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Research paper

A Review of Hybrid Generation Systems

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Abstract

The use of hybrid generators has been embraced widely as a modern way of producing sustainable energy. Particularly, this approach has been fundamental in the extension or the development of new power grids that have played an important role in powering the rural areas. From a different perspective, the hybrid power generators have played a key role in the management of various inefficiencies in the production of electricity. The production of electricity via diesel generators is subject to operational challenges related to the fluctuating prices of diesel. On the other hand, wind energy is intermittent in nature, hence a limited reliability. In this regard, it will be a remedial move to adopt the use of various hybrids to internalize these shortcomings. The advantages of one particular element in a given hybrid will compensate for the shortcomings of a given element within the same hybrid. There exist a variety of hybrids that are used in the generation of electricity in the modern world. A typical hybrid will harness or store energy from two or more sources. Therefore, this paper will present a literature review of the nature of various hybrids that are used in the modern world. Some of these hybrids include; Wind-hydrogen system, Wind-hydro system, Wind-diesel system, Wind-compressed air system, and the Wind-solar system. These hybrids have been embraced to mitigate the intermittent nature of wind energy. Additionally, this paper will shed light on the impacts of these hybrids to the various societies in which they are deployed. Particular emphasis will also be laid on the distribution of these hybrids across the globe. Lastly, this paper will highlight the various problems that face these hybrid generators and offer recommendations and possible solutions.

***Keywords**:* Wind-hydrogen system, Wind-hydro system, Wind-diesel system, compressed air system, wind-solar system.

1. Introduction

The Hybrid Generating systems have become a very common avenue of generating sustainable energy in the modern world. The success of this particular method of power generation is widely attributed to the technological advancements in the field of renewable energy. Additionally, various engineers, as well as power consumers, were driven to the further development of the hybrid power generation system following the overall rise in the cost of fossil fuels. In this view, the Hybrid Renewable Energy Systems have proven to be effective stand-alone sources of power. Following the high-efficiency levels of this framework, power distribution has been enabled across various rural as well as marginalized regions across the globe. Consequently, this expansion in the power grid has extended the developmental potential of various rural regions, hence a relatively improved global economy [1].By structural definition, a hybrid energy system is comprised of the strategic combination of two or more forms of renewal energy for the purposes of producing energy. The fundamental reason for this combination is to improve the efficiency of power production as well as the overall Kilowatts produced by a given hybrid plant. Subsequently, the hybrid renewable energy systems also assist in the development of a more optimal balance in the supply of energy within a given power grid. The hybrid renewable energy systems are categorized into a variety of examples. Major examples of hybrid power generation mechanisms include biomass-wind-fuel cell, photovoltaic-wind hybrid, which are renewable concepts in the generation of energy. The biomass-wind-fuel cell incorporates the incorporation of about 60 percent of a biomass system and 20 percent of a set of wind energy [1]. Another 20 percent of this combination is comprised of fuel cells that are diminishing in nature. Cumulatively, this combination results in the generation of energy with an optimal utilization of the available resources. On the other hand, a hybrid energy system might exist in the form of a photovoltaic-wind system. Particularly, this system incorporates the combination of wind power and the deployment of an array of photovoltaic sources. This type of hybrid generation has a higher effectiveness throughout the year. Notably, this hybrid exploits the solar panel in the generation of electricity during the summer. Conversely, the same system uses the wind turbines effectively during the winter period to ensure an optimal harnessing of power. In this regard, power production remains at optimal levels all through the year [2]. Comparatively, the hybrid system is better and more efficient as opposed to other stand-alone projects like geothermal, tri-generation, hydroelectric, and solar. The renewable hybrid power system is a more efficient method of power generation. Such a system incorporates the use of four renewable sources of energy, which include wind, biomass, energy, and hydrogen.

2. Wind Hybrid Power Systems

As the name suggests, the wind hybrid power systems deploy the combination of various wind turbines with other modes of power generation. Following the intermittent nature of the wind as a source of energy, it is ideal that its use includes a hybrid. The use of a hybrid will cover for the periods where the wind speeds are too low to be effective in the generation of an adequate supply of power. All other systems that can be combined with wind energy system will be explained in detail including process technique, advantages, challenges, case study, and figures as shown below.

