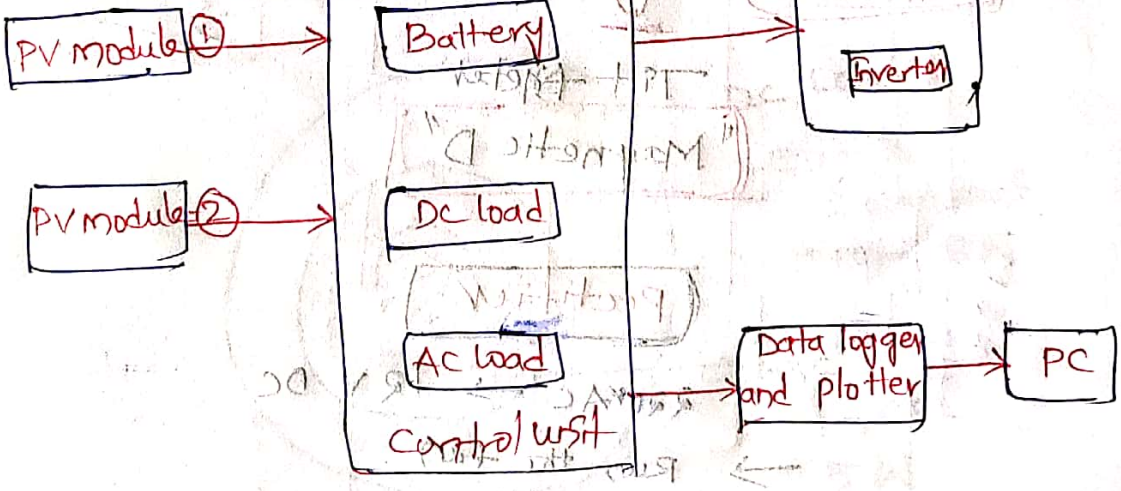
Solar PV Training & Research System

Components :-

This system can be completed by assembling of following components

- → PV modules (or) power generating unit
- → Artificial source of radiation
- → Structure of PV module
- → DC-DC Converter
- → Inverter
- → Data logger and plotter
- → Batteries
- → Load
- → Measuring



Hologen Regulator

Maximum Load 4500 W

6 tube Hologen Lamp

150 W each bulb

6 x 150 = 900 W

6 tube Hologen Lamp

150 W each bulb

6 x 150 = 900 W

Total = 1800 W

Solar panel ① 40 W

Back

Solar panel ② 40 W

Type : poly - Crystalline

mono - Crystalline

V_{oc} = 21.6 V

I_{sc} = 2A

V_{pm} (max peak voltage) = 18.33 V

I_{pm} (max peak current) = 2.39 V

Cooling purpose

8 Fan 12V DC 1A

8 Fan 12 V DC 1A

TiH Meter

Magnetic D'

Rectifier

220 V AC → 12 V DC

→ Run the fan

→ charge the Battery

Control unit

Module Temparatur : 1 -50 to 199.9°c

LED : 1 Diode ① Diode ②

Voltmeter : AC, DC Ammeter : AC, DC

Battery ① 12.V 4.5 AH

Battery ② 12.V 4.5 AH

PV module ①

PV module ②

pot meter 0 0-200 Ω

Solar charge controller :

