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# Optimization of Renewable Energy Systems: A Review

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## ABSTRACT

In the contrary of decrease of fossil energy nowadays, the demand of energy, the global warming, and continuous increase in oil prices have got attention all over the world. Since without energy life is an imaginary, the newly emerging renewable energy technologies are hope fully at least minimizing the problem that comes from the shortage of energy or an imbalance of distribution of energy among countries and within a country. To satisfy the need for power, hybrid renewable energy system is becoming an emerging and widely under application for electrification of remote rural areas where the grid extension is difficult and not economical in the past few decades all over the world. These systems incorporate a combination of one or more renewable energy sources such as solar photovoltaic, wind energy, micro-hydro, biomass energy, geothermal and may be conventional generators for backup. This survey paper compiles renewable energy systems with their advantages and limitations, hybrid wind and solar energy systems with different system components of hybrid energy system, provides detailed review of work done for optimization of renewable energy systems and give gap analysis to develop a general model to find an optimal combination of energy components for a typical rural community for minimizing the total net present cost of the system through the life time of the project. The highlights of the components and some simulation technique tools are also discussed.

**Keywords:** Renewable Energy, Wind Energy, Solar Energy, Hybrid Renewable Energy System, Optimization.

## I. INTRODUCTION

The natural capacities of the earth for supplying fossil energy will not ever lasting. Nowadays, in addition to exponentially increasing energy demands, the global warming, depletion of conventional energy sources and continuous increase in oil prices have been diverting worldwide attention for the development and utilization of renewable energy sources. So due to such and rapid increment of industrialization all over the world, the need for energy was rapidly increases from time to time and also depletion of fossil fuels has been occurred which leads an initiation for the need of alternative inexhaustible sources of energy to satisfy the continuously increasing energy demand. Another important reason to reduce our consumption of fossil fuels is the growing global warming phenomena. Environmentally clean and friendly used power generation technologies have to play an important role for the future power supply. The renewable energy is inexhaustible, abundant, renewable and clean without producing greenhouse gases, numerous researches carried out to optimize the size of hybrid photovoltaic and wind power generating systems in recent years [1]. These technologies are including power generation from naturally endless, inexhaustible and renewable energy sources, such as wind, PV(photovoltaic), MH (micro hydro), biomass, ocean wave, geothermal and tides which are naturally replenished.

### *Necessity of Renewable Energy*

So far, supply of electricity from extension of main grids and installation of diesel generators are used as an option for the electrification of rural villages. Grid expansion to such areas is practically impossible to satisfy the need of the society due to either financially high cost or practically not feasible as these locations are geographically isolated, sparsely populated and have a very low power demand. Using diesel generators for electricity has also harmful effect on the environment in addition to their higher cost of fuel, maintenance and operation. Consequently, rural areas are dependent on local solutions for electricity to get its supply. These areas have been using sources of electricity with multi dimension high impact, such as Kerosene for lighting, diesel for milling and pumping, traditional biomass as source of energy for cooking and dry cells for radio and tape recorders. However, the current increase in oil price and the negative effects of fossil fuels on the environment motivates to search for other alternative (preferably renewable) sources of energy.

Ever increasing utilization of renewable is the key to a cleaner and sustainable energy in the future; however, there are certain technical issues that can decrease usage of renewable generation in power system. These are concepts related to reliability and quality.

When we mean reliability, it is an amount of power that a renewable source of energy such as solar and wind can produce depends on availability of the employed source. For instance, since sun radiation and wind speed are depending on climate change and vary from time to time, therefore the output power of a solar energy system or a wind power will never be constant. Hence, high penetration of renewable into a power network can result in risk of making the entire network less reliable. On the other hand, Power quality issues are an important factor of a power system particularly these days that new electrical devices are sensitive to voltage variation. Power quality of a power system is measured by level of voltage variations, level of frequency variation and harmonics. To control the reliability and quality issue and to overcome the challenges around renewable energy from designing through installation up to the end usage of the society, one has to understand the types and nature of each renewable source.

## II. Types of Renewable Energies

There are several renewable energy sources that are **becoming more and more prevalent around the world, but it is still not the dominant energy resource** today. The most prevalent are listed below with their brief descriptions.

### A. Solar Energy

Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into the flow of electrons to obtain direct current electricity using semiconductors that exhibit the photovoltaic effect. To generate direct current (DC) electricity from solar, certain solar panels comprising a number of cells containing a semi-conducting material, which is used to convert solar energy into a usable form of energy is needed. When the sun light is shining on the solar cell there is flow of electrons and thus produce electricity. When there is no light shining to the panel, no electricity produced. Many PV have been in continuous outdoor operation on Earth or space for over 30 years. The solar cells that are reached on the panel and used on calculators and satellites are photovoltaic cells or modules. This PV module consists of many PV cells wired in parallel order to increase current and in series to produce a higher voltage. When saying a PV panel, it means any number of PV modules and when we speak of array it means any number of PV panels. Individual PV cells are typically only a few inches in diameter, but multiple cells can be connected to one another in modules, modules can be connected in arrays, and arrays can be connected in very large systems [2].

PV panel convert sunlight to DC electricity. The PV generated electricity is relatively cheap in maintenance and does not need in fuel or oil supplies. However, PV energy is available when enough irradiance is accessible.

***Advantages of Solar Power***

Solar energy was the most abundant form of energy and it has a lot of advantages over other forms of energy including renewable. It is environmentally clean, doesn't have pollution and much abundant renewable source. Once installation cost was covered it is cheap and free of charge throughout its life time. Solar cells make absolutely no noise at all. On the other hand, the giant machines utilized for pumping oil are extremely noisy and therefore very impractical. Very little maintenance is needed to keep solar cells running. There are

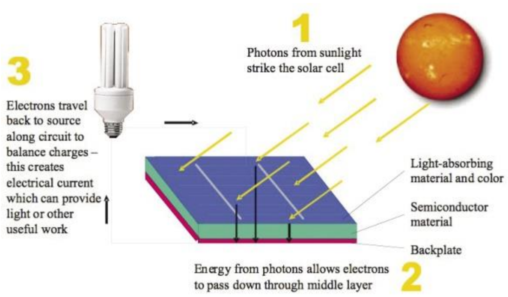


***Fig 1.*** *Process of Photovoltaic cells* [3]

no moving parts in a solar cell which makes it impossible to really damage them. In the long term, there can be a high return on investment due to the amount of free energy a solar panel can produce, it is estimated that the average household will see 50% of their energy coming in from solar panels.

***Disadvantages of Solar Power***

- Solar panels can be expensive to install resulting in a time-lag of many years for savings on energy bills to match initial investments.
- Electricity generation depends entirely on a countries exposure to sunlight; this could be limited by a countries climate.
- Solar power stations do not match the power output of similar sized conventional power stations; they can also be very expensive to build.
- Solar power is used to charge batteries so that solar powered devices can be used at night. The batteries can often be large and heavy, taking up space and needing to be replaced from time to time.

**B. Wind Energy**

Among the various non-conventional energy sources, wind energy is one of the emerging potential sources of energy for the societies especially in the rural area. Wind energy results from air in motion due to pressure gradient that is caused by the solar energy irradiating the earth. Winds are produced by an irregular solar heating of the earth's land and sea surfaces. Thus, they are a form of solar energy. On average, the ratio of total wind power to incident solar power is on the order of two present, reflecting a balance between input and dissipation by turbulence and drag on the surface. Wind is the movement of air resulted by the irregular heating of the Earth's surface at different time. It happens at all scales, from local breezes created by heating of land surfaces that lasts some minutes, to global winds caused from solar heating of the Earth. Wind power is the transformation of wind energy into more utile forms, it possesses energy by virtue of its motion and produce electricity using wind turbines.