2.1. Wind-Hydrogen System

Storing wind energy, in most cases, is considered as a rather difficult task. The wind energy is harnessed and electrolyzed chemically to produce hydrogen [3]. Hydrogen is easily stored in cylinders and other avenues as opposed to raw wind energy. After the hydrogen is stored, it can be used in the production of supplementary energy in the event where the energy produced by the wind or any other source is insufficient to meet the demands of the community. Producing energy from hydrogen is a relatively new procedure, but it is equally effective because of its complexity. Ideally, the energy stored in hydrogen can be used in the generation of electricity through the process of the fuel cell combustion. Following the combustible nature of hydrogen, other power plants prefer the use of a combustible engine that is connected to a turbine generator that produces sufficient electricity [4].Conversely, the storage of hydrogen has been faced with a variety of operational challenges. For example, hydrogen causes significant harm to the machines and other materials that are used in the storage. A common harm associated with the storage of hydrogen is the embrittlement of the materials. Scientifically, embrittlement is associated with the diffusion of hydrogen into metallic objects resulting in fracture and the formation of brittles. The use of harnessed hydrogen in the generation of electricity has been deployed in several countries across the globe. A good example is the proposed commercialization of this idea by the Wind Hydrogen Company in Australia and the United Kingdom [5]. Particularly, this company is focused on the provision of affordable energy in rural areas where electricity from the national grid is rather expensive or inaccessible. Apart from Australia, this technology has been tested in various other countries, such as Utsira in Norway, KoluelKaike in Argentina, Lolland in Denmark, Prince Edward Island Wind-Hydrogen Village in Canada, Bismarck in the United States of America, and the Ladymoor Renewable Energy Project (LREP) in Scotland. Most of these plants have managed to produce an average of 0.4 Megawatts [6].

2.2. Wind-Hydro System

As suggested by the name, this system of hybrid combines the use of wind energy and moving or stored water. It is imperative to note that this particular combination has been subjected to a variety of feasibility tests since its inception in the late 1970s. With an experimental plant set up at the Wreck Cove hydroelectric plant, the wind was used to run turbines that would pump water into various reservoirs [7]. Fundamentally, these reservoirs were used to store water energy that would be used to provide hydro-electric power. Therefore, in this particular hybrid wind power was dedicated to the pumping water into reservoirs that were widely referred to as a depiction of the volume of grid energy. The figure below illustrates an example of an example of a renewable power system comprised of wind turbines, a water storage and hydro power generation, which are interconnected electricity distribution network.

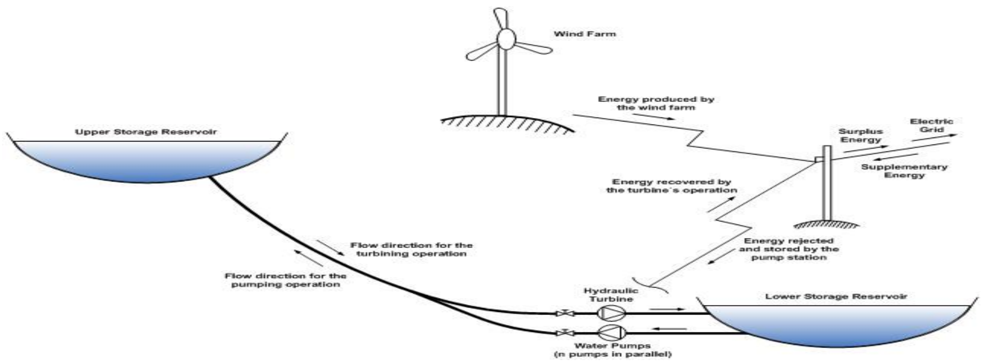

Figure 1: Wind-Hydro System

2.2.1 Advantages and Disadvantages of Wind-Hydro System

While the wind is widely considered as an intermittent source of energy, it is imperative to note that its full potential is very instrumental in the production of energy. In the event where wind energy is used to drive turbines that pump water in a vertical capacity, its effectiveness is virtually unmatched. After the water is pumped vertically to the storage reservoirs, it develops a relatively stable potential energy that is very crucial in the production of hydro-electric energy. Additionally, the reservoir is used to control the overall flow of water, which in turn regulates the amount of hydroelectric energy produced. With the rough understanding of the working mechanism of this combination, this hybrid can be used optimally in areas, especially islands that have a relatively smaller power grid. However, it is imperative to note that the wind is intermittent hence its reliability is rather seasonal or unpredictable in polluted environments.