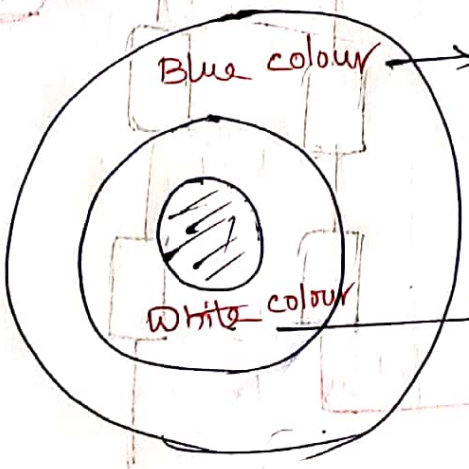
Dc I/P

DC load

Battery ①

Battery ②

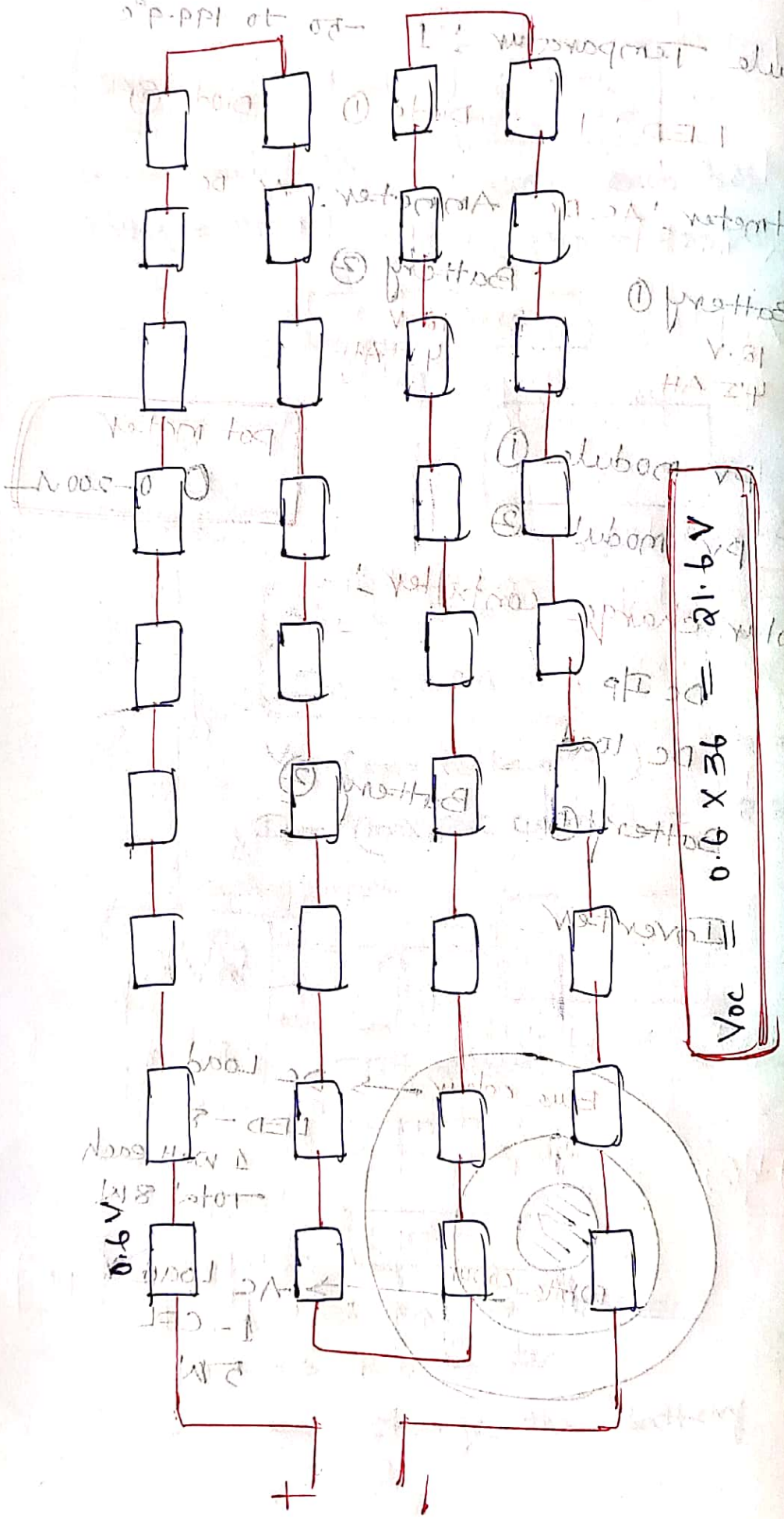
Inverter



DC Load
LED - 8
1 watt each
total 8W

AC Load
1 - CFL
5W

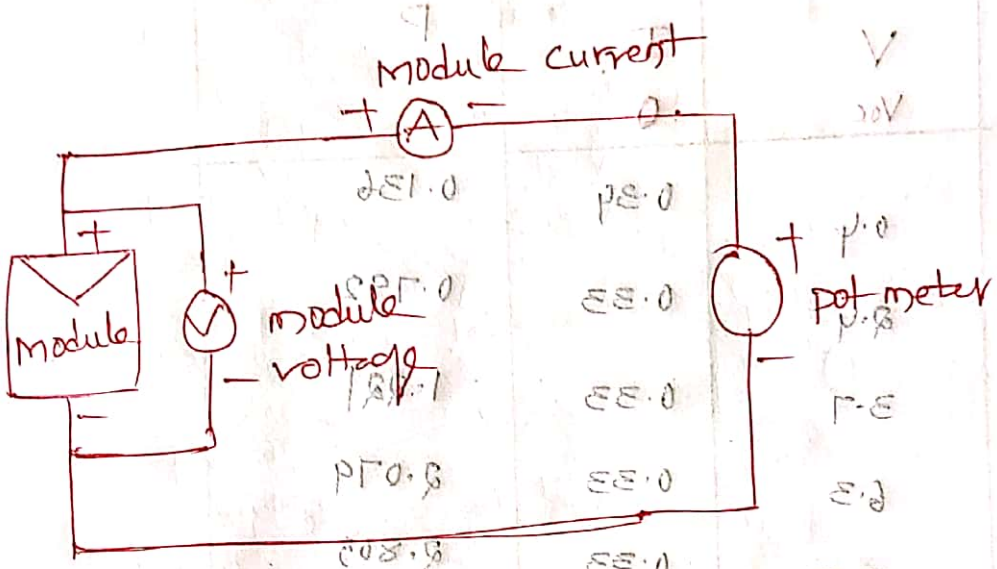
Solar panel ÷



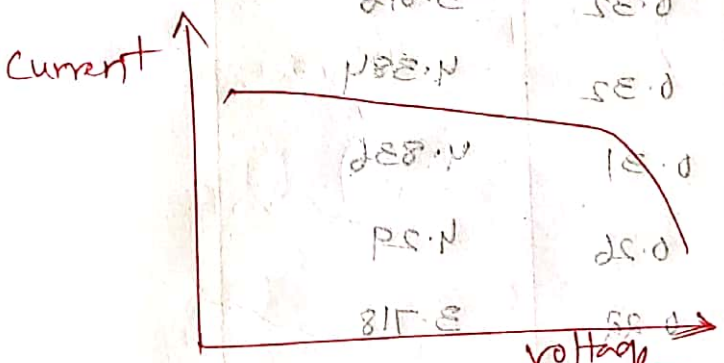
Experiment ①

Objective:

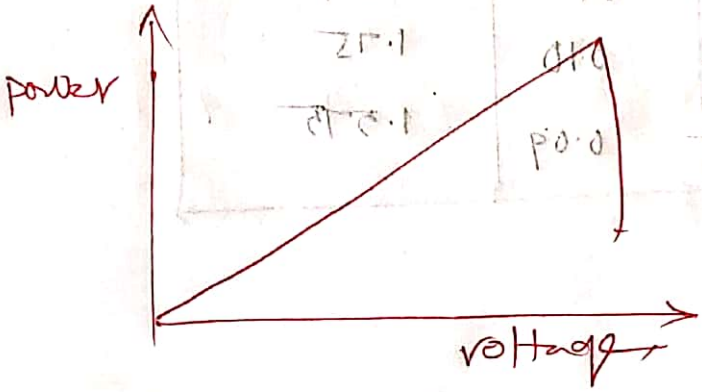
To demonstrate the I-V and PV characteristics of pv module with varying radiation and temparature level.



I-V characteristics of PV module



P-V characteristics of pv module.



Observation !

I-V and P-V charc. of pv module!

S.NO. Radiation Temp

404. 35

V Voc	I 0	P
0.4	0.34	0.136
2.4	0.33	0.792
3.7	0.33	1.221
6.3	0.33	2.079
8.5	0.33	2.805
9.9	0.33	3.267
11.3	0.32	3.616
13.7	0.32	4.384
15.6	0.31	4.836
16.5	0.26	4.29
16.9	0.22	3.718
17.0	0.19	3.23
17.3	0.14	2.422
17.4	0.11	1.914
17.5	0.10	1.75
17.5	0.09	1.575

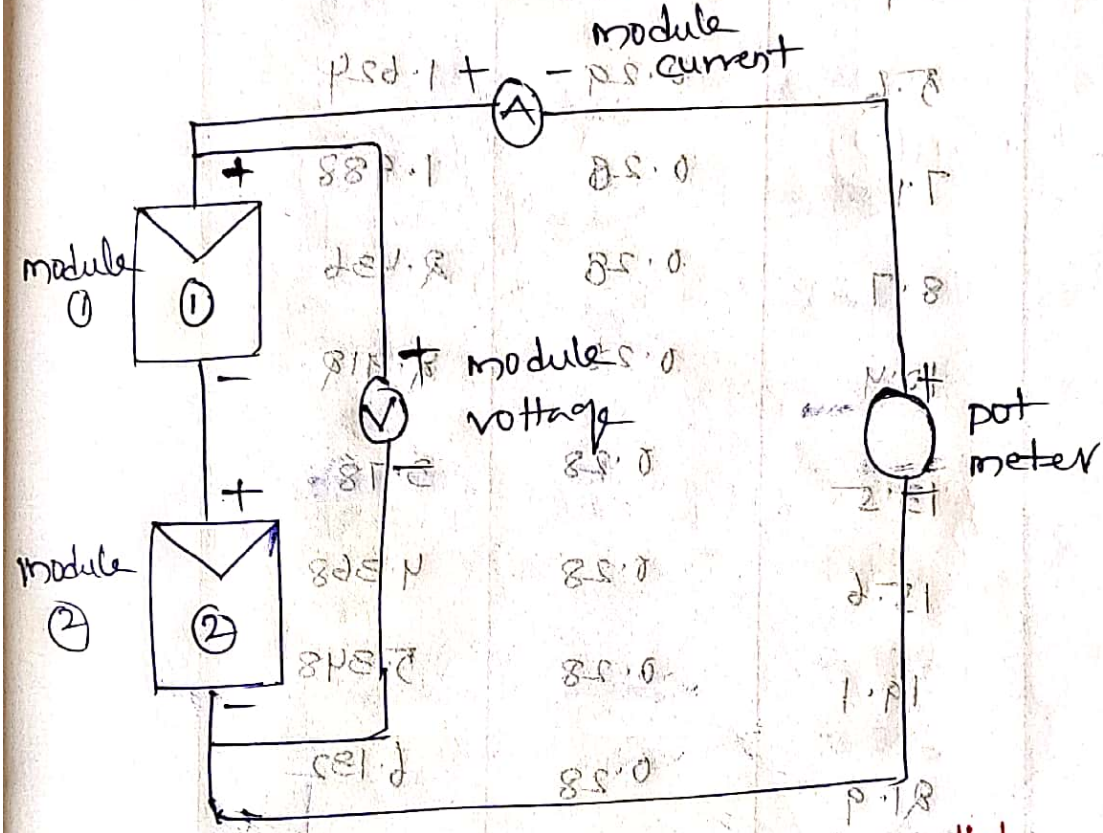
Experiment : 2

objective :

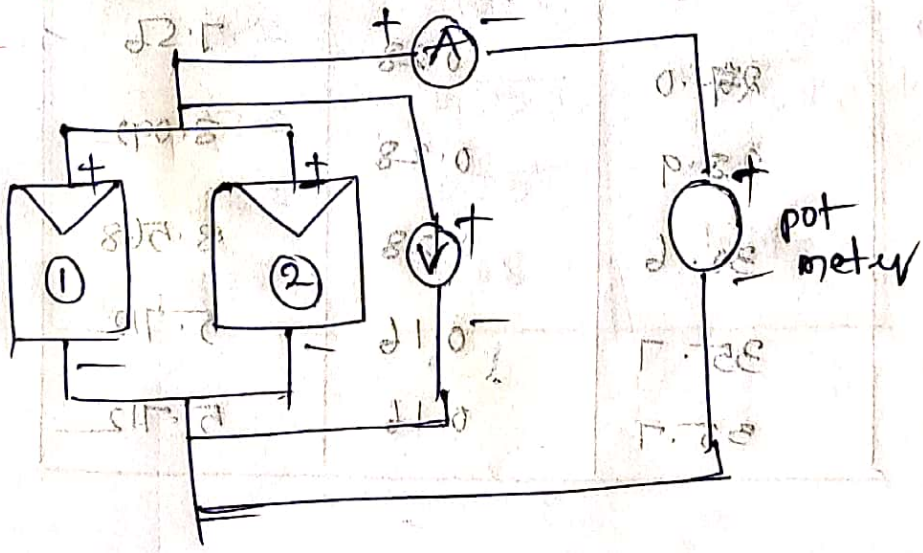
To demonstrate the I-V and P-V characteristics of series and parallel combination of pv modules.

