HYBRID POWER GENERATION MODEL USING SOLAR AND WIND ENERGY

SONARGAON UNIVERSITY (SU)

Submitted by

Md. Rahat Khan	ID: BME2001020284
Sreejib Mistri	ID: BME2001020285
Pikul Biswas	ID: BME2001020286
Humayun Kabir	ID: BME2001020287
Shuvrajit Mondal	ID: BME2001020289

Under the Supervision of

Niloy Sarkar
Assistant Professor
Department of Mechanical Engineering.
Sonargaon University. (SU)

Date of Submission: September, 2023

DECLARATION

We hereby declare that the undergraduate thesis project work reported in this thesis has been performed by us under the supervisor of Niloy Sarkar and this work has not been elsewhere for any purpose (except publication).

Md. Rahat Khan
ID: BME2001020284

Sreejib Mistri
ID: BME2001020285

Pikul Biswas
ID: BME2001020286

Humayun Kabir
ID: BME2001020287

Shuvrajit Mondal
ID: BME2001020289

ACKNOWLEDGEMENT

All praise and thanks to Almighty Allah who has enabled us with mercy to represent the reported study of “**Hybrid Power Generation Model Using Solar and Wind Energy”**.

The authors would like to express thanks to a supervisor, Niloy Sarkar, Assistant Professor, Department of Mechanical Engineering, Sonargaon University, Dhaka, for his sincere guidance, kind cooperation, supervision constant encouragement and valuable suggestions in this thesis and project work with powerful instruction. Special thanks to Md. Mostafa Hossain, Department Head, Faculty of Mechanical Engineering, Sonargaon University, Dhaka, for providing and offering valuable support as an administrator.

ABSTRACT

As the race for global industrialization begin late in 18th century, the developing technology made humans to depend on energy, so as the energy crisis begins, in this modern era, electricity become a most essential need of human beings, from household to industrial work. So, the purpose of the project is to generate electricity without using non-renewable resources and pollution. Since, renewable standalone energy generation system have disadvantages, which need to be overcame by hybrid systems. Wind and solar energy have being popular ones owing to abundant, ease of availability and convertibility to the electric energy. This work covers realization of hybrid energy system for multiple applications, which runs under a designed circuitry to utilize the solar and wind power. And a designed circuitry for more efficient results, and inverters to convert the electrical energy as per demand.

List of Contents

List of Figure

List of Table

Chapter- 1

Introduction

1.1 Introduction

Hybrid Renewable Energy Systems (HRES) are becoming popular as stand-alone power systems for providing electricity in remote areas due to advances in renewable energy technologies and subsequent rise in prices of petroleum products. A hybrid energy system, or hybrid power, usually consists of two or more renewable energy sources used together to provide increased system efficiency as well as greater balance in energy supply. Most of us already know how a solar/wind power generating system works, all these generating systems have some or the other drawbacks (considering standalone system), like Solar panels are too costly and the production cost of power by using them is generally higher than the conventional process, it is not available in the night or cloudy days. Similarly Wind turbines can't operate in high or low wind speeds. Solar hybrid power systems are hybrid power systems that combine solar power from a photovoltaic system with another power generating energy source. This would create more output from the wind turbine during the winter, whereas during the summer, the solar panels would produce their peak output. Hybrid energy systems often yield greater economic and environmental returns than wind, solar, geothermal or regeneration stand-alone systems by themselves.

1.2 Objectives:

The objectives of conducting this project are,

- To study about renewable energy sources.
- To study about renewable energy sources used in Bangladesh.
- To design a model for power generation using solar and wind energy.
- To construct the model measure relatable date.
- Street lightings covering a large area.
- Traffic signalling and in many applications.
- Discuss energy market in Bangladesh.
- Design a wind – solar hybrid system for a selected suitable location.

1.3 Problem Identification & Motivation

With the world oil crisis, dangers of overdependence on oil pushed for the development of alternative energy sources. Current international trend in electricity generation is to utilize renewable energy resources. Solar, wind, biomass, micro hydro systems can be seen as suitable alternatives to conventional power. With the expectation of promoting electricity generation based on non-conventional renewable energy, the Government of Bangladesh introduced an Energy Policy to achieve a 10% target of power generation through non-conventional renewable energy by year 2015 and 20% by 2020 [1].

According to the wind energy resource atlas of Sri Lanka developed by the National Renewable Energy Laboratory (NREL) of the United States, there are 5,000km^2 of windy areas with good to excellent wind resource potential in Bangladesh. The windy area represents about 6% of total land area of Sri Lanka and this windy area could support 24,000MW [4].

Bangladesh is situated close to the equator, therefore receives an abundant supply solar radiation year around. Solar radiation over the island does not show a marked seasonal variation, though significant spatial differentiation could be observed between the lowlands and mountain regions. Over most parts of the flat dry zone, which accounts for two-thirds of the land area, solar radiation varies between 4.5 – 6.0 kWh/m^2/day. Solar radiation levels remain as low as 2.0 – 3.5 kWh/m^2/day over the high plains of hill country due to the significant cloud cover over most parts of the day [5]. Thus, a substantial potential exists in the dry zone of Sri Lanka for harnessing solar energy.

So far these vast renewable energy resources, wind and solar, are not sufficiently harnessed for electricity generation in Sri Lanka. Thus, in this thesis a hybrid renewable power generation system integrating the available solar and wind resources will be investigated in detail for a specific location.

1.4 Problem Statement

Since the sources of both individual solar and wind energy are not stable and often inconsistent. It is required to hybridize the power generation of wind and solar energy source with batteries bank as the storage to overcome the periods without wind or solar energy supplies a stable and constant power generation. However, in the case of wind power, it is totally different to the conventional fossil fuel, nuclear power plant and hydroelectric power station. Meanwhile, wind energy is one of the least expensive renewable energy technologies currently. PV cells or photovoltaic is

Commonly known as solar cells, it able to convert the thermal energy from sunlight into direct current electricity. Solar energy offered major advantages which are better than other renewable energy such as no noise pollution during the power generation and insignificant periodic maintenance required. (Subramanian and Alluyada, 2012)

Although the solar and wind energy are known as dependable and widely available renewable energy sources in Malaysia, but the intermittent energy sources will cause the power generator to produce a fluctuating output. For example, we could not generate energy using a standalone PV system at night or during a cloudy day because there is no solar radiation. Similarly, the varying wind speed will affect the amount of energy generated by a standalone wind turbine system. . In other words, both standalone systems do not present desirable efficiency in generating energy.

Conventional solar systems occupy valuable land to absorb the sun light with larger solar panel as possible. Therefore, compact design is required to overcome the constraint of space due to the land pricing keep increasing and sun tracking solar systems are experienced in higher cost of installation.

Hence, in the project, hybrid solar and wind turbine system was introduced for the operation in day and night. In daylight hours, solar system can achieve the highest efficiency during the sunny day. Wind turbine able to function during day and night time without any restriction of climate with at least of wind. In order to achieve the highest efficiency for renewable energy systems in whole day, hybrid solar wind turbine system is one of optimum solution to generate the energy in anytime and all weather conditions.

1.5 Aim

This research is aiming to design the model of hybrid solar wind turbine in single setup and then investigate the feasibility of the hybrid solar vertical wind turbine system, energy output and storage.

1.6 Scope of study

1. Weather data collection of solar radiation and wind speed at Bangladesh
2. Modelling of hybrid solar vertical wind turbine in CAD Software, SolidWorks.
3. Simulation of hybrid solar wind turbine would be carried out with separated into individual standalone system due to the constraint of software ability.
4. Wind Turbine would be simulated by Computational Fluid Dynamics (CFD) based on wind speed data at Southern Region Bangladesh.
5. Solar system would be simulated in HOMER based on solar radiation data during sunny day daylight hours.

Chapter- 2

Renewable Energy in Source Bangladesh

2.1 Solar Energy

Bangladesh is situated between 20.30 - 26.38 degrees north latitude and 88.04 - 92.44 degrees east which is an ideal location for solar energy utilization. Daily average solar radiation varies between 4 to 6.5 kWh per square meter. Maximum amount of radiation is available on the month of March-April and minimum on December-January. Different R&D Organizations, Institutes and Universities are collecting solar insolation at different parts of Bangladesh. Some of them are presented in this chapter.

2.1.1 Available Solar Insolation Data

At present, solar insolation data can be found from the following sources:

- Renewable Energy Research Centre (RERC), Dhaka University (DU) is the only source which has got long-term measured data of Dhaka city in Bangladesh [UNESCAP 2000]. The published data are average of results of hourly measurements of over three years global (G) and diffuse (D) radiation with Employ Precision Pyrometer.
- Bangladesh Meteorological Department has 34 sunshine recording stations situated generally in towns and cities.
- Department of Mechanical Engineering, Bangladesh University of Engineering (BUET) and Technology, has also got time series data of Dhaka city.

Apart from the above-mentioned sources, few other organizations or institutes have also measured time series of global radiation, direct or beam radiation, diffuse radiation, sunshine hours and temperatures of different parts of the country. But for meticulous estimation and simulation of different solar energy applications several other parameters are required which are not available at the moment. Monthly Global Solar Insolation at different cities of Bangladesh and Daily Average Bright Sunshine hour at Dhaka city are presented in Table 2.1 and 2.2 respectively.

Monthly Global Solar Insolation at Different Cities of Bangladesh (in kWh/m^2/day)

Month	Dhaka	Rajshahi	Sylhet	Bogra	Barishal	Jessor
January	4.03	3.96	4.00	4.01	4.17	4.25
February	4.78	4.47	4.63	4.69	4.81	4.85
March	5.33	5.88	5.20	5.68	5.30	4.50
April	5.71	6.24	5.24	5.87	5.94	6.23
May	5.71	6.17	5.37	6.02	5.75	6.09
June	4.80	5.25	4.53	5.26	4.39	5.12
July	4.41	4.79	4.14	4.34	4.20	4.81
August	4.82	5.16	4.56	4.84	4.42	4.93
September	4.41	4.96	4.07	4.67	4.48	4.57
October	4.61	4.88	4.61	4.65	4.71	4.68
November	4.27	4.42	4.32	4.35	4.35	4.24
December	3.92	3.82	3.85	3.87	3.95	3.97
Average	4.73	5.00	4.54	4.85	4.71	4.85

Source : Dr. Shahida Rafique, Dhaka University, recorded from 1988 to 1998

Table2. 1 Monthly Global Solar Insolation at Different Cities of Bangladesh (in kWh/m2 /day)

Month	Daily Mean	Maximum	Minimum
January	8.7	9.9	7.5
February	9.1	10.7	7.7
March	8.8	10.1	7.5
April	8.9	10.2	7.8
May	8.2	9.7	5.7
June	4.9	7.3	3.8
July	5.1	6.7	2.6
August	5.8	7.1	4.1
September	6.0	8.5	4.8
October	7.6	9.2	6.5
November	8.6	9.9	7.0
December	8.9	10.2	7.4
Average	7.55	9.13	6.03

Table2. 2 Daily Average of Bright Sunshine Hours at Dhaka (Average period: 1961 to 1980)

2.1.2 Application of Satellite Remote

Sensing for RET Projects Unfortunately, all the measured data of above-mentioned sources are collected for main cities of the country, which are electrified and not a prospective site for RET application. The surface topology has a major influence on micro-climate resulting in highly variable wind resources and significantly variable solar resources over small areas. Due to this reason, for assessment of RET projects in the far-flung areas of Bangladesh, Satellite Remote Sensing technology can be applied.

Hourly global insolation from satellites with a ground resolution of a few kilometres reproduce data sets with a relative Root Mean Square Error (RMSE) of typically 20-25% [Perez et. al. 1999]. But it has been found out from rigorous analysis that for hourly data, the satellite data become more accurate than a local ground station if the distance from the station exceeds 34 km [Perez et. al. 1997]. At present, many organizations provide remote sensing data, gathered from geo-stationary or polar orbiting satellites, appropriate for RET project appraisal.

NASA has recently launched a renewable energy resource web site called "Surface meteorology and Solar Energy Data Set (SSE)" available in the Internet free-of-charge. Another advantage of user friendly SSE is linked with the Renewable Energy Project Analysis Software (RETScreen) which will be used in this thesis work for analysis of RET Projects in Chapter 6. Application of SSE for solar energy resource assessment is presented in the next topic.

2.1.3 SSE for Solar Energy Resource Assessment

SSE data set is formulated from NASA satellite- and reanalysis-derived insolation and meteorological data for the 10-year period from July 1983 through June 1993. Results are provided for 1°latitude by 1° longitude grid cells over the globe. The SSE global data set makes it possible to quickly evaluate the potential of renewable energy projects for any region of the world and is considered to be accurate for preliminary feasibility studies of renewable energy projects [Charles H. Whitlock et. al. 2000].

2.1.3 SSE provides:

- over 100 satellite-derived meteorology and solar energy parameters ü monthly averaged from 10 years of data
- data tables for a particular location ü colour plots on both global and regional scales
- global solar energy data for 1195 ground sites

Estimated uncertainties of SSE data set for solar energy parameters are found by comparing with (1) World Radiation Data Centre (WRDC) ground measurement data (2) RETScreen Ground Monitoring 8 Stations Weather Database and (3) The RETScreen database available from the RETScreen Website which are shown in Table.

Parameter	Global sites WRDC	Global sites RETScreen	Renewable sites RETScreen
Solar Insolation (kWh/m2/day)	14.2%	13.0%	
Near-Surface Air Temperature (K) (10 meter altitude)		< 243 K = 3.2% > 263 K = 1.1% linear variation between 243 K and 263 K	1.2%
Heating Design Temperature (K)			1.3%
Cooling Design Temperature (K)			1.4%
Summer mean daily design range (K)			0.9%
Heating degree-days below 18° C (degree-days)			14.6%

Table2. 3 Estimated Uncertainty with SSE Data sets [SSE, 2000]

2.1.4 Example of SSE Application

Thanchi is one of the remotest thana (sub-district) located in the Chittagong Hill Tracts regions of Bangladesh. People of Thanchi suffer from inconvenience due to poor communication system of the area, particularly with the district town. The local river “Shangu” is navigable only for five months in a year. By an engine boat it often takes 15 hours and by road 2 days with a night halt to reach the district town Bandarban. National electricity grid is not present in Thanchi and chances of extending them is also bleak in the near future. So, Thanchi is an ideal place for application of RETs, especially Solar Photovoltaic.