2.3. Wind-Diesel System

According to [8] ,this particular hybrid combines the use of wind turbines as well as the diesel generators. While this hybrid is focused majorly on the use of wind energy and diesel, its efficiency is reliant on a variety of ancillary machinery as well as systems. This equipment includes various avenues in which energy can be stored, devices that can facilitate the conversion of power, and specific machines that are used to generate electricity. It is imperative that the engineers who are associated with the hybrid system embrace the use of a framework that provide very little or no harm to the environment. The focus should lay emphasis in areas surrounding the point(s) of generation. The incorporation of the wind in this particular hybrid is very fundamental in the mitigation of the negative environmental impacts that are as associated with diesel as a fuel [9]. Additionally, the wind covers the economic uncertainties that surround diesel following the unpredictable fluctuation in the global prices of fuel. As a modern avenue to generate electricity, this hybrid deploys a series of sophisticated forms of technology. The fundamental aim of these sets of the complex technological framework is to balance the intermittent nature of wind energy with diesel, which is relatively controllable. Subsequently, this combination is aimed at developing the most optimal amount of energy that will meet the characteristically variable demand for power. Noteworthy, the performance of the efficiency of the wind-diesel systems can be measured empirically. Ideally, this measurement is established as a comparative ratio between the amount of wind power used and the amount of energy produced by the hybrid [9]. For instance, a situation where the wind power is estimated at say 70% penetration rate, then the energy produced by the hybrid will be assumed to contain 70 percent of wind energy. Most plants deploy the use of wind turbines with speed regulators to control the penetration rate of wind. Other firms prefer the use regulators that manage the various demands, especially those related to the heating load as used in the Mawson plant. Conversely, plants like the Coral Bay prefer storing the wind energy in a flywheel. Most recently, Ramea plant in Canada initiated the conversion of the wind-diesel plant to a more effective wind-hydrogen plant. On a global context, the use of wind-diesel hybrids is relatively present in a variety of communities. In Australia, this project is presently at the Bremer Bay Plant, Coral Bay, Denham, Hopetoun, King Island, Cocos, Queensland, Thursday Island, and the Rottnest Island. The King Island, in particular, has developed a smart grid that facilitated the expansion of the megawatts produced from 2 megawatts to 3 megawatts [5]. In Antarctica, the wind-diesel hybrid is found in the Ross Island and the Mawson Station. The hybrid is also present in the United States of America in various power plants in Alaska like the Kotzebue, Tin City, Hooper Bay, Nome, and the Savoonga. In Africa, the wind-diesel hybrid power generators have been used in Kenya in the town of Marsabit with a wind penetration of 46 percent. However, it is worth noting that Forya in Norway, the King Island in Australia, and the Rathlin Island in the United Kingdom have a wind penetration of 100 percent. As such, it creates an implication that very little diesel generators are used in these hybrids. Various temporary wind-diesel hybrid generators have been established in Northern Canada [1]. Various Northern Canada mining sites like the Ungava Peninsula, Lac de Gras, and Nunavik have developed this hybrid. The hybrid development is a way of saving fuel that is used in the generating of electricity to operate the mining machinery as well as the lighting of the mining shafts.

2.4 Wind-Compressed Air System

Practically, for the successful production of the wind-compressed air system, there are power stations that use compressed air energy storage (CAES). When utilizing compressed air energy storage, electrical energy is majorly used to compress air and then further stored in underground facilities like abandoned mines. Consequently, during periods when there is a high demand for electricity, the air is then released to power turbines using natural gas [10]. By definition, natural gas is a fossil fuel that is formed when many layers of plant and animal matter, which are in their decomposing stage are normally exposed to excess heat and pressure for thousands of years. In the recent
past, countries have adopted the use of wind-compressed air system, which evidently makes the use of renewable more attractive. The aspect is attributed to the fact that it allows the wind power that is generated at night to be stored till daylight hours when demand goes up. Notably, in the event where the process of power generation succeeds, the technology decreases the importance of building natural gas plants that would be used to supply peak power demand. Consequently, governments increase the storage of generated power, since the use of renewable energy has gone up. Some renowned company, SustainX, in West Lebanon, New Hampshire has in the recent past shown a 40-kilowatt prototype and is in the process of successfully completing a one-megawatt system. The new development is expected to be completed next year in collaboration with the power company AES [11].Notably, it can be seen that power stations in Japan, McIntosh, Germany, and Alabama make great use of CAES. It is common for limitations to be experienced which are derived from the need to use natural gas, thus clearly implying that these systems do not make use of renewable energy, and they also experience energy losses. The diagram below illustrates the wind-compressed air system from the wind vanes, power generation and interconnection with the electricity distribution system.

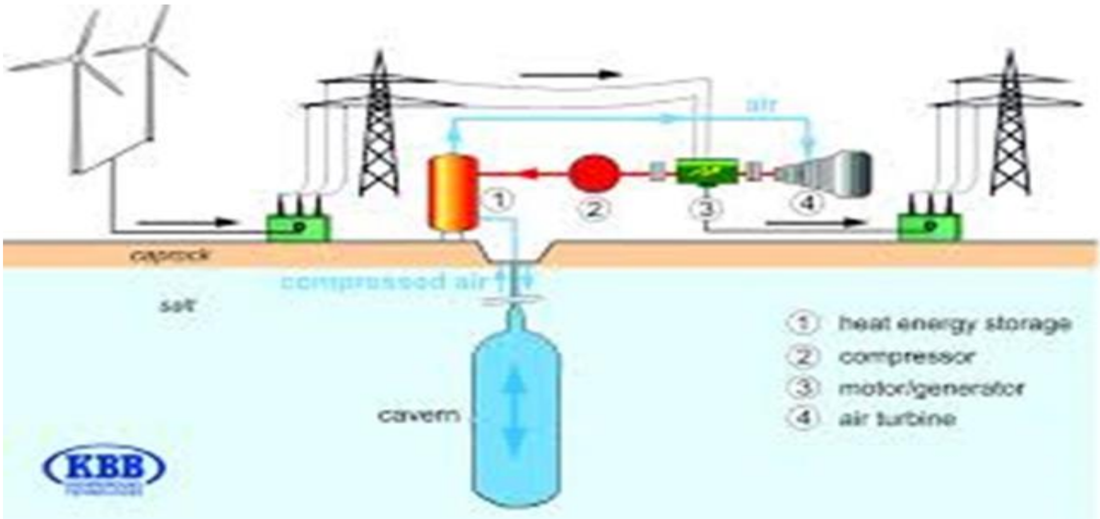

Figure.2 Wind-Compressed Air System

2.5. Wind-Solar System

It is imperative to note that the combination of solar photovoltaic and wind has the advantage that these two sources complement each other since the peak functioning times take place during different times of the day and year. Evidently, the power generation of such a system is constant and tends to fluctuate less than the two subsystems separately. Notably, solar energy is fluctuating, and the generation capacity of the diesel generation is usually limited to a certain range. Therefore, it is viable to put into consideration battery storage to optimize the contribution of solar energy to the generation of the hybrid system overall. For instance, in the recent past a case study was conducted across seven countries, and it clearly showed that generating costs can be decreased by also incorporating the isolated grids and mini-grids into a hybrid system. Despite this fact, financing costs used for diesel-powered electricity grids that use solar photovoltaics are very important and usually depend on the ownership structure of the power plant [12]. Although costs are significantly reduced, the economic benefits achieved are not significant and can even be negative in the case of private entities, for instance, independent power producers. Considering a better part of the United States, wind speeds are usually slow in the summer in times when the sun shines brightest for long hours. It is also notable that the wind is strong in the winter when there is less sunlight. Due to these peak operating times, hybrid wind and solar systems produce power when it is needed. Many hybrid systems usually stand alone and normally operate on off-grid, implying that they are not connected to a distribution system that utilizes electricity. In the event where neither solar nor the wind systems are producing, most of the hybrid systems provide power using batteries and an engine generator that is normally powered by conventional fuels like diesel [9]. In some instances, engine generators are used to provide power and also recharge batteries in the event where they run low.It is evident that engine generators are widely incorporated into the system, making it more complex. It has also reduced the size of the components, which are needed for the system, but in other cases modern electronic controllers are used to operate the systems automatically. Companies keep in mind and appreciate the fact that the storage capacity must be large to accommodate the supply needs of electricity during periods where batteries are not charging. Normally, battery banks are usually sized to support the supply of electricity for the duration of one to three days [8].

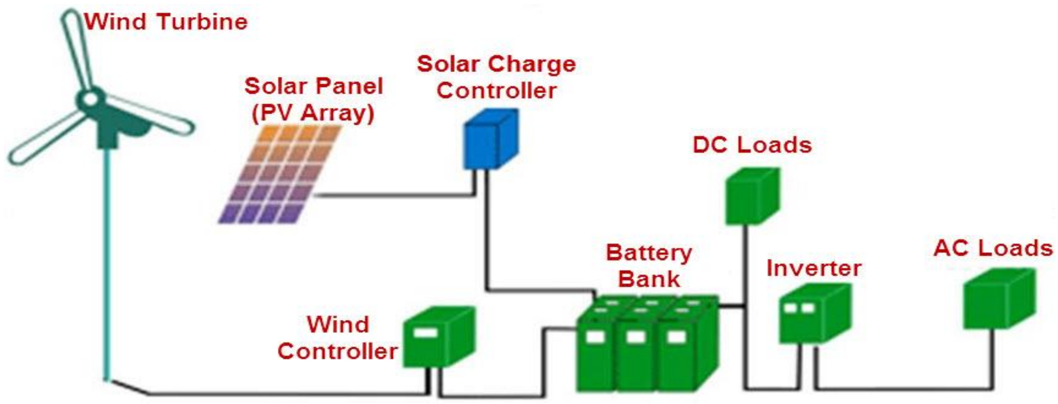

Figure.3: wind-solar system

The wind-solar building is a major example of a hybrid system utilizing the wind and solar systems. For instance, in Guangzhou, China, the Pearl River Tower mixes solar panels on its windows and several wind turbines at different levels of the main structure thus allowing the tower to be energy positive. The wind-solar lighting is lighting pylons that are a combination of solar panels and wind-turbines at the top. They are spread majorly in several parts of China and are seen to allow the space occupied to be efficiently utilized with energy production units that complement each other [4]. Evidently, most models use the horizontal wind turbines, but in the recent past, models have been using vertical axis wind turbine

4. Conclusion

In conclusion, this report encompasses background about the hybrid system that became a common technique for producing electrical energy globally. Also, it includes displaying some modes of power generation that can be combined with wind energy system including hydrogen, hydro, air compressed, diesel, solar systems and this in turn plays a significant role in addressing intermittent nature of the wind as a source of energy. Furthermore, this reports involves displaying some countries that implemented these projects. Therefore, the adoption of the use of hybrid systems in the generating of electricity has played an imperative role in the mitigation of the challenges that faced various stand-alone methods of power generation. Additionally, the hybrids have expanded the power grid into the rural areas, hence empowering various socioeconomic activities.

References

[1] Rule, T. A. (2014). Solar, wind and land : conflicts in renewable energy development (2nded.). London ; New York, NY: Routledge, Taylor & Francis Group.
[2] Shepherd, W., & Shepherd, D. W. (2014). Energy studies (2nd ed.). London : Imperial College Press.
[3] Acosta, M. J. (2014). Advances in Energy Research. Volume 19 (2nd ed.). Hauppauge: Nova Science Publishers, Inc.
[4] Towler, B. F. (2014). The future of energy (3rd ed.). London ; Waltham, Massachusetts :: Academic Press.
[5] Khajepour, Amir, Fallah, M. S., & Goodarzi, A. (2014). Electric and hybrid vehicles technologies, modeling, and control : a mechatronic approach (2nd ed.). Chichester, West Sussex, United Kingdom: Wiley.
[6] Al-Khoury, R., & Bundschuh, J. (2014).Computational models for CO2 Geosequestration & compressed air energy storage (1st ed.). Boca Raton: CRC Press.
[7] Dittrich, T. (2015). Materials concepts for solar cells (1st ed.). New Jersey: Imperial College Press.
[8] Peng, H. (2015). Fiber-shaped energy harvesting and storage devices (2nd ed.). Heidelberg ; New York : Springer.
[9] Irvine, S. J. (2015). Materials challenges : inorganic photovoltaic solar energy (1st ed.).
[10] Cambridge: Royal Society of Chemistry. Kuo, W. (2014). Critical reflections on nuclear and renewable energy : environmental protection and safety in the wake of the Fukushima nuclear accident (1st ed.). Hoboken, New Jersey: John Wiley & Sons.
[11] O'Hara, K. D. (2014). Earth resources and environmental impact (1st ed.). Hoboken: Wiley.
[12] Peeters, M., & Schomerus, T. (2014). Renewable energy law in the EU : legal perspectives on bottom-up approaches (2nd ed.). Cheltenham, UK: Edward Elgar Publishing.