① To connect two module in series :

Circuit diagram :



② To connect two module in parallel.



Observations:- Series circuit

Temp = 33.7 Radiation = 337

Voc	I	P
0.4	0.29	0.116
1.5	0.29	0.435
3.4	0.29	0.986
5.6	0.29	1.624
7.1	0.28	1.988
8.7	0.28	2.436
10.4	0.28	2.912
13.5	0.28	3.78
15.6	0.28	4.368
19.1	0.28	5.348
21.9	0.28	6.132
24.5	0.28	6.86
27.0	0.28	7.56
28.9	0.28	8.092
30.6	0.28	8.568
35.7	0.16	5.712
35.7	0.16	5.712

observations: parallel circuit.

Temp: 36.5 Radiation = 385

Voc	I	P
0.6	0.65	0.39
1.3	0.65	0.845
1.9	0.65	1.235
3.3	0.65	2.145
5.2	0.65	3.38
7.2	0.65	4.68
8.1	0.64	5.184
9.1	0.65	5.915
11.9	0.64	7.616
12.7	0.64	8.128
13.9	0.64	8.896
15.3	0.63	9.639
16.3	0.60	9.78
17.0	0.55	9.35
18.0	0.35	6.3
18.7	0.08	1.496

Experiment : 3

Objective :

To show the effect of variation in tilt angle of PV module.

Observations :-

S.No	Tilt degree	Radiation W/m²	Volt (V)	Current (I)	P (Watt)
1	0	420	10.2	0.30	3.06
2	5	412	9.5	0.28	2.66
3	10	403	8.9	0.26	2.31
4	15	376	8.2	0.24	1.96
5	20	372	7.6	0.22	1.67
6	25	354	7.0	0.21	1.47
7	30	336	6.4	0.19	1.21
8	35	270	5.8	0.17	0.98
9	40	236	5.4	0.16	0.86

observation ② :

S.No	Tilt (degree)	Radiation W/m²	Voltage (V)	Current (I)	Power (Watt)
1	0	394	15.0	0.30	4.5
2	5	382	13.7	0.28	3.83
3	10	320	12.7	0.26	3.3
4	15	291	11.9	0.24	2.85
5	20	286	10.9	0.21	2.28
6	25	212	9.8	0.190	1.86
7	30	194	9.2	0.18	1.65
8	35	148	8.4	0.17	1.42
9	40	143	7.8	0.15	1.17

Experiment : 4

Objective :

To demonstrate the effect of shading on module output power.

observations :

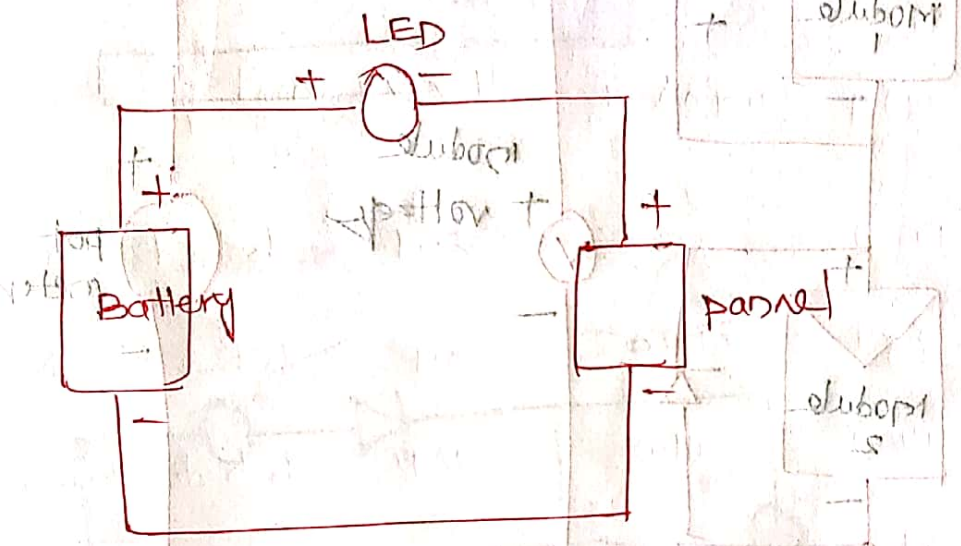
S.No	Type of shading element	V volts	I (Ampere)	P (Watt)
1	No cell shaded	12.8	0.32	4.09
2	Single cell shaded	7.2	0.17	1.22
3	Two cell shaded	4.4	0.10	0.44
4	Four cell shaded	2.4	0.05	0.12
5	Nine cell shaded.	0.8	0.00	0.0

Experiment: 5

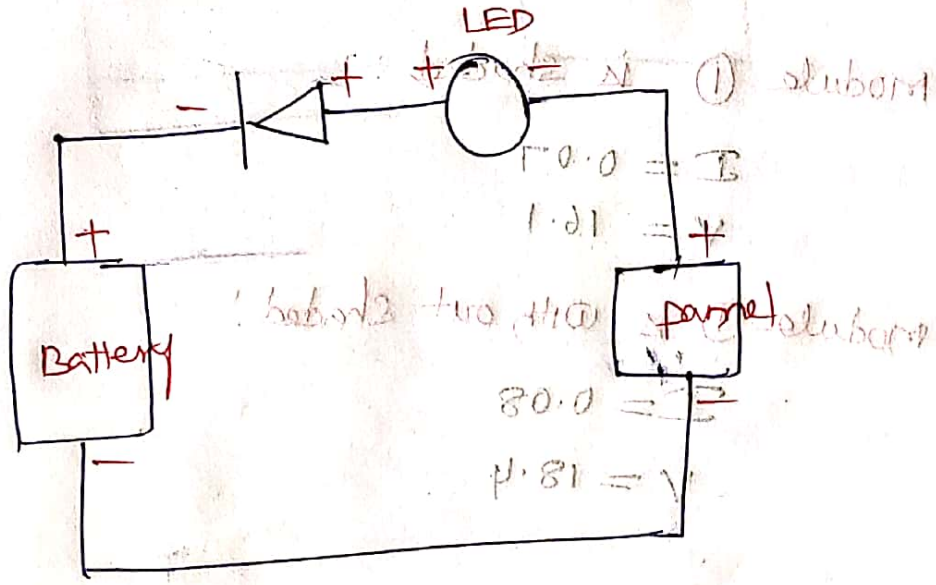
Objective :

To demonstrate the working of diode as bypass diode and blocking diode.