For using the RETScreen Solar Photovoltaic Project Model, site specific solar insolation and temperature data has to be fed. These two parameters can be obtained from SSE web site with respect to the latitudes and longitudes of Thanchi and presented in Table 2.4 and 2.5.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10 Year Average Daily Insolation	4.88	5.41	6.22	6.14	5.68	3.62	3.43	3.67	4.09	4.51	4.32	4.47

Table2. 4 Average Daily Radiation on Horizontal Surface in Thanchi (in kWh/m2 /day)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10 Year Average Temperature	18.4	20.6	23.6	24.5	25.2	26.0	25.8	25.8	25.4	24.4	22.0	19.2	23.4

Table2. 5 Average Temperature in Thanchi (in °C)

2.2 Solar and Wind Energy Resource Assessment (SWERA) Project

In most of the developing countries, renewable resource information is absent or inadequate. This is one of the major barriers for wide-spread deployment of RETs in these countries. Understanding this obstacle, UNEP is carrying out a 3-year long “Solar and Wind Energy Resource Assessment (SWERA)” project with GEF fund. The overall goal of this project is to promote the integration of wind and solar alternatives in national and regional energy planning and sector restructuring as well as related policy making. The project will enable informed decision making and enhance the ability of participating governments to attract increased investor interest in renewable energy.

2.2.1 Components

Five components of SWERA are shown in Table

Components	Activity
Solar Resource Assessment	✓ Solar Resource Assessment ✓ Gather Relevant Meteorological Data from National or other Archives ✓ Develop Solar Resource Maps ✓ Generate Time-Series Data ✓ Relate short -term satellite-derived time series to long-term ground-based time Series ✓ Conduct Cross-Model Comparisons and Validation Studies
Wind Resource Assessment	✓ Review of Existing Wind Surveys and Assessment Methodologies ✓ Gather Existing Relevant Wind Data ✓ Process Data Sets and Perform Critical Analysis of Data Quality ✓ Adjustment of Surface Observations using WAsP methods ✓ Generate High-Resolution Wind Maps ✓ Prepare Wind Atlas ✓ Conduct Cross-Model Comparisons and Validation Studies
Integration with Geographic Information System (GIS)	✓ Develop standard GIS datasets ✓ Develop GIS Toolkit ✓ Needs assessment for in-country partners ✓ Establish global archive
National Application of the SWERA tools and information	✓ Alternative business development scenarios in energy supply ✓ Marketing and presentation of the alternative energy development projections to investors
Management and Coordination	✓ Coordination of project activities ✓ Meetings

Table2. 6 Components and Activities of SWERA

2.2.2 Solar Resource Assessment of Bangladesh by the SWERA Project

High resolution (approx. 0.05 o to 0.15 o , 1-3 hourly) site/time specific solar resource datasets will be derived from geostationary satellite - INSAT and METEOSAT5. It is expected that since INSAT has higher spatial resolution and METEOSAT has higher time resolution the combination will give the best product. Maps and GIS data sets of monthly and yearly sums of Global Radiation and of Direct Radiation covering the land areas of Bangladesh will be made available with an expected accuracy of better than 10% with respect to the annual sum of solar radiation. The maps will be based on 3 years of time series data with a time resolution of 1 hour. Bangladesh will have:

- Access to enhanced solar resource maps and expanded databases including national validation results and expanded time series information.
- The capacity to use the data in an effective manner to facilitate solar technology investment.
- Understanding of how the resource data are developed

- Improved ability to undertake measurement programs for further validation data ü site-specific pre-feasibility studies

2.3 Wind Energy

In Bangladesh, some early studies on wind energy prospects were made by Professor Muhtasham Hussain of Dhaka University and his colleagues [Hussain et. al 1986], as well as some enthusiasts from Bangladesh University of Engineering and Technologies (BUET). The Bangladesh Meteorological department has wind speed measuring stations in towns and cities. Data from earlier measurements and analysis of upper air data by CWET India show that wind energy resource of Bangladesh is not good enough (>7 m/s) for grid connected wind parks [GEF 2001]. Wind data from Bangladesh Meteorological Department and different previous and ongoing wind resource assessment projects are briefly described in the subsequent sections.

2.3.1 Wind Data from Bangladesh Meteorological Department

Most of the previous wind speed data in Bangladesh is available from the Bangladesh Meteorological Department. Average values calculated from such wind data during 1961 to 1993 are presented in Table.

Some of the meteorological stations have automatic data logging systems which record wind-speed data onto paper rolls but rest are recorded by office stuff. These are collected and set to the Headquarters in Dhaka where they are entered on computer and made available at an agreed cost to interested parties in addition to their being used for weather forecasting purposes. From experience reported by those interested in wind energy in measurements at low heights and relatively inaccurate instruments.

Bangladesh Centre for Advanced Studies (BCAS) obtained and reviewed Bangladesh Meteorological Department records with a view to establishing the prospects for wind energy and the following information about the wind climate in Bangladesh had been found:

- ✓ Wind speeds at most Met Office stations appear to be low, with typical annual mean wind speeds of 2 to 4 knots or 1 to 2 m/s, at heights between 5 to 10 meter above ground level.
- ✓ Wind speeds appear to be higher in the east of the country than the west.
- ✓ Wind speeds in the coastal areas appear to be higher than inland. ü Wind speed exhibits a strong seasonal cycle, lowest in the winter and higher in the summer.
- ✓ Wind speed exhibits a diurnal cycle, generally peaking at noon and weakest at night.

Site	Reference height (m)	Annual average wind speed (m/s)
Teknaf	5	2.16
Cox's Bazar	10	2.42
Patenga Airport	5	2.45
Kutubdia Island	6	2.09
Sandip Island	5	2.16
Hatia Island	6	2.08
Bhola Island	7	2.44
Khepupara	10	2.36
Comilla Airport	6	2.21

Table2. 7 Annual average wind speed of different sites of Bangladesh during 1961 to 1993

Map of Bangladesh showing annual average wind speed in knots. Number in parentheses represent old data and number outside are data collected by Hussain et. al. in 1986

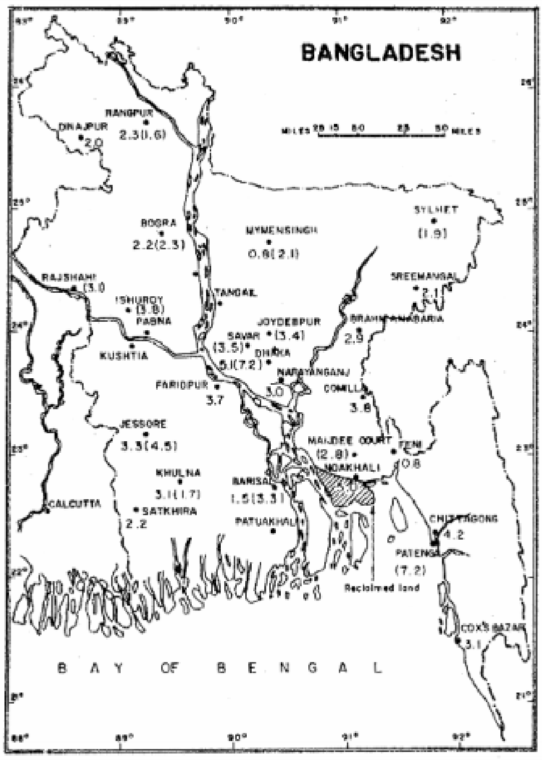


Figure 2. 1 Map of Bangladesh showing annual average wind speed in knots.

The Wind Energy Study (WEST) Project of Bangladesh Centre for Advanced studies (BCAS) was an attempt to collect wind-speed data through technically sound monitoring system, since no such study had previously been done in Bangladesh. The project was approved by Aid Management Office, Dhaka (AMOD) in September,1995. BCAS has been provided with necessary technical assistance and cooperation by Energy Technical Support Unit (ETSU), Harwell, UK in the implementation of the project. Local Government Engineering Department (LGED) helped in installation of the wind monitoring masts, collection and dispatch of data cards from the monitoring sites to BCAS Headquarters at Dhaka on regular basis.

Table2. 8 Monthly average wind speeds from seven WEST stations

Month	Monthly Mean Wind Speed (m/s)	Standard Division of Wind Speed (m/s)	Peak Wind Speed (m/s) (Date/Time)	Lull Period (Hours)	Coefficient of Variation	Prevailing Wind Direction
August' 96	5.88	0.65	19.83 (21/08:40 hr)	9.47	0.13	SW
September' 96	3.77	0.57	21.92 (28/07:00 hr)	140.5	0.2	SW
October' 96	2.18	0.46	23.17 (29/20:50 hr)	426.33	0.23	N/NE
November' 96	1.98	0.48	13.17 (5/06:40 hr)	236.33	0.29	N/NE
December' 96	3.35	0.48	9.42 (7/09:10 hr)	12.33	0.16	N
January' 97	3.18	0.44	10.25 (22/13:00 hr)	36.5	0.15	W/SW
February' 97	3.37	0.42	14.42 (1/09:50 hr)	19.33	0.14	SW
March' 97	4.84	0.5	35.25 (23/04:30 hr)	6.67	0.12	W/SW
April' 97	4.93	0.57	35.67 (7/06:40 hr)	7.67	0.13	W/SW
May' 97	6.28	0.63	21.5 (19/15:40)	6.83	0.11	W/SW
June' 97	7.31	0.68	24 (27/07:30 hr)	20.67	0.1	W/NE
July' 97	7.34	0.65	20.67 (10/05:40 hr)	3.09	0.1	W
Average (Aug' 96-Jul' 97)	4.54	0.54		0.26	0.01	

Table2. 9 Wind energy potential in Kuakata (Sensor Height: 25m)

2.3.3 Frequency

The frequency distribution were constructed for one year data collection period. The shape of the frequency curves is generally found to be skewed due to low frequency for high speed values and high frequency for low speed values. Significant variations were observed in the monthly frequency distribution specially between periods of high and low wind speed months. In the case of Patenga station for example, the frequency above 4m/sec was above 70% in June compared to less than 7% in November. The frequency distribution for entire data collection period showed in the Table

2.3.4 Diurnal Variation

The diurnal cycles showed that wind speed reaches its maximum during 12 to 15 hours and minimum during early morning. The available data showed that diurnal variation is high in June to August and low in the winter season (November to January).

2.3.4 Wind Direction

Wind Roses were developed by using one year's wind direction data for all stations. By analysing the wind rose, it was found that wind blows mainly from two directions (NE and SE) in all stations except at Kuakata. Wind blows from north-east direction in the winter season and from south-east direction during summer season. But at Kuakata, wind blows from south-west direction during the summer and from north-east direction in the winter.

Month	Name of Wind Monitoring Stations						
	Patenga	Cox's Bazar	Kutubdia	Teknaf	Noakhali	Kuakata	Char Fassion
July' 96	76.78	65.09	-	70.81	-	-	-
August' 96	65.77	63.66	-	57.97	60.74	81.14	59.46
September' 96	32.82	34.14	36.89	34.49	25.93	45.14	25.3
October' 96	25.07	36.18	43.64	31	16.53	18.01	25.43
November' 96	6.62	24.54	35.49	18.84	5.35	5.53	LOST
December' 96	12.86	19.76	40.3	16.49	5.22	21.26	28.96
January' 97	22.78	25.96	41.73	24.53	6.85	27.15	23.63
February' 97	17.41	20.81	35	21.9	14.58	29.18	21.75
March' 97	32.86	28.52	40.66	26.39	24.13	55.98	35.78
April' 97	27.94	18.7	31.37	15.23	24.05	56.02	37.22
May' 97	58.42	45.56	61.07	33.4	48.48	78.83	55.76
June' 97	73.84	59.56	79.14	40.49	64.7	87.94	70.53
July' 97	70.45	60.37	79.12	48.9695	63.75	90.46	49.55
August' 97	68.67	53.29	66.5099	50.99	43.73	-	55.49
September' 97	-	30.67	45.05	16.11	27.62	-	32.2
Average	42.31	39.12	48.92	36.26	33.20	66.29	45.39

Table2. 10 Percentage frequency of wind speed above 4m/s

2.4 TERNA Project

TERNA Project was initiated by Bangladesh Atomic Energy Commission (BAEC) and the Rural Electrification Board (REB). Site selection took place in March 1996. In cooperation with GTZ of Germany, measurement systems were installed and the collected data was analysed as part of a training course for REB-engineers.

TERNA Project has collected wind data in four selected sites with the help of Rural Electrification Board (REB). The sites were located at –

(1) Patenga

(2) Anwara

(3) Teknaf and

(4) Feni.

The project concluded that "the mean annual wind velocities are to low" [GTZ, 2001]. The monthly average wind speed at Patenga is shown in Table.

For comparison, the wind speed values of BCAS and GTZ (whatever available) are shown in Table. The difference proves the point that wind-speed could vary considerably even at a small distance.

