : Battery current will be used with negative sign if battery supplies the power to the load.