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Experimental Design of Small Horizontal Axis Wind Turbine for Home Electricity

Abdlmanam S. A. Elmaryami[1]*, Al Hussain A. Abdalrahman[2],
Rahel G. Rahel[3] and Mahmoud Abdelrazek Ahmida[4]
[1], [3]Bright Star University [BSU], El-Brega, Libya
[2]The Libyan Academy for Postgraduate Studies; Al-Bayda, Libya
[4]The Libyan Academy for Postgraduate Studies; Ajdabiya, Libya

Abstract. In recent years, the energy production by wind turbines has been increasing, because its production is environmentally friendly; therefore, the technology developed for the production of energy through wind turbines brings great challenges in the investigation. The use of wind energy worldwide has overgrown in recent years to reduce greenhouse gas emissions. Wind power is free, but the installation and maintenance of wind turbines still remain costly. Wind vitality is the second biggest wellspring of sustainable power source after hydropower. However, it has not yet accomplished full matrix equality with fossil vitality sources. In this work experimental design of small HAWT for home electricity has been designed and analysed in the laboratory at the Libyan Academy for Postgraduate Studies, Al-Bayda-Libya. Experimental work was used in this paper to evaluate the wind energy data in Al-Bayda, East of Libya. The field tests and measurements proved that the present turbine is efficient and has long life-time and needs minimum maintenance. Wind turbines convert wind energy into electricity. The efficiency of this conversion is measured by comparing the incoming winds speed and the output power. From the experimental work it was found that the present turbine is efficient, easy to construct and assembly, has long life-time and needs minimum maintenance, suitable for different sites such as urban, suburban, rural, and sea coast and the output power of the turbine covers the consumption of many electric devices.

Key words: Al-Bayda-Libya, Horizontal axis wind turbine (HAWT), Wind power's design Aerodynamic, Wind speed, Betz limit, Power Generation, Local Ecology, wind turbine blades, Gearbox, Generators, Converter, Anemometer, Tachometer, Multimeter

Introduction

Libya is a country located in North Africa. Libya, is an oil exporting nation in North Africa covers an area of approximately 1,750,000 km^2 with a 2000 km long coast (Khalil, & Asheibe, 2015). The country has a population of about 6 million, which includes 166, 610 non-nationals. Libya tends to be a significant nation in the Mediterranean basin and the richest in North Africa in terms of natural resources. In recent times, Libya has become one of the world's primary energy sources since it is the largest natural gas exporter and oil exporter (Ekhlat et al., 2007). Like other countries, Libya suffered from high conventional energy prices, environmental issues, rapid demand growth and high energy consumption. Libya's major source of income is oil and the country depends greatly on the oil it produces as the major source of income (Ibrahim, 2006). It is worth noting that Libya has a high potential of renewable energies, especially wind energy and solar energy, which can create local jobs, drive local economies and reduce carbon pollution (Hallett, & Clark-Lowes, 2017). However, Libya wants to reduce the dependence on oil as its source of income through improved investment in the natural gas, fisheries, mining, and tourism industries (Otman, & Karlberg, 2007). Libya attempts to use the large resources it derives from oil to invest in infrastructures that will support the quick realization of oil dependence as its major source of income. Libya wants to achieve these projects by setting up designs, development, and implementations that will support the achievement of this project. In addition, Libya is planning to make itself one of the most influential economic countries that mediate between Europe and Africa in commercial terms. In recent times, there have been signs that Libya is likely to move towards liberalization, economic reform and a decrease in the government's direct role in the country's economy (Martinez, 2007). Libya has plans to reduce dependency on oil as the main source of income and invest more in agriculture, fisheries, tourism, natural gas and mining. Diversification is a critical issue since the current production rates indicate that the Libyan oil reserves are less likely to last past this decade (Gawdat, 2011). In this manner, the long-term health of the economy relies heavily on maintaining a petroleum sector that is self-sustaining. The agricultural sector has become a top government priority with hopes that the manmade river, a $30 billion project will help tap water from underground aquifers to reduce dependence on food import and reduce water shortage in the country. Demand for oil resources will reduce greatly if the natural gas, tourism, fisheries, and mining industries designed and implemented effectively. Only with effective investment and implementation of these industries, that Libya will achieve its aim of reduced dependency on oil as a major source of income. Other renewable energy such as the wind energy and solar energy will help Libya reduce the dependence on oil. These renewable energies will help Libya reduce the dependence on oil as a major source of income if their components are properly and effectively designed, manufactured, and implemented (Gawdat, 2011). A Run of Libyan's man-made river hydroelectricity model (LMR HEM), a simple model of S. P. P. to study the effect of increasing the boiler pressure on the efficiency of the model, a water pump to study the effect of the impeller blades number on the pump performance, solar water pump model to study the effect of the impeller blades number on the pump performance where designed and studied (Elmaryami, El-Garoshi, Mohammed, & Abraheem, 2022; Elmaryami, Khalid, Abdulssalam, Alssafi, & Mohamed, 2021; Elmaryami, Sousi, El-Garoshi, Othman, 2021; & Abdlmanam, et al., 2022).

In this paper experimental design of small HAWT for home electricity has been designed and analyzed in the laboratory at the Libyan Academy for Postgraduate Studies, Al-Bayda-Libya. Experimental work was used in this research to evaluate the wind energy data in Al-Bayda, East of Libya.

The field tests and measurements proved that the present turbine is efficient.

The present turbine is easy to construct and assembly.

The turbine is suitable for different sites such as urban, suburban, rural, and sea coast.

The output power of the turbine covers the consumption of many electric devices.

The turbine has long life-time and needs minimum maintenance.

Libya is one of the oil exporters and natural gas exporters to become one of the top lists of primary energy sources in the world. On the other hand, Libya, like other countries in the world suffers from high energy consumption, high conventional energy prices, and environmental issues, combined with rapid demand growth. As a result, the Renewable Energy Authority of Libya (REAOL) was founded to promote the development of renewable energy in Libya to increase the utilization of renewable energy from 6% to 10% by 2020. provide the potential of renewable energy resources in Libya and implement future projects for the utilization of renewable energy. The study shows that there is huge potential for renewable energy in Libya, especially solar and wind. The Libyan government will have to be a more aggressive target in the promotion of renewable energy to achieve environmental sustainability in Libya (Mohamed, & Masood, 2018).

