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Impacts of Wind Speed, Pressure and Altitude on Different Types PV Module Performance

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ABSTRACT

Photovoltaic (PV) module is electronic equipment that converts the light from the sun or from other source directly to electricity. There are different types of PV modules according to active elements. Active elements have the responsibility to convert the light photons into electricity. The performance of modules is a function of their efficiency and efficiency measures the conversion capability of modules. The ability of PV module to convert light into electricity is highly dependent on weather conditions like ambient temperature, module temperature, humidity, altitude, atmospheric pressure, and wind speed and wind pressure. Various studies have showed that PV module conversion ability decreases with increase in temperature and has also proved that module cooling increase the module performance. The immediate objective of the research project is to measure the light conversion ability of the different type's solar panels against different weather/environmental parameters. In this experimental work, a system which consists of different devices and sensors has been developed that uses temperature sensors, wind sensor and pressure sensor to quantify the interactions between solar panels and the environment. The different conditions of the weather like ambient temperature, atmospheric pressure and wind speed etc has been measured through respective sensors at ground and at different heights from the ground and finally the results with respect to solar panels performance has been compared.

The efficiency of modules is directly related to their output power. A module with greater output power has greater efficiency. The results were compared with respect to their output power and the results were showing that module output power increases with height and wind speed. The results showed the impacts of height, wind speed and atmospheric pressure on monocrystalline module were more than the polycrystalline and amorphous silicon PV module.

Keywords: Weather Impact; Photovoltaic Modules; Arduino; Wind Sensor; PLX-DAQ; Environmental Parameters.

1. INTRODUCTION

.The supply of energy is a key factor in modern societies. Global warming is the dangerous issue of the modern world. the Old fossil fuel sources, in particular coal and natural gas have been projected as the dominant energy source contributing for energy generation are the main cause of environmental pollution and global warming. Now, in the world, because of climate change, air pollution and energy insecurity, energy production has been transformed from non-renewable energy re-sources to renewable energy re-sources i.e. clean energy re-sources. Clean sources of energy are nearly does not exhaust GHGs and other air pollutants and has almost no contribution in global warming and air pollution. Renewable energy sources i.e. wind, solar and water and renewable sources are the valuable alternatives to fossil fuels. Today in the world, renewable energy exploration, development and demand is on upward trend. By the end of 2017, more than 26% estimated renewable energy generation provided and renewable energy accounted for an estimated 18.1% of total final energy consumption. In 2018, 181GW electricity from renewable sources was produced and global renewable power capacity--including hydropower-- rose to approximately 2,378GW. The fig below shows the global renewable electricity generation 2018 [2].