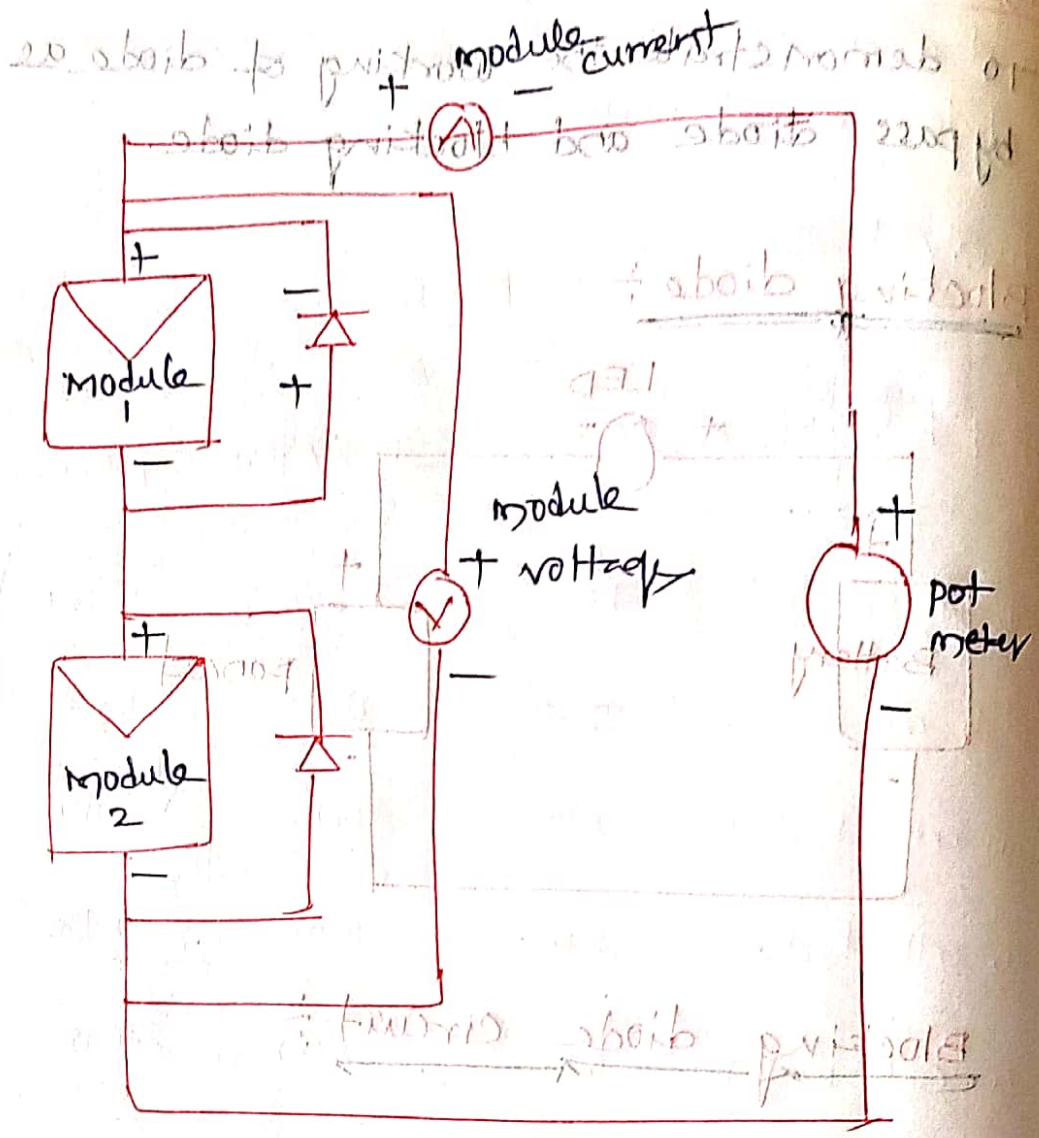
Blocking diode :



Blocking diode circuit :



Bypass diode circuit diagram



module ① is shaded :

I = 0.07

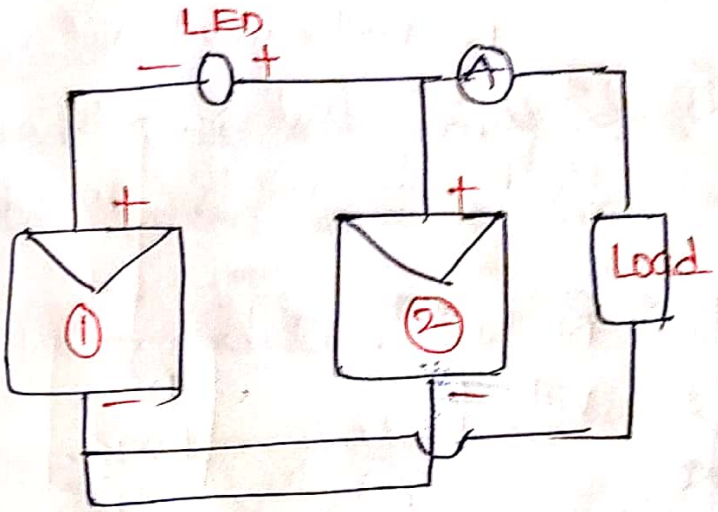
V = 16.1

module ① is with out shaded !

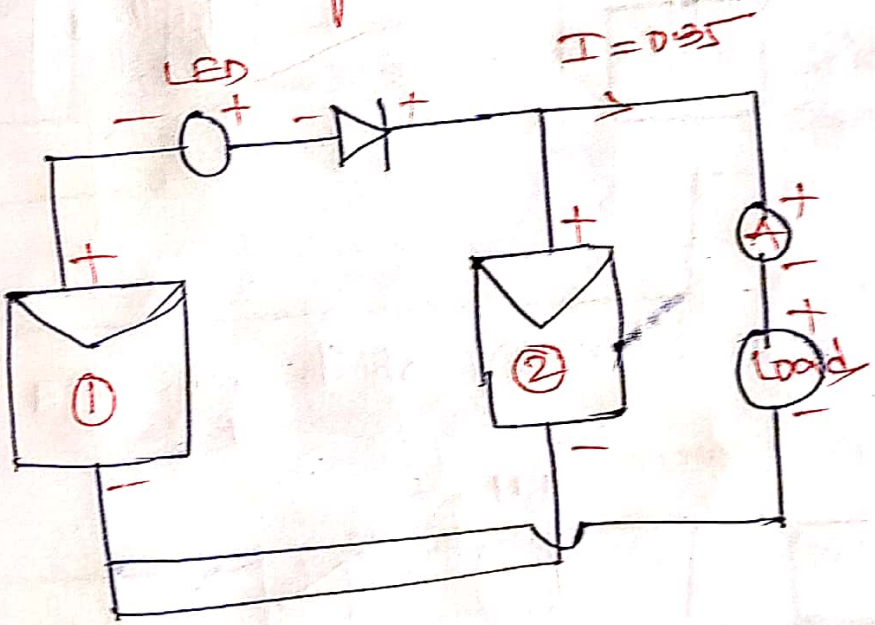
I = 0.08

V = 18.4

With No blocking diode :-



With Blocking diode :-



Experiment: 6

Objective:

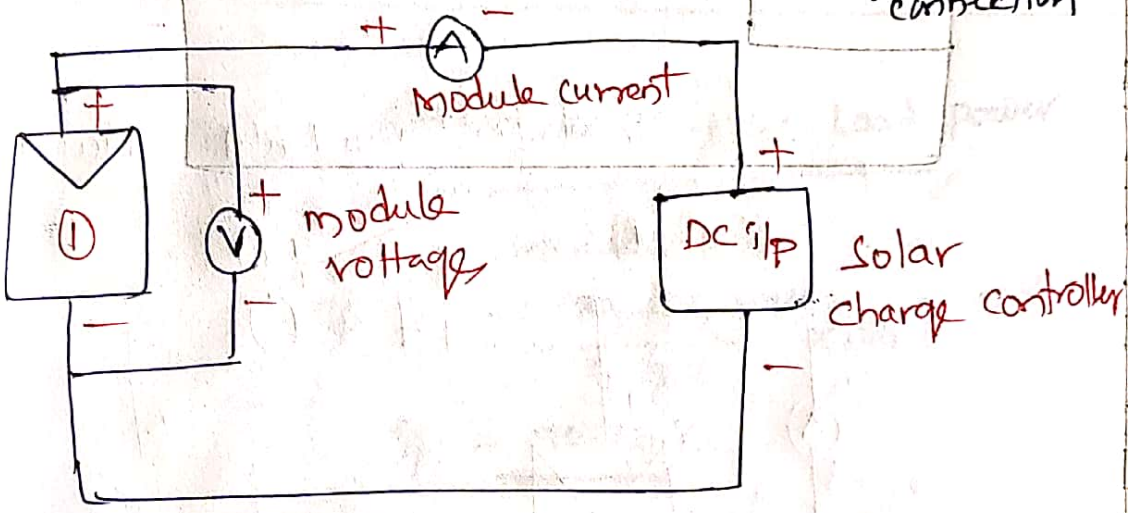
To Find efficiency of charge controller.

PV system with DC Load and Battery.