Month	1995	1996
January	-	-
February	-	-
March	6.7	-
April	7.2	-
May	7.7	8
June	8.1	6.9
July	8	8.4
August	7.4	3.5
September	6.8	3.9
October	6.2	3.2
November	4.4	2.6
December	4.2	2.2

Table2. 11 Monthly average wind speed at Patenga [TERNA 1996]

Month	Patenga			
	(GTZ)		(BCAS)	
	1995	1996	1996	1997
January	-	-		3.25
February	-	-		2.66
March	6.7	-		3.13
April	7.2	-		2.88
May	7.7	8		4.95
June	8.1	6.9	8.75	5.83
July	8	8.4	5.87	5.67
August	7.4	3.5	5.32	5.13
September	6.8	3.9	3.36	-
October	6.2	3.2	3.2	-
November	4.4	2.6	2.61	-
December	4.2	2.2	2.97	-

Table2. 12 Comparison of Wind Data of BCAS and GTZ

2.5 WERM Project

Sustainable Rural Energy project, in collaboration with BUET (Bangladesh University of Engineering and Technology) and BIT (Bangladesh Institute of Technology), Chittagong, has taken up a study on titled "Wind Energy Resource Mapping (WERM)" in the year 2000. WERM has identified twenty wide resource measuring sites (including existing seven sites of WEST Project) for wind resource assessment.

2.5.1 Main Objectives of WERM

- To identify the most potential wind energy sites of the country.
- To determine the standard Weibull characteristics for those locations to design various Wind Energy Conversion Systems (WECS) suitable for Bangladesh. ·

- To compare various wind speed characteristics with other sources, as for example, from satellite wind mapping data.
- To select suitable Wind-Driven Systems (either independent Electricity Generating Systems or Wind Diesel Hybrid Systems) based on the above information. · To procure, install and performance test of those system.

2.6 Feasibility Study on R & D on Renewable Energy by IFRD

Recently a project on "Feasibility Study on R&D of Renewable Energy (Solar, Wind, Micro-Mini Hydro)" has been undertaken by the Institute of Fuel Research Development (IFRD), of Bangladesh Council of Scientific and Industrial Research (BCSIR). Under this program, wind speed data have been collected in the following sites:

i) Saint Martin (offshore island)

ii) Teknaf

iii) Meghnaghat, Dhaka

The maximum velocity obtained at St. Martins Island is 20 m/s and yearly average wind speed in 4.9 m/s. The maximum velocity obtained at Tecknaf is 16 m/s and yearly average wind speed in 3.8 m/s.

2.6.1 Wind Speeds in Saint Martin's Island

Available wind speeds in Saint Martin's Island are presented in the Table below.

Month	V_{av} (m/s)	V_{max} (m/s)
January	5.08s	23.32
February	4.71	19.78
March	4.29	18.94
April	3.58	20.03
May	5.75	26.30
June	5.96	29.80
July	5.33	24.20
August	5.96	20.40
September	4.79	17.70
October	4.17	15.90
November	3.79	14.50
December	4.08	15.20

Table2. 13 Monthly average wind speeds in the island [IFRD, 2002]

Chapter-3

LITERATURE REVIEW

3.1 Solar Energy

The sun is the largest energy source of life at the same time, it is the ultimate source of all energy (except power of geothermal). The sun radiates 174 trillion kWh of energy to the earth per hour. In other words, the earth receives 1.74 x 10 17 watts of power from the sun (Breeze P., 2009).

Characteristics of the sun is simplified as follows : mass 2× kg, beam length 700.000 km, age 5× years and estimated roughly 5 billion more years of life. The surface temperature of sun is approximately 5800 K while the internal temperature is approximately 15.000.000 K. High temperature reactions is due to the transformation of hydrogen in helium. The process of the nuclear fusion, which is characterized from the following reaction 4 →

Energy, is the result of the sun high temperature and the large amounts of energy emitted continuously. It is calculated that for each gram of hydrogen, that is converted to He, sun radiates energy equal with U= 1.67× kWh. The solar energy is emitted to the universe mainly by electromagnetic radiation. (SAO, 2014)

The estimated distance from the sun is 150,000,000 km while the sun is stationed and spins around by the earth in an elliptic orbit. The light having the travelling speed of 300,000 km/sec to overcome the aforesaid distance, it consumed

Approximately 8.5 minutes. Actinic of emitted radiation is removed by the aster to the space and the intensity of radiation J, is calculated by the equation below:

P is presenting the electromagnetic radiation power and d is presenting the distance from the sun. It is estimated that one-third of the radiation is reflected back. The rest of energy will be absorbed and retransmitted to the space while the earth reradiates just as energy as it receives and creates a balance of energy balance at the level of temperature which is suitable for life. Solar energy can be used to generate electricity directly with the photovoltaic panels. (Duffle and Beckman, 2013

3.2 History of Photovoltaic

Photovoltaic is defined that using sun light to generate the electricity. Sunshine hits photovoltaic cells or a mirror arrangement and electricity is generated. In the second half of 20th Century, the development of photovoltaic cells technology was moving rapidly, although Edmond Becquerel has observed the effect of photovoltaic in 1839. A Cambridge scientists Adams was published his first research report of photovoltaic report in 1877. Next, selenium solar cell was built by Charles Frits in 1883, even though the efficiency less than 1% but it is similar to contemporary silicon solar cells. First modern silicon solar cells were manufactured in 1954 by Chapin, Fuller and Person, the solar element with p-n junction was achieved 6% efficiency of system. The cost of initial commercial manufactures was high and relatively low efficiency in 5 – 10%. In addition, the solar cells were mainly made by crystalline material such as crystal silicon (c-Si). (Patel, 2006)

3.3 Photovoltaic Structure

The photovoltaic cells structure is quite straightforward. It consists of 6 different layers of materials as shown in Figure 2.1. First of all, the efficiency of photons absorption is increasing due to the assistance of black cover glass surface, the glass is protecting the cell from the the anti-reflective coating. The travelling distance of the Photons was minimized by contact grid, so that it able to reach the semiconductors. The heart of the photovoltaic system is consisting of semiconductors p and n in the form of two thin layers. Lastly, the back contact is contributing for the better conduction. (Luque and Hegedus, 2009)

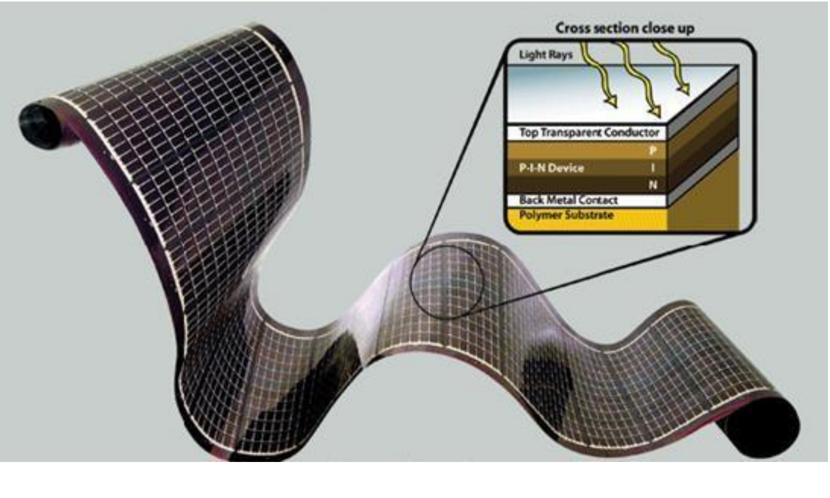


Figure 3. 1 Basic structure of a generic silicon PV cell (Toothman, 2012)

3.3.1 Semiconductors p-n type

The photovoltaic cells that mentioned previously consist of 2 semiconductors p-n which are both made of crystalline silicon. The n-type semiconductor is created when some of their atoms of the crystalline silicon are replaced by atoms of another material which has higher valence band like phosphorus. Consequently an n- type semiconductor is being created which has a surplus of free electrons in

Its valence band. On the other hand a p-type semiconductor is created when some of the atoms of the crystalline silicon are replaced by atoms with lower valence like boron and the result is the creation of another material with deficit of free electrons and is known as p-type semiconductor. These missing electrons are called holes. (Duffie and Beckman, 2013)

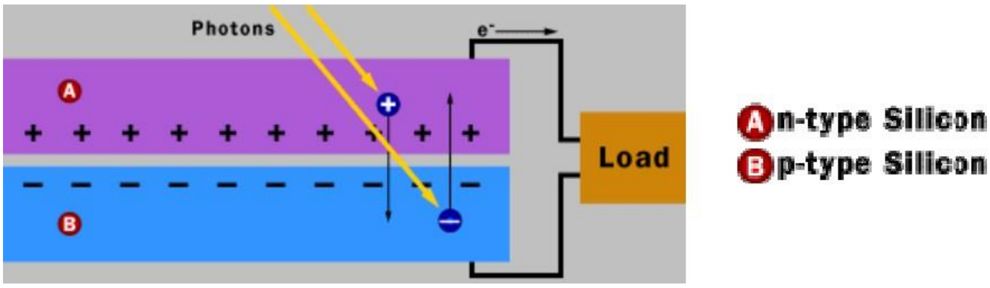


Figure 3. 2 Operation of a PV cell (Toothman, 2012)

The p-n junction is created while semiconductors are touching together, depletion region is formed when the electric field is setting up in that particular region. In Figure 2.2, it is observed that diffusion from one semiconductor to the

Other one that can able to make the electrons move this process is created that Particles with positively charged in one direction and particles with negatively charged in opposite direction. (Luque and Hegedus, 2009)

3.3.2 Photovoltaic Effect

The sun light beam is the main key to create the photovoltaic effect. Electrons will be stimulated when the photons in the photovoltaic cell exposed to the sun light beam. The electrons will jump into the conduction band after it starts moving rapidly, and then holes in the valence band leaved by electrons. Holes of nearby p-side are combining with electrons attracted from opposite direction which is n-side

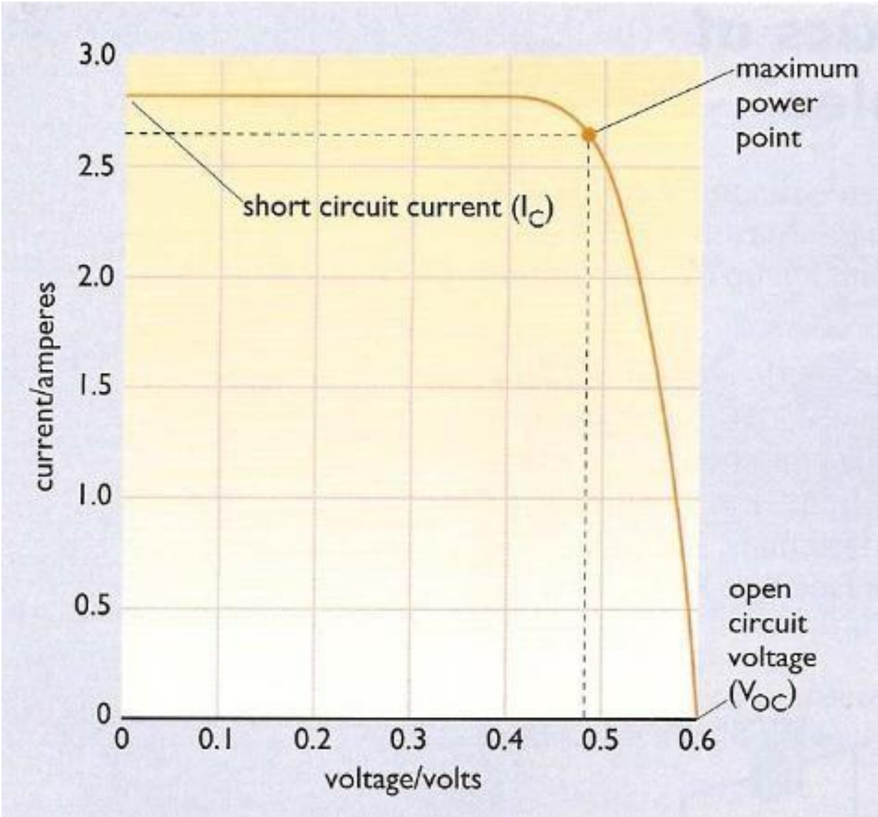


Figure 3. 3 I-V curve of a typical silicon PV cell under standard test conditions (Tzanakis, 2006)

Finally, international standard test conditions are established, in order to measure the power output of photovoltaic cells. The level of irradiance is defined as 1000 W/m², with the reference of air mass 1.5 solar spectral irradiance distributions and cell junction with temperature of 25°C. (Luque and Hegedus, 2009)

3.3.3 Main Cell Types

The material that is used widely in the industry for the production of photovoltaic cells is silicon. Silicon can be found inside the sand in the form of silicon oxide (SiO2). The final product is characterized by high purity 99.99999%. The photovoltaic cells of silicon are distinguished in four categories, depending on the structure of the basic material from which they are made and the particular way of their preparation. The types are the following ones:

Single-Crystal Silicon: The basic material is monarchy stallion silicon. In order to make them, silicon is purified, melted, and crystallized into ingots. The ingots are sliced into thin wafers (Wafer~300μm) to make individual cells. The efficiency of a single crystal silicon cell oscillates between 13-16% and it is characterized by a high cost for the manufacture and has a dark blue colour. (Patel, 2006)

Polycrystalline Silicon: The particular cell is relatively large in size and it can be easily formed into a square shape which virtually eliminates any inactive area between cells. Its efficiency oscillates between 10-14% and it is characterized by lower cost silicon which is used for its manufacture and has light blue colour. (Luque and Hegedus, 2009)

Ribbon Silicon: Ribbon-type photovoltaic cells are made by producing a ribbon from the molten crystal silicon instead of an ingot. Its efficiency is around 13% and is very expensive with a limited industrial production. (Luque and Hegedus, 2009)

Technology which uses thin film solar cells while the total thickness of a semi- conductor is about 1µm. Amorphous or thin film silicon cells are solids in which the silicon atoms are much less ordered than in a crystalline form. By using multiple junctions this kind of photovoltaic cells achieve maximum efficiency which is estimated at about 13% while the installation cost is reduced. Furthermore the output of an amorphous silicon cell isn't decreased as temperature increases and is much cheaper to produce than crystalline silicon. (Patel, 2006)

3.3.4 Main Parts of a Photovoltaic System

In the figure 2.4, photovoltaic system is consisting of various devices. The complete photovoltaic system is constituted by inverter, charge controller and batteries.