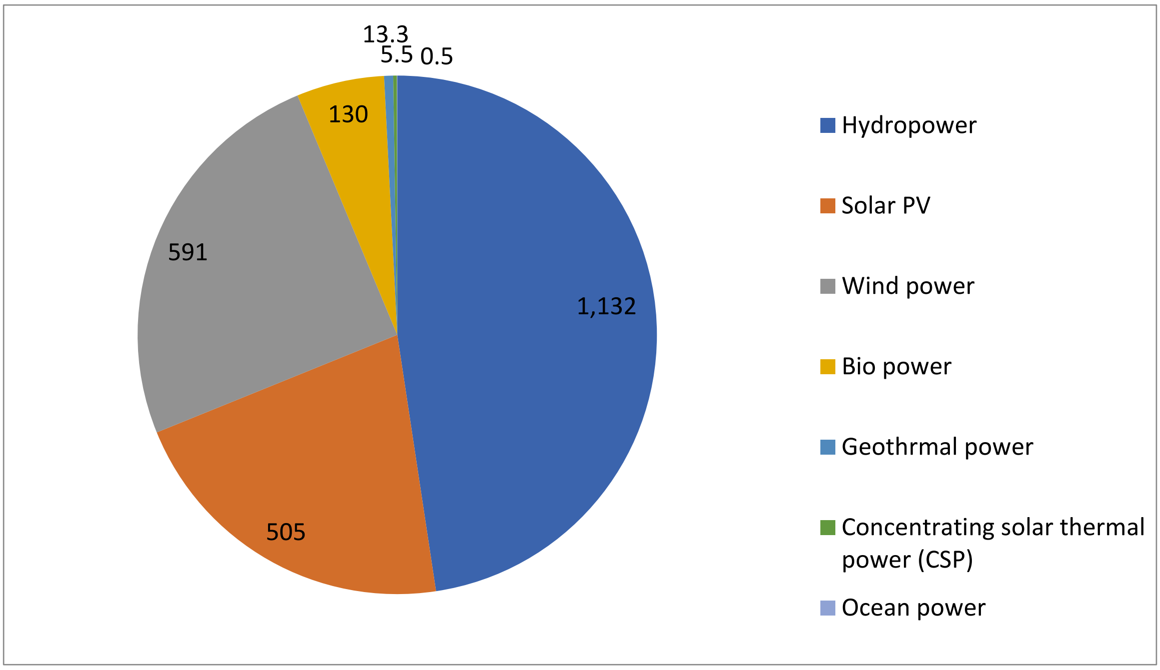

Figure 1.1: Global renewable power shares till 2018

Below table shows the top countries total renewable power generation as the end of 2018.

Table 1.1: Total generation of renewable power by country wise

Total renewable power capacity(including hydropower)	China	US	Brazil	India	Germany
Bio-power generation	China	US	Brazil	Germany	India
Geothermal power	US	Indonesia	Philippine	Turkey	NewZealand
Hydropower	China	Brazil	Canada	US	Russia
Solar PV	China	US	Japan	Germany	India
CSP	Spain	US	South Africa	Morocco	India
Wind power	China	US	Germany	India	Spain

Pakistan is facing a dreadful challenge of energy shortage with the demand outweighing its supply. The energy shortage has detrimentally affected all sectors of economy leading to an annual loss of up to 3% of the GDP. Pakistan's existing energy mix is greatly hanging on exorbitant fuels, like oil, coal and gas. Below fig shows the basic energy mix in MW of the country.

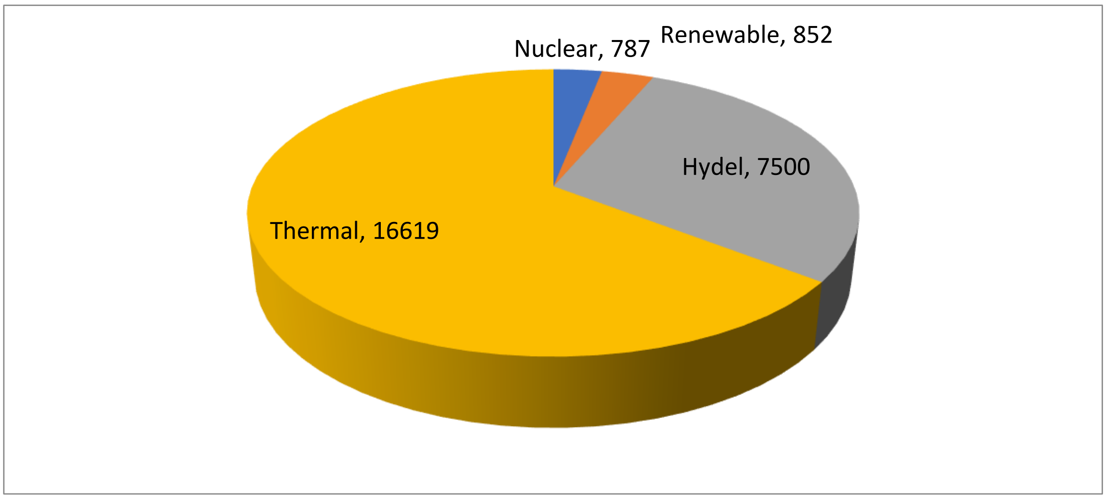

Figure 1.2: Pakistan energy mix 2019

In Pakistan, luckily huge potential of renewable energy especially solar energy, wind energy and hydroenergy is available. Most places of the country receive high solar light whole year i.e. 4.5-7.0kWh/ square meter/ day approximately, the summer season is long as compared to winter and the estimated potential capacity for installation of solar PV power of Pakistan is 1,600GW which is 40% greater than present consumption. Pakistan can produce large amount of electricity from solar rays. In most places of the country, sun shines nearly eight to nine hours per day and more than 300 days in the year, so Pakistan has an enormous rooftop electricity generation potential. Based on presently range of possible PV efficiencies, area of 1 squarekilometer has potential to generate 40-55MW power. The GoP is promoting the use of solar panels for electricity generation through the Feed-in-Tariff (FiT)/Upfront Tariffs for up to 100MW and net metering for up to 1MW.

II. LITERATURE REVIEW

The performance of PV module greatly depends on its basic characteristics. A solar panel with high conversion efficiency has good performance. Solar panel conversion efficiency is defined as the ratio of maximum electrical output power to the total power of incident radiations i.e.:

$$\eta\% = \frac{Pme}{Prad} \times 100$$

Where

'Pme' is the maximum electrical output power and is equal to the product of maximum voltage and maximum current. 'Prad' is the total power of light incident upon the surface of solar panel and is equal to the product of solar panel area and solar intensity. The above equation can also be written as:

$$\eta\% = \frac{Im \times Vm}{Jin \times Ap} \times 100 \text{----------------------} (1)$$

Where 'Im' represents the maximum current of solar panel, 'Vm' represents the PV module maximum voltage, 'Jin' is the incident intensity of rays and 'Ap' represents the PV module surface area.

Fill Factor is a parameter of solar panel that affects its efficiency. It is the ratio of maximum electrical output power to the product of open circuit voltage and short circuit current. Mathematically:

$$FF = \frac{Im \times Vm}{Uoc \times Isc}$$

Where FF stands for Fill Factor, Uoc represents the open circuit voltage and Isc is the short circuit current of the solar panel.

The above equation can be written as:

$$Im \times Vm = Uoc \times Isc \times FF \text{---------------------} (2)$$

By substitution equation (2) in equation (1), the below equation is achieved.

$$\eta\% = \frac{Uoc \times Isc \times FF}{Jin \times Ap} \times 100$$

The above equation shows that efficiency of solar panel depends on the open circuit voltage, short circuit current and fill factor.

PV modules performance also disturb by the particular region weather factors in which they are installed. Among it, the most severe is ambient temperature and module temperature. Many researchers have been conducting research studies on this major issue in different regions in the world. Researchers have been examining the impacts of different cooling methods on PV modules to reduce its temperature and save the module from overheating. Primarily, there are two methods of cooling like passive cooling and active cooling. Passive cooling does not need supply of power and active cooling requires.

III. PROSPECTS AND RESEARCH AIM

The performance of the PV modules not only greatly depends on its basic characteristics but also on the environmental parameters. Among it, temperature is the most important weather condition that influenced the performance of the PV modules. The researchers indicated that the maximum efficiency of the PV module can be achieved by changing the ambient temperature around it. The PV modules are produced at STC, but when they are used for domestic or commercial purposes in a particular area, the weather conditions like ambient temperature, atmospheric pressure, wind speed etc affect its performance for that particular area. The PV module's performance changes with actual location and prevailing environmental conditions to which they are subjected. Different types of modules and arrays studied with different climates of different locations have been taken into account by researchers. Researchers also have been working on how to reduce the PV modules temperature and examined different cooling mechanisms.

In past research work, researchers worked on the cooling impacts on PV module performance has investigated and showed that cooling decreased the temperature of PV module and hence increased the efficiency of PV module. Several indoor and outdoor research works have been done to examine the effects of cooling over single PV module or multi PV modules. A researcher conducted an experimental study on Polycrystalline PV module in controlled conditions. He used two solar panels one with heat sink and other without heat sink and found that relative efficiency increased by 9% [3]. Another experimental study conducted; as cooling solar panels by evaporation. This study was based on outdoor, back surface of one solar panel was wetted and exposed to surroundings and other solar panel was placed as reference. The results showed that more than $20C^0$reduction in PV panel temperature occurs and around 14% relative efficiency was observed [4].