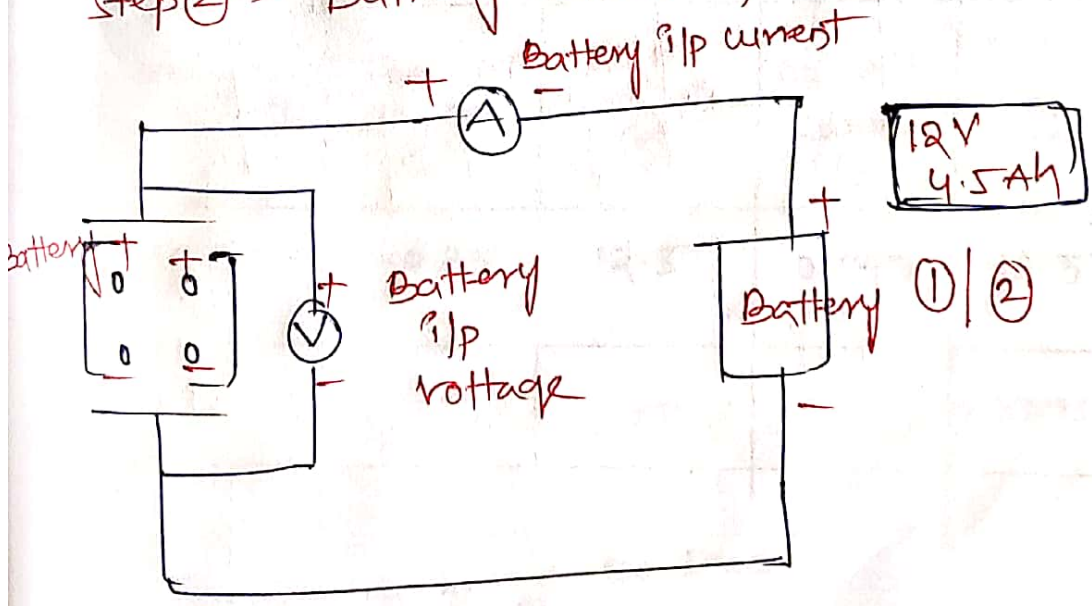
$V_o = DV_i$ D → duty cycle

Step ① → To Give input to charge controller.

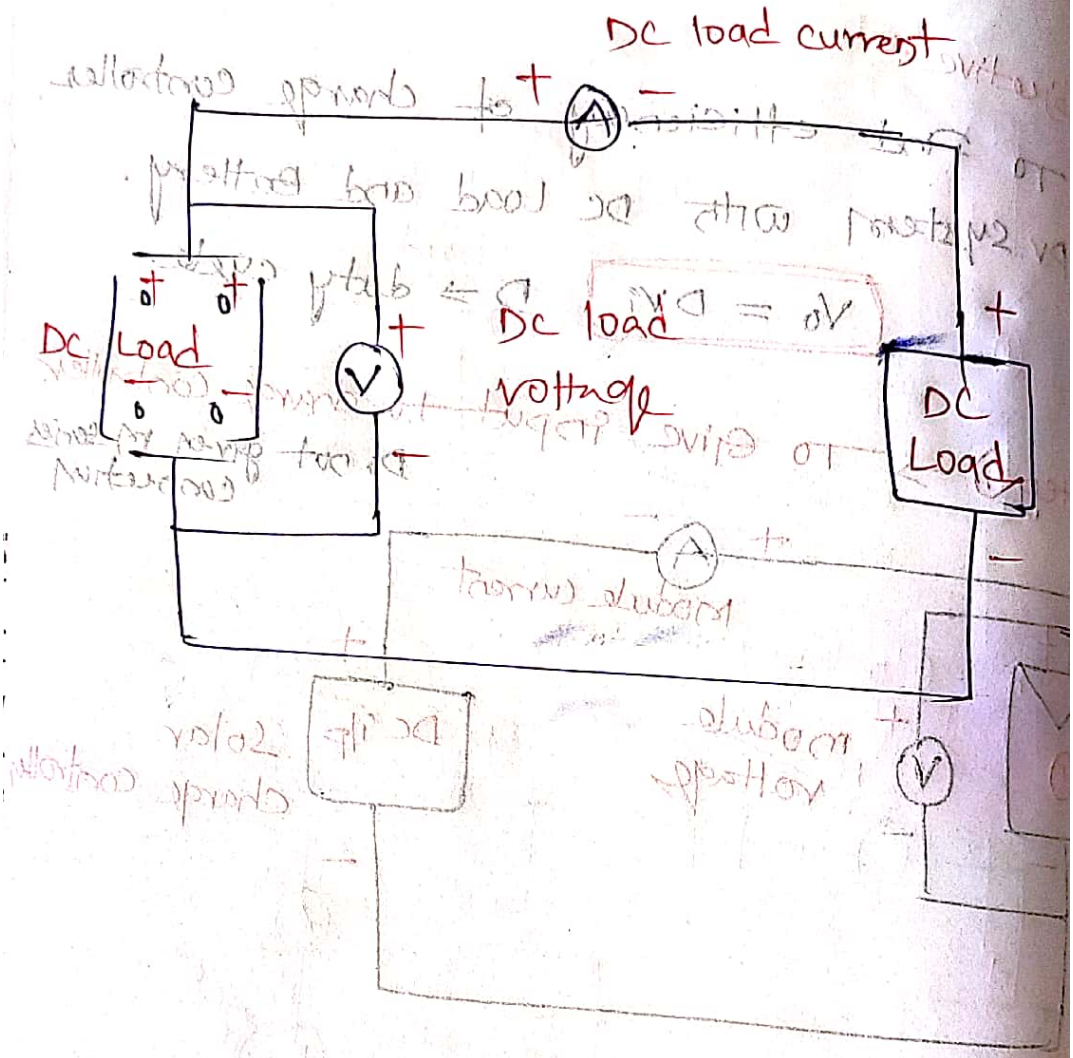
Do not given in series connection

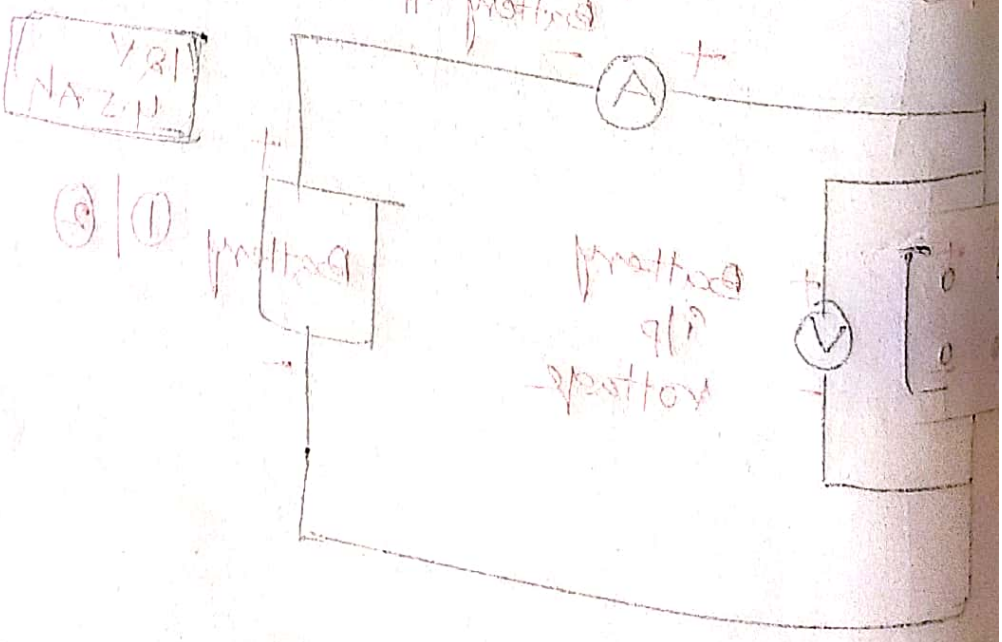


Step ② → Battery connection



Step ⑤ → DC Load connection :





observation table :-

Module current	module voltage	Battery Current	Battery voltage	DC Load current	DC Load voltage
0.33	14.6	-0.09	13.2	0.349	13.1
$P_m = 4.818\ W$		$P_B = -1.188\ W$		$P_L = 4.5719\ W$	

$$\eta = \frac{\text{Battery power} + \text{DC Load power}}{\text{Module power}}$$

$$\eta = \frac{-1.188 + 4.5719}{4.818} \times 100$$

$$\eta = 70.23\ \%$$

Without module :-

Module current (I)	module voltage (V)	Battery current (I)	Battery voltage (V)	DC load current (I)	DC load voltage (V)
0	17.7	-0.35	12.5	0.347	12.5
$P_m = 0\ W$		$P_B = -4.375\ W$		$P_L = 4.3375$	

$$\eta = \frac{\text{DC Load}}{\text{Battery Load}}$$

$$\eta = \frac{4.3375}{4.375}$$

$$\eta = 99.14$$

Experiment : 7, 8

Objective:

~~observations~~ :-

To find efficiency of Inverter. PV system with AC load and battery.