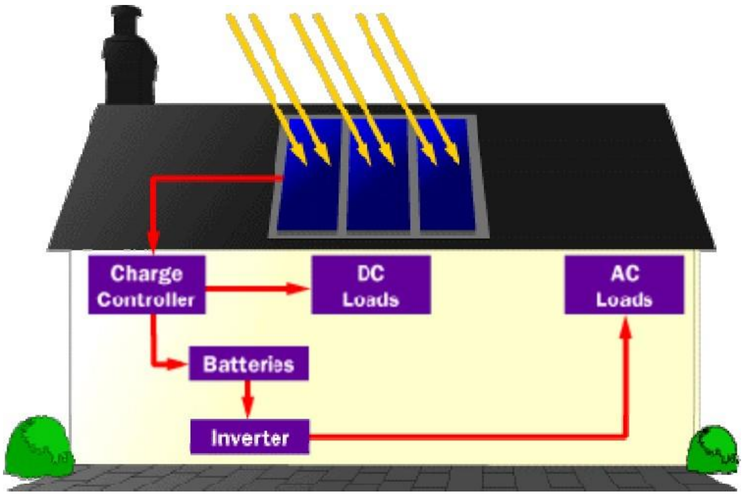


Figure 3. 4 General schematic of a residential PV system (Toothman, 2012)

In this renewable energy system, the energy produced by Photovoltaic cell is stored in the batteries. Furthermore, Energy will be supplied to the system, it generally happens at nights, cloudy days and days which are required higher electrical demands. Deep-cycle batteries is the most common type of batteries and commonly be used. Deep-cycle batteries are categorised as type of lead-acid battery and advantages of wide range of usage. Nickel-cadmium battery is very costly, but the energy stored can be discharged at the higher level than lead-acid battery and high level of durability. (Kaldellis, 2012)

Before the photovoltaic system connects to the grid, it is required to consider the characteristics of the batteries as follows:

Battery total capacity is representing the total load of battery (Ampere hour) that the energy capable to be stored in the battery.

Battery voltage is defined according to the electrolyte type and the elements number.

Discharge depth represents that the battery discharge level which is capable to achieve in daily.

The cost per kWh represents that the total electrical energy to be calculated while the batteries supplying the power during the life cycle.

The battery operational life shows that the battery life cycle in the photovoltaic system, the battery has to be replaced after 5-6 years operation.

Operating temperature represents that battery capacity is reduced as temperature goes down, and increased as temperature goes up.

Charge controller is an important device for the battery life cycle. In the operation mode of charge controller, the life of battery will be reduced if overcharge occurs in the battery. In order to increase the battery life, the charge controller will block the electrical load continuously flowing in while the batteries are fully charged. (Mousavi and Fathi, 2009)

The inverter is an important device that able to convert alternative current (AC) from direct current (DC Alternative current usage is essential and crucial, since it has been widely used for all variety of industry sector and domestic uses. It is used, generally, in cases where a source of continuous electric voltage is allocated and where an alternative electric voltage is used, as it happens with the installed PV cells on the buildings. The efficiency of the inverter is quite high and varies between 93% and 96%. (Shagar and Vinod, 2012

3.3.5 Main Principles of PV Systems

A photovoltaic cell is rarely used in single set or individually, since it is unable to supply sufficient power and voltage of electronic device requirement. Due to this reason, it needs more set of photovoltaic cells be coupled together and to be connected parallel or in series for energy production, in order to achieve the higher power output and voltage as possible.

A typical photovoltaic system is made of 36 individual 100 cm² silicon photovoltaic cells and auxiliary devices which are lead-acid batteries with a typical

voltage of 12 V. This system has the capacity of producing more than 13V during cloudy days and can charge a 12 V battery. (Duffie and Beckman, 2013)

a photovoltaic cell. Each parameter of the photovoltaic cell can be determined and calculated by using the I-V curve as shown in Figure 2.5. (Patel, 2006)

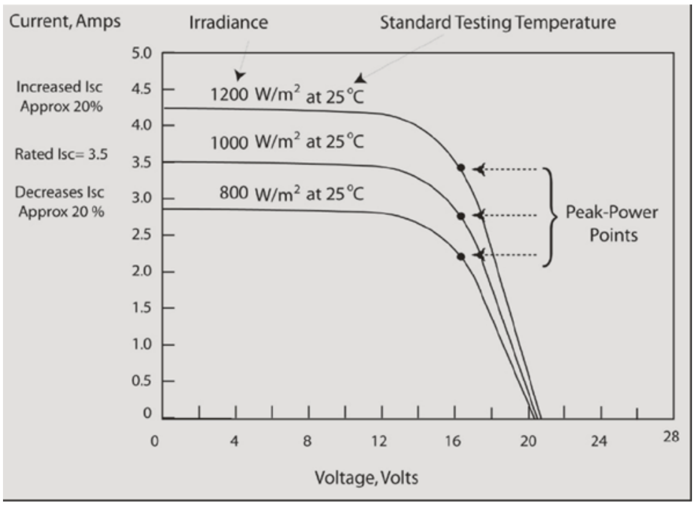


Figure 3. 5 I-V curves in different intensities of solar irradiance (Patel, 2006)

In real conditions, the function of a photovoltaic system may be varied because of the intensity fluctuation of the solar radiation over a period of time. When the light of photovoltaic cells, which supplies an electrical resistance, changes, the power point shifts. This point can be seen experimentally, if the electric power, which is provided by the PV cell with a given power density E and applied on a variable electric resistance. Since the resistance varies, fluctuations can be measured in current and voltage by using the appropriate measurement devices; ammeter and voltmeter. In Figure 2.5, it can be observed that presents a peak point in the

3.3.6 Advantages of PV Systems

Photovoltaic modules can easily penetrate in remote areas since the electrical power that produce comes from a reliable, free from pollution and independent source, the sun. Photovoltaic systems can be economically feasible, since it can help in a large extent the viable growth of a region. Moreover they can produce electric current during cloudy days and the current that produced is a direct current (DC). Photovoltaic systems were manufactured in order to function in unfavourable conditions and it has a very small weight. It is possible installed on the ground, on the roofs of buildings or on any other location where sun light beams can reach on the photovoltaic cell surface easily (Kaldellis, 2012). The principal advantages of PV systems are:

- A long life cycle since it can provide power for more than 20-25 years
- Zero operation cost, because it does not consume fuel or materials.
- Low variability of system efficiency and more reliable results.
- Maintenance cost is low.
- No sound pollution in the period of operation.
- Energy conservation.
- Keep the environment clean and away from pollution of the CO_2 emissions in atmosphere.

A photovoltaic system is installed with an optimum power output of about

1 kW, in a year's period operation can save around 1300 kWh of electrical energy and 800 kg of CO_2 emission. (Luque and Hegedus, 2009)

3.4 Wind Energy

3.4.1 The Wind

Wind is the continuous movement of atmospheric air masses and is determined by its speed and orientation. This movement derives from the changes and the differ values of the atmospheric pressure while these values are the result of the solar heating of different parts of the earth's surface. Despite the fact that the atmospheric air moves horizontally and vertically as well, only its horizontal movement is actually considered as wind. (Breeze, 2009)

values of the atmospheric pressure while these values are the result of the solar heating of different parts of the earth's surface. Despite the fact that the atmospheric air moves horizontally and vertically as well, only its horizontal movement is actually considered as wind. (Breeze, 2009)

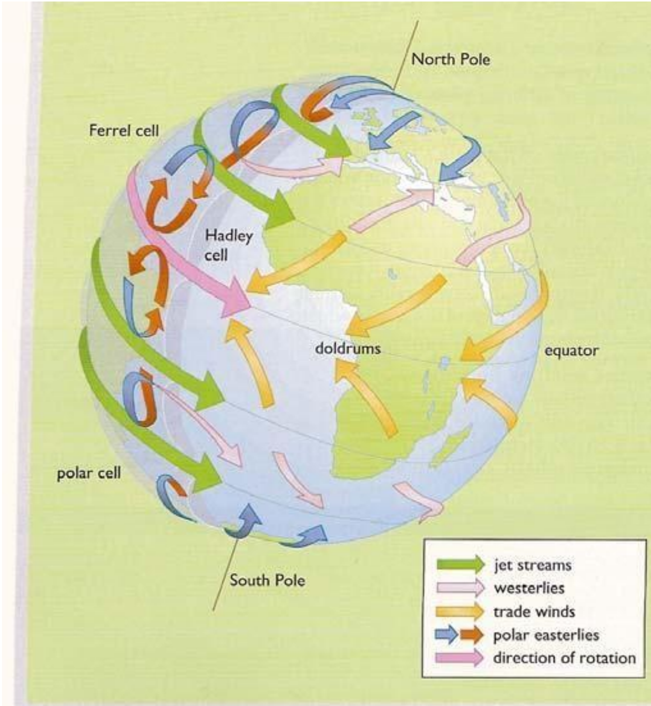


Figure 3. 6 The global wind circulation (Tzanakis, 2006)

Many scientists support that the proper exploitation of the wind energy can resolve in a way the world's energy problem. For instances, the energy needs in here hardly constitute the one tenth of the wind energy potential of the country. Nowadays a total of 59,100 MW of wind generated capacity is installed around the world, with an average annual growth rate of 29 percent over the last ten years as it can be seen from Figure 2.7. Although each coin has two sides and thus wind energy can't be easily predicted neither can its continuous operation. Wind is a form of energy with low density, something which implies that large structures have to be made for its exploitation. (Wagner and Mathur, 2009)

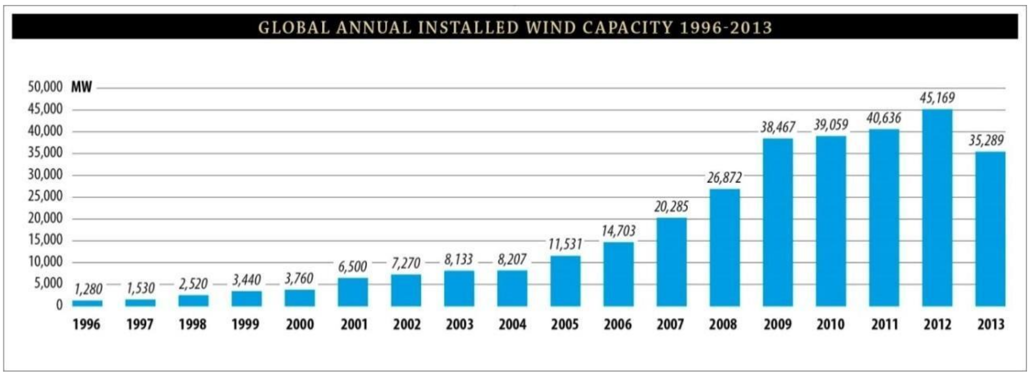


Figure 3. 7 Worldwide installed wind capacity the last 17 years (GWEC, 2014)

Undoubtedly the wide use of the wind energy and its efficient exploitation is going to improve the global energy balancing without overloading at the same time the environment with dangerous gases.

3.4.2 History of Wind Energy

The exploitation of the wind energy is as old as the human existence on the Earth. It played an important role in the humanity's improvement mostly the use of the wind energy in sailing, irrigation and agriculture.

The wind energy was firstly used by man in sailing boats. In addition historical and archaeological reports support that wind machines were used by Chinese and Egyptians. Specifically wind energy propelled boats that were used by Egyptians along the River Nile in 5000 B.C while Chinese were pumping water with the use of simple windmills in 200 B.C. (NAJAH, 2012)

In Europe, it is assumed that windmills appeared just before 1200 AD and they were transferred by the crusaders on their way back. The first recorded reference was in 1185 AD which mentions a windmill in the village of Wheedle in England. (Manwell et al., 2009)

During the dark ages windmills appeared in Holland, in Spain, in Portugal, in France and in Italy. In Holland they were used for the pumping of waters from areas that were located in a lower level than that of the sea. The type of windmill that was used during that era in Europe was mainly horizontal axis with four blades. Another type of windmill which was widely used during the renaissance period was a slow multi blade windmill as illustrated in the Figure 2.8:- (Manwell et al., 2009)

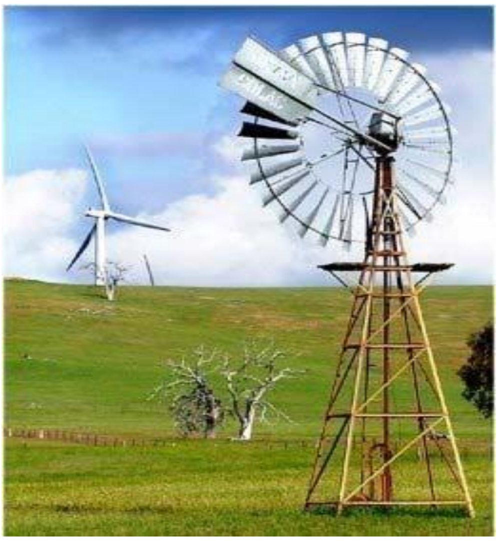


Figure 3. 8 A multi-bladed wind turbine (NAJAH, 2012)

In the beginning of our century the Danish produced electricity from the wind, while in America windmills with a metallic structure were used for electricity production as well. From 1870 until 1930 Chicago became the biggest industrial centre for windmills production with an estimated production of about 6 million units over that period. In 1891 an experimental wind turbine was operated in Denmark with 2 electric generators and a rotor blade with a diameter of 22.8 metres under the supervision of professor P.La. Court. In addition during 1930 the Baltic machine was manufactured with a power potential of 100 KW with the design supervision of Sabanin and Yuriev. Finally in 1940 an experimental wind turbine with two blades was manufactured in the Vermont in U.S.A which was rated at 1.25 megawatts in winds of about 30 mph. (Jain, 2011)

In the recent years that followed after the Second World War, the use of the atomic energy along with the low prices of the oil significantly limited the interest for the exploitation of wind energy. However the environmental pollution and the energy crisis made the technologically developed countries to show an intensive interest for this pure and ancient energy source. (Wagner and Mathur, 2009)

3.4.3 Wind Turbine Types

The machines, which were proposed to harness the wind energy, are considered as wind turbines. Wind turbines are categorized according to the orientation of their axes in comparison with the flow of the wind. There are various types of modern wind turbines, which are distinguished in the following two main categories: horizontal axis and vertical axis turbines. (Fernando et al., 2007)

Modern wind turbines are also classified as high rotation speed ones and low rotation speed ones, depending on a non-dimensional value known as the tip speed ratio (λ); this is defined as the ratio of the speed of the extremities of a windmill rotor to the speed of the free wind, and is illustrated below. A useful measure is provided by this ratio, based on which the different characteristics of the wind turbines can be compared.