Current Situation of Renewable Energy Resources in Libya

The usage of mobile phones has been hugely accepted by Malaysians especially Libya energy sources currently being used are largely unsustainable. It is predicted that the current oil reserve will serve Libya for the next thirty years but these statistics have not been verified (Fogarty, & Lamb, 2012). Even though this is true, the country would need to look for alternative energy sources before the 30 years expires. Libya has been famously known for being a major supply of non-renewable fuel in form of oil and natural gas. However, research has shown that the country is lying on huge potential resources that can be used to generate renewable energy which would be sufficient for domestic use and be exported to countries in Europe (Michaelides, 2012). Currently, much of the renewable source of energy is not being utilized. The country uses 42% of heavy fuel, 20 % light fuel, 38% natural gas and zero % of renewable energy. One of the potential renewable sources that it could look into is the solar energy. Being a country that receive ample amount of solar energy throughout the year, it can tap a lot of energy from the sun which can be used in the industry and for lighting purposes (Sorensen, 2010). This could be practiced on both small and large scale level. It could also tap energy from the wind (Mukherjee & Chakrabarti, 2004). The average speed of wind in Libya studied in 2004 was seen to be 12-14 mph at 40m altitude. This is lower than the wind speed of other countries that generate energy from wind. Tides could also be used to generate a small amount of energy (Sioshansi, 2011). With the current energy crisis and the feared doom of depletion of natural oil, the country has also started exploring ways in which it can obtain energy from renewable sources (Mulvaney, 2011). The Renewable Energy Authority of Libya (REAOL) has put on measures which to increase renewable energy source use by 2020 to 10% which is currently below 1%. It is targeting to develop various wind farms and other renewable power generation plants which will enable it achieve its goals. The renewable energy sources in Libya are underutilized and form less than 1% of the energy used in the country. The country has used renewable energy in form of biomass, photovoltaic energy, wind energy and solar thermal energy. PV energy is the most popular and has been used since 1976. Currently there are over 100 PV stations all over the country. The PV beside the installation costs involves no further costs. These have been used more in electrifying the rural areas. Solar energy is almost totally untapped except for the solar bond created in 1994 whose purpose has been to desalinate water. Wind energy has been used for water pumping water (Kurokawa, Ito, Vleuten, & Faiman, 2009). The country however has a plan to increase the current use of renewable resources from 1% to 10% by the year 2020. These are the estimated increase by the type of source. This project is expected to cost around 184m Libyan Dinar. Plans are also underway to set up PV plants in three main locations which are projected to produce 45MW every year. Currently, renewable energy is not available to most Libyan citizen. However, by the time the project stated above is completed, all Libyans will be able to access clean energy. This project is intended to be the start of the road towards the transformation of the Libyan energy from then non-renewable form to the renewable form (Hiscock, 2012). Although the initial cost is seen to be high in comparison to the price of oil, it is believed by the time this project is completed, the cost of creating renewable energy will have reduced to a cost which is reasonable as a result of technological development in this field. Solar energy is the energy source of with the highest potential (Ummel, & Wheeler, 2008). The cost of producing solar energy which equals one barrel of oil is quite high at around $50. However, it still lower compared to the cost of a barrel of oil which is about $70. Libya is the part of middle North Africa with area of almost 1.8 million km^2. Approximately 90% of this area can be considered as hot sunny desert that helps to generate solar energy as renewable source. The sun duration ranges from 3000 to 4000 hour per year. Libya introduced renewable sources for producing electricity because of having a one of the highest solar radiation in the world. It has many villages and remote areas situated far away from the nationwide network. These regions having less population cannot be connected to grid because it demands more cost in spite of need of small amount of energy. In this concern, solar energy has been introduced widely in these remote areas due to its use with ease and being cost-effectively in several applications (Ummel, & Wheeler, 2008). According to the MED-CSP (Trans Mediterranean interconnection for concentrating solar power) scenario, it can be predicted that solar electricity will be the most important part of renewable energy sources for Libya till year of 2050 (Kurokawa, 2014). At present time, there are about 2000 thermo siphon solar water heaters that are placed in all over the country. For this, in 1976, the Centre for Solar Energy Research and Studies (CSERS) has been established that is responsible for research and development of solar water heating technologies (Abdunnabi, & Loveday, 2014). Some appreciable initiatives like solar system projects and programs have been taken by CSERS that helped to aware the people about use of this renewable resource. This technology can be said a reliable source for rural electrification in Libya. In 2007, REAOL has been also established that assists different industries and companies, which produce renewable energy. Developing 1-dimensional transient heat transfer axi-symmetric MM to predict the hardness, determination LHP and to study the effect of radius on E-LHP of industrial quenched steel bar and to protect the component from failure bending and deformation (Abdlmanam, & Omar, 2012; Elmaryami, & Badrul, 2021); Abdlmanam, & Omar 2012; Elmaryami, Khalid, Alamaria, Alashebe, & Khaled, 2021; Elmaryami, & Omar, 2021).

Solar energy source is the one with the largest potential for creation of renewable energy in nature. Moreover, unlike other renewable energy sources such as biomass which have some detrimental effects on the environment, production of solar energy has absolutely no known effects on the environment (Miller, & Spoolman, 2014). This is because it does not release any greenhouse gases to the environment. The country is located in the desert and receive adequate amount of solar radiation throughout the year. The amount of solar radiation reaches its peak around June and July (Figure 3 (a)) when the country receives around 7.5 KWhr/m^2 per day and there are no dark clouds to obscure the sun. Most of this land has been left unutilized since it is unproductive. As a matter of facts, the solar radiation in most parts of the country is 2,470 kWh/m^2/day. This is because the country is located at the core of the solar belt. It is also a large country with an area of 1.6 million km^2. Research has shown that every km^2 in the desert can generate energy equivalent to 1.5 million barrels of oil annually, which is the amount of oil Libya produces every year (Mohamed, Al-Habaibeh, & Abdo, 2013). This means that if the large percentage of the Libyan land which currently lay unused could be utilized. Most of the oil producing oil is a major hurdle but has to be overcome. In fact the country is planning to tap this energy then export it to countries in Europe. The country has a great potential for solar energy production and is ranked second in the world. It comes second after Algeria which has the highest potential for energy. Egypt which has a lower potential has already started out on a project used to generate solar energy. The other counties like Yemen, Morocco and Syria. What makes solar an important source of energy is the fact that it is available in immense quality, harvesting of this energy has no known effect on the environment either. Furthermore, solar energy can be utilized on small scale by families using small solar panels which are easy to acquire besides the large scale production. The country has shown no effort previously in the harvesting of solar energy (Boyle, 1996). However, with the plans underway, it will be possible for the country to generate enough energy from the sun for domestic purposes and export. Although solar energy is seen to be inefficient since it requires large panels and technology of storage has not been fully established, it is believed that with development of technology, these challenges will be overcome. Wind energy has not been developed properly in Libya because there is a need of more maintenance timely. Libya is more dependent on fossil fuels for generating electricity. It shows that this country is not secure in energy sector that can affect its economy in future. Due to this, country can also face some problems like exhaustion of valuable non-renewable energy resources, adverse effect on climatic conditions and global warming (Boyle, 1996). In order to avoid these problems, different regulatory bodies decided to include renewable energy as power source. In year 2000, the Libyan electricity utility GECOL with the Centre for Solar Energy Studies (CSES), started to identify the existence of potential renewable energy resources in form of wind energy and construct and develop commercial wind farms to generate electricity economically. In 2004, the wind speed survey was conducted by these authorities that indicated about high potential for wind energy in Libya. It raised the possibility of production of wind energy in Libyan coastal areas. In Libya, a contract has been signed to install 25 MW as a pilot project, through which several wind mills will be established and wind energy will be produced in future (Alsuessi, 2015). Through this project, technical knowledge will also be transferred to the selected candidates, who will work in the field of wind power technology in coming projects. Therefore, main emphasis of this project is on building a wind farm through best engineering experience and giving training to local engineers on the projects. In addition, Libya has contracted another project to obtain the reliable solar and wind data throughout Libya that will allow for analysing effectively the available wind and solar resources anywhere in the country (Harvey, 2010). Both projects aim to prepare and generate wind energy in Libya. For using wind as renewable source, this strategy allows Libya to collect needed information and knowledge that will be beneficial for it further to develop the favourable environment for wind energy production. In order establish wind tower in Libya, some projects were started at different locations. For this, responsible authorities started a research on selection of best sites for installing wind towers to generate wind energy. This project was conducted to collect the wind data available from 16 meteorological stations in Libya at different height levels. This research helped to select proper sites for wind energy projects and to establish first wind farm in Libya. Figure 1 (b) shows top seven average wind speed all time year and month. Wind pattern in Darna is better than other levels in Libya.

Wind rose for Darna indicates that north-east coast is favourable for supportive wind conditions. Average wind speed in different months can generate different level of power in Darna. Overall, this location is more supportive for generation of wind energy. These all data were used to describe wind speed distribution through Weibull distribution. In this, the variations in wind speed are determined by the two functions that are probability density function and cumulative distribution function. All data were interpreted through statically analysis that gave appropriate information about a suitable site for establishing wind farm. On the basis above research, renewable energy authorities concluded that in Libya, Darna could be regarded as a suitable place that have high capability to generate wind energy. In Darna, wind conditions were optimum for production of wind energy. It was obvious from data analysis that in Darna, average wind speed was recorded 9.8, 10.8 m/s at height of 50,100 meters respectively. This wind speed pattern was most favourable among different locations in Libya. With this, at that location, mostly, wind flows from north east coast to south-west coast, so, Libya has started to construct a 61.75 MW wind farm at Al-Fetaih, near Derna on the north east coast. It is also estimated for installation of a power plant in Libya in two stages that for construction of a power plant consisting of two wind farms of 60 MW, total installation costs will be 103 million Euros. Cost of wind tower depends on the plant size, height, capacity, etc. In addition, this country has also planned to start other wind projects at different regions like south eastern and south western regions due to having good conditions.

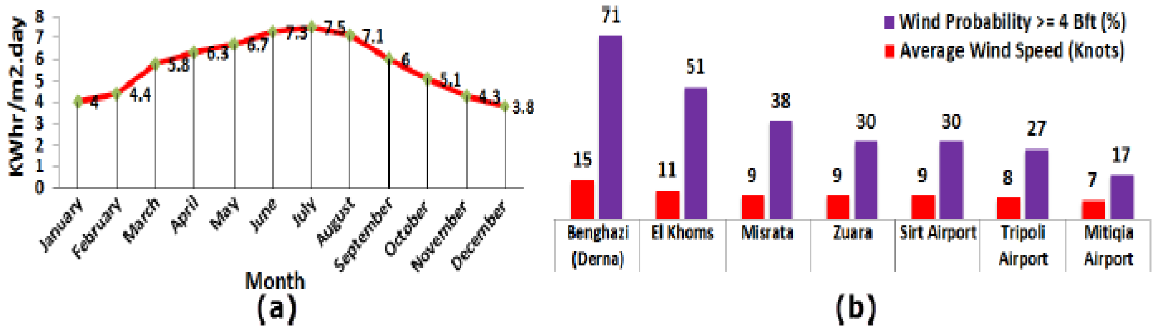


Figure 1. (a) Average monthly solar radiation, and (b) top seven average wind speed all time year

Renewable Energy Action Plans

REAOL was founded to promote the development of RE in Libya. A goal has been set by REAOL to reach 10% of the energy supply from renewable energy resources by the year of 2020 as shown in Figure 4. Although Libya has a great potential for production of energy from renewable sources, not much has been done to utilize this energy formerly. However, since the year 2006, the governments have developed a plan that is expected to see the country increase its production of energy from renewable sources from less than 1% to 6% in the near future. This would include construction of several plants to tap energy from the sun and the wind (Olsson, 2015). This would comprise the construction of several wind farms expected to generate a total of 750 MW, PV centre should generate 50MW and solar heaters which should generate 100 MW. This is anticipated to be realized through increased government spending in this area. The government plans to use $52.7 billion on this project in the 2012 budget alone (Kandt, Hotchkiss, Walker, Buddenborg & Lindberg, 2011). The plan would be executed by development of four wind farms in several stages, creating extensive PV grid system in different location including the remote areas and expanding the solar heating factories by encouraging outside investors to invest in these projects.

The government also plans to increase the demand for renewable energy by implementing the national program that promotes the use of solar heating systems in the residential areas. By the year 2020, the country plans to have expanded the renewable projects set up to increase the utilization of renewable energy from 6% to 10%. This means that the country will have promoted a wide based solicitation of renewable energy through various forms. The government therefore plans to utilize the renewable energy sources to their full potentiality by the year 2050 in order to satisfy the energy requirements of the country and still export the excess energy. This means that by 2050, Libya will be using the renewable energy more that the fossil energy a reverse of the situation as it is now. Since the country has been a supplier of fuel to other country, it wishes to have developed its renewable energy industry to produce enough energy for export to Europe through the use of undersea cables. In line with this thought, the country unveiled a $3 billion plan and contracted Abu Dhabi’s Al Maskari Holdings in December 2010. This corporation is mandate to create an energy hub meant to supply domestic energy needs and have the ultimate goal of supplying energy to Europe through the Mediterranean. The project plans to incorporate renewable energy and conventional sources of energy such as natural gas and utilize the high-voltage subsea transmission line connecting Libya and Italy (Kandt, Hotchkiss, Walker, Buddenborg & Lindberg, 2011).

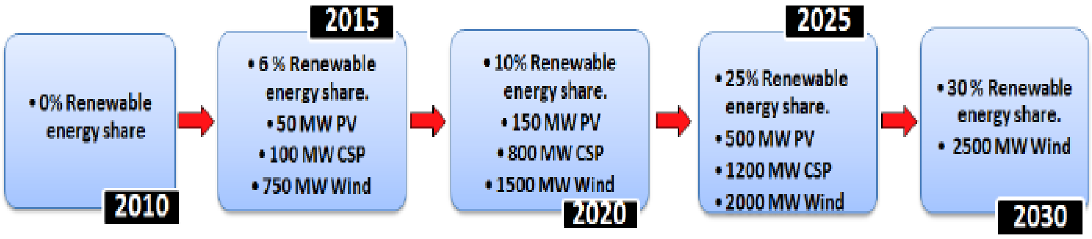


Figure 2. Renewable energy authority of LIBYA action plans

Process of Implementation of Renewable Energy Technologies in Libya

For implementation of any renewable resource project, it is very necessary to recognize applicable stakeholders and possible project locations. After identifying stakeholders and potential projects, they should be engaged to ensure bout protection of area or location, full utilization of resources and good decision making (Balfour & Shaw, 2011). On the absence of needed requirements after appropriate review, lawsuits may be taken or work orders can be cancelled. It is required to estimate the cost and determine funding options before starting work on a solar project. After fulfilment of these all requirements, the project can be implemented. To evaluate the effects of the project can be a beneficial approach to enhance the success rate of such projects in the future. The Middle East and North Africa (MENA) regional renewable energy project provides different opportunities for Libya country to develop its CSP (centre solar power) technology at wider scale. In this concern, Libya has conducted a feasibility study to select a site for a 50-100 MW CSP plant. There are different locations in the country that provides good solar conditions for establishment of the solar plant. The Tripoli is selected to establish a CSP station due to good solar energy conditions. It provides the daily solar radiation with great intensity for whole year (Rizzuti, Ettouney, & Cipollina, 2007). This project is planned to perform in two stages, first is related to launch of its first CSP Plant of 100 MW and second is related to export its power to the Europe. The stakeholders are GECOL, REAOL, CSES, Ministry of Planning &Finance, Libya, Spanish Abengoa Solar Company, energy savings performance contractors, property owners, environmental groups and local government. Among them, REAOL and Spanish solar company Abengoa are major stakeholders that have made a contract for establishing CSP plant in Libya country (Rizzuti, Ettouney, & Cipollina, 2007). The response has been positive to the solar project by the public, community, solar installer and the governing agencies. Stakeholders will be engaged throughout the project. The engagement process will be based on the project objectives and interests of the stakeholders. It will be maintained through establishing good communication network with the stakeholders and conducting meetings related to needs and requirements of the project (Salazar, 2008). For this, a technical agreement has been made by REAOL with Spanish company (Abengoa), which will install CSP plant in Libya. This company is engaged through the Clean Technology Fund in concern of the funding. With this, it is required that a portion of production should be met by renewable electricity supply (Boyle, 1996). Green certification process is part of accountability to maintain renewable energy facilities. Apart from this, there is need of a long-term power purchasing guarantees from the government that can reduce the cost of installation. Local government will have to engage in this project by providing supportive schemes like tariffs and subsidiaries. In addition, a contract will have to be made with property owner because installation of a solar plant needs a large land. All the legal requirements will have to be fulfilled while making these contracts with different stakeholders (Bauer, 2015). In this project, some review processes will be required to follow. It will have to be ensured about the environmental protection processes. Surroundings will be protected by preservation or conservation ways that will support the guarantee of green energy production (Pacetti, Passerini, Brebbia, & Latini, 2012). Requirements will be relevant to codes for local and national requirements, electrical codes and environmental goals. Contracts will be made under the control of legal authority that will avoid future conflicts between manufacturing company and regulatory boards. Review of availability of needed resources will be required that will give assurance for continuous supply of resources for establishment of plant in future. With this, it will be also followed that by which source, funding requirements are being fulfilled like grants or incentives or third-party financing agreements. Agreements can be in form of an Energy Savings Performance Contract (ESPC), Utility Energy Services Contract (UESC), or Power Purchase Agreement (PPA) that will be reviewed properly (Gazzo, Gousseland, Verdier, Kost, Morin, Engelken, & Eichhammer, 2011). All legal formalities and codes are followed or not that will be reviewed before implementing the project. It is necessary to review the requirements of all authorizations, laws, acts and orders and funding options before beginning of the work on this project (Gielen, 2012). It is estimated that 50% of the funding can be arranged from traditional financing sources and remaining can be collected as soft loans, grants or other support schemes. The major funding source for this project is the Clean Technology Fund (CTF) that can provide about 10-15% of the capital cost same as other North African countries. The CTF Trust Fund Committee uses some criteria before funding like potential for greenhouse gases emissions savings, cost-effectiveness, capacity to demonstration and implementation of the project. Other major sources of finance will be World Bank Group (WBG) and the African Development Bank. These organizations are more committed towards this program. The World Bank Group and the African Development Bank also has collaborated with other donors for launching a program to scale-up CSP in this region. Other sources may be bilateral aid agencies and support schemes launched by government. On the basis of per unit cost, currently, CSP is highly expensive than other renewable resources like wind. With the help of scale up, expected cost will be reduced in coming time. Initial capital cost is estimated between $4,500 and $7,150/kW that is a big investment for this country (Balfour & Shaw, 2011). Total cost to establish a solar tower of 100 MW will include costs for tower, owner and labour costs, engineering and site preparation, thermal energy storage, power block, receiver system and heliostat field (Rosa, & Ordonez, 2021). It can be expected that total cost for this plant will be $978 million, in which costs for the solar field and receiver system have a large portion while the thermal energy storage and power block costs are as a little part (Rizzuti, Ettouney, & Cipollina, 2007). In addition, operating and maintenance costs like replacement of receivers and mirrors, mirror washing, etc. will be significant. It is also estimated that operating and maintenance costs will be approximately $0.04/kWh (Mostafaeipour, & Mostafaeipour, 2009). It is necessary to implement the project in proper manner. All requirements for this project should be provided effectively. The project will be ready to be implemented after identifying project location, technology and size. All stakeholders previously mentioned will be engaged and all requirements will be considered before implementation of the project. For manufacturing the plant, all workers and engineers will be guided by project manager to perform different production and operational activities in this project. In this concern, documentation for all activities will be required on daily basis. Project should be completed on time and within the budget estimated. Moreover, there will be requirement of managing the information and providing updates to different authorities on progress, future work and any conflict or issue (Mason, & Mor, 2009). After construction, governing authorities will inspect the quality of the work and system. The installing company will fill all needed applications and documentation and all paper work will be reviewed. Any enquiry will be answered by the company regarding the plant installation. It is forecasted that solar energy equal to one barrel of oil from this project would be collected at a cost of approx. US$ 50. Moreover, this cost is expected to fall to around US$ 20 in coming years (American Wind Energy Association. 2012). Therefore, it can be said that cost efficiency will come with the time and advancement in technology. It is because the cheaper technology will support to reduce the plant cost in the future. Decrease in oil supply and raise in oil prices would make this project more feasible. It is expected that it will make available cheaper energy than other resources and will not have a negative impact on the property and environment. It will generate renewable energy in the form of electricity that will be beneficial for the rural areas of the country. Additionally, it will generate more jobs by CSP investments in this country. After generating electricity through this project, country can be able to provide this energy to European countries that can be proved as its large revenue source. The drawback of the project can be related to the initial cost of the project. There will be a possibility that this project would not cover its initial costs.

Barriers of Implement and Development of Renewable Technologies in Libya

Libya, being a country which is predominantly an oil producing nation, has many policies and regulations that favour this trade. Unfortunately, this works against the development of the renewable energy sector. The existing national policies in Libya are focused more on the contemporary sources of energy which has been given major incentives (Bauer, 2015). In order to promote the renewable energy sector, there is need to evaluate the regulation laws and policies and energy and develop new policies that favour the renewable energy industry. The lack of balance in regulation regarding energy can make the penetration of the alternative sources of energy to the market hard. The government of Libya has subsidized its oil for the domestic market so that the citizens can access fuel at lower prices. This works at the detriment of the alternative sources of energy which, because of the high cost of production, are more expensive and can thus not beat the price of oil. A major challenge that faces the renewable energy sources is their intermittent nature. Solar energy and wind energy can only be tapped at specific times and may not be available at other times. This increases inefficiency since the energy cannot be taped at all times. Geothermal power, although continuously available, faces major challenges in energy storage and management of the facilities. Technological development in renewable energy industry is still at its juvenile stage which explains the existence of the myriad technical challenges. The projects related to renewable sources also take long to be implemented as some of them are untested and require pilot projects to be conducted first. This, coupled with the problem of corruption, hinders the speedy transition from non-renewable energy to renewable. Most of the organization and industries in the country may be unfamiliar with the existence of the renewable energies and may thus prefer to use the old sources of energy. They may also be aware of the renewable energy but have since they believe it is inefficient fail to invest in it. The costs involved in changing infrastructure and the uncertainty of the new source of power is a source of repulsion to entrepreneurs (American Wind Energy Association. 2012; Ghodsi, Ziaiefar, Mohammadzaheri, & Al-Yahmedi, 2019). As such, the power project may generate enough power but because of low demand, they may end up collapsing. This can be overcome by coming up with policies that require institution to utilize renewable energy and creating awareness among the public on the need to switch to renewable energy. Renewable energy projects are often small compared to the existing non-renewable energy projects. As such, they do not enjoy the benefits that come with increased economies of scale which results in higher operating costs. Moreover, since the renewable energy sector has not been given much focus in Libya previously, it faces additional challenges. For instance, the new project may require new information on things such as weather patterns of precipitation, wind and solar radiation which may not be currently available (Ghodsi, Ziaiefar, Mohammadzaheri, & Al-Yahmedi, 2019). The investors would therefore need to invest first in carrying out survey before embarking on the main project. The cost of production of energy using the renewable sources therefore ends up exceeding the other non-renewable alternatives making investors to choose the latter. This high costs and poor technological development in the industry makes it difficult for people to invest in it collapsing.

The rise in global temperature and severe climate change worldwide has increased environmental concerns. Now-adays, more than 90% of the world's electricity comes from fossil fuels (World-Bank 2015), and that energy production plays a vital role in global warming. Any changes in this field can have a significant impact on the environment. Wind can offer a few focal points, for example, being boundless, contamination free, and requiring negligible or no fuel. Sustainable power source and particularly wind vitality does not emanate any CO_2 (Khare, Nema, & Baredar, 2016). in the air—therefore it shields us from a worldwide temperature alteration too. This is the motivation behind why numerous nations are utilizing wind vitality as a wellspring of energy. By creating so much energy by all nations, 33% of the total populace still lives without power. Wind vitality frameworks have made it conceivable to reap savvy control age. Numerous researchers, therefore, have attempted to change or alleviate the negative impacts of global warming, with much of this effort coming from the energy sector (Schwartz, Heimiller, Haymes, & Musial, 2010). Wind essentialness is the most talented and potential wellspring of imperativeness, regardless of the way that its achievable quality changes from place to put (Charabi, Al Hinai, Al-Yahyai, Al Awadhi, & Choudri, 2019). Wind energy advancement look over by staggering differences over latest three centuries. Steady progression in development with twist appliance, for instance, control devices, ideal outline, and mechanical drive plan setup has made it a beneficial wellspring of imperativeness. The shortcoming is of disturbance defilement, which is generously not as much as other power plants (Mone, Hand, Bolinger, Rand, Heimiller, & Ho, 2017). In comparison to fossil fuels, the impact of renewable energy sources on the environment is negligible. These sources, for example, have no direct CO_2 or NOx emissions.

From solar panels to wind turbine generators, a wide range of devices can convert ambient energy into a more useful form, like electricity (Abdul-Wahab, Charabi, Al-Mahruqi, Osman, & Osman, 2019). Among these devices, wind turbines are some of the most popular and accessible methods of converting ambient energy to electricity. However, wind energy, like most other sources of renewable energy, has high capital costs, but during the past decade, this trend has changed tremendously. Stat- ics show that the cost of wind production has dropped enormously in recent years, from two million dollars per M.W. to one million in the last decade (Abdul-Wahab et al., 2019). This achievement has made it possible to see wind power plants with increasing frequency in both developed and developing countries. As a Middle Eastern, oil-dependent country, Libya has started in a new direction on its path of development.

A simplified block diagram of wind energy management system is shown in Figure 3. The figure shows the conversion of wind energy into electrical energy through a generator, coupled to wind turbine. The kinetic energy of the wind is converted into rotational motion which in turn is coupled with a generator.

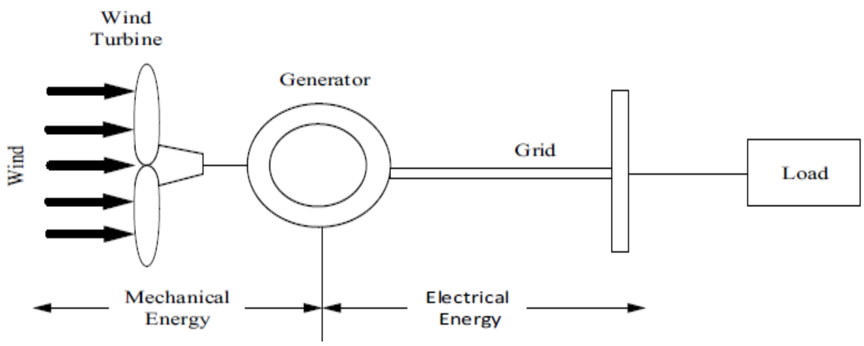


Figure 3. Conversion of Wind Energy into Electrical Energy

The country is trying to change its electricity production industry from one that is entirely oil-based to one that is more reliant on sustainable “greener” energy sources (Dolatabadi, Mohammadi, Abapour, & Tohidi, 2017; Smith, O'Malley, Osborn, Piwko, & Thomas, 2012). The main two options for this plan are solar and wind energy. Although Oman’s sunny weather provides a unique opportunity for solar energy generation, the country’s wind power potential must not be neglected. As of this article’s writing, Oman has no industrial wind power stations, and the country’s wind turbines are mainly used for research purposes. However, this situation is changing, beginning with developing an understanding of the country’s wind power potential. An incorrect estimation of wind energy needs or the use of low-performance equipment not only reduces the benefits of the project, but also might lead to economic disaster (Energy, 2010).

Wind vitality is known for its straightforwardness (Energy, 2010). and restricted space needy (Vision, 2015). The vast majority and lodging edifices have free vitality generation office (Lindenberg, 2009). Seaward breeze control ventures have turned into a pattern in European countries (Wiser, & Bolinger, 2019). For a spotless atmosphere, sustainable power source is an unquestionable requirement (Caduff, Huijbregts, Althaus, Koehler, & Hellweg, 2012), and it will keep going for quite a while with less maintenance (Pérez, Márquez, Tobias, & Papaelias, 2013). Inexhaustible Sustainable Energy In the advancement of sustainable power source, there are numerous obstructions including venture. Every one of these obstructions is not understood by just mechanical, social, political (Gaddada, & Kodicherla, 2016). or monetary components (Kodicherla, Gaddada, & Shaik, 2017).

Without access to sound information on the cost of wind power technology, it is difficult for decision-makers, if not impossible; to evaluate which wind turbine technologies will most fit their national circumstances. The fast growth and cost reductions in the installed wind energy technologies mean that even data aged one or 2 years will substantially overestimate the cost of power from wind energy technologies. There is also a significant amount of perceived knowledge about the cost and performance of wind power generation technologies that are not accurate or is misleading. Significant knowledge of the cost and performance of wind generation technologies is also viewed that is not right or misleading.

Studies on the viability and economic potential of wind energy have recently spread worldwide. Kumar and (Kodicherla, Kan, & Nanduri, 2020). have explored the outputs of four statistical methods to evaluate Weibull param eters for wind energy applications in four selected sites, located in northern Ethiopia. (Kodicherla, Kan, & Nanduri, 2020). have evaluated wind power capacity and wind energy cost estimates for electricity generation systems in eight selected locations in Tigray (Ethiopia) (Nema, Nema, & Rangnekar, 2009). explored the potential of wind energy and developed an economic assessment of the water pumping system in various wind power conversion systems. In three selected Fiji Island stations (Elmaryami & OMAR, 2015).

have investigated the potential of wind power-assisted wind hydrogen production using different types of turbines. The literature also reflects different foci around wind turbines. Many researchers have worked on defining the shape and structure of wind turbines and their effects on aerodynamics (Akpinar, & Akpinar, 2006; Abdul-Wahab, Fessehaye, Yetilmezsoy, Al-Ghafir, Al-Barashdi, Al-Hajri, & Al-Bulushi, 2019; Elmaryami, & Omar, 2011). Others have tried to improve the performance of current turbines by optimizing placement and hub height (Elkinton, Manwell, & McGowan, 2008; Elmaryami, & Omar, 2013; Elmaryami, Alsoussi, Gomaa, & Abd-Allah, 2017). Despite these efforts, the stochastic nature of wind speed makes wind energy generation difficult for some places. A deep understanding of the specifications of each wind turbine and complete statistical data on wind velocity in any given location can begin to address this problem. These data must be processed and matched to a potential turbine to give a realistic and feasible answer to the suitability of any given piece of wind power equipment.

Developing MM & transient computer simulation of industrial quenched steel bar to determine the LHP of quenched steel bar in different medium & different temperatures were analysed to protect the component (Elmaryami, & Omar, 2013; Elmaryami, Elshayeb, Omar, Basu, & Hasan, 2013; Omar, & Elmaryami, 2013; Ahmida, M. A., Elmaryami, Boukhrias, & El Menshaz, 2022; Omar, Elshayeb, Elmaryami, & Pahat, 2009).

Theory

- **Wind energy calculation formula**

$$P = 1/2\ \rho\ AV^3 \tag{1}$$

- **Betz theory**

The maximum power that can be produced by the wind wheel is:

$$P_{max} = 8\ /\ \mathbf{27}\ \rho\ AV^3 \tag{2}$$

By dividing the equation (2) and equation (1), we can derive the maximum efficiency of the wind turbine theory.

$$\eta = 16\ /\ 27 = 0.593$$

Method and Components

The rotor design: The rotor is a four-blade type, which is known with its high efficiency and balance as shown in Figure 4.

Figure 4. The used blade

Gear box: It consist of two gears as shown in Figure 5.a. and 5.b.

Figure 5. a, Big Gear

Figure 5. b. Small Gear

The Generator: The generator converts the mechanical energy of the spinning turbine shaft into electricity. The present wind turbine generates electric power by using a DC generator, which produces DC with 12 V which increase according to turbine speed as shown in Figure 6.

Figure 6. The generator

Nacelle: The case or housing from steel which is mounted on the tower and includes the gear box as shown in Figure 7.

Figure 7. The nacelle

Wind vane: Measures wind direction and communicates with the yaw drive to orient the turbine properly with respect to the wind as shown in Figure 8.

Figure 8. The wind vane

Tower and Base: The function of the tower is to hold up the turbine in the blowing wind as shown in Figure 9. Tower height is an important factor in the design.

Figure 9. The tower of the designed model

Charging controller: Stabilizing the voltage and protecting the battery from over-charging.

Figure 10. The charging controller

Battery: The function of the battery is to receive the electric energy from wind turbine generator then deliver it to the electric devices.

Figure 11. The used battery

Inverter: To convert from 12V DC to 220VAC.

Figure 12. The inverter of the model

Turbine Assembly

After manufacturing and construction of the different components of the turbine, these components are assembled as shown in Figure 13.

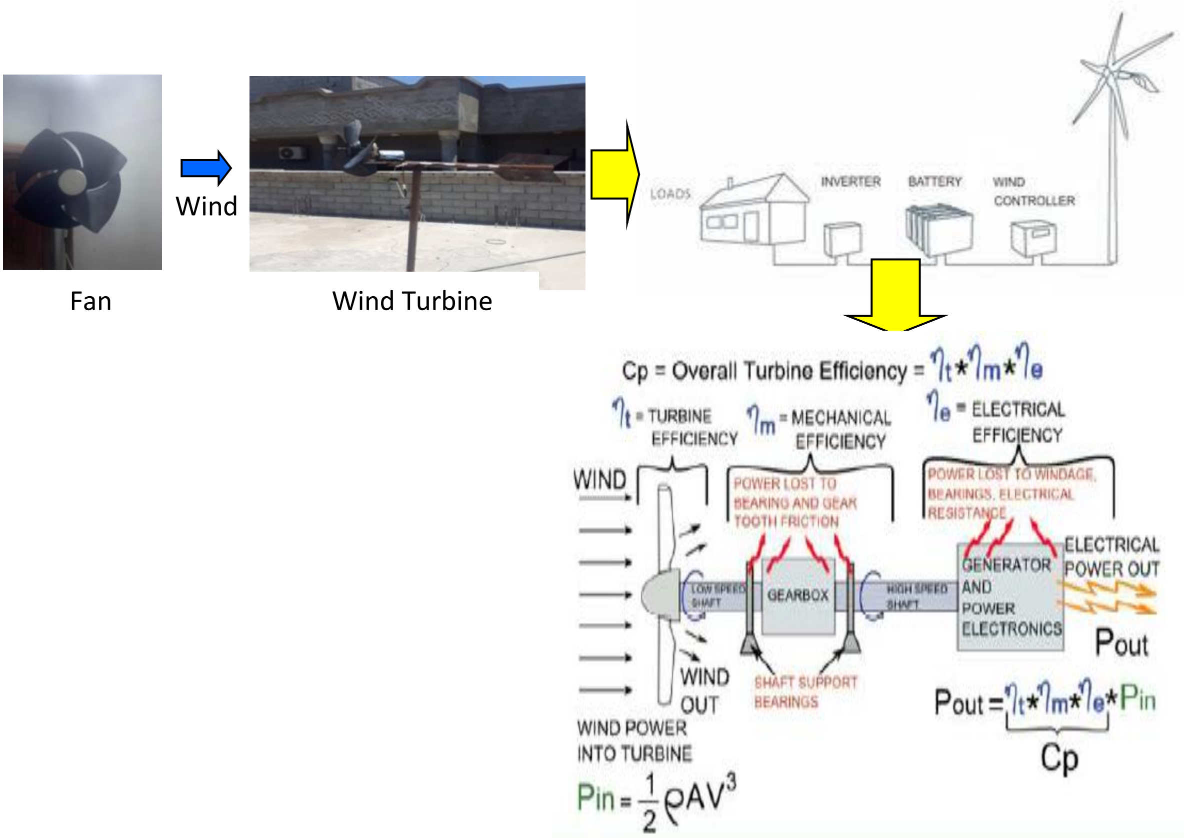


Figure 13. Using the fan provide wind power, and measure the output and efficiency of wind turbine

Turbine Specification

Type: 4 Blade, Upwind, Rotor diameter: 0.23 m, Tower height: 1.6 m, Blade pitch control: None, Fixed Pitch, Start-up wind speed: 1.6 m/s, Rated wind speed: 4.46 m/s, Cut-out wind speed: None, Rated power: 500 Watts referring to invertor enhancement, Transmission: Simple two-gear mechanism.

Results and Discussion

The turbine was tested on various wind speeds; the measurements were conducted by Anemometer, Multimeter and Tachometer to measure the wind speed, voltage and current, the rotor speed (rpm) respectively. The results were shown in Table 1 and Figure 15.

Devices used in measurements shown in Figure 14.a, 14.b and 14.c.

Figure 14.a. Multimeter **Figure 14.b. Tachometer** **Figure 14.c. Anemometer**

Table 1. Summary of the inputs and output power

Wind speed	Power input	Rotor speed	Output voltage DC	Output current	Output power
1.60 m/s	0.410 W	185 RPM	13.0 V	0.03 A	0.390 W
2.50 m/s	1.500 W	230 RPM	17.0 V	0.06 A	1.020 W
3.60 m/s	4.740 W	318 RPM	20.0 V	0.15 A	3.000 W
4.16 m/s	7.320 W	380 RPM	24.0 V	0.20 A	4.800 W
4.70 m/s	10.56 W	405 RPM	26.0 V	0.36 A	9.360 W
5.00 m/s	12.71 W	454 RPM	28.2 V	0.40 A	11.28 W
5.55 m/s	16.90 W	468 RPM	30.0 V	0.50 A	15.00 W

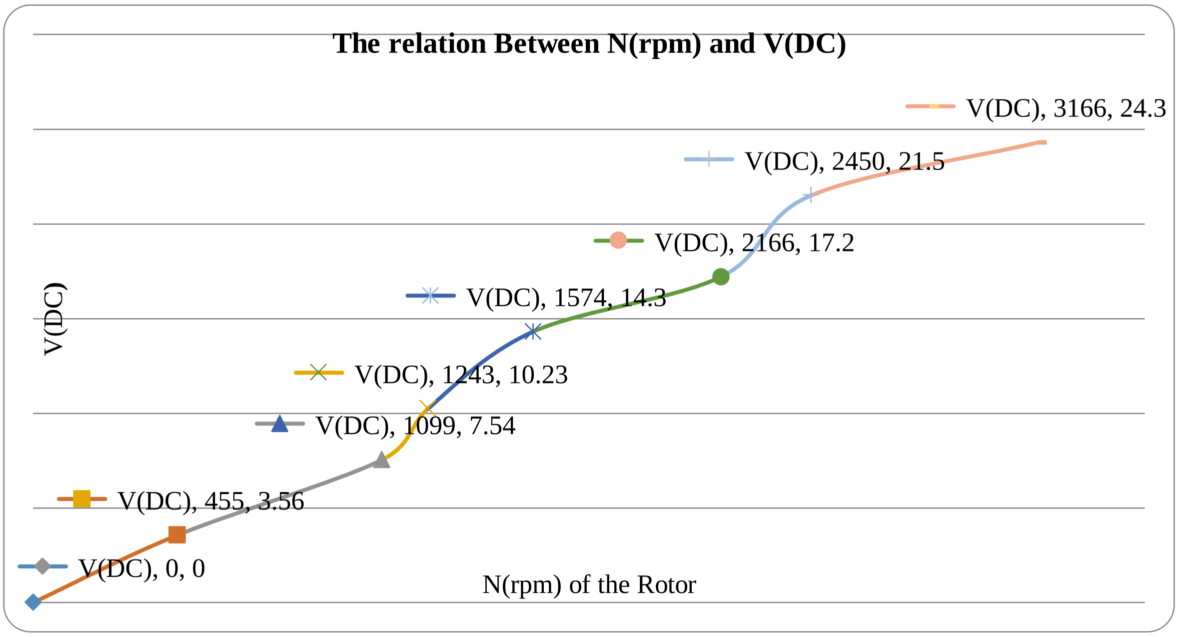
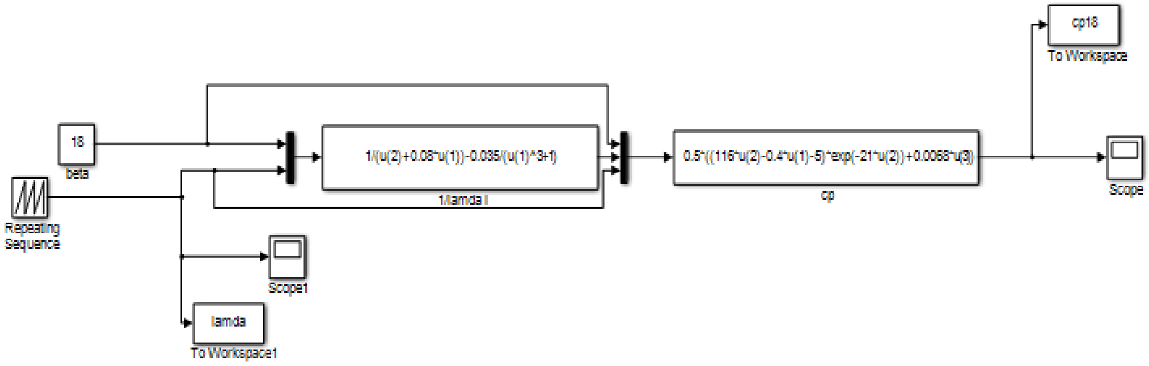


Figure 15. The relation between the wind speed and the wind power



Conclusions & Recommendation

Conclusions

The results of this investigation show that:

a. The field tests and measurements proved that the present turbine is efficient.
b. The present turbine is easy to construct and assembly.
c. The turbine is suitable for different sites such as urban, suburban, rural, and sea coast.
d. The output power of the turbine covers the consumption of many electric devices.
e. The turbine has long life-time and needs minimum maintenance.

In general:

Libya can be a good place for renewable energy producing companies, which can find huge availability of conventional resources in this country. It can also be concluded that Libya can improve its economic environment by using low-cost renewable energy sources and generating more revenues effectively. In this country, wind energy can be used for various purposes like electricity generation, communication systems, and mechanical activities. With this, solar energy can be used in street lighting, communication system, and electricity for houses and warming pool water. This will be beneficial for the country in the production of electricity at a low cost and will provide economic benefits in terms of revenue. It can also be concluded that Libya has implemented effective strategies for developing its renewable energy but there are different challenges and barriers such as legal, political, economic, and financial barriers in implementing and developing renewable energy technologies in Libya. These barriers will make the development of renewable energy in Libya difficult, but they can be resolved by effective planning and execution by the government. The government will have to take initiatives to improve the conditions for the investors to invest in these types of projects that will help to generate solar and wind energy for benefit of the country. For this, the Libyan government will have to provide financial support and remove legal and political issues for the investors so that they could be able to invest in energy projects to great extent.

Recommendation

a. Improving the turbine efficiency by using lighter blades.
b. Developing a simple brake system.
c. Developing a control system for turbine orientation
d. Using charging controller similar to the one used in (PV) system.

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Ethics

1) This material is the authors' own original work, which has not been previously published elsewhere.

2) The paper is not currently being considered for publication elsewhere.

3) The paper reflects the authors' own research and analysis in a truthful and complete manner.

4) The paper properly credits the meaningful contributions of co-authors and co-researchers.

5) The results are appropriately placed in the context of prior and existing research.

6) All sources used are properly disclosed (correct citation). Literally copying of text must be indicated as such by using quotation marks and giving proper reference.

7) All authors have been personally and actively involved in substantial work leading to the paper, and will take public responsibility for its content.

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