Observations :-

I_{pv}	V_{pv}	P_{pv}	I_b	V_b	P_b	I_{dc}	V_{dc}	P_{dc}	I_{in}	V_{in}	P_{in}	I_{AC}	V_{AC}	P_{AC}
0.33	13.6	4.488	-0.32	12.3	-10.086	0.34	12.3	4.268	0.74	12.2	9.028	0.023	220.1	5.0623

With AC load

I_{pv}	V_{pv}	P_{pv}	I_b	V_b	P_b	I_{IN}	V_{IN}	P_{IN}	I_{AC}	V_{AC}	P_{AC}
0.34	13.8	4.692	-0.46	12.4	-5.704	0.73	12.3	8.979	0.023	221	5.0853

$$\eta_{\text{charge controller}} = \frac{\text{DC Load power} + \text{Inverter I/p power}}{\text{module power} + \text{Battery power}}$$

$$\eta_{cc} = \frac{4.268 + 9.028}{4.488 + 10.086} = 91.23\%$$

$$\eta_{\text{Inverter}} = \frac{\text{output power of Inverter (O/P) (AC)}}{\text{Input power of Inverter I/P DC}}$$

$$\eta_{In} = \frac{5.0853}{8.979} = 56.6\%$$

Scanned with CamScanner

Experiment : 9

objective :

To draw the charging and discharging characteristics of battery.

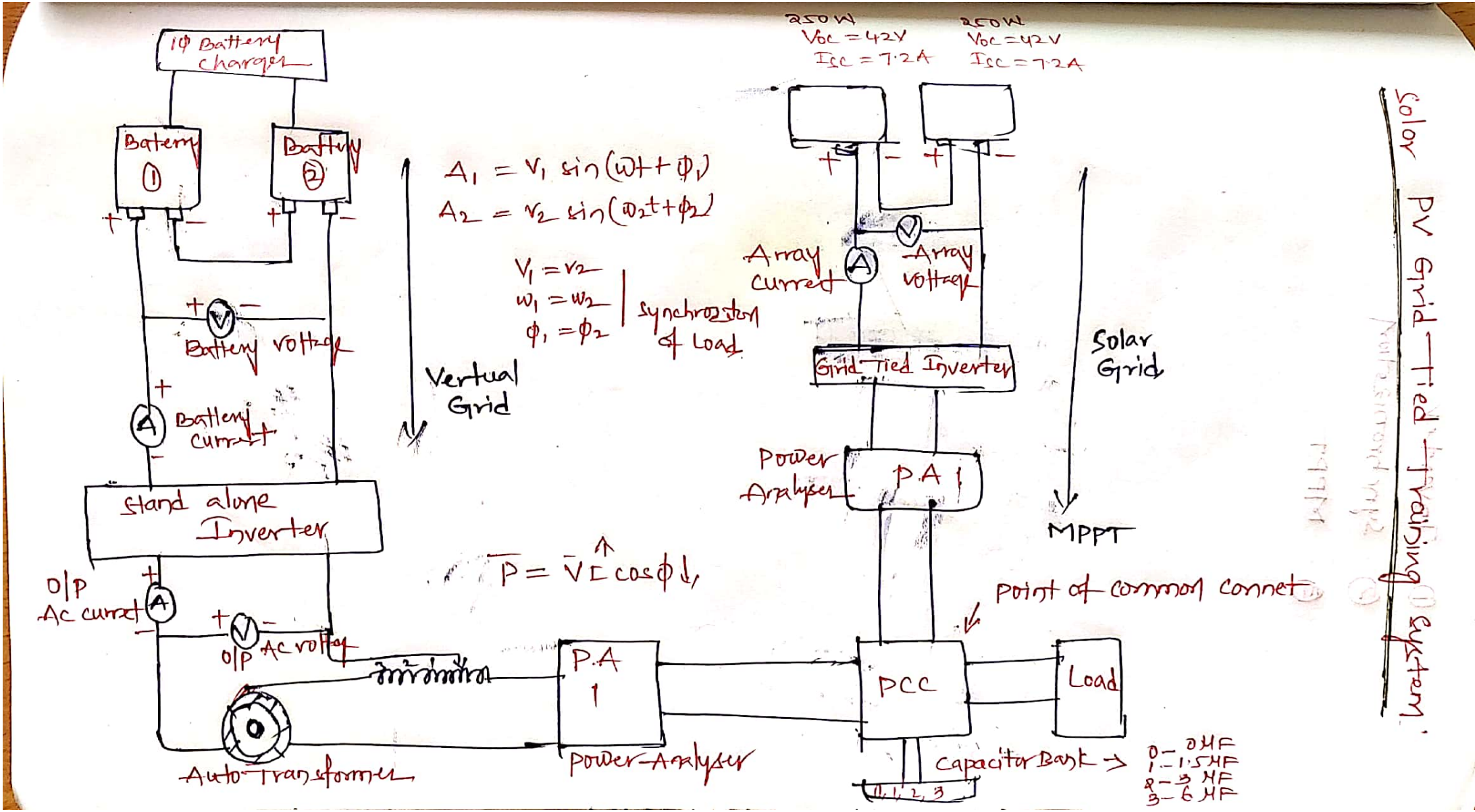
observations :

Table for charging battery :

time	module current	module voltage	Battery current	Battery voltage	Battery power
5 min	0.30	14.8	0.231	13.5	3.1185

Table for discharging battery :

Time	Battery current	Battery voltage	Battery power
0	0.745	12.4	9.238
5	0.738	12.3	9.0774
10	0.731	12.3	8.9913
15	0.726	12.3	8.9298
20	0.722	12.2	8.8084
25	0.719	12.2	8.7718

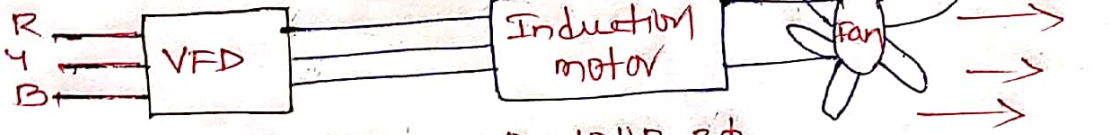


VFD – Variable Frequency Drive

P = 15 KW.