Where ω is the angular velocity in radians per second, R is the radius of the rotor in meters and is the wind velocity in meters per second.

In addition, the rotation speed of a wind turbine depends on its aerodynamic parameters and its wind blades size. Moreover, the interconnection of the turbine to the electric grid plays an

3.4.4 Vertical Axis Wind Turbine (VAWT)

Vertical axis wind turbines are different from traditional wind turbines in that their main axis is perpendicular to the ground. Their configuration makes them ideal for both rural and urban settings and offers the owner an opportunity to offset the rising cost of electricity and to preserve the environment. Besides, they do not need the complicated head mechanisms of conventional horizontal axis turbines. (Fernando et al., 2007)

VAWTs are not affected by the direction of the wind which is useful in areas where the wind changes direction frequently or quickly. VAWTs are better able to harvest turbulent air flow found around buildings and other obstacles. This situation is more common in areas where people live. VAWTs are ideal for both rural and urban applications including roof top installations.

The generator or other devices can be installed at the ground level, making it simpler to install or maintain. VAWTs do not kill birds and wild life, it is because the slow moving and highly visible. VAWTs can be significantly less expensive to build. They produce less noise compare with horizontal ones. VAWTs are more aesthetically pleasing.

3.4.5 Savonius Turbine

Savona's is a type of VAWT, which uses a rotor that was introduced by Finnish engineer S. J. Savonius in 1922. Savonius turbines are one of the simplest turbines. Aerodynamically, they are drag-type devices. In its simplest form it is essentially two cups or half drums fixed to a central shaft in opposing directions. Each cup or drum catches the wind and so turns the shaft, bringing the opposing cup or drum into a flow of the wind. This cup or drum then repeats the process, so causing the shaft to rotate further and completing a full rotation. This process continues all the time the wind blows and the turning of the shaft is used to drive a pump or a small generator. (Abraham and Plourde, 2012)

These types of windmills are also commonly used for wind speed instruments such as the anemometer. Modern Savonius machines have evolved into fluted bladed devices, which have a higher efficiency and less vibration than the older twin cup or drum machines. (Manwell and McGowan, 2009)

3.4.6 Principles of Savonius Rotor Wind Turbine

Savonius turbines are one of the simplest turbines. Aerodynamically, they are drag- type devices, consisting of two blades (vertical – half cylinders). A two blades savonius wind turbine would look like an "S" letter shape in cross section as shown in Figure 2.9.

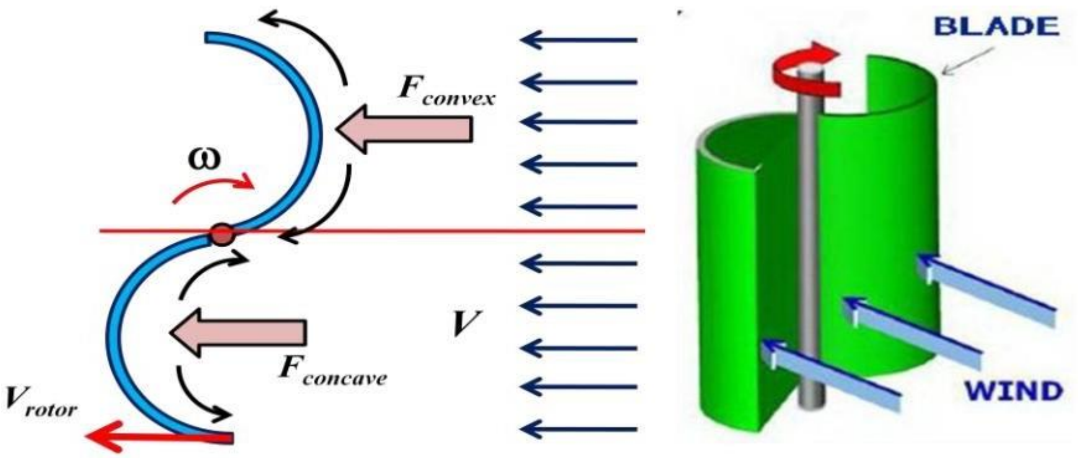


Figure 3. 9 Schematic drawing showing the drag forces exert on two blade savours.

Because of the blades curvature, the blades experience less drag force ( ) when moving against the wind than the blades when moving with the wind). Hence, the half cylinder reason, Savours

Frequency (Mohan N. 2009). Therefore, power electronic converter also known as switching converter because the output is controlled by switches.

AC-DC Rectifier

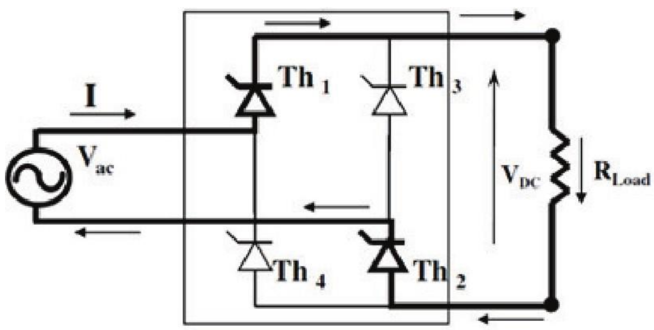


Figure 3. 10 Full-bridge, single-phase, AC-DC controlled rectifier circuit.

Energy Storage System

The two main types of batteries used in hybrid systems are nickel- cadmium and lead-acid. Nickel-cadmium batteries are restricted in use for few systems due to higher cost, lower energy efficiency and limited upper operating temperature. Lead-acid batteries is still the most common type for the hybrid systems (Mahmoud 2009).

Lead–acid batteries are usually used for energy storage in hybrid systems to store surplus energy, to regulate system voltage and to supply load in case of insufficient solar radiation and/or wind. Only 2 or 3 days of autonomy is required for batteries in wind–PV hybrid systems, while 5 to 6 days of autonomy are necessary in separate PV or wind systems (Deshmukh and Deshmukh, 2008). Other storage means can be used but lead–acid batteries are a low-cost, maintenance-free and highly efficient technology.

A lead acid battery in its basic construction is made of more than one electrochemical cells interconnected in such a way to provide the required voltage and current. Lead acid battery is constructed of two electrodes , the positive one consists of lead dioxide and the negative consists of pure lead (Pb). The empty space between the two electrodes is filled with diluted sulphuric acid ( ). The voltage of the battery depends on cell temperature and the density of the acid solution, also its density changes with temperature and charge state. A battery with a 12V nominal voltage is constructed of 6*2V lead acid cells. The upper and lower limits of charging.

Chapter- 4

Design and Implementation

4.1 Working Principle

The principal component of the Solar System is the Sun, a G2 fundamental grouping star that contains 99.86% of the framework's known mass and rules it gravitationally. The Sun's four biggest circling bodies, the goliath planets, represent 99% of the staying mass, with Jupiter and Saturn together involving over 90%.

The rest of the objects of the Solar System (counting the four earthbound planets, the smaller person planets, moons, space rocks, and comets) together contain under 0.002% of the Solar System's aggregate mass.

Most vast protests in circle around the Sun lie close to the plane of Earth's circle, known as the ecliptic. The planets are near the ecliptic, though comets and Kuiper belt objects are regularly at fundamentally more noteworthy edges to it.

All the planets, and most different items, circle the Sun a similar way that the Sun is pivoting (counter-clockwise, as saw from over Earth's North Pole). There are exemptions, for example, Halley's Comet.

The general structure of the graphed locales of the Solar System comprises of the Sun, four moderately little inward planets encompassed by a belt of for the most part rough space rocks, and four goliath planets encompassed by the Kuiper belt of for the most part frosty articles.

Stargazers once in a while casually isolate this structure into discrete areas. The internal Solar System incorporates the four earthly planets and the space rock belt. The external Solar System is past the space rocks, including the four monster planets.

Since the revelation of the Kuiper belt, the peripheral parts of the Solar System are viewed as an unmistakable area comprising of the articles past Neptune.

Most of the planets in the Solar System have optional frameworks of their own, being circled via planetary items called normal satellites, or moons (two of which, Titan and Ganymede, are bigger than the planet Mercury), and, on account of the four mammoth planets, via planetary rings, thin groups of little particles that circle them as one.

The vast majority of the biggest normal satellites are in synchronous pivot, with one face for all time moved in the direction of their parent.

A large portion of the planets in the Solar System have auxiliary frameworks of their own, being circled via planetary items called common satellites, or moons (two of which, Titan and

4.2 Block Diagram of This Project

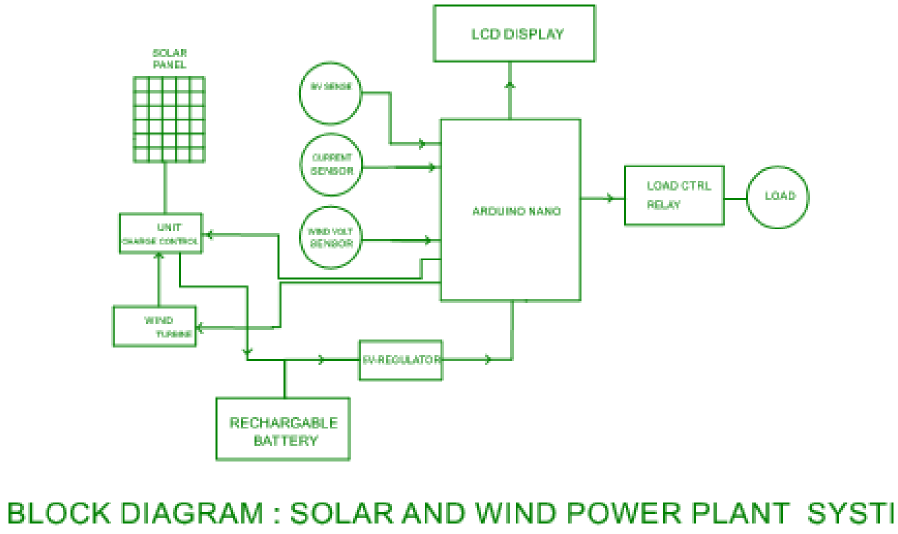
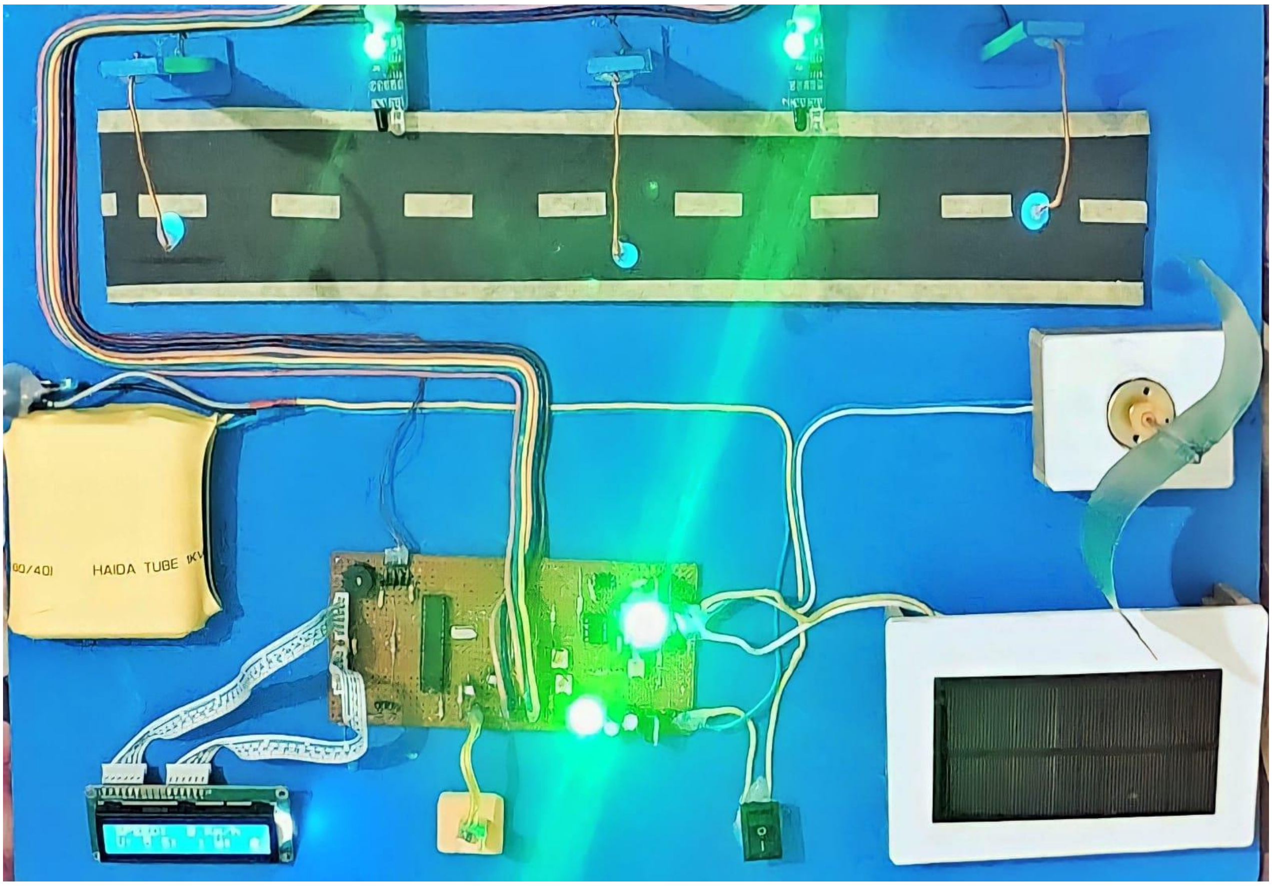