In 2017, a detailed research study based on outdoor experiment was done. In this experiment, two solar panels were used; one was with water-cooling and with Aluminum heat sink and the other as reference without water-cooling and heat sink. When results were compared, it had seen that more than 3% efficiency increased [5]. Furthermore, a researcher attempts to investigate the effects of air velocity on two solar panels namely; monocrystalline and polycrystalline and this attempt was based on controlled & indoor conditions. The result shows that module temperature was dropped by $17.2C^0$and the module efficiency and power output increased from 10 to 12% with air velocity [6]. Another research carried out recently, based on simulation study upon silicon solar cells inside wind tunnel to examine the elevation and wind direction impacts on PV panels efficiency. This study involves six solar panels designed in two columns and three rows, facing towards south at an angle of 30 degree. The results show that maximum increase in efficiency occurs when the strikes the solar panel from back i.e. wind comes from the north [7].

The prime focus of this research is to compare the performance of different types PV modules against different weather parameters impacts. In methodology, only single PV module was considered of 3 different types, namely; monocrystalline, polycrystalline, thin film amorphous silicon. All modules were of same ratings and module, pressure sensor and Cup Anemometer was mounted on approximately 20 feet high stand and temperature sensor was fixed with the PV module back surface. This study do not considered reference solar panel and simply the study examines the wind speed, atmospheric pressure, and wind pressure and altitudes impacts on solar panel performance.

2.1 Research aim

This research study aims to investigate the impacts of speed of natural wind, atmospheric pressure and pressure of wind at different altitudes on different types of PV modules efficiency in terms of voltage, current and output power without any water or heat sink material procedure of cooling involving. In this study, only procedure of natural convection cooling is taking into account and this experiment is based on outdoor conditions.