Freq = 0–60 Hz

AC, 3ϕ



No. of Blades : 7

Fan Diameter : 86cm

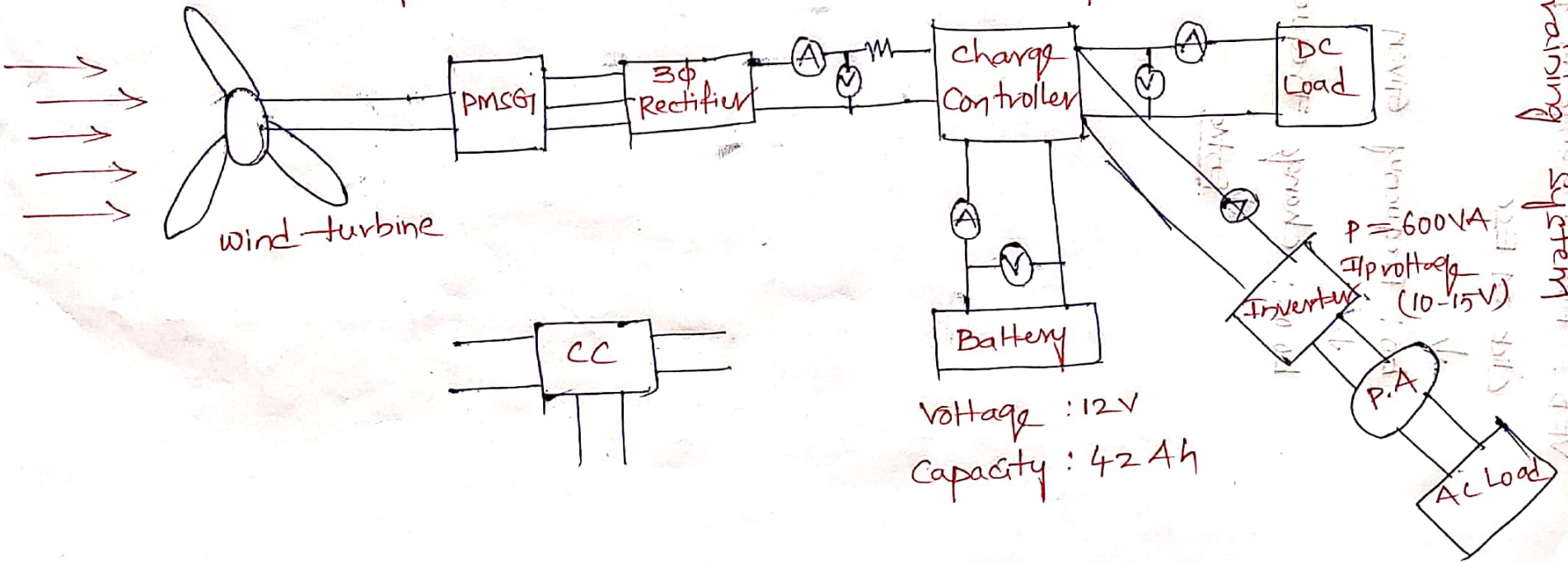
P → 10 H.P, 3ϕ

I = 14 A

Rotation Speed N = 2850 rpm

Rated; P = 500 W

Rated Load voltage : 12V



P = 600 VA

Ip voltage (10–15V)

Voltage : 12V

Capacity : 42 Ah

Wind Energy Training System

Wind Energy Training System

Experiment-1

Objective:

Evaluate the efficiency of charge controller.

Observations:

(a) Load running with battery only

S.No	Battery Current	Battery Voltage	Battery power	DC Load Current	DC Load Voltage	power Consumed by DC Load	Inverter Input Current	Inverter Input Voltage	power consumed by Inverter	Efficiency of charge Controller
DC Load 1 Bulb	1.83	11.86	21.703	1.71	11.76	20.1096				92.6547
2 Bulb	3.5	11.72	41.02	3.36	11.5	38.64				94.1979
3 Bulb	5.1	11.59	59.109	4.95	11.26	55.737				94.295
4 Bulb	6.68	11.46	76.552	6.51	11.02	71.7402				93.7133
AC+DC Load	7.49	11.61	86.958	1.68	11.52	19.353	5.62	11.69	65.697	97.8064
1	12.5	12	150	1.76	11.4	20.064	10.3	11.8	121.54	94.41
2	21.2	11.7	248.04	1.73	11.0	19.03	18.8	11.4	214.32	94.07
3	25.8	11.4	294.12	6.75	10.7	72.225	18.5	11.2	207.2	95.00

(5) Load running with battery as well as turbine:

S.No VFD Freq	Turbine Current	Turbine voltage	Turbine power	Battery current	Battery voltage	Battery power	DC Load current	DC Load Voltage	Power consumed by DC Load	Inverter Input current	Inverter Input voltage	Power consumed by Inverter	Efficiency of charge controller
1	6.2	12.2	75.64	4.5	12.1	54.45	-0.01	11.7	0.117	10.5	11.9	124.95	

Experiment-2

Objective:

Find out the start up speed and cut-in speed of wind turbine experimentally.

Observations:

observe the start up speed and cut-in speed of wind turbine:

Results:

Start-up speed and cut-in-speed are found as follows.

→ Start-up speed : 3.5 m/s (at which turbine starts to rotate)
(average of 20 readings)

→ cut-in speed : 4.1 m/s (at which turbine starts to generate some power)

Experiment : 3

Objective :

Evaluate the Tip speed ration (TSR) at different wind speeds.

Observations :

1. Diameter of blades = 1.2m
2. Wind speed and angular velocity :

S.No	Wind velocity (m/s)	Angular velocity RPM	TSR
1	3.3	680	12.947
2	3.5	784	14.074
3	5.2	870	10.51
4	5.9	939	10.00
5	7.1	1042	9.82

$$\text{TSR } \lambda = \frac{\omega R}{V}$$

λ = Tip Speed ratio

ω = Angular velocity

$$\omega = \frac{2\pi N}{60}$$

N = rpm of turbine

R = Radius of turbine = 0.6m

v = Wind velocity.

Experiment: 4

Objective:

Evaluate the coefficient of performance of wind turbine.

Observations:

S.NO	Turbine current	Turbine voltage	Turbine power	Wind speed	wind power	Coefficient of performance (Cp)
1	0.5	11.4	5.7	51.66	4.21	0.11
2	1.3	11.5	14.95	55.06	4.3	0.27
3	2.1	11.6	24.36	76.59	4.8	0.318
4	3.0	11.7	35.1	94.6	5.15	0.37
5	4.5	11.1	49.95	152.61	6.04	0.327
6	5.4	11.2	60.48	208.3	6.7	0.29
7	7.4	11.3	83.62	209.23	6.71	0.399
8	8.7	11.4	99.18	288.6	7.47	0.343
9	10.4	11.5	119.6	324.89	7.77	0.368
10	11.1	11.6	128.76	425.33	8.5	0.302
11	11.6	11.6	134.56	452.93	8.68	0.297
12	13.4	11.8	158.12	527.09	9.13	0.299
13	15.1	12.0	181.2	541.07	9.21	0.334
14	17.3	12.2	211.06	628.2	9.68	0.335
15	18.1	11.7	211.77	645.89	9.77	0.327
16	19.7	12.0	236.4	779.07	10.4	0.303

Calculation :-

① wind power = P(wind) = $\rho \times A \times v \times v / 2$

where ρ = Air Density = 1.225 kg/m³

A = Swept Area = pi × R × R

∴ R = Radius of turbine = 0.6m

V = wind velocity

② Generated power = Turbine power

③ Coefficient of performance = $\frac{\text{Generated power}}{\text{wind power}}$

Experiment : 5

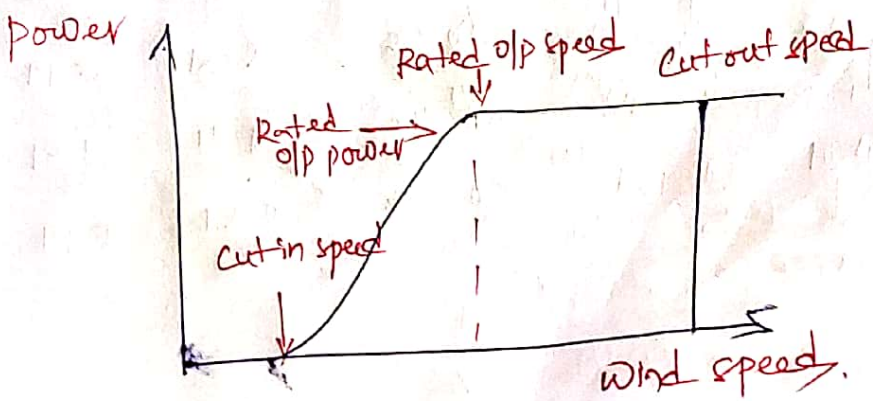
objective :

Draw the Turbine power Vs Wind speed curve.

Observations :

S.No	Wind speed m/s	Turbine Current (A)	Turbine voltage (V)	Turbine power (W)
1	3.5	1.9	11.4	21.66
2	4.4	6.4	11.7	74.88
3	7.2	10.9	12.2	132.98
4	7.4	11.2	11.9	133.28
5	8.5	14.9	12.3	183.27
6	9.3	16.8	12.5	210
7	9.5	17.9	12.5	223.75
8	9.6	19.8	12.7	251.46

Typical wind turbine power o/p with steady wind speed.



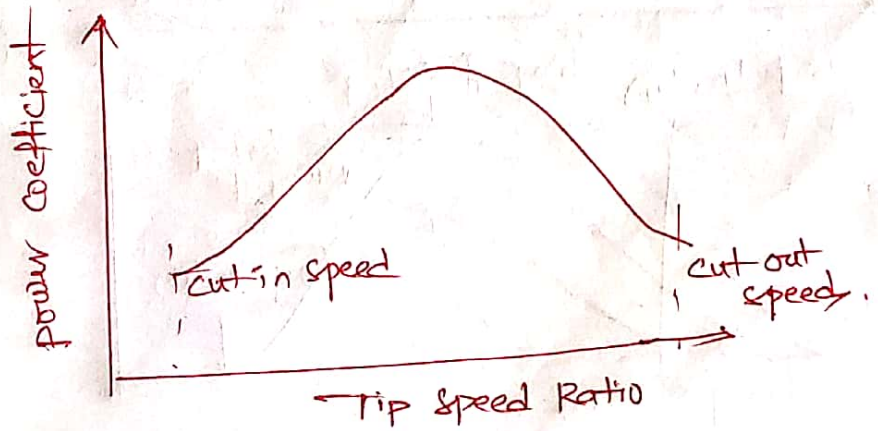
Experiment : 6

Objective :

Draw the curve b/w TSR and Coefficient of power.

Observations :

S.No	wind speed (m/s)	RPM	Turbine current (A)	Turbine voltage (V)	Turbine power (W)	Angular velocity ω	wind power	TSR	Cop
1	4.5	821	3.9	12.0	46.8	85.974	63.092	11.463	0.74
2	5.8	914	6.6	11.6	76.56	95.713	135.08	9.901	0.566
3	6.6	1050	10.3	11.9	122.57	109.95	199.05	9.995	0.615
4	7.8	1102	15.0	11.8	177.0	115.40	328.56	8.876	0.538
5	6.6	855	5.5	11.5	63.25	89.53	199.05	8.139	0.317
6	7.15	920	7.4	11.7	86.58	96.342	253.079	8.084	0.342
7	8.3	981	8.6	11.8	101.48	102.73	395.88	7.426	0.256
8	8.6	1106	13.2	12.3	162.36	115.82	440.38	8.080	0.36



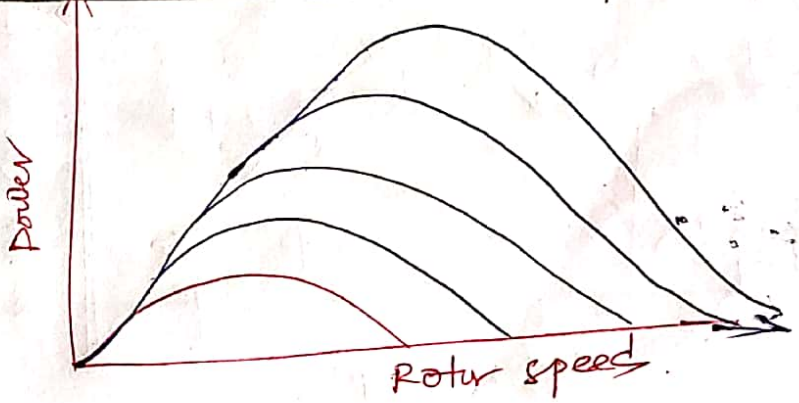
Experiment : 7

objective :

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

observations :-

S.No	Turbine current	Turbine voltage	Turbine power	Wind speed	RPM
1	0	11	0	6.3	304
2	3.5	11.3	39.55	6.3	650
3	4.7	11.5	54.05	6.3	650.8
4	5	11.5	57.5	6.3	651
5	4.3	11.5	49.45	6.3	819.9
6	3.9	11.5	44.85	6.3	820.9
7	4.7	11.5	54.05	6.3	832.8
8	3.9	11.5	44.85	6.3	832.8
9	4.2	11.5	48.3	6.3	835
10	4.7	11.5	54.05	6.3	840.5
11	4.7	11.5	54.05	6.3	844.7
12	5.2	11.5	59.8	6.3	844.7
13	4.6	11.5	52.9	6.3	844.7
14	4.4	11.5	50.6	6.3	847.3
15	4.9	11.5	56.35	6.3	847.8



Experiment: 8

Objective:

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

Observations: @ parameters with changing wind speed

S.No	Turbine voltage (V)	Turbine current (A)	Turbine power (W)	Battery voltage (V)	Battery current (A)	Inverter I/P current (A)	Inverter I/P voltage (V)	Inverter O/P current (A)	Inverter O/P voltage	Inverter O/P power Factor	Wind speed	Wind power (W)
1	11.8	7.9	93.22	11.6	2.9	10.2	11.4	0.428	230.6	0.99	7.44	98
2	11.8	8.7	102.66	11.7	1.8	10.2	11.5	0.43	233.2	0.99	7.32	99
3	11.8	8.9	105.02	11.7	1.9	10.2	11.5	0.43	235.2	0.99	8.27	100
4	12.1	11.4	137.94	11.5	0.5	10.3	11.7	0.434	237.7	0.99	9.00	102
5	12.2	12.6	153.72	11.9	1.7	10.4	11.8	0.431	239	0.99	9.48	10.3
6	12.5	19.8	247.5	12.2	4.0	10.5	12.0	0.437	239.1	0.99	9.48	10.4

(b) parameters with changing Load value:

S.No	Turbine voltage (V)	Turbine current (A)	Turbine power (W)	Battery voltage (V)	Battery current (A)	Inverter I/P current (A)	Inverter I/P voltage (V)	Inverter O/P current (A)	Inverter O/P voltage (V)	Inverter O/P p.f	Load (W)
1	12.1	11.4	137.94	11.9	0.7	10.2	11.7	0.428	238.4	0.99	101
2	12.8	11.7	149.76	11.4	-6.9	18.5	11.2	0.821	219.5	0.99	179

Experiment : 9

Objective :

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

Observations :

(a) parameters with changing with speed :

S.NO	Turbine current (A)	Turbine voltage (V)	Turbine power (W)	Battery voltage (V)	Battery current (A)	DC Load Current (A)	DC load voltage (A)	Wind speed (m/s)
1	0	2.0	0	11.5	3.4	10.9	3.45	2.91
2	0	2.0	0	11.5	3.4	10.9	3.45	3.30
3	0.3	11.3	3.39	11.5	2.9	10.9	3.45	4.00
4	1.1	11.2	12.32	11.5	3.5	10.9	3.45	4.72
5	2.1	11.3	23.73	11.5	2.9	11.0	3.45	4.93
6	3.2	11.5	36.8	11.6	1.6	11.0	3.47	5.78
7	3.9	11.5	44.85	11.6	1.9	11.1	3.48	5.78
8	5.4	11.7	62.1	11.8	0.02	11.2	3.5	6.76
9	6.2	11.8	73.16	11.9	1.2	11.3	3.52	7.032
10	7.1	11.9	84.49	11.9	1.9	11.3	3.52	7.15
11	7.7	11.9	91.63	11.9	2.2	11.5	3.56	7.78
12	10.1	12.2	123.22	12.1	4.5	11.7	3.59	8.05
13	11.3	12.5	141.25	12.2	6.1	11.9	3.62	9.3
14	13.0	12.6	163.8	12.4	7.8	12.0	3.64	9.33

(b) parameters with changing Load :-

S.No	Turbine Current (A)	Turbine voltage (V)	Turbine power (W)	Battery voltage (V)	Battery current (A)	DC load voltage (V)	DC load current (A)	DC Load power (W)	Wind Speed
1	9.7	12.6	122.22	12.5	7.9	1.82	12.1	22.02	9.3
2	10.5	12.6	132.3	12.4	7.1	3.63	11.9	43.197	9.3
3	10.8	12.5	135	12.4	5.4	5.40	11.8	63.72	9.3
4	9.3	12.3	114.39	12.3	2.5	7.10	11.6	82.36	9.3