As the needs wind energy increases in the past few decades, it is important to do in the direction of obtain the maximum effective and efficient energy from the farm. This leads the reader to think the factors can affect wind energy. The output of wind energy was affected by the wind speed, Cross-section of the windswept by rotor, Conversion efficiently of rotor, Generator and Transmission system.

Theoretically it is possible to get 100% efficiency by halting and preventing the passage of air through the rotor. However, a rotor is able to decelerate the air column only to one third of its free velocity. A 100% efficient wind generator is able to convert maximum up to 60% of the available energy in wind into mechanical energy. In addition to this, losses incurred in the generator or pump decrease the overall efficiency of power generation to 35% [4].

To get electric from wind the following components are involved in the installation process.

- Wind Turbine (WT) that converts wind energy into rotational (mechanical) energy.
- Gear system and coupling (G/C). It steps up the speed and transmits it to the generator rotor.
- Generator (G). That converts rotational energy into electrical energy.
- Controller(C) that Senses wind direction, wind speed generator output and temperature and initiates appropriate control signals to take control action.
- Yaw motor gear- The area of the wind stream swept by the wind turbine is maximum when blades face into the wind.

Configuration of the blade angle with respect to the wind direction to get maximum wind energy can be achieved with the help of yaw control that rotates wind turbine about the vertical axis. In smaller wind turbines, yaw action is controlled by tail vane whereas, in larger turbines, it is operated by servomechanism.

***Advantages and disadvantages of wind power***

Wind energy gives us many advantages, which can justify why it is one of the fastest-growing energy sources in the world. Research efforts are aimed at addressing the challenges to greater use of wind energy. Thus, to get maximum efficiency of the field, it is important to the reader to focus on the following benefits and limitations of wind power [5].

*Advantages of Wind Power*

1) Land-based utility-scale wind is one of the lowest-priced energy sources available today, costing between two and six cents per kilowatt-hour, depending on the wind resource and the particular project's financing. Since the price of electricity from wind farms is fixed over a long period of time and its fuel is free, wind energy mitigates the price uncertainty that fuel costs and decreases the effects of using traditional sources of energy.

- **It's a clean fuel source:** Wind energy doesn't have any impact on the environment and also doesn't pollute the air like power plants that rely on combustion of fossil fuels, such as coal or natural gas, which emit particulate matter, nitrogen oxides, and sulphur dioxide causing human health problems and economic damages. Wind turbines don't produce atmospheric emissions that cause acid rain, smog, or greenhouse gases.
- **Sustainability of the source:** As mentioned earlier Wind is a form of solar energy which is caused by the heating of the atmosphere by the sun, the rotation of the Earth, and the Earth's surface irregularities. For as long as the sun shines and the wind blows, energy generated can be used to send power across the grid.
- **Wind turbines can be built on existing farms or ranches:** This greatly benefits the economy in rural areas. Farmers and ranchers can continue to work the land because the wind turbines use only a fraction of the land. Wind power plant owners make rent payments to the farmer or rancher for the use of the land, providing landowners with additional income. In addition, it serves the society as to become job opportunity, serve as domestic source of energy including the local community and can play a role in the development of world economy.

Even though Wind Power is most reliable forms of renewable energy, there may be certain challenges to get an efficient output. Some of these challenges are listed below

- **Wind power must still compete with conventional generation sources on a cost basis:** Depending on how energetic a wind site is, the wind farm might not be cost competitive. Even though the cost of wind power has decreased dramatically in the past 10 years, the technology requires a higher initial investment than fossil fuelled generators.
- **Good wind sites are often located in remote locations, far from cities where the electricity is needed:** Transmission lines must be built to bring the electricity from the wind farm to the city. However, building only some transmission lines could significantly reduce the costs of expanding wind energy.
- **Wind resource development might not be the most profitable use of the land:** Land suitable for wind-turbine installation must compete with alternative uses for the land, which might be more highly valued than electricity generation.
- **Turbines might cause noise and aesthetic pollution:** Although wind power plants have relatively little impact on the environment compared to conventional power plants, concern exists over the sound produced by the turbine blades and visual impacts to the landscape.
- **Turbine blades could damage local wildlife:** Small birds have been killed by flying into spinning turbine blades. Most of these problems have been resolved or greatly reduced through technological development to establish wind plants.

## C. Hydropower

Hydropower is the extraction of energy from falling water (from a higher to a lower altitude) when it is made to pass through an energy conversion device, such as a water turbine or a water wheel. A water turbine converts the energy of water into mechanical energy, which in turn is often converted into electrical energy by means of a generator. Alternatively, hydropower can also be extracted from river currents when a suitable device is placed directly in a river.

Hydropower is one the oldest and largest renewable power sources and accounts for close to 10% of our nation's electricity. Hydropower plants convert the energy of flowing water into electricity. This is primarily done by damming rivers to create large reservoirs and then releasing water through turbines to produce electricity. Hydropower results in no emissions into the atmosphere but the process of damming a river can create significant ecological problems for water quality and for fish and wildlife habitat [6].

### *a. Biomass Energy*

Biomass is one of the most important sources in the rural area for energy productions supplied by agricultural products. Effective connecting of bio-energy can energize entire rural areas many society of the country like India where nature offers various types of biomass. This energy is also available in the form of biodegradable waste, which is the rejected component of available biomass [7].Biomass energy refers to the process of making fuels from plants and animal wastes either locally or with simple technology. This resource is, organic matter in which the energy of sunlight is stored in chemical bonds. When the bonds between carbon, hydrogen and oxygen molecules are broken by digestion, combustion (or) decomposition these substances release stored energy.

To get biomass energy there is a conversion of organic matter to Energy through certain process. In alcohol fermentation, the starch in organic matter is converted to sugar by heating. This sugar is then fermented and finally ethanol is distiller and then blended with another fuel. An aerobic digestion converts biomass, especially waste product such as municipal solid waste and market waste. In this process, the facultative bacteria break down the organic material in the absence of oxygen and produce methane and carbon dioxide. Bioconversion is a non-polluting, environmentally feasible and cost-effective process [8]. The effluent and digester residues are rich in nitrogen and phosphorus, which can be recycled back to the soil as a fertilizer [9]. By using this method, we can derive 70% of the energy. The biomass is mixed with water and stored in an airtight tank. The organic wastes (Municipal Solid Waste) are collected separately and dried natural method and shredded to the maximum particle size of 2 – 4 mm. This was stored in a plastic container at room temperature and was characterized and it was used during all anaerobic digestion treatment. Domestic sewage was collected from a college campus before disposal. It was used in all anaerobic digestion experiment for diluting the feedstock to achieve the required total solids concentration for the present investigation.