Figure 4. 1Block Diagram of this Projects

4.3 3D VIEW



Chapter-5

Hardware and Component Disruption

5.1 List of Component with Price

SL No:	Component Name	Quantity	Price
1	Microcontroller (PIC 16F73)	1	450
2	LCD	1	300
3	DC Motor	2	150
4	12v Rechargeable Battery	1	100
5	Step Up X-former	1	300
6	DC Fan	1	100
7	DC LED Bulb	1	50
8	Crystal (16MHz)	1	20
9	7805 Regulator	1	30
10	Capacitor 122MFD/35V	8	50
11	LED	10	40
12	Power Switch	2	40
13	Diode SR560	2	30
14	N-Chanel FET	3	100
15	Some Resister	Some	20
16	Optocuplar	1	30
17	Hit sink	1	50
18	Connector	1	20
19	IC Bess	2	50
	Total Price		

Table 5. 1 Component List with Price

5.2 Solar Panel

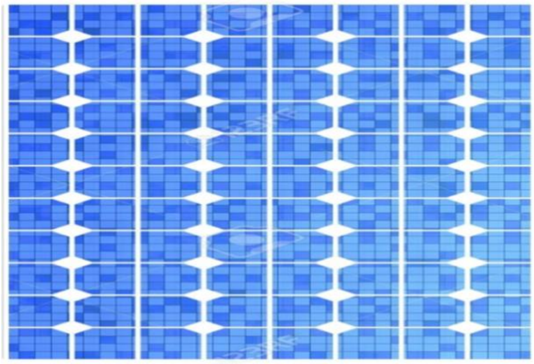


Figure 5. 1 Solar Pannel

- Mono Crystalline solar panel
- Cost effective
- More efficient and reliable
- Made of bulk type silicon

5.2.1 How Solar Cells Work — Components & Operation of Solar Cells

Since a solar cell is the only generator in a solar PV system, it is one of the most important parts in a solar PV system. In the following paragraphs, a simple introduction of a solar cell and how it operates is discussed, with reference links for better understanding.

5.2.1. A solar cell:

A solar cell is a solid-state electrical device (p-n junction) that converts the energy of light directly into electricity (DC) using the photovoltaic effect. The process of conversion first requires a material which absorbs the solar energy (photon), and then raises an electron to a higher energy state, and then the flow of this high-energy electron to an external circuit. Silicon is one such material that uses such process. A solar cell structure is shown in figure 1 and a solar panel configuration in figure.

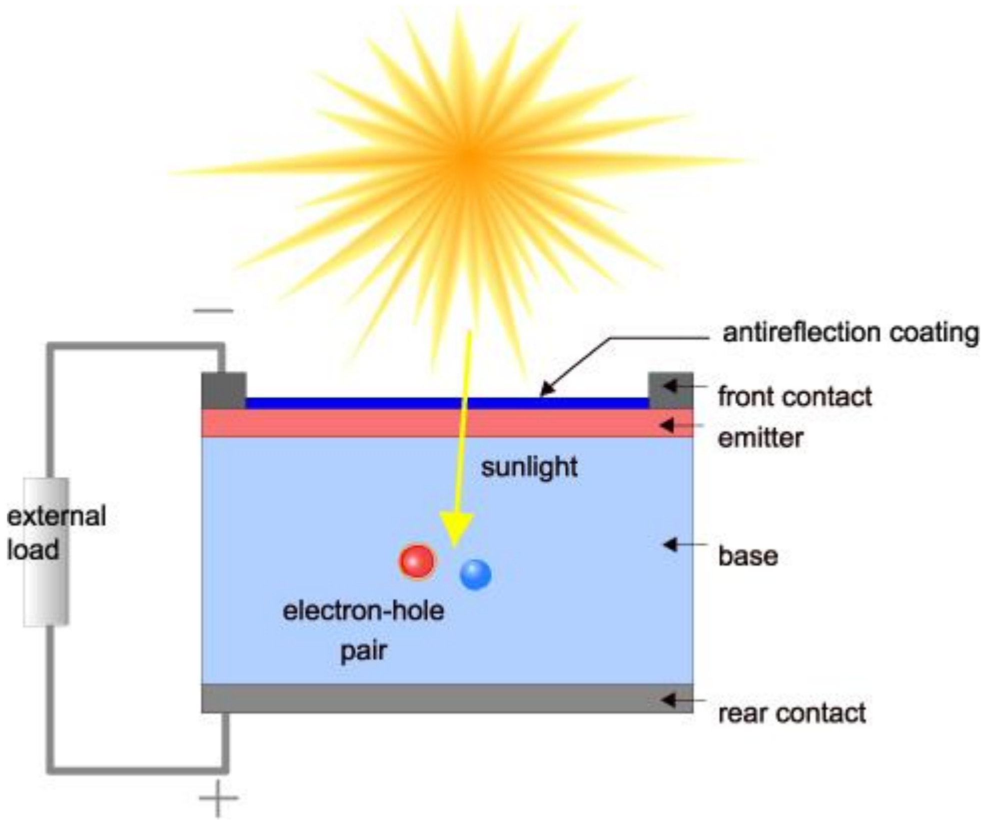


Figure 5. 2 Solar Cell

5.2.1. B PV cells:

PV cells are most commonly made of silicon, and come in two common varieties, crystalline and thin-film cells, as detailed in table 1.

	Bulk type / Wafer-based (Crystalline)			
	Mono-crystalline Si	Poly-crystalline Si		Poly-crystalline band
Pros	• High efficiency	• High efficiency with respect to price		-
Cons	• Increased manufacturing cost caused by the supply shortage silicon			-
	Thin-film type			
	Amorphous Si	CIGS	CdTe	Polymer organic
Pros	• Low price	• Low price • Able to automate all manufacturing process		• Low manufacturing • Can be more efficient (still in research)
Cons	• Low efficiency	• Low efficiency		

Table 5. 2 PV cell details

5.2.1. C p-n junction:

It is formed by joining p-type (high concentration of hole or deficiency of electron) and n-type (high concentration of electron) semiconductor material. Due to this joining, excess electrons from n-type try to diffuse with the holes of p-type whereas excess hole from p-type try to diffuse with the electrons of n-type. Movement of electrons to the p-type side exposes positive ion cores in the n-type side, while movement of holes to the n-type side exposes negative ion cores in the p-type side, resulting in an electron field at the junction and forming the depletion region

5.3 IC PIC16F73 (Microcontroller)

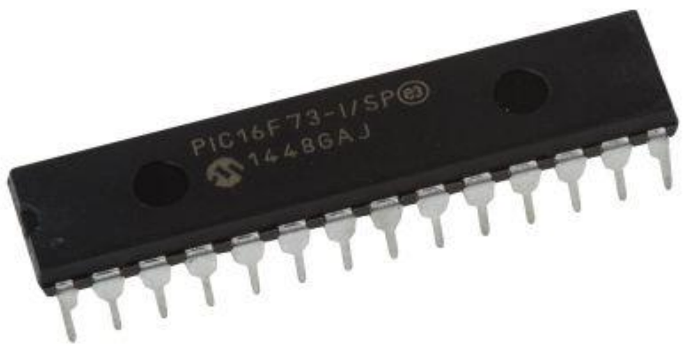


Figure 5. 3 PIC 16F73 (Microcontroller)

5.3.1 It contains following components:

- Central processing unit (CPU)
- Random Access Memory (RAM)
- Read Only Memory (ROM)
- Input/output ports
- Timers and Counters
- Interrupt controls
- Analog to digital converters
- Digital analogue converters
- Serial interfacing ports

5.3.2 PIC Microcontroller Architecture

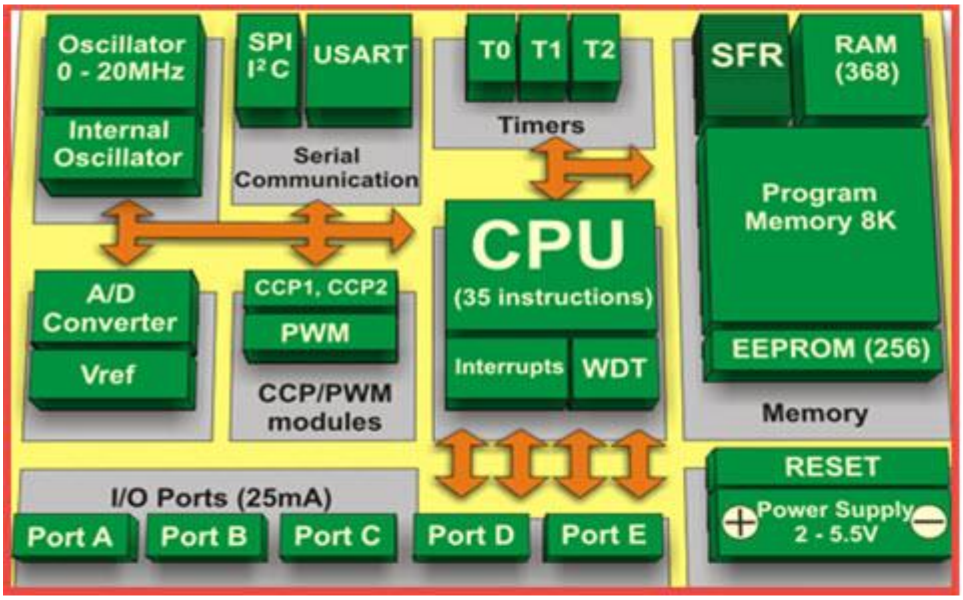


Figure 5. 4 PIC Microcontroller Architecture

The term PIC stands for the peripheral interface controller was developed in the year 1993 by "Microchip Technology". Firstly, this controller was developed for supporting PDP computer to regulate its peripheral devices, and thus, termed as a peripheral interface device.PIC microcontrollers are very fast and executing a program can be made easy compared with other controllers. The architecture of this microcontroller based on "Harvard architecture". The specifications of this microcontroller include wide availability, ease of programming, serial programming capacity, large user base, interfacing of microcontroller with other peripherals, etc.

5.3.3 What is a Peripheral Interface Controller?

PIC (peripheral Interface Controller) is the world's smallest microcontroller that can be programmed to carry out a vast range of tasks. These programming and the simulated process of this microcontroller can be done by a circuit-wizard software. PIC microcontroller is an IC and its architecture comprises of CPU, RAM, ROM, timers, counters and protocols like SPI, UART, and CAN which are used for interfacing with other peripherals. Applications of microcontroller include industrial purpose. The advantages of using this microcontroller

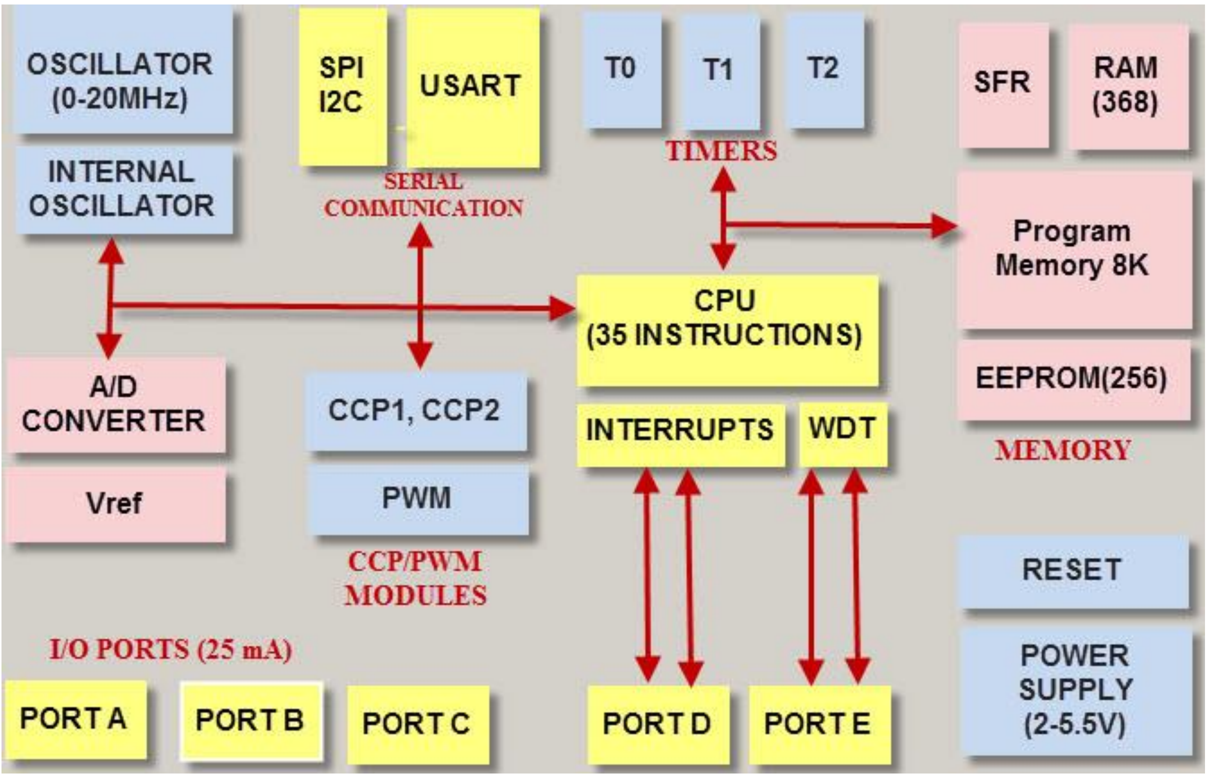


Figure 5. 5 Central Processing Unit (CPU)

5.3.4 Central Processing Unit (CPU)

PIC microcontroller's CPU is not different like other microcontroller CPU, which includes the ALU, controller unit, the memory unit, and accumulator. ALU is mainly used for arithmetic and logical operations. The memory unit is used to store the commands after processing. The control unit is used to control the internal & external peripherals, and the accumulator is used to store the final results and further process.

5.3.5 Memory Organization

The memory module in the PIC microcontroller architecture consists of Random Access Memory, Read Only Memory and STACK.

Figure 5. 6 Memory Organization

5.3.6 Memory Organization

5.3.6. A RAM (Random Access Memory)

RAM is used to store the information temporarily in its registers. It is categorized into two banks, each bank has so many registers. The RAM registers are categorized into two types, namely SFR (Special Function Registers) and GPR (General Purpose Registers).

5.3.6. B GPR (General Purpose Registers)

As the name implies, these registers are used for general purpose only. For instance, if we want to multiply any two numbers by using this microcontroller. Usually, registers are used for multiplying and storing in other registers. So, GPR registers don't have any superior function,-CPU can simply access the data in the registers.

5.3.6. C Special Function Registers

As the name implies, SFRs are used only for special purposes. These registers will work based on the function assigned to them, and these registers cannot work as a normal register. For instance, if you cannot use the STATUS register for storing the information, SFRs are used for viewing the status of the program. So, a consumer cannot change the SFR's function; the function is given by the retailer at the time of built-up.

5.3.6. D Memory Organization

The memory organization of Peripheral Interface Controller includes the following

- Read Only Memory (ROM)
- Electrically Erasable Programmable Read Only Memory (EEPROM)
- Flash Memory
- Stack

5.3.7 I/O Ports

The PIC microcontroller consists of 5-ports, namely Port A, Port B, Port C, Port D and Port E.

5.3.7 A BUS

BUS is used to transfer & receive the data from one peripheral to another. It is categorized into two types like data bus and address. Data Bus is used to transfer or receive the data.

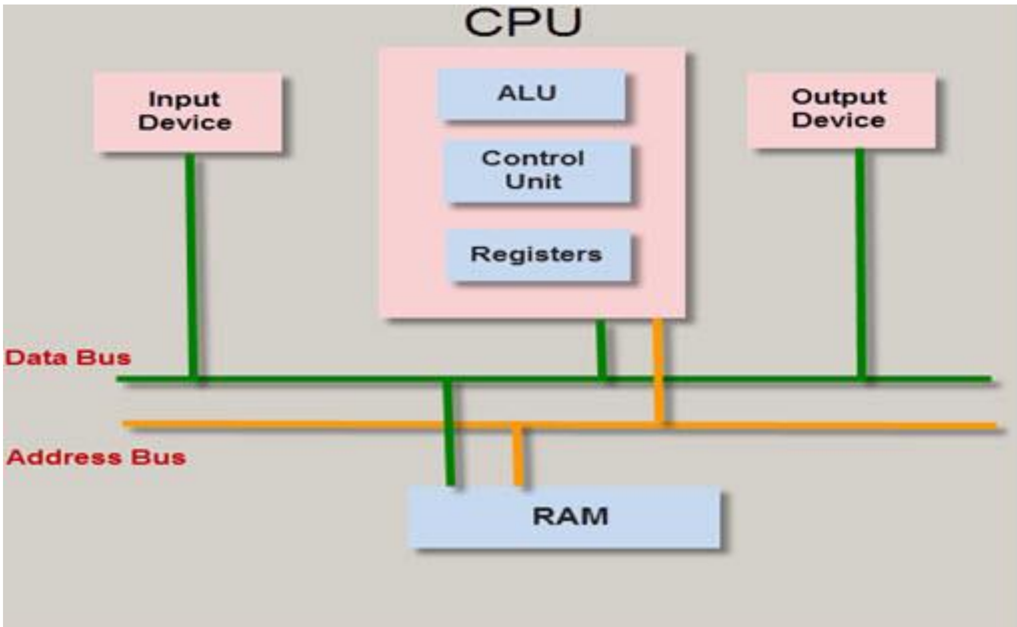


Figure 5. 7 BUS

The address bus is used to transfer the memory address from the peripherals to the central processing unit. Input/output pins are used to interface the exterior peripherals; both the UART & USART are serial communication protocols, used to interface with serial devices such as GPS, GSM, IR, Bluetooth, etc.

5.3.8 A/D Converters

A/D converter is used to convert analogue voltage values to digital voltage values. An A/D module in Peripheral Interface Controller comprises of 5-inputs for 28-pin devices & 8-inputs for 40-pin devices. The operation of the A/D converter is controlled by special registers like ADCON0 & ADCON1. The upper and lower bits of the converter are stored in registers like ADRESH and ADRESL. In this process, it needs 5V of an analogue reference voltage.

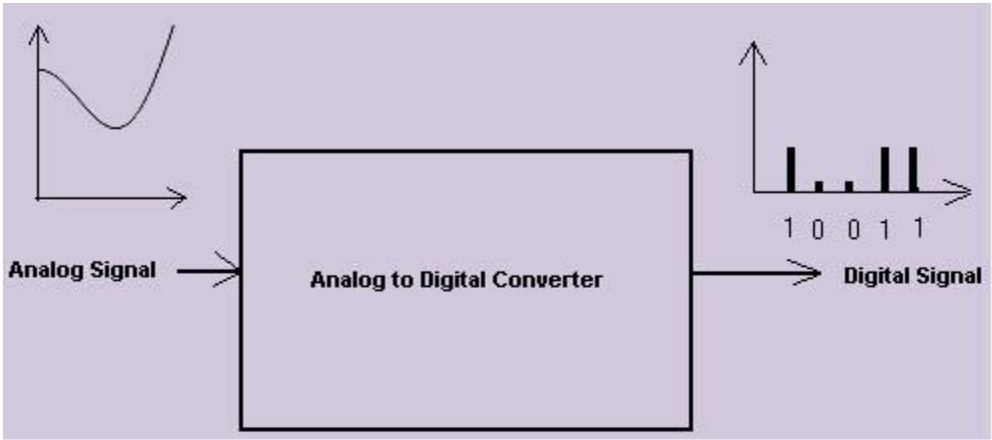


Figure 5. 8 Ana log to digital Converter

5.3.8 Timers/ Counters

PIC microcontroller has four-timer/counters wherein the one 8-bit timer and the remaining timers have the choice to select 8 or 16-bit mode. Timers are used for generating accuracy actions, for example, creating specific time delays between two operations.

5.3.9 Interrupts

PIC microcontroller consists of 20 internal & 3-external interrupt sources which are allied with different peripherals like USART, ADC, Timers, and so on.

5.3.10 Serial Communication

Serial communication is the method for transferring one-bit data at a time sequentially over a communication channel.

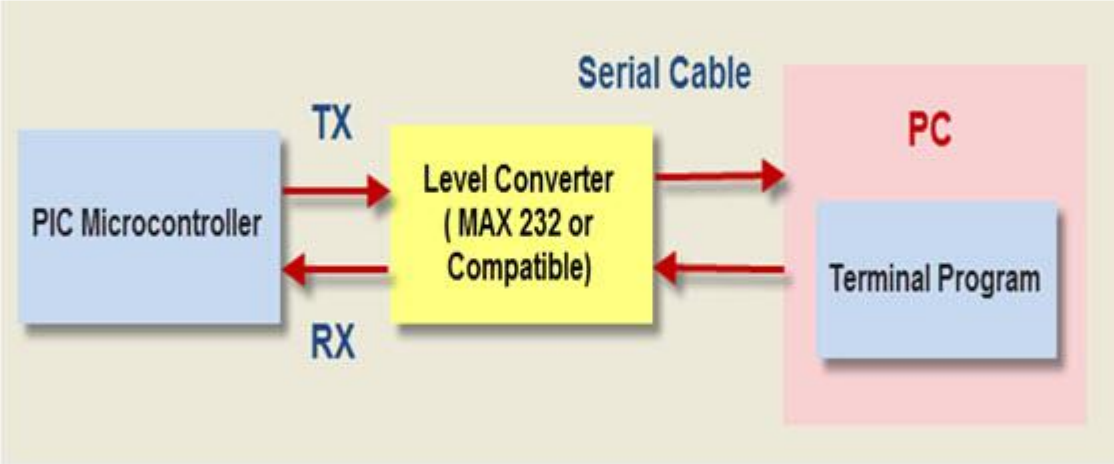


Figure 5. 9 Serial Communication

5.3.10. A USART

The term USART stands for "Universal synchronous and Asynchronous Receiver" and Tx which is a serial communication for two protocols. USART is used for transmitting & receiving the data bit by bit over a single wire with respect to CLK pulses. The Peripheral Interface Controller consists of two pins TXD & RXD. These pins are used for transmitting & receiving the data serially.

5.3.10. B SPI Protocol

The term SPI (Serial Peripheral Interface) is used to send information between PIC microcontroller and other peripherals like sensors, SD cards, and shift registers. This microcontroller supports 3-wire SPI communications between two devices on a common CLK source. The data rate of this protocol is more than that of the USART.

5.3.10. C I2C Protocol

The term I2C stands for "Inter-Integrated Circuit", and it is a serial protocol, used to connect low-speed devices like EEPROMS, A/D converters, microcontrollers, etc. PIC microcontroller supports this communication between two devices which can work as both Master & Slave device.

5.3.11 Oscillators

Oscillators are used for timing generation. This microcontroller comprises of external oscillators such as crystal oscillators or RC oscillators. Where the crystal oscillator is associated with the two pins of the oscillator. The capacitor value is connected to each pin that chooses the operation mode of the oscillator. These modes are the high-speed mode, crystal mode, and the low-power mode. In the case of RC oscillators, the resistor value and capacitor decide the CLK frequency and the clock frequency range from 30 KHz to 4MHz.

5.3.12 CCP Module

The term CCP stands for "capture/compare/PWM" where it works in 3-modes such as compare mode, capture mode, and PWM mode.

5.3.13 Capture Mode

This mode captures the signal arrival time, or in other words, when the pin of this mode goes high, it captures the Timer1 value.

5.3.14 Compare Mode

Compare mode performances as an analogue comparator. When the value of the timer1 reaches a certain reference value, then it produces an o/p.

5.3.15 PWM Mode

The PWM mode offers pulse width modulated o/p with a 10-bit resolution and programmable duty cycle.

5.3.16 Applications of Peripheral Interface Controller

The applications of PIC microcontroller involve in peripherals, video games, audio accessories, etc. For a better understanding of this microcontroller, the following project demonstrates its operation.

5.4 LCD Display

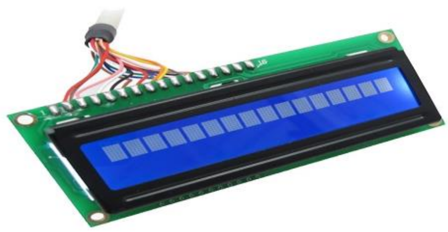


Figure 5. 10 2x16 LCD Display

- LCD (Liquid Crystal Display) screen is an electronic display module
- These modules are preferred over seven segments and other multi segment LEDs

5.4.1Construction and Working Principle of LCD Display

5.4.2 What is a LCD (Liquid Crystal Display)?

A liquid crystal display or LCD draws its definition from its name
itself. It is combination of two states of matter, the solid and the liquid. LCD uses a liquid crystal to produce a visible image. Liquid crystal displays are super-thin technology display screen that are generally used in laptop computer screen, TVs, cell phones and portable video games. LCD's technologies allow

An LCD is either made up of an active matrix display grid or a passive display grid. Most of the Smartphone's with LCD display technology uses active matrix display, but some of the older displays still make use of the passive display grid designs. Most of the electronic devices mainly depend on liquid crystal display technology for their display. The liquid has a unique advantage of having low power consumption than the LED or cathode ray tube.

5.4.3 How LCDs are constructed?

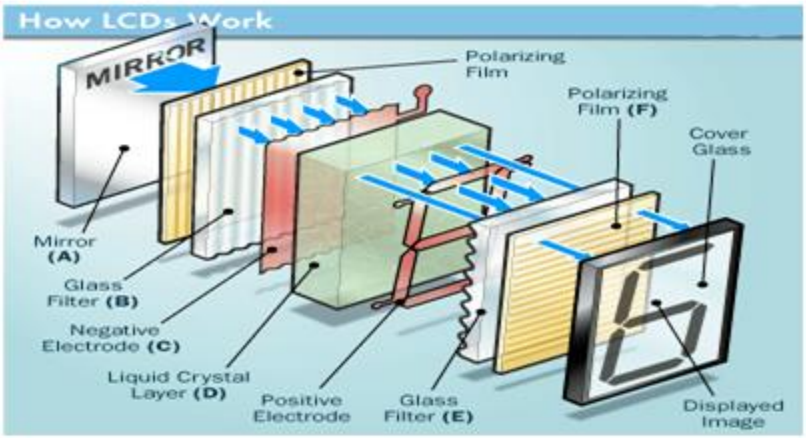


Figure 5. 11 LCD Construction

5.4.4 Simple facts that should be considered while making an LCD:

1. The basic structure of LCD should be controlled by changing the applied current.
2. We must use a polarized light.
3. Liquid crystal should able be to control both of the operation to transmit or can also able to change the polarized light.

As mentioned above that we need to take two polarized glass pieces filter in the making of the liquid crystal. The glass which does not have a polarized film on the surface of it must be rubbed with a special polymer which will create microscopic grooves on the surface of the polarized glass filter. The grooves must be in the same direction of the polarized film. Now we have to add a coating of pneumatic liquid phase crystal on one of the polarized filter of the polarized as the light strikes it at the starting stage.

Thus the light travels through each layer and guided on the next with the help of molecule. The molecule tends to change its plane of vibration of the light in order to match their angle. When the light reaches to the far end of the liquid crystal substance, it vibrates at the same angle as that of the final layer of the molecule vibrates. The light is allowed to enter into the device only if the second layer of the polarized glass matches with the final layer of the molecule.

5.4.5 How LCDs Work?

The principle behind the LCD's is that when an electrical current is applied to the liquid crystal principle of blocking light. While constructing the LCD's, a reflected mirror is arranged at the back. An electrode plane is made of indium-tin oxide which is kept on top and a polarized glass with a polarizing film is also added on the bottom of the device. The complete region of the LCD has to be enclosed by a common electrode and above it should be the liquid crystal matter.

Next comes to the second piece of glass with an electrode in the form of the rectangle on the bottom and, on top, another polarizing film. It must be considered that both the pieces are

5.4.6 Advantages of an LCD's:

- in comparison to some mill watts for LED's
- LCDs are of low cost
- Provides excellent contrast
- LCD's are thinner and lighter when compared to cathode ray tube and LED

5.4.7 Disadvantages of an LCD's:

- Require additional light sources
- Range of temperature is limited for operation
- Low reliability

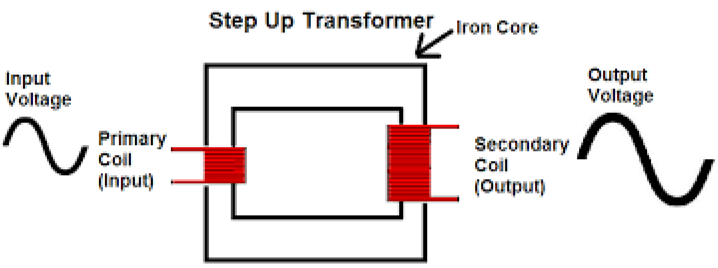


Figure 5. 12 Transformer

A step-up transformer acts as a voltage-increasing device. The amount by which it increases the input voltage depends on the ratio of the number of turns in the primary coil to the number of turns in the secondary coil.

Though step-up transformers increase the voltage of the output voltage, it comes at a price. Transformers are simply conversion devices. They do not create voltage or power. So if a step-up transformer increases voltage, it decreases current. If it doubles the voltage output, the current output gets cut in half. So that the output signal now has half the current capability as the input signal. Step-up transformers never create power; they only convert it into different form

5.6 12V Rechargeable Battery

Figure 5. 13 12v Rechargeable Battery

The battery is an essential component of electric car. It serves for ensuring start of the engine. In addition, the battery is a supplier of electric energy in an onboard network of the car. Typically, the battery consists of a container which is divided by partitions into cells.

In these cells they are called banks there are several interconnected special units. 12-volt car battery has 6 of these cells. Each of these units contains a set of positive and negative electrodes.

Chapter- 6

Data Calculation

Solar output clear sunny day

SL NO	Date	Time (Clock in hrs)	Temp (Degree Celsius)	Voltage (V)	Courent flow (A)
1	13-September-2023	9:00:00 AM	29	17	0.17
2		12:00:00 PM	34	19	0.157
3		3:00:00 PM	31	18	0.166

Solar output light cloudy

SL NO	Date	Time (Clock in hrs)	Temp (Degree Celsius)	Voltage (V)	Courent flow (A)
1	14-September-2023	9:00:00 AM	27	15	0.2
2		12:00:00 PM	32	18	0.166
3		3:00:00 PM	29	16	0.18

Solar output rainy day

SL NO	Date	Time (Clock in hrs)	Temp (Degree Celsius)	Voltage (V)	Courent flow (A)
1	15-September-2023	9:00:00 AM	22	9	0.33
2		12:00:00 PM	29	16	0.187
3		3:00:00 PM	25	13	0.23

The output of wind turbine is varied due to difference in velocity of wind and swept volume of wind by rotor diameter test with blade diameter of 3mm

SL NO	Wind Velocity (km/h)	Blade shaft speed (rpm)	Generator shaft speed (rpm)	Voltage (V)	Courent flow (A)
1	8	60	130	6	0.12
2	10	72	220	8.2	0.14

Chapter- 7

Discussion and future scope

7.1 DISCUSSION

1. China - 34%.

2. united states-21%.

3. German -6%.

4. India -4%.

5. Brazil-4%.

6. Bangladesh -1.9249%.

That why future is bright and more investment and produce more electricity or power.

[20] Hulk Energy Machinery 2011

Chapter- 8

Conclusion

8.1 Consolation

Reaching the non-electrified rural population is currently not possible through the extension of the grid, since the connection is neither economically feasible, nor encouraged by the main actors. Further, the increases in oil prices and the unbearable impacts of this energy source on the users and on the environment, are slowly removing conventional energy solutions, such as fuel genet based systems, from the rural development agendas. Therefore, infrastructure investments in rural areas have to be approached with cost competitive, reliable and efficient tools in order to provide a sustainable access to electricity and to stimulate development. Renewable energy sources are currently one of the most, if not the only, suitable option to supply electricity in fragmented areas or at certain distances from the grid. Indeed, renewable are already contributing to the realization of important economic, environmental and social objectives by the enhancement of security of energy supply, the reduction of Greenhouse gases and other pollutants and by the creation of local employment which leads to the improvement of general social welfare and living conditions. Hybrid systems have proved to be the best option to deliver “high quality” community energy services to rural areas at the lowest economic cost, and with maximum social and environmental benefits. Indeed, by choosing renewable energy, developing countries can stabilize their CO2 emissions while increasing consumption through economic growth.

8.2 ADVANTAGES

The advantages covered by the propose system are listed as,

- Overcoming disadvantages of standalone renewable electrical energy generation system.
- Producing much more efficiency as two or more renewable energy generation system working together in the terms of electrical energy generation.
- Since, the system doesn’t have microcontroller or microprocessor the complexity of system testing and understanding became easy in terms of difficulties.
- System maintains is remarkably reduced and becomes easy.

8.3 DISADVANTAGES

There’s no system without having a disadvantage. So as, the system have disadvantages as follow:

- The first time installation cost is huge in terms of finance.
- The circuit designing complexity is more as there in no micro-computer for controlling action.

8.4 APPLICAATION

Some of the applications for the purpose system are listed follow,

- The system is used for domestic purpose.
- Street lighting, Traffic signals.
- Various monitoring systems.
- Powering up for communication system.
- Pump irrigation Systems.
- Small Boats like watch.
- As per requirement of electrical energy the system can be either designed or updated for higher energy requirement.
- When ac mains supply is not available, the proposed system can be used as emergency system with only few changes.
- So, it can be used for almost every electronic, mechanic, viz. system needing/ require electric energy to work on.

RFERENCES:

[1] T.S. Bajaj Deodar and A. Seethe Kumar, “Design of high step up modified for hybrid solar/wind energy system,” Middle-East Journal of Scientific Research 23 (6) pp. 1041-1046, ISSN 1990-9233, 2015.

[2] Walla Elsa fee Malik Elam in, “Hybrid wind solar electric power system,” report, University of Khartoum, Index-084085, July 2013.

[3] Sandeep Kumar and Vijay Garg, “Hybrid system of PV solar/wind & fuel cell,” IJAREEIE, Vol. 2, Issue 8, ISSN 2320-3765, August 2013.

[4] Rakeshkumar B. Shah, “Wind solar hybrid energy conversion system- literature review,” International Journal of Scientific Research, Vol. 4, Issue 6, ISSN 2277-8179, June 2015.

[5] Ugur FESLI, Raif BAYIR, Mahmut OZER, “Design & Implementation of Domestic Solar-Wind Hybrid Energy System”, Zonguldak Karallas University, Department of Electrical and Electronics Engineering, Zonguldak, Turkey.

[6] Nazih Moubayed, Ali El-Ali, Rashid Outbid, “Control of an Hybrid Solar-Wind System with Acid Battery for Storage”, Wesaw Transactions on Power System, Laboratory of Science in Information and System (LSI), Axe-Marseille University, France

[7] A. Testa, (2010). "Optimal design of energy storage systems for stand- alone hybrid wind/PV generators," in Power Electronics Electrical Drives Automation and Motion (SPEEDAM), *2010 International Symposium*, 1291-1296.

[8] An-Najah National University (2012). *Application of wind energy*, Retrieved on December 4, 2014, from http://www.najah.edu/page/3215

[9] Breeze P., (2009). *Renewable Energy Focus Handbook.* Elsevier Inc.

[10] D. W. Hart, (2007). *Introduction to Power Electronics*: Upper Saddle River: Prentice-Hall International, Inc., 2007.

[11] D. Pupin, (2010). Analysis of diffusion paths for photovoltaic technology based on experience curves. *Solar Energy, vol. 64*, 331-340.

[12] Danish Wind Industry Association, (2011). Retrieved on November 30, 2014, from http://www.windpower.org/en/tour

[13] Dassault System (2011). *Productivity: Experience the Benefits of SolidWorks*.

Deshmukh, MK, Deshmukh, SS (2008). Modelling of hybrid renewable energy systems. *Renew Sustain Energy Rev, 12*, 235–249.

[14] Duffie, J.A. and Beckman, W.A., (2013). *Solar Engineering of Thermal Processes*. 4th ed. John Wiley and Sons, Inc.

[15] Fernando D. B., Hernán D. B., and Ricardo J. M., (2007). Wind Turbine Control Systems: Principles, Modelling and Gain Scheduling Design. *London: Springer-Verlag.* 39-45

[16] Flex sol arc ells (2014). Retrieved on November 23, 2014, from http://www.flexsolarcells.com/index_files/OEM_Components/Flex_Cells

/specification_sheets/21_FlexSolarCells.com_PowerFilm_Solar_PT15-300_Specification_Sheet.pdf

[17] Global Wind Energy Council (2014). *Worldwide installed wind capacity the last 17 years*. Retrieved on December 2,2014 from http://www.gwec.net/wp-content/uploads/2014/04/4_21-1_global-annual-installed-wind-capacity- 1996-2013.jpg

[18] Hayashi, T., Yan, L. and Suzuki, K. (2004). *Wind Tunnel Tests on a Three-stage Out-phase Savona's Rotor*. Retrieved on November 26, 2014, from http://www.2004ewec.info/files/231400_tsutomuhayashii_01.pdf

[19] HOMER (2014). *Energy Modelling Software for Hybrid Renewable Energy Systems*. Retrieved on December 10, 2014, from http://homerenergy.com/

[20] Hulk Energy Machinery, (2011). *Solar panel manufacturing*. Retrieved on November 30, 2014, from http://www.hulkenergy.com.

[21] I. Daut and M. Irwanto (2010). Potential of Solar Radiation and Wind Speed for Photovoltaic and Wind Power Hybrid Generation in Perlis, Northern Malaysia, *IEEE journal 2010*, 132-137

[22] J.B.V. Subrahmanyam and P. Alluvia, (2012). Development and Perspectives of a Hybrid Solar-Wind System, *Engineering Technology & Applied Science Research 2(1)*, 177-181

[23] J.F. Manuel and J, G. McGowan (2009). *Wind Energy Explained, Theory, Design and Application,* 2nd Ed, John Wiley & Sons Ltd, UK.

[24] J.K. Kalel's (2010). *Stand-alone and hybrid wind energy systems*, Woodhead Publishing Limited.

[25] J.P. Abraham and B.D. Plourde (2012). Summary of Savona's wind turbine development and future applications for small-scale power generation. *Journal of renewable and sustainable energy, 4(4)*, 241-264

[26] Jain, P. (2011). *Wind Energy Engineering*, McGraw-Hill, New York

Appendix A

```
#include <16F72.h>
#use delay (clock = 16000000)

FLOAT BV, I, W, TP;

Void main ()
{
 lcd_gotoxy (1,1);
 print (lcd_putc, "  WELCOME TO    ");
 lcd_gotoxy(1,2);
 printf(lcd_putc, "     BUBT       ");
 delay_ms(1500);

 lcd_gotoxy(1,1);
 printf(lcd_putc, " SUBMITTED BY:  ");
 lcd_gotoxy(1,2);
 printf(lcd_putc, "                ");
 delay_ms(1500);

 lcd_gotoxy(1,1);
 printf(lcd_putc, " Name");
 lcd_gotoxy(1,2);
 printf(lcd_putc, " Name ");
 delay_ms(1500);
 lcd_gotoxy(1,1);
 printf(lcd_putc, " Name ");
```

```
 delay_ms(1500);
  while(true)
  {
    lcd_show();


      set_adc_channel( 0 );
      BV = read_adc();


      set_adc_channel( 1 );
      I = read_adc();
      W=(BV*I);


      set_adc_channel( 2 );
      TP = read_adc();
      CHGC=RC0



  }  // END while(true)


}  // END MAIN()



///////////////////////////////////////////////////////////////////////////////


void lcd_show(void)
{
```

```
   lcd_gotoxy(1,1);
   printf(lcd_putc, "B:%2.1f    ",BV);


   lcd_gotoxy(10,1);
   printf(lcd_putc, "TP:%2.1cC ",TP;


   lcd_gotoxy(1,2);
   printf(lcd_putc, "I:%1.2fA  P:%2.1fW ",I,W);
}

////////////////////////////////////////////////////////////////////////////
void SYS_CTRL(void)
{
    IF( BV > 14.5 )
     output_LOW (CHGC);
    IF( BV < 13.4 )
     output_high (CHGC);
}
```