IV. RESULTS

1.1 PV Modules Output Power at Ground:

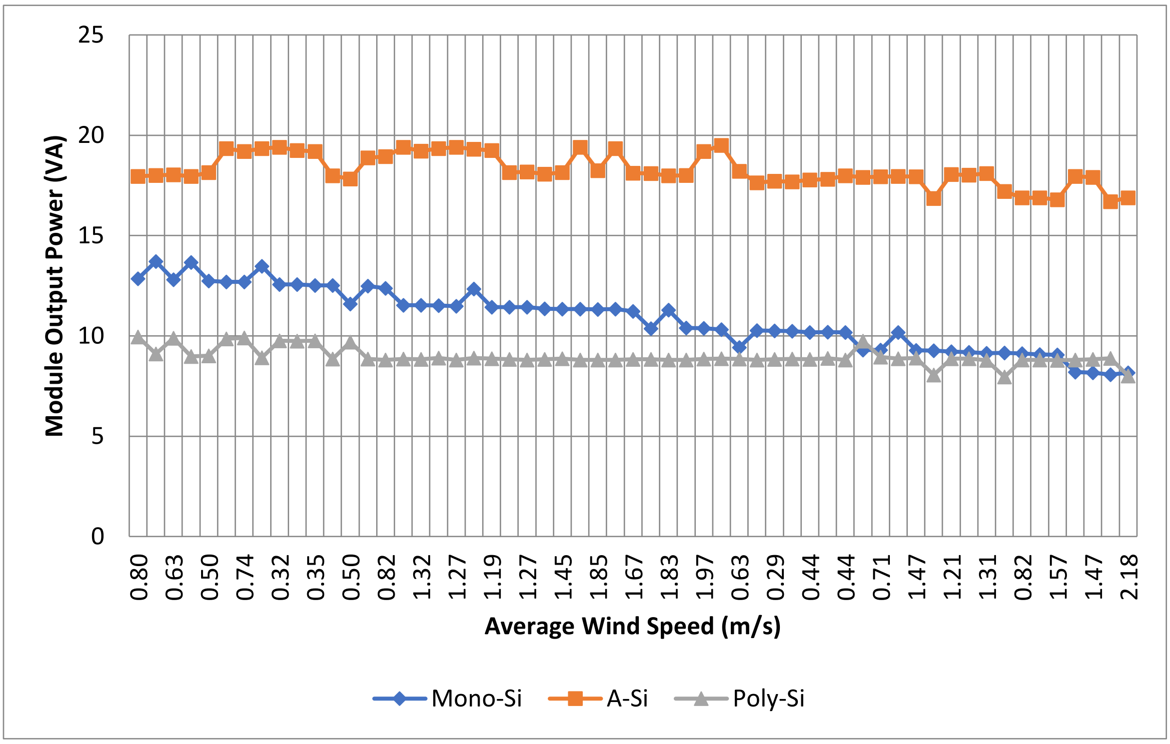

Fig 4.1

Sketch between Module Output Power & Average Wind Speed

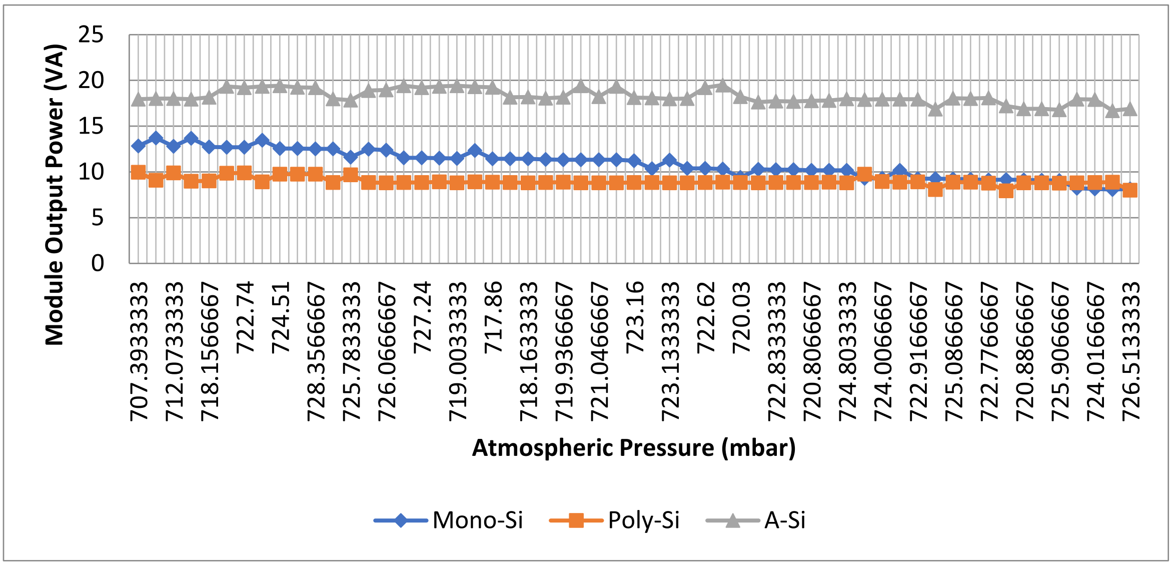

Fig 4.2: Sketch of Module Output Power with respect to Average Atmospheric Pressure

1.2 PV Modules Output Power at 2.43 Meters height:

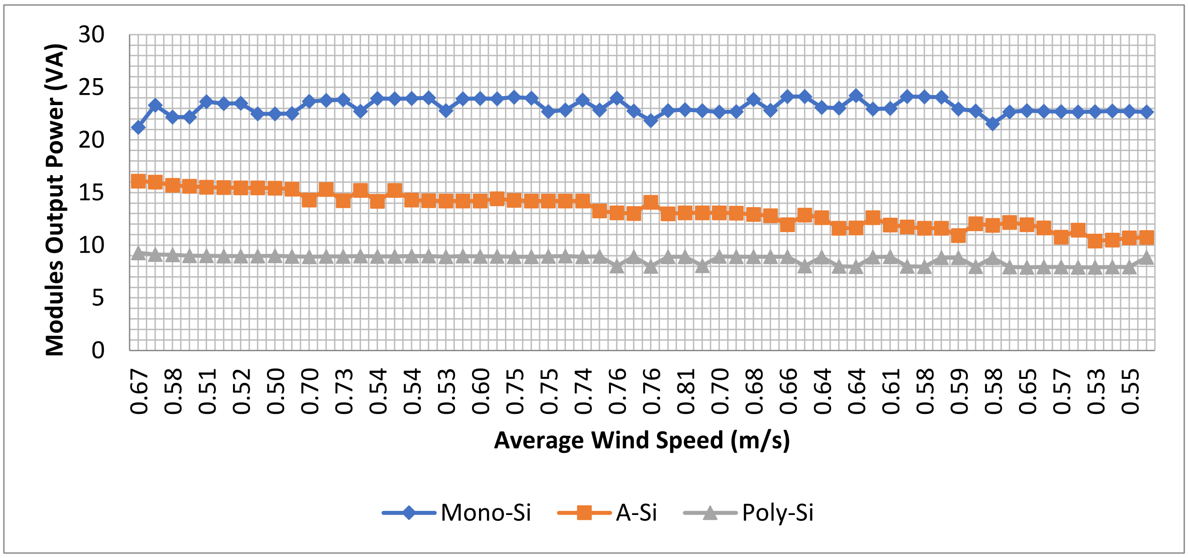

Fig 4.3: Chart between Output Power and Average Wind Speed

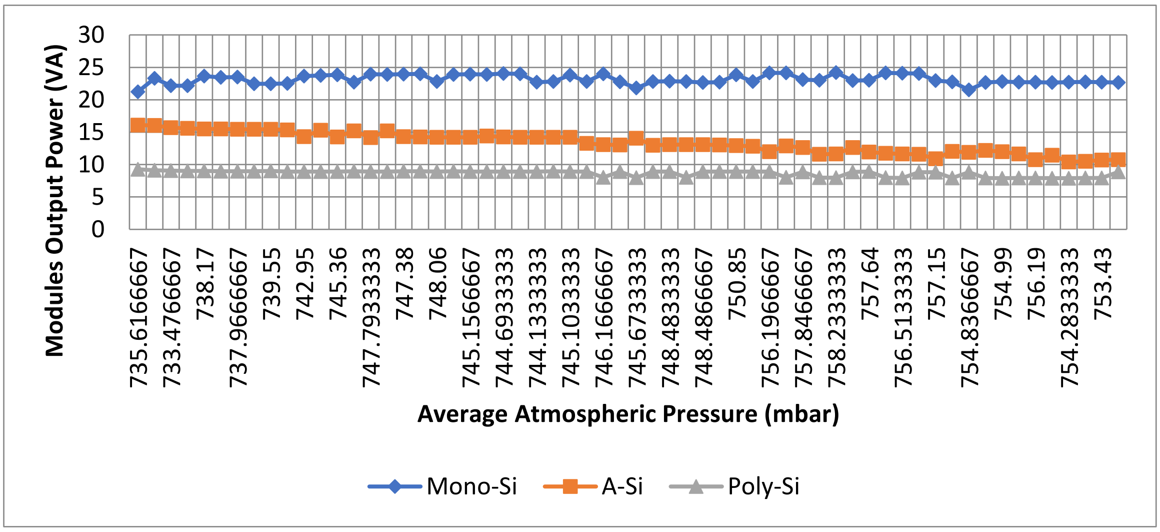

Fig 4.4 Output Power & Average Atmospheric Pressure graph

1.3 PV Modules Output Power at 4.57 Meters height:

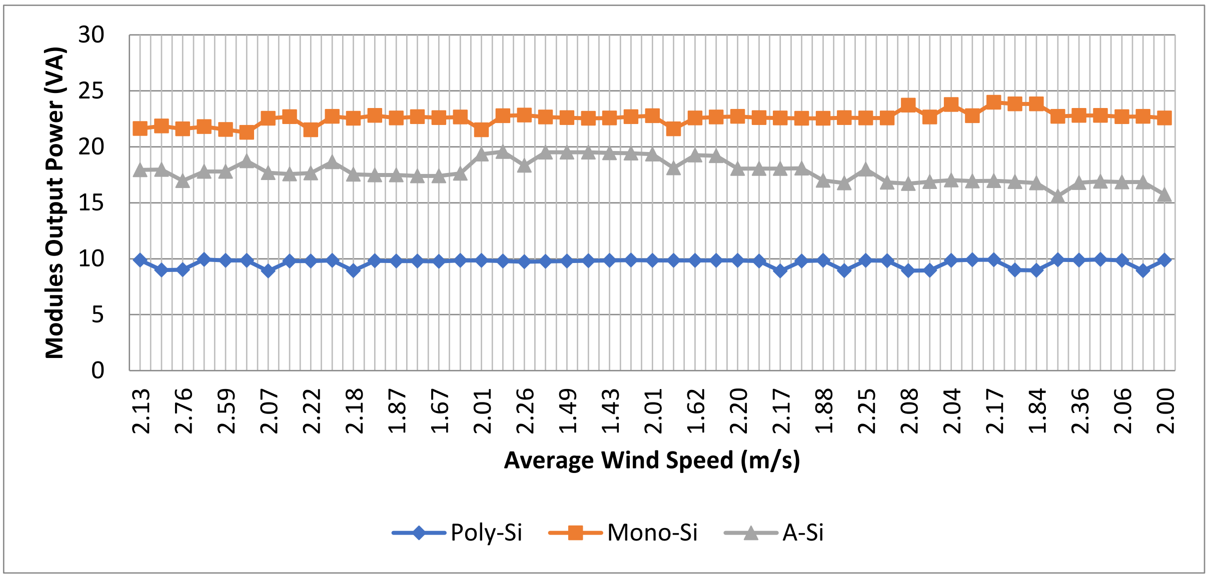

Fig 4.5: Module Output Power versus Average Wind Speed

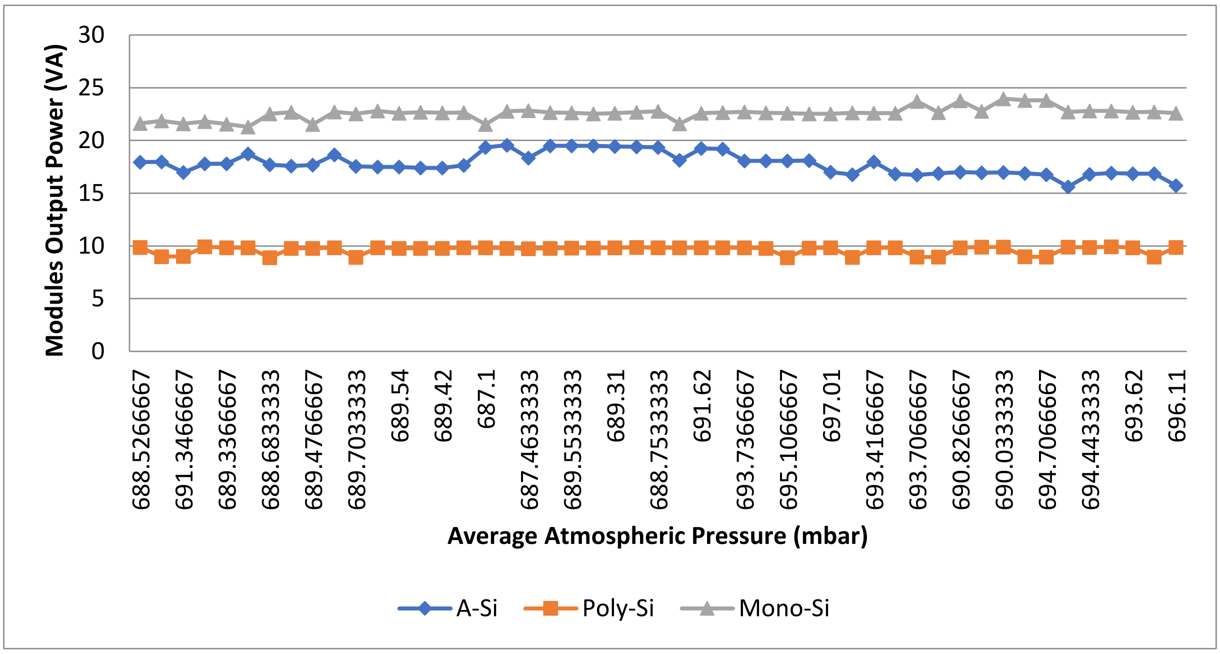

Fig 4.6: Module Output Power versus Average Atmospheric Pressure

V. CONCLUSION

The conclusions of this experimental work can be summarized as follows:

- On Monocrystalline Photovoltaic Module, the impacts of wind speed and atmospheric pressure at ground and mentioned heights were more as compared to other two solar panels.
- The temperature difference between atmosphere and module was low for Amorphous Silicon Photovoltaic panel as compared to Poly-Si and Mono-Si Photovoltaic panels.
- The curve obtained for module output power and wind speed was approximately the same with the module output power and atmospheric pressure.
- At ground, Amorphous Silicon Photovoltaicpanels produced more power as compared to other PV panels.
- At 2.43 & 5.47 meters, Monocrystalline Photovoltaicpanels produced more power than the other two PV panels.

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