### *b. Geothermal*

Geothermal electric capacity in the United States is over 3,000 MW. Geothermal power plants use high temperatures deep underground to produce steam, which then powers turbines that produce electricity. Geothermal power plants can draw from underground reservoirs of hot water or can heat water by pumping it into hot, dry rock. High underground high temperatures are accessed by drilling wells, sometimes more than a mile deep. In one sense, this geothermal energy is not renewable, since sometime in the future the core of the earth will cool. That time is so far off (hundreds of millions of years) that that we think of it as renewable.
Most geothermal power plants are located in the western United States, but some coastal regions of Virginia (near Wallops Island) have geothermal power potential. Geothermal heat pumps use compressors to pump heat out of the earth (for winter heating) or into the earth (when running as air conditioners in summer). The energy they pump into and out of the earth is renewable, since it is replaced by the cycle of the seasons. The energy that runs the compressor can either be renewable or conventional

## III. Hybrid Renewable Energy Systems

The Hybrid Renewable Energy Systems (HRES) are a combination of two or more renewable energy source or at least one renewable source to conventional source and it can be either grid connected or better to be in stand-alone mode due to its advances in renewable energy technologies and power electronics converters which are used to convert the unregulated power generated from renewable sources into useful power at the load end [10]. In addition to the above-mentioned usage there is the most important advantage of HRES nowadays is that to make best use of the renewable power generation technologies operating characteristics and to obtain efficiencies higher than that could be obtained from if a single power source is implemented for specific area. Various aspects must be taken into account when working with hybrid systems for the generation of electricity. Reliability and cost are the most important aspects of these; it is possible to justify many directions that, the hybrid generation systems are usually more reliable and less costly than systems that rely on a single source of energy due to climate change [11, 12]. In various research papers [13, 14, 15], it has been proven that hybrid renewable electrical systems in off-grid applications are economically viable, especially in remote locations. In addition, climate can make one type of hybrid system more profitable than another type. For example, photovoltaic hybrid systems (Photovoltaic–Diesel–Battery) are ideal in areas with warm climate.

In general, supply security, reduced carbon emission, improved power quality, reliability and employment opportunity to the local people as needed are the main reasons why for the deployment of the above discussed energy systems are important. Since the RE resources are climate dependant in nature therefore, hybrid combinations of two or more power generation technologies, along with storage can improve system performance. Since it combines two or more renewable energy resources with some conventional source (diesel or petrol generator) along with storage, it can overcome the challenges that come from changes of climate and full fill the demand of the specific area. It was becoming popular and the most advantageous and well known for remote area power generation applications due to advances in renewable energy technologies and subsequent rise in prices of petroleum products. The Economic aspects of these technologies are sufficiently promising to include them in developing power generation capacity for developing countries.

The demand for electricity is increasing day by day all over the world, which cannot be fulfilled by non-renewable energy sources alone even if their environmental impacts are under mined. Renewable energy sources such as solar and wind is universal and environmental friendly once installed for the society. The renewable energy sources as mentioned above, are recently emerging alternative options to full fill the energy demand, but unreliable due to the stochastic nature of their occurrence. Hybrid renewable energy system (HRES) sources like wind turbine and solar system combine as Solar–wind hybrid renewable energy system to overcome the weakness of one source standalone by the strength of the other source at that time.

On the other hand, various mathematical models, design and simulation models of the elements are used to make up these systems easy for implementation. The difficulty of designing these models by considering all of the components of the hybrid systems mainly depends on the type of application (simulation, design, etc.) and interest of the designer. A lot of authors [10, 16, 17, 18] have been writing their papers about the optimum economic designs for hybrid systems as PV and/or Wind and/or Diesel systems with energy storage in batteries. Usually, the optimum design is done by minimizing the Net Present Cost (NPC) investment costs plus the discounted present values of all future costs during the lifetime of the system or by minimizing the levelized Cost of Energy (LCE) total cost of the entire hybrid system divided by the energy supplied by the hybrid system and give their own justification for each way.

Hybrid energy systems may or may not be connected to the main grid of that country. They are generally independent of large centralized electric grids and are used in rural remote areas especially for those areas impossible to give electricity from central grid due to a lot of factors [19]. In many remote areas of the world, the availability, reliability, and cost of electricity supplies are major issues today. The typical standard solution for time being is to use diesel or petrol generators to meet power requirements in areas distant from established electricity grids. There are a number of problems with running stand-alone diesel or petrol generation, including noise, pollution and high running maintenance costs. Generators can also be inconvenient to use in wide. Due to the high running and maintenance costs, continuous operation of a generator may not be financially viable [20].

The use of hybrid energy systems, incorporating PV and wind resources, in remote locations can overcome or at least limit some of the problems associated with generator only systems. The use of these renewable energy-based systems could help reduce the operating cost through the reduction in fuel consumption, increase system efficiency and reduce noise and emissions [21]. But, when there are such PV-wind hybrid systems are usually equipped with diesel generators to meet the peak load demand during the short periods when there is a deficit of available energy to cover the load demand [22]. To decrease the need of a diesel generator, a battery bank can be used. Battery life is enhanced when batteries are kept at near 100% of their capacity or returned to that state quickly after a partial or deep discharge. The use of PV modules only does not protect batteries against deep discharges always. During periods of little or no sunshine, the load draws more energy than the PVs can replace. A more dynamic source of energy is a wind turbine. Adding a wind turbine to a system would protect batteries against deep discharges and thus extend their life [21, 22].

### A. Importance of Hybrid Energy

Renewable energy sources are inexhaustible, abundant and a great hope in the future for the world population especially for the societies which are far and can't be served from national grid. But, since the implementation of standalone energy source has its own limitation, it is better to consider the hybrid system. Hybrid system can cover the weakness of one source by the strength of the subordinate source when there is change of climate. Hybrid power system consist of two or more renewable energy source such as wind generators, solar etc of charge batteries and provide power to meet the energy demand up to the desired quantity, by studying the nature of the local geography and other details of the place of installation. These types of renewable systems are usually not connected to the main utility grid. They are also used in stand-alone applications and operate independently and reliably. The best application for these types of systems is in remote areas of the world, such as rural villages, in telecommunications etc. The importance of hybrid systems has grown as they appear to be the right solution for a clean and distributed energy production. By using wind/ PV hybrid systems, we can get the following importance over using it standalone [5].

- Continuously, the daily output of the system is stable, since both energy sources may offset the variations in output mutually. The overall system will be generating power during the day and during the night, since wind power isn't limited by sunlight even though the amount varies. Of course, production will be higher during the day but it doesn't drop to zero at night.
- Seasonal variations are offset. Solar PV systems are more productive during the summer, and wind turbines are more productive during the winter since the weather tends to be windier. Viewed on a yearly basis, the seasonal variations in production are balanced.
- If the installation is off the grid, smaller battery banks are required for backup. It is possible for the system to operate with smaller energy storage, since one of the two sources operates day and night. Batteries are also subject to a less aggressive charge/discharge cycle, increasing their service life.
- If a backup diesel gen-set is important to use, it can also be sized smaller. There is less uncertainty with respect to the combined wind and solar energy supply. If there is need to use a generator, it will be less frequently and for shorter periods of time.
- Generally, by applying Hybrid energy system we get the following main advantages in comparison to single source based system:
- Higher reliability
- Reduced energy storage capacity especially where different sources have complementary behaviour.
- Better efficiency.
- Minimum levelized life-cycle electricity generation cost, when optimum design technique is used

### B. Implementation of Hybrid Renewable Energy System

Seasonal dependence of the standalone renewable energy resources is the most important reason to install a hybrid energy supply system. The Solar PV wind hybrid system suits to conditions where sunlight and wind has seasonal shifts [23]. Because of the sun radiation does not uniform the entire day and the wind does not blow throughout the day a single source will not be a suitable choice to achieve the required demand. A hybrid arrangement of combining the power harnessed from both the wind and the sun and stored in a battery can be a much more reliable and realistic power source as subordinate. The load the system will be powered using the stored energy in the batteries even when there is no sun or wind due to climate change. Hybrid systems are usually built for design of systems with lowest possible cost and also with maximum reliability by considering all the constraints which can be affect the quantity of generated power. Becoming high cost of solar PV cells makes it less competent for larger capacity designs. This is why the wind turbine comes into the picture, the main feature being its cheap cost as compared to the PV cells. Battery is needed to the system to store solar and wind energy produced during the day time. During night time, the presence of wind is an added more advantage, which increases the reliability of the system. In the monsoon seasons, the effect of sun is less at the site and thus it is must to use a hybrid wind solar system to full fill the local demand.

The system components of wind and PV hybrid systems are as follows.

**a) Photovoltaic solar power**

Solar panels are an intermediate apparatus to convert solar energy into the electrical energy. Solar panels can convert the energy directly or heat the water with the induced energy. PV (Photo-voltaic) cells are made up from semiconductor structures as in the computer technologies. Sun rays are absorbed with this material and electrons are emitted from the atoms. This release activates a current. Photovoltaic is known as the process between radiation absorbed and the electricity induced. Solar power is converted into the electric power by a common principle called photo electric effect. The solar cell array or panel consists of an appropriate number of solar cell modules connected in series or parallel based on the required current and voltage to be obtained.

b) **Wind Power**

The wind energy is one of a renewable source of energy. Wind turbines are an apparatus used to convert kinetic energy or power from the wind into electric power. Electric generator inside the turbine converts the mechanical power into the electric power. The energy production by wind turbines depends on the wind velocity acting on the turbine at that time. Wind power is able to feed both energy production and demand in the rural areas. It is used to rotate a windmill which in turn drives a wind generator or wind turbine to produce electricity.

**c) Batteries**

The batteries in the system provide to store the electricity that is generated from the wind or the solar power or from both systems. Any required capacity can be obtained by serial or parallel connections of the batteries depending on the demand. The battery that provides the most advantageous operation in the solar and wind power systems are maintenance free dry type and utilizes the special electrolytes. These batteries provide a perfect performance for long discharges.

**d) Inverter**

Energy stored in the battery is drawn by electrical loads through the inverter, which converts DC power into AC power. The inverter has in-built protection for Short-Circuit, Reverse Polarity, Low Battery Voltage and Over Load.

**e) Microcontroller**

The microcontroller compares the input of both Power system and gives the signal to the particular relay and charges the DC Battery. The DC voltage is converted into AC Supply by Inverter Circuit. The MOSFET (IRF 540) is connected to the Secondary of the centre tapped transformer. By triggering of MOSFET alternatively, the current flow in the Primary winding is also alternative in nature and we get the AC supply in the primary winding of the transformer.

**C. Model of the Hybrid System Components**

One of the important procedure in Optimizing HES was modelling its components to make it suitable for further computations. Various modelling techniques are developed, to model HWPVS components, in previous studies [25, 11, 26]. For a hybrid PV/wind system with storage battery, in this survey paper, three principal components the PV generator, the wind turbine and the battery storage and other additional accessories such as inverter,

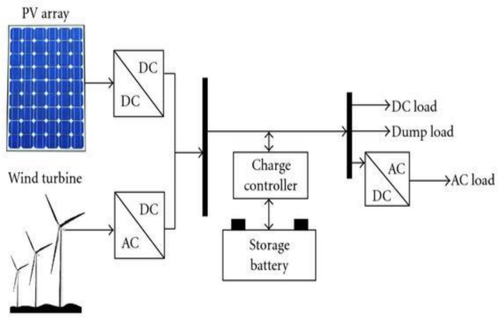


***Fig 2.*** *System components of wind and PV hybrid systems* [24]

Controller, and other accessory devices and cables are mentioned. The sizing optimization method can help to guarantee the lowest investment with adequate and full use of the solar system, wind system and battery bank, so that the hybrid system can work at the optimum point. The PV array and wind turbine installed together to satisfy the load demand of the particular place. When energy sources (solar and wind energy) are abundant, the generated power, after satisfying the load demand, will be supplied to feed the battery until it is full charged. On the contrary, when energy sources are poor, the battery will release energy to assist the PV array and wind turbine to cover the load requirements until the storage is depleted. In order to get the maximize power of the hybrid system performance, individual components must be need to be modelled first and then their mix can be evaluated to meet the load demand [27]. A general methodology for modelling PV, wind turbine, battery bank and diesel generator are described below.

***Modelling of PV array***

The aim was to design the performance of PV generator to its maximum power. Thus, we need to describe the PV modules to its maximum power output behaviours for PV system assessment.

Here a mathematical model for estimating the power output of PV modules is mentioned. The estimation is carried out using a computer program which uses a subroutine for determining the power output of a PV module. Using the solar radiation available on the tilted surface, the ambient temperature and the manufacturers data for the PV modules as model inputs, the power output of the PV generator, $P_{PV}$ , can be calculated according to the following equations [17, 28] .

$$P_{PV} = \eta_g N A_m G_t \qquad (1)$$

Where, $\eta_g$ is the instantaneous PV generator efficiency, $A_m$ is the area of a single module used in a system ($m^2$), $G_t$ is the global irradiance incident on the titled plane (W/$m^2$) and N is the number of modules.
All the energy losses in a PV generator, including connection losses, wiring losses and other losses, are assumed to be zero. The instantaneous PV generator efficiency is represented by the following equation [29].

$$\eta_g = \eta r \, \eta pt[1 - \beta t \,(Tc - Tr)] \quad (2)$$

Where: -$\eta_r$ is the PV generator reference efficiency, $\eta pt$ is the efficiency of power tracking equipment which is equal to 1 if a perfect maximum power point tracker is used, Tc is the temperature of PV cell (°C), T is the PV cell reference temperature and $\beta_t$ is the temperature coefficient of efficiency, ranging from 0.004 to 0.006 per °C for silicon cells.

Based on the energy balance proposed by [30], the PV cell temperature can be expressed as follows:

$$T_c = T_a + G_t \left(\frac{\tau\alpha}{U_L}\right) \qquad (3)$$

Where: - $Ta$ , is the ambient temperature (°C), U is the overall heat loss coefficient (W/$m^2$ per °C), τ and α represent, respectively, the transmittance and absorptance coefficients of PV cells. The overall heat loss coefficient (τα / $U_L$) can be estimated from the nominal operating cell temperature (NOCT) as follows:

$$\frac{\tau\alpha}{U_L} = \frac{NOCT - 20}{800} \qquad (4)$$

Consequently, the instantaneous PV generator efficiency can be formulated by

$$\eta g = \eta r \eta pt \left\{1 - \beta t(T_a - T_r) - \beta t G t \left(\frac{NOCT-20}{800}\right)(1 - \eta r \eta pt)\right\} \qquad (5)$$

Where: - $\eta pt, \beta t \, NOCT, A_m$ are parameters that depend on the type of module, and given by the manufacturer of the modules.

***Wind Turbine Model***

A WTG produces power $Pw$ when the wind speed $V$ is higher than the cut-in speed $Vci$and is shut-down when $V$ is higher than the cut-out speed $Vco$. When $Vr < V < Vco$ ($Vr$ is the rated wind speed), the WTG produces rated power$Pr$. If $Vci < V < Vr$, the WTG output power varies according to the cube law.

The following equations are to be used in order to model the WTG [31].

$$P_w = \begin{cases} P_r\left(\frac{V^3 - V_{ci}^3}{V_r^3 - V_{ci}^3}\right), & V_{ci} \leq V \leq V_r \\ P_r, & V_{ci} \leq V \leq V_r \\ 0, & V_{co} \leq V \text{ or } V \leq V_r \end{cases} \qquad (6)$$

Where,

$$P_r = \frac{1}{2} C_P \rho_{air} A_w V_r^3 \qquad (7)$$

In this equation, $C_P$, $\rho_{air}$ $and$ $A_w$are the power coefficient, air density, and rotor swept area, espectively.

Since the height of the wind turbine has a large high effect on the energy available from the system, the adjustment of the wind profile for height during installation can be taken into account by using a height adjustment equation. This equation was taken from the power law which is applied for the vertical wind speed profile, as shown in equation below [32].

$$V = V_i \left(\frac{H}{H_i}\right)^{\alpha} \qquad (8)$$

Where V is the wind speed at hub height H, $V_i$ is the wind speed measured at the reference height $H_i$ and $\alpha$ is the power law exponent who varies with the elevation, the time of day, the season, the nature of the terrain, the wind speed and the temperature. According to many authors, the typical value of 1/7 corresponding to low roughness surfaces and well exposed sites, is used in this study [33, 32].

***Modelling of the Storage Battery***

At any hour *t*, the state of charge of the battery $C_{bat}(t)$ is related to the previous state of charge$C_{bat}$ $(t-1)$ and to the energy production and consumption situation of the system during the time from $t-1$ to *t*. During the charging process, when the battery power $P_{bat}$ flows toward the battery (i.e., $P_{bat}$>0), the available battery state of charge at hour *t* can be described by:

$$C_{bat}(t) = C_{bat}(t-1) + \frac{P_{bat}(t) \times \Delta t}{100 \times C_T} \qquad (10)$$

Where, $\Delta t$is the simulation step time (which is set equal to 1 hr), and $C_T$ is the total nominal capacity of the battery in kilowatt-hour. On the other hand, when the battery power flows outside the battery (i.e., $P_{bat}$<0), the battery is in discharging state. Therefore, the available battery state of charge at hour *t* can be expressed

$$C_{bat}(t) = C_{bat}(t-1) - \frac{P_{bat}(t) \times \Delta t}{100 \times C_T} \qquad (11)$$

To stay the battery life for long time, the battery should not be over discharged or overcharged. This means that the battery $C_{bat}$ at any hour *t* must be subject to the following constraint.

$$(1 - Pmax) \leq C_{bat}(t) \leq Bmax \qquad (12)$$

Where: $-Pmax\ and\ Bmax$ are the battery maximum permissible depth of discharge and $C_{bat}$ respectively.

**D. Problem Formulation of The Hybrid System**

The major concern in achieving the designed objectives in optimizing of the proposed hybrid PV and wind renewable energy system by applying any suitable technique is to identify each variables and component involving in the system, formulate the objective function containing all the involved variables and components with the meaningful constraints which can affect the function so that the load demand can be economically and reliably satisfied. Hence, the objective function of the optimization problem with its overall system components are found subject to the following two points:

1. Minimizing the total net present cost ($C_T$) involved to the system,
2. Ensuring that the load is served according to certain reliability criteria.

The objective function z, which is going to be minimized $i.e$ cost function is generated by the summation of the present worth values (PWs) of all the initial or capital investments, the replacement costs of the system components, the yearly operation and maintenance costs, cost of diesel generator and the salvage values of the equipment. Thus, the objective function can be formulated as:

$$\min z = min \sum_{k=1}^{3}(I_k + R_k + OM_k + DG_k) \qquad (1)$$

Where, the index $k$ is to account for PV, wind and batteries; $I_k$ is the capital or initial investment of each component $k$; $R_k$ is the PW of the replacement cost of each component $k$; $OM_k$ is the PW of the operation and maintenance costs of each component k; $DG_k$ is cost of diesel generator.

To find the optimum of this problem, there should be a set of constraints that satisfied with any feasible solution throughout the system operations must be designed and/or formulated based the real conditions observed around real problem. The constraints that ought to be met, while minimizing the objective function, should ensure that the supplied load is served the demand according to some pre-designed reliability criteria.

## IV. Designed Constraints of the Problem

To solve the above objective function, a set of constraints that must be satisfied with any feasible solution throughout the system operations as the following:

### A. Power Generated Constrain

The total transferred power from PV and WG to the battery bank is calculated using the following Equation

$$P_{Total}^{k}(t) = N_{PV} . P_{PV}^{k}(t) + N_{WG} . P_{WG}^{k}(t) \quad (2)$$

$$1 \le k \le 365 , \quad 1 \le t \le 24 \quad (3)$$

The power generated from each source $P_{gen}$ (i) must be less than or equal to the maximum capacity of the source as:

$$P_{gen}(\boldsymbol{i}) < P_{gen;\boldsymbol{max}}(\boldsymbol{i}), \quad (4)$$

Where $i$ is Number of sources.

### B. Power Balance Constraint

The total power $P_{Total}$ generation of the HRES sources must cover the total load demand($\boldsymbol{P_{demand}}$), the total power losses ($P_{Losses}$) and storage power ( $P_{Storage}$) if used.

$$P_{Total} = \boldsymbol{P_{demand}} + P_{Losses} + P_{Storage} \;\; or \;\; P_{supply} \ge \boldsymbol{P_{demand}} \quad (5)$$

### C. Battery constraints

At any time, the SOC of the battery bank should satisfy the following constraints:

$$E_{B;\boldsymbol{min}} \le E_{B}\,(\boldsymbol{t}) \le E_{B;\boldsymbol{max}} \quad (6)$$

$$E_{B}(t+1) = E_{B}(1-\sigma) \quad (7)$$

At any time, the hourly power generated by $DG, \boldsymbol{P_{DG}}$should be less than or equal the DGrated power, $\boldsymbol{P_{DGr}}$as shown in the following equation:

$$\boldsymbol{P_{DG}(t)} \le \boldsymbol{P_{DGr}(t)} \quad (8)$$

### D. Probability of Power Loss

- LOPL **of the system should be less than allowable** LOLP **reliability index as shown in the following equations:**

$$LOLP\_HP < LOLP\_HP_{index} \quad (9)$$

The available capacity of the battery is calculated as below

- If $P_{Total}^{k}(t) = P_{L}^{k}(t)$, then the battery's capacity remains unchanged

  Where the input power of DC/AC converter $P_{L}^{k}(t) = \frac{P_{Load}^{k}(t)}{n_i}$, $P_{Load}^{k}(t)$ is load demand for $i^{th}$hour and $k^{th}$ day
- If $P_{Total}^{k}(t) > P_{L}^{k}(t)$ then the surplus power, $P_{Surp}^{k}(t) = P_{Total}^{k}(t) - P_{L}^{k}(t)$, is used to charge the battery and new capacity of battery is obtained by Equation (11). If the battery's State of Charge (SOC) reaches 100%, the surplus power will be wasted in a dummy resistive load
- if $P_{Total}^{k}(t) < P_{L}^{k}(t)$ then the battery supplies the shortage in the power and the new battery capacity is obtained by Equation (11).

Also, whenever the battery's SOC falls below a minimum allowable limit, i.e. maximum DOD, the hybrid system will not be able to work reliably and, as a result, the optimization constraint will be violated. The simulation is performed over a year of operation with one-hour time steps

## V. Simulation Tools

As discussed above under Hybrid Renewable Energy System, the technical and economic analyses of a hybrid system are essential for the efficient utilization of renewable energy resources. When we use multiple generation systems, hybrid system solution is complex and requires to be analysed thoroughly. This requires an appropriate and suitable software tools and models which can be used for the design, analysis, optimization and economic planning. On literatures a number of software have been developed to assess the technical and economic potential of various hybrid renewable technologies to simplify the hybrid system design process and maximize the use of the renewable resources. Some commonly used hybrid system analysis software tools are reviewed next [34].

Nowadays there are a lot of software tools and programs available for analysing and designing of renewable based energy systems. These tools are now commercially available and most of the tools are open source for researchers. It is found in the literature that there are more than 50 software tools available [35]. These tools are study detailed in literatures [36, 34]. As shown in these literatures the most frequently applied software tools are HOMER (Hybrid optimization method for electric renewable), HOGA (Hybrid optimization by genetic algorithm) and HYBRD2. Here under, the first two software tools are discussed.

### A. HOMER

The Hybrid Optimization Model for Electric Renewable (HOMER), developed by NREL (National Renewable Energy Laboratory, USA) in 1993 [34], is the most popular widely used by many researchers, freely available and user-friendly software. The software is suitable for carrying out quick prefeasibility, optimization and sensitivity analysis in several possible system configurations consisting of the software can model photovoltaic modules, wind turbines, biomass power, hydro power, generators, micro turbines, storage batteries, grid connections, fuel cells and even electrolysers. The National Renewable Energy Laboratory (NREL) USA has developed HOMER for both on-grid and off-grid systems [34].

It is used to model a power system physical behaviour and its life cycle cost, which is the total cost of installing and operating the system over its lifetime. HOMER allows the modeller to compare and choose many different design options based on their technical and economic merits. It also assists in understanding and quantifying the effects of uncertainty or changes in the inputs.

As discussed in the HOMER's user manual handout, HOMER performs three principal tasks: simulation, optimization and sensitivity analysis based on the raw of input data inserted by user. In the simulation process, the achievement of a particular power system configuration for each hour of the year is modelled to determine its technical feasibility and life cycle cost. In the optimization process, many different system configurations are simulated in search of the one that satisfies the technical constraints at the lowest life cycle cost. In the sensitivity analysis process, multiple optimizations are performed under a range of input assumptions to judge the effects of uncertainty or changes in the model inputs. Optimization determines the optimal value of the variables over which the system designer has control such as the mix of components that make up the system and the size or quantity of each. Sensitivity analysis helps assess the effects of uncertainty or changes in the variables over which the designer has no control, such as the average solar radiation or the future fuel price.

HOMER is used to simulate the operation of a system by calculating the energy balance for each of the 8760 hours in one year. For each hour, it compares the electric and thermal demand under consideration in the hour with the energy that of the hybrid system can supply in that hour, and calculates the flow of energy to and from each component of the system. For systems that include batteries or fuel-powered generators, the software also decides, for each hour, how to operate the generators and whether to charge or discharge the batteries. It performs energy balance calculations for each system configuration that it is required to consider. It then determines whether a configuration is feasible, that is, whether it can meet the electric demand under the specified conditions, and estimates the cost of installing and operating the system over the lifetime of the project. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel, and interest [37].

Even though it was repeatedly used by many researchers Homer has the following limitations in its application [35, 34]:

- HOMER allows only single objective function for minimizing the Net Present Cost (NPC) as such the multi-objective problems cannot be formulated by this software. After optimization process HOMER makes chart for the optimized system configurations based on NPC and does not rank the hybrid systems as per levelized cost of energy.

- HOMER does not consider depth of discharge (DOD) of battery bank which plays an important role in the optimization of hybrid system, as both life and size of battery bank decreases with the increase in DOD. Therefore, the DOD should either be optimized or be included in sensitivity inputs of the Homer.
- HOMER does not consider intra-hour variability.
- HOMER does not consider variations in bus voltage.

### B. HOGA

Hybrid Optimization by Genetic Algorithm (HOGA) is a hybrid system optimization program developed by the Electric Engineering Department of the University of Zaragoza (Spain). The optimization is carried out by means of Genetic Algorithms, and can be Mono-Objective or Multi Objective. It allows optimizing of hybrid systems consisting of a photovoltaic generator, batteries, wind turbines, hydraulic turbine, AC generator, fuel cells, electrolyser, hydrogen tank, rectifier, and inverter. The loads can be AC, DC, and/or hydrogen loads. The simulation is carried out using 1-hour intervals, during which all of the parameters remained constant. The control strategies are optimized using Genetic Algorithms. It can be downloaded and used free of charge.

## VI. Optimization of Hybrid Renewable Energy System

Optimization is a branch of mathematics and computational science that studies the method of achieving the best possible result of the defined optimization problem under given circumstances. It is central to any problems which involving decision making, mainly in Mathematics, engineering, economics, transportation medicine and any field of study where decision making process was needed. The task of decision making requires choosing the most suitable of the time between various given alternatives. The measure of goodness of the alternatives is described by an objective function involved for the problem, the conditions to be satisfied for the pre-designed use [38]. Hence to give the best decision of the time, we have to understand different Optimization theory and methods and how to deal when selecting the best alternative in the sense of the given objective function.

These Optimization techniques are broadly classified as conventional (deterministic) and non-conventional (stochastics) which are applied to solve the given problem based on the problems on hand.

Numerous conventional optimization techniques are pre-designed algorithmic formulas and have been designed to solve a wide range of optimization problems, such as Linear Programming, Nonlinear Programming, Dynamic Programming or Combinatorial Optimization [39]. But, many of these existing exact or conventional optimization techniques applied to real-world problems suffer a lot of problems such as: difficulties in passing over local optimal solutions; risk of divergence; difficulties in handling constraints or numerical difficulties related to computing first or second order derivatives. These are due to increase the number of the variables in the problem, non-linearity of the problem, non-differentiability of the problems or totally stochastic nature of the problems. All of such techniques are derivative dependant.

To overcome these problems, the non-conventional (stochastics) techniques were proposed in the early 70‟. Unlike exact methods, (meta) heuristic methods are simple to apply and more power full to locate the global optimal of the given problem by being often based on criteria of empirical nature. These techniques are responsible for the absence of any guarantee for successfully identifying the optimal solution [40].

Many optimization problems encountered in the field of Power Systems may be approached using non-conventional techniques due to robustness in nature. Operating a HRES requires optimizing its performance while satisfying its physical and technical constraints. Therefore, these nature inspired optimization tools, techniques and applications have found popularity to achieve these goals. The application areas and ability of global convergence of such Natured Inspired Computational Intelligence Techniques are based on the nature of the problems, interest and experience of the researcher. Different scholars have applied these nature inspired techniques to Optimize wind and solar hybrid renewable energy system to satisfy the power demand of the society. Some of the literatures are reviewed as follows.

## VII. Work Done for Optimization of Renewable Energy Systems

Renewable Energy is a future hope for energy expansion for society all over the world due to its abundance in nature, environmentally clean and affordable cost once its installation was made. To overcome the shortage of energy observed nowadays in all countries particularly in developing country like Ethiopia, an expansion of renewable energy needs great attention. In order to satisfy the demand of energy, proper sizing and optimizing the HRES is an important. In this review paper, several studies related to using Optimization of HRES by different nature inspired Computational Intelligence Technique and simulation tool as an alternative solution for the conventional energy have been discussed.

Based on this how scholars use the techniques to optimize the hybrid wind and PV renewable energy system to get the optimum result are given below.

Satish Kumar R. et al. [20] have developed a paper on new approach of optimum design for a hybrid PV/Wind energy system in order to optimize the total net present cost of the system in order to assist the designers to take in to consideration both the economic and ecological aspects when designing the system .They have used photovoltaic panels, wind turbine s and storage batteries to get the hybrid system and employ, the Optimization Technique Genetic Algorithm to minimize the formulated objective function $i.e$ the total cost of the system and ensure that the load is served reliably. In their work they design a computer program by using MATLAB code to formulate the optimization problem by computing the coefficients of the objective function and arrive at the conclusion that GA converges very well and feasible for sizing the hybrid system. Additionally, they got a number of potential optimal solutions under this technique and PV-wind hybrid energy systems are the most economical and reliable solution for electrifying remote area loads.

Abd El S. [41] has developed a new formulation technique for optimizing the design of a photovoltaic (PV)-wind hybrid energy home system, incorporating a storage battery. The main objective of his study was to minimize the formulated objective function, which is the total cost of the proposed hybrid system and also to ensure that the load is served according to certain reliability criteria, by maintaining the loss of power supply probability (LPSP) of the system lower than a certain predetermined value. The method was done by designing computer program using MATLAB code in a two M-files, to simulate the proposed hybrid system and to formulate the optimization problem by computing the coefficients of the objective function and the constraints. Genetic algorithm (GA) optimization technique was applied to yield the optimum PV, wind turbine and battery ratings. The results verified that PV-wind hybrid systems feature lower system cost compared to the cases where either PV-alone or wind-alone systems are used and reached at conclusion that the hybrid systems are the most economic and reliable for electrifying of the remote area loads.

Myeong Jin K. et al. [42] have design a method for hybrid energy system (HES) that integrates both fossil fuel energy systems (FFESs) and new renewable energy systems (NRESs) demands to be bring renewable energy in to reasonable cost range for the users. Their objective was to optimize the component size of a HES consisting of three types of NRESs and six types of FFESs while simultaneously minimizing life cycle cost (LCC), maximizing penetration of renewable energy and minimizing annual greenhouse gas (GHG) emissions. An elitist non-dominated sorting genetic algorithm is utilized for multi-objective design of HES simultaneously considering three objectives namely: life cycle cost, penetration of renewable energy and greenhouse gas emissions optimization. By this method a set of trade-off optimal solutions was derived from a number of possible solutions within a reasonable computation time.

Koutroulis et al. [43]have used genetic algorithm to optimize the sizes of the components making up a standalone hybrid energy system constructed of PV panels, wind turbines, and a battery bank. In this work, they have try to consider the type and the number of each component have been optimized, realizing minimum cost while covering the load requirement with zero load rejection. The simulation results showed the effectiveness of using genetic algorithm for the purpose of optimization of the proposed net present cost of the objective function.

Mohamed A. Mohamed et al. [44] have introduced a method for an optimal sizing algorithm for a hybrid renewable energy system using smart grid load management application based on the available generation. Their goal was to minimize the system cost with the state of insuring the load demand and satisfying a set of optimization constraints. Load shifting as one of smart grid applications has been introduced to get a distributed load profile, reduce the entire system cost and reduce CO2 emission. PSO has been presented to determine the optimum size of the system components. The simulation results affirmed that PSO is the promising optimization techniques due to its ability to reach the global optimum with relative simplicity and computational proficiency contrasted with the customary optimization techniques. Finally, parallel implementation of PSO has been utilized to speed up the optimization process, and the simulation results confirmed that it can save more time during the optimization process compared to the serial implementation of PSO.

Motaz Amer et al. [45] have proposed a method for the optimization of the power generated from a Hybrid Renewable Energy Systems (HRES) Swarm Optimization Technique (PSO) in order to achieve a typical of load demand. They have mentioned that PSO is preferred due to its advantages over the other techniques for reducing the Levelized Cost of Energy (LCE) and optimizing the system. They have defined the problem and formulate the objective function and this function is introduced taking in consideration fitness values sensitivity in particle swarm process. The algorithm structure was built using MATLAB software. PSO was proved its high intensity and sensitivity in solving such optimization problems. Beside the availability of the approach to control the production of the power generated using the load demand as the main input with both the total power losses of the whole system and the availability of the power stored in the both cases stand alone with battery storage or stand alone with grid storage.

Jemaa et al. [46] have proposed a methodology to optimize the configuration of hybrid energy systems using fuzzy adaptive Genetic Algorithms. Fuzzy adaptive GA changes the mutation and crossover rates dynamically to ensure population diversity and prevent premature convergence. They have got the result that, optimal number of PV cells, wind turbines and batteries that ensures minimal total system cost whilst guaranteeing the permanent availability of energy to meet demand. They have modelled the PV, wind generator and load stochastically using historical data of hourly wind speed, solar irradiance and load data. Their objective function to be minimized was the cost with the technical size as the constraint.

Kamaruzzaman et al. [47] reviewed the application of genetic algorithms in optimization (finding optimum component sizing and operational strategy) of hybrid system consisting of pico-hydro system, solar photovoltaic modules, diesel generator and battery sets. It is focused on maximizing the power output the renewal energy system components while trying minimizing the use of generator to provide for the load demand, thus minimizing the total operation cost. The authors show that the use of Pico hydro in the renewable energy set-up is an important sizing determination. The main advantage is that the turbine can operate 24 hours and can provide enough flowing water into the gathering chamber. The price of the Pico hydro turbine is much less compared with other sources of renewable energy.
L.Kadi et al. [48] have proposed a methodology of sizing standalone wind power systems using the genetic algorithm(GA). Studies have proved that the genetic algorithm converges very well and the methodology proposed is feasible for sizing standalone wind power systems. A procedure used for optimizing the size of a wind-energy system stand alone was presented here. The designed method was applied for the sizing of wind system that is considered to produce a power to domestic load in the Bechar area, Algeria. The result of the analysis indicates that a wind system power output can be optimized to suit specific applications with variable or constant power loads. For the specific system considered in this study, the results indicate that the optimal wind system that resulted in the minimum capital cost is (2, 11) for the numbers of wind turbine and height respectively.

Eftichios Koutroulis et al. [49] Presented a methodology for optimal sizing of stand-alone PV/WG systems to suggest, among a list of commercially available system devices, the optimal number and type of units ensuring that the 20-year-round total system cost is minimized subject to the constraint that the load energy requirements are completely covered, resulting in zero load rejection. Genetic Algorithm was used to minimize the cost (objective) function and the result was compared to conventional optimization methods such as dynamic programming and gradient techniques, have the ability to attain the global optimum with relative computational simplicity. Their conclusion from the simulation result is that, the hybrid PV/WG systems feature lower system cost compared to the cases where either exclusively WG or exclusively PV sources are used.

Abdullrahman A. et al. [50]Have proposed an optimum sizing methodology to optimize the configuration of a hybrid energy system (HES) based on Genetic Algorithm (GA). The proposed methodology considers the effect of wind turbine parameters such as rated speed and rated power on electricity cost and compares the performance of various HES. The proposed method was applied to the analysis of HES which supplies energy for remote village located in the northern part of Saudi Arabia. They have concluded that: The optimum sizing depends on renewable energy fraction (REF) and system reliability (LPSP). Hence, to meet load demand at high reliability and at high REF, there is an extensive increase in the system sizing. For the load demand in this study, the most economical systems are the hybrid PV/WT/Bat/DG, hybrid WT/Bat/DG, and hybrid PV/WT/DG as they result in a lower COE compared to the other hybrid energy systems. They have proved that proposed HES is always feasible compared to diesel system for all diesel price higher than 0.15$/litre. The COE of diesel system increases more rapidly than the COE of HES with an increase in diesel price.

Ade Mellit et al. [51] have proposed methodologies based on artificial intelligence techniques (neural networks, genetic algorithms and fuzzy-logic) as alternatives to conventional techniques to solve a wide range of problems in various domains. Their purpose was to use neural networks and genetic algorithms for the prediction of the optimal sizing coefficient of Photovoltaic Supply (PVS) systems in remote areas when the total solar radiation data are not available. First, the genetic algorithm (GA) is used for determining the optimal coefficients for each site by minimizing the optimal cost (objective function) and used to determine the number of PV modules and the capacity of the battery. Then they applied a feed-forward neural network (NN) for the prediction of the optimal coefficient in remote areas based only on geographical coordinates; for this, 36 couples for the training of the network and 4 couples have been used for testing and validation of the model. The simulation results have been analysed and compared with classical models in order to show the importance of this methodology.

Benatiallah et al. [25] have presented a new methodology for calculation the optimum size of a Wind system by using a Long-term data of wind speed for every hour of the day. They define that the objective function is the total cost, where the total cost is the sum of initial cost, an operation cost, and a maintenance cost. The authors were used to calculate the average power generated by a wind turbine for every hour of a typical day in a month. They applied the investigation the genetic algorithm (GA) for optimally sizing a wind power system. The authors have determined an optimal configuration of wind generating systems, where total cost is more optimal using GA. A computer program has been developed to size system components in order to match the load of the site in the most cost. A cost of electricity, an overall system cost is also calculated for each configuration. The study was performed using a graphical user interface programmed in MATLAB.

B. Heyrman et al. [52] have proposed a generic and an efficient model for hybrid renewable-conventional electrical energy systems. The simulation model is successfully validated by means of HOMER software. Moreover, two control strategies for electrical power dispatch are described. The authors have used Genetic algorithm technique, for optimizing the size of system components of the formulated problem and the overall cost of the system is minimized. The results show a dependence of the size of the system components on the meteorological characteristics of the area under consideration, which validate the proposed methodology. Better system reliability, robustness and efficiency were achieved with the minimum total cost. The results have shown the proposed optimization study is definitely important for power system planning to maximize the system performance, as well as, minimizing the total cost. The performance and cost are highly dependent on the correct choice of all components sizing.

Kamaruzzaman Sopian et al.[53] have been compiled the application of genetic algorithms in optimizing the system components of hybrid energy system consisting of Pico hydro system, solar photovoltaic modules, diesel generator and battery sets. The aim was intended to maximize the use of renewable system while limiting the use of diesel generator. They use constant daily load demand for derivation of annual load and Power derived from the hybrid to meet the demand. Their Optimization technique of the system has been based on the component sizing and the operational strategy. They have employed Genetic algorithms programming to evaluate both conditions in minimizing the total net present cost for optimum configuration. They have considered several operation strategies while forming the vectors for optimum strategy. Random selection of sizing and strategy is used to initiate the solution for the problem which will have the lowest total net present cost. Sensitivity analysis is also performed to optimize the system at different conditions.

Satish Kumar Ramoji et al. [54] have presented a paper on new methodology for optimal sizing of a Hybrid PV/Wind energy system. They have used Genetic Algorithm (GA) and Teaching Learning Based Optimization (TLBO) to design the hybrid PV-wind system which consists of photovoltaic panels, wind turbines and storage batteries. Optimization techniques are utilized to minimize the formulated objective function of the proposed hybrid system. The authors also made comparison of the two optimization techniques for optimal sizing of Hybrid PV/Wind energy system. They have designed the program, using MATLAB code to formulate the optimization problem by computing the coefficients of the objective function and got the optimal solution. In this work the results have shown that the GA converges very well and the proposed technique is feasible for sizing either of the PV-wind hybrid energy system, stand-alone PV system, or stand-alone wind system and also the PV-wind hybrid energy systems are the most economical and reliable solution for electrifying remote area loads.

Hanieh Borhanazad et al. [55] have presented a new methodology for Optimizing of micro-grid system using by using Multi Objective Particle Swarm Optimization (MOPSO) to assess the appropriateness of a micro-grid system, the cost-effectiveness of the system and the quality of service. Here, optimization of a Hybrid Micro Grid System (HMGS) is investigated. A hybrid wind/PV system with battery storage and diesel generator is used for this purpose. The power management algorithm is applied to the load, and the MOPSO method is used to find the best configuration of the system and for sizing the components. They have concluded that this optimization model produces appropriate sizing of the components for each location desired area. The result has shown that, the use of HMGS was a good alternative to promote electrification projects and enhance energy access within remote Iranian areas or other developing countries enjoying the same or similar climatic conditions.

Saeid Lotfi Trazouei et al. [56] have come up with new method for optimal design of a stand-alone hybrid solar-wind- diesel power generation system using comparative analysis of Particle swarm optimization and ant colony optimization. The main objective of this paper was to minimize the net present cost of hybrid system for lifetime of project (here 20 years) considering by reliable supply of load and loss of power probability (LPSP) reliability index. The authors compared the results of these algorithms together and have shown as it is faster and more accurate than others and has more certain design in comparison to PSO and ACO algorithms. They used the mathematical model of various parts of hybrid system. Then the purposed algorithm was applied and gives that result is faster and more accurate than other algorithms and has more certain design in comparison to PSO and ACO algorithms.

Tafreshi S. M. M. et al. [57] model a micro grid using MATLAB and GA to solve the sizing problem with some restrictions. They evaluate the system considering costs and benefits such as: the cost function annualized capital, replacement, operational, maintenance, fuel costs and annual earning by selling power to grid. SA algorithm is used to solve the optimal sizing problem for renewable energy generations and combined heat and power (CHP) units in a hybrid energy micro grid in [38].

Stochastic variability of renewable energy resources and the heat and power requirements are considered in order to meet customer requirements with minimum system annual cost.

Menniti et al. [58] propose a methodology to determine the optimum sizing and configuration of a grid-connected hybrid Photovoltaic/Wind system by using the Optimization Technique Particle Swarm Optimization, including energy storage systems and ensuring that the system total cost is minimized while guaranteeing a highly reliable source of load power. They base their analysis on simulation techniques.

Ajay Kumar Bansal et al. [59] have introduced a Artificial Intelligent method to design the hybrid PV/wind system. They have constructed the cost of hybrid system as objective function which includes initial costs, yearly operating costs and maintenance costs. The hