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Reviewing the factors of the Renewable Energy systems for Improving the Energy Efficiency

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ABSTRACT
Electricity demand around the globe has increased alarmingly and is increasing at high rates. Therefore, electricity supply by the conventional resources is not sufficient right now and the generation of electricity by these resources is causing pollution worldwide. As the recent world is moving towards the alternative and renewable resources of energy that include sun, wind, water, and air. This paper focuses on reviewing the renewable energy sources used to improve the energy efficiency. This paper presents how the maximum power generation capacity can be achieved using these sources. Main focus of this paper is on solar and wind power that is freely available all around the globe. This paper concludes that there are certain factors that should be considered while generating power from these sources. The factors include the calculation of radiation data, storage size and capacity calculation, and geographic dispersion of the plants.

Keywords-Factors of renewable energy systems, Factors for improving energy efficiency

I. Introduction to Renewable energy

The energy that comes from natural resources and is reloaded naturally within the time is called renewable energy. These resources include (1) rain, (2) tides, (3) geothermal (4) heat, (6) sunlight, and (7) wind [1]. By using renewable energy, the use of conventional fuels is cut down and the ways in which renewable energy can replace the conventional fuels are: (1) Heating; (2) Motor Fuels; (3) Off-grid energy services; (4) Electricity Generation [3].

Consumable forms of energy are generally produced by converting the renewable energy through sophisticated technologies. Sun's energy works as a raw material for technologies to convert the energy into a consumable form. Sun's energy has various direct and indirect impacts on the earth in the form of solar radiation, gravitational forces, geothermal etc. These impacts work as a source of energy to be converted as they have built in potential of energy, but at the same time these sources have limitations, for instance they are disseminated and not easy to get and manage. Further, their potential varies from region to region as some regions are too cold and some are too hot as well. These limitations offer challenges in the field of technology and economy. It is pertinent to mention here that experts have successfully overcome all challenges. A lot of work has been done in the field of collecting the energy from natural resource, its conversion at low cost, minimizing the setup and maintenance cost and improving the consistency of energy [2].

The new developments in the field of technology assisted the improvement in the capacity of energy production in order to improve the efficiency of renewable energy. These developments were madefor all types of natural power generation resources. The major contribution of the technology development can be seen in the field of wind energy where the capacity factor increased from 20% to 30% in the period of about 30 years[4]. Another factor which is considered as very critical by experts in the capacity building is the maintenance of power generation technologies and equipment. It is essential to properly maintain the performance of all types of power generation equipment by the operators in order to keep the capacity at consistent levels. In case of poor maintenance, energy losses can be significant and an annual power generation may be compromised. This compromised power generation will in turn lead to the shortfall of consumable energy.

II. Factors affecting renewable energy

A number of factors affect the energy generation and energy efficiency of natural renewable energy resources. In order to determine the factors that can affect the efficiency of the resources of renewable energy, there is a need to analyse the resources. The efficiency can be improved by a variation of the resources and the corresponding factors.

(1) Generating the Solar Energy Radiation Data

Producing solar energy radiation data is essential for developing, designing and measuring the efficiency of the system based on solar energy. According to the Bulut[5], solar radiation data must be available for setting up the renewable energy system such as photovoltaic and thermal due to the critical role played by locations in determining the solar radiation intensity and an overall efficiency of the energy system.

Solar energy is now being used as a major source for fulfilling ever increasing energy demands; therefore due to its positive impact on the environment, its importance has been highly recognized [6]. The weather and radiation data are difficult to calculate due the nature of data. Bulut[5] mentioned that data relating to temperature and radiation do not always keep changing even then it is not possible to determine its values and predicts. Hence,the variance calculation is also difficult to calculate. However at the same time, stress has been made by researchers on the calculation and prediction of weather variable calculations. Due to its high importance of measuring and improving energy efficiency, significant work performed to develop a model for assisting in calculating and predicting weather variability[6].

The simple analysis of a renewable energy system can be performed by measuring solar radiation at given location. Data of radiation can be measured using one of the two methods. The first one is the measurement of solar radiation at a place which is horizontal to the sun or the measurement of the area perpendicular to the radiation. The second one relates to the PV system which is sensitive to the sun movement. In both the methods,an angle of the installed PV system will have to be determined in order to determine the solar radiation as system efficiency is also dependent on the slope of the module.

Mohandes[7] found that time series and regression analysis are commonly used approaches for studying weather variables. The usefulness in synthetic variable expressed in mathematical expression lies in its flexibility for integrating in computer programming. Bulut[5] conducted a study to develop a trigonometric equation by using radiation data of the Istanbul city and proposed for its usage in improved solar energy system designs.

The PV system also uses sunlight to create an electric field by converting radiation with the use of cells. Investigation of PV efficiency is possible with the measurement of electric current as its intensity is dependent on voltage, temperature, solar radiation and its continuum and wind pace. The most important scale to check the efficiency of the PV system is its conversion rate measurable under a simulated environment [8]. Recording and analysing PV performance provides data to determine the working of PV mechanisms and its different parts and also help in establishing reasons of system success and failure;and also reveal the extent of system reliability. According to Tripathy and Saxena[9],analysing PV system performance assists in establishing the validity of approaches used for system performance measurement.

Accurate modelling for measuring PV system performance requires ascertaining of all independent variables affecting performance and also recognizing their nature of the relationship with performance. Ayompe[10]analysed solar radiation, the environment temperature and the area in which PV system is installed, cell temperature, and wind speed. Analyzer suggested that it is essential to measure correctly and predict the cell temperature as the PV system's efficiency is dependent on the cell temperature up to very extent. After the correct estimation of cell temperature and inverter performance, it becomes possible to calculate the energy output from the PV system.

(2) Generating Wind Data

The inconsistencies in the wind power generation must be analysed essential in order to make sure the smooth running of energy demand and supply system. For this purpose, not a single wind turbine or wind farm, but a thorough study of wind farms integrated in the core energy systemshould be conducted. The wind does not flow always at the same speed at a specific site; but this is its unique feature that due to continuous solar energy and the atmospheric temperature difference of different areas of the earth, it always keeps blowing [11]**.**This weak relation between wind and energy production can be controlled to offer consistent energy production irrespective of the fact of volatility in the wind pace of the wind farm location. Therefore when considering wind energy supply, it is not relevant to consider changes in wind energy supply to total supply when the production level of wind farms is at the minimum level due to a wind pace. At the most important, still wind energy's share in total energy production is about 10%;therefore its inconsistent supply does not have much to do with total energy supply variability.

Wind production changes due to changes in weather and wind conditions. These changes can take place even in seconds as well, and it is obvious forchanges to take place with the change in the season. It is vital for wind energy management to predict the variations over sphere time to time. Further, it is also important to consider when wind power is integrated with other energy sources and also to use a wind power system at its ideal capacity. Energy systems have inherent characteristics in their mechanism to give output variations at different levels of supply and demand, but system management allows to handle these variations due to their flexible configurations and integration[10].

Due to variations in wind speed, a wind farm’s yearly energy production cannot be equal to generator energy production capacity. The total capacity of the farm is obtained through the mentioned ratings on the generators multiplied by the total hours in a year. The ratio of actual capacity in a year to this written capacity is known as the capacity factor [12]. Further mentioned by Shahan[12]that transparent data based wind off shore capacity factor ranges from 27% to 54% and onshore wind energy capacity factor ranges from 24% to 50.6%.Wind energy capacity factor is different from other energy plants which operate on fuels as there are other factors like wind speed variations in wind farm location and capacity of generators in relation to the turbine’s cleared area. According to the Shahan[12], a small, cheaper generator would produce higher capacity factor, but its output in the form of electricity would be less ata high wind speed. On the other hand, a large costly generator would add a little extrain the capacity factor and may not work properly when wind speed is very low depending upon the features of the generator.

According to the study released by the U.S. Department of Energy [13], the capacity factor of the output generated by wind farm is increasing with technological improvements. In the period of 2008-2010, capacity factor in the United States ranged between 28.1%-32.3% [14].

(3) The Geographic Separation

For assuring the smooth supply and demand of electricity, accumulating electricityismade in different forms, i.e. wind, solar or tides to a single transmission grid is necessary. Various researches have endorsed the significant role played by a common transmission grid in controlling sully and demand of electricity [15] [16][13] [17][18] [19]. Stoutenburg[20] observed that collective energy produced from wind and wave farms located in the same geographical area reduces the inconsistencies of both power generation sources individually. If wind power farms located at the distance of a few hundred kilometres of each other are interconnected, then this will result in getting rid of hours of the zero power as the interconnection will accumulate wind farms.

Palutikof[21] analysed the effects of geographical distribution on performance of the wind turbine. Simulation was based on the study of hourly wind data of wind turbine located in widely dispersed areas of England.When the data for individual sites were analysed, the researchers noted that 100% of rated capacity of output change in per 1000 hours were about zero to 4.2h and 50% of rated capacity of output change in per 1000 hours were 5.7 to 39h.When three sites were considered interconnected, then it was noted that there were no hours when output was 100% changed, and in 1000h there were zero to 1.9h when output was changed by 50%.Archer and Jacobson[16] connected the 19 geographically scattered wind power sites hypothetically located in the region of the Midwest, England. Study results indicated that by connecting sites, approximately 33% of annual average production of wind power will be as useable as energy produced using coal.

Furthermore, the result proved that accumulated wind energy produced by 19 sites located at a different geographical location were 4 times more than the energy produced by installing the wind farm at one site.The critical aspect of having dispersed wind farms was that each additional site adds up the energy power to the total energy of dispersed sites at a diminishing rate.The study recommended that for part of energy production, whichremainsinconsistent, can be used during charging batteries or producing hydrogen.

It is noteworthy that inconsistencies in the interconnected sites of wind power generation capacities in the long term can be considerably less as compared to the inconsistencies of the hydropower generating capacities over the longer period [22].Katzenstein[19] conducted a study to evaluate the yearly production capacity of 16 prototypes of 1.5MW turbines installed during the period of 1973 to 2008 in the Central and Southern Great Plains of the United States. Researchers compared the estimated annual production of prototypes with the recorded production of hydropower in the same time period.The standard deviation from the estimated average annual wind production during the period from 1973 to 2008 was about 6%. In case of the estimated wind, production standard deviation was 2% of the average yearly production.The highest deviation from the average wind power during one year was recorded at 14% to 10% and for hydro power highest deviations ranged 26% to 23%.Analysis indicated that long-standing changes in production from interconnected wind sites intheUnited States were 50% of the changes in hydro power production during a long period of time.

Furthermore, photovoltaic sites are not the exceptions and also PV sites interconnectivity lead to reduction in inconsistencies [23] [24].According to the study of Mills [24], 3D split between photovoltaic sites are necessary to bring changes in production by de-linking the sites located at the distance of 20, 50 and 150 kilometres over the time period of 15, 30 or 60 minutes respectively.Mills and Wiser [23] critically appraised the previous research conduct to evaluate the impact of scattering on the volatility of photovoltaic output.On the basis of secondary research, they were of the opinion that with significant location and diversity in PV sites, output volatility caused due to the clouds can be minimized to the certain extent as it is less related as compared to the volatility caused due to a continual movement of the sun.

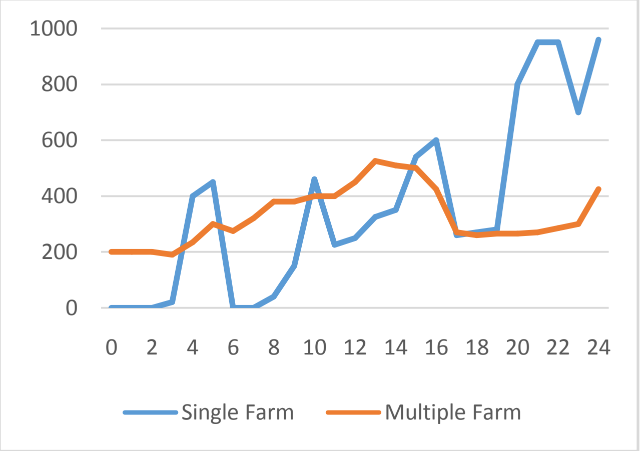

Figure 1: The smoothing effects of geographical dispersion of a single wind farm and distributed wind farms, both rated at 1000MW

Adopted from: Variability of wind power and other renewables (International Energy Agency, 2004)

(4) Storage Size Variation

Another method for improving inconsistencies in supply and demand of energy as described by Wilson [25] is to store excess energy in batteries, turbine nacelles or in underground caverns produced at the site [26].Benitez [27] examined (with the help of a linear mathematical optimization program) the combination of energy produced by wind and water. The results indicated that if the wind and hydro power is stored using pumped hydro storage facility and by making huge water reservoirs, the combination of both reduces the energy production using gasandHybrid PV; and wind energy plant production variability can also be eliminated by using battery storage as its procedures were developed by Ekren and Ekren[28].

Managing the highest production capacity of wind and solar systems in order to maximize the high power demand can reduce the time when available power from the wind, water and solar sources are less than the demand. Hence, this will reduce the need of other sources like coal and oil to produce energy for meeting demands.The extra capacity with WWS production plants can be used to produce hydrogen after meeting energy demands. According to the Delucchi and Jacobson [22],an extra capacity must be utilized in production of hydrogen useable in heating processes and transportation. Furthermore,Delucchi and Jacobson [22] argued that having high spare capacity in the WWS energy generation systemwill have two certain benefits. One is that extra capacity will help in meeting the peak and essential demands; and second is extra capacity will reduce the time period when production is less than the requirements. But it is pertinent to mention here, installing spare capacity and storage facility bear huge costs. When production will be higher than the demand then the storage cost for hydrogen will have to tolerate. Whenever, extra WWS power will be produced, it will bring extra hydrogen and it may not happen that supply and demand of hydrogen coexist.

V2G technology is generally used in providing assistance in managing energy loads when demand is very high, rotating reserves, regulate power supplies or to offer a storage system which can store energy in a decentralized location where the system is generating inconsistent energy[22].Kempton and Tomic[29], and Andersson[30] investigated the financial requirements associated with V2G for managing energy loads, where production technology is conventional, and proposed the circumstances in which benefits of having V2G can be more than the associated cost of V2G.In other words, it was noted by the researchers that the cost of batteries, extra electronic equipment, wiring costs and the extra production cost can be offset by using V2G as it eliminates or minimize the usage of expensive energy production sources and manages the peak demands and reduces the time in which peak demands is not met.Furthermore, examination of V2G systems revealed that it enables storage of energy at decentralized places in order to manage the inconsistencies in renewable energy demand and production [31].

Two important calculations were made by Kempton and Tomic[32] related to use of V2G systems inthe USA:

1. The V2G systemregulates the energy production by keeping the voltage smooth at certain frequencies in short breaks when the wind forms supplies 50% of electricity demand. In this scenario, 3.2% of the light-duty vehicle fleet would have to use the stored energy in assuring the necessary adjustment of wind power production.

2. V2G system is used to assist in managing inconsistencies in wind power supply occurring on an hourly basis by working as operating resources onwind farms supplies 50% of electricity demand. In this scenario, 38% of the light-duty vehicle fleet would have to use the stored energy for smooth running of the whole system.

Subsequently, a study of Archer and Jacobson [33] suggests that for managing variation in wind power supply and assuring that production remain 20% above of production (in an interconnected wind form of the US), 23% of the LDV fleet must use stored energy.

(5) Storage Efficiency Variation

It is possible to store energy in some other forms when it is not required. The stored energycan then be converted back into energy form for consumption. According to Carnegie[34], two attributes are attached to the storage of energy; one is technology and application, and second is power and energy. They suggested that application and technology used in storing energy must complement each other. Furthermore, applicationsarerequired to manage loads when supply and demand is different which require large energy storage capacity as in case of hydroelectric power. On the other hand, when voltage stabilization is required an application likethe flywheel will be required which has a strong responsive power capacity. Therefore, other factors that are related to the technology and application of storage of energy are discharged frequency, duration of the discharge, response time, depth of discharge, and response time[35]. The efficiency of the storage devicesis dependent on the energy productivity and discharge duration. The storage efficiency of storage devices varies from 60% to 90% with the changes of technology. For the battery life cycle ranges arefrom 5000 to 10,000; and for Pumped hydroelectric, capacitors, compressed air energy, cycles ranges are from 10,000 to 100,000.

According to the Delucchi and Jacobson [22], V2G is an appropriate approach to be applied for matching the demand of energy from wind, water and solar energy resources. V2G costs are in three different aspects. They tend to decrease the storage capacity of batteries. Extra energy is required for managing the operations of the batteries; and batteries drop the energy in the charging and discharging process, and retrieving the operation of the storage device. Delucchi and Jacobson [22]analysedthe costs attached to the V2G application in Li-ion batteries and found that:

- Battery life is based on 45000 cycles and if it is a usage period in less than 30 years than its replacement cost will be zero and batteries will be costing at \$0.01–\$0.02 per kWh diverted to V2G.
- If the batteries are utilized for about 30 years, and with V2G technology loss of the battery's capacity is at the minimum then V2G cycling will be about \$0.03/kWh to \$0.11/kWh depending on the application in which it is used.
- If the batteries are utilized for more than 30 years and with V2G cycling start loss capacity of energy as does during batteries charging and discharging. The V2G technology will cost about \$0.05–\$0.26/kWh.

Delucchi and Jacobson [22] presented the cost as per kWh diverted to V2G. If the cost of all renewable energy stored in batteries using V2G technology is to determine then it can be obtained by multiplying the cost per kWh diverted by the percentage of kWhsdiverted to the total kWh of produced via wind, water and solar energy sources. Furthermore, researchers estimated that the percentage of diversion will not increase from 25% with careful design.Andthe operation of energy farm management and with the latest application use of V2G cycling, the additional cost to ensure that wind, water and solar energy powers meet the demand with the supply must not increase than $0.02/kWh.

(6) Plant Size Variation

Integration of the power plant installed at different locations can lead to a low level of variation in productivity of energy plants [36]. Further, if the energy plants are independent in terms of their weather conditions then it also becomes possible to some extent to predict their productivity. Each day of the year weather condition changes, therefore it is important for maintaining smooth energy production to calculate the output of all renewable energy plants and analyse the factors which contributes to the fluctuation in the output of energy plants [37].

According to research conducted by Broders[38], an integrated power plant and cumulative output are presented bythe probability distribution function. This is the function that demonstrates the probability of the output of energy plants. For assurance of reliability in production levels in 360 days and 24/7, it is inevitable to record and summed the probability distribution function of production for predicting the expected power generation. The standardization probability distribution function of up to some desired limits would indicate the required number of power plants at a different geographic location that would also be independent in terms of various ecological factors.

Broders[38]simulated the impacts of variation in the size of the plants and noted that as the number of plants increases whose energy are stored in one location; and their dependence decreases in the number of hours when energy demands are not met then it is expected that total production will decline and energy will remain unexploited.

III. Conclusion

All the above reviews of different studies and discussions show that it is important to determine and consider the factors in order to build high performance renewable energy systems. It is very important to calculate the radiation data of solar energy as it provides the basis for the solar energy power systems. Sun’s energy needs to be calculated in order to determine that how much can be achieved at a specific place. On the other hand, if the energy is to be produced by wind then it is important to calculate the wind data as it will provide the basis for the wind power systems. In both the cases, solar and wind data needs to be collected or generated in different locations in order to know about the variation of the power capacity. In the case of solar, low sunlight and high sunlight areas are to be chosen and the angle of cells to sun and temperature must be considered. The more appropriate things require the more accurate data. In the case of wind, low wind and high wind areas are to be examined. After determining these factors, there is a need to consider the other factors too, as they would also contribute to the performance improvement. Plant size and geographic separation will play a positive role in improving the efficiency of the power systems. Due to geographic separation, plants will be dispersed across different locations and it will help in producing large amounts of energy and will provide consistency to an extent in the power generation. In case, one location has the unfavourable climatic conditions at the time and the other has highly favourable climatic conditions then they will complement each other. In this way, plant size will be reduced and the cost of one plant will be decreased but the efficiency will be improved. In a similar way, there is another factor that contributes a lot in renewable power systems i.e. storage. By variation in the size of the storage and the type of storage, it is also possible to increase the consistency of the power systems. The bigger size of the storage will offer the greater the energy backup time. In this way, consistency will increase and the efficiency of power supply will also be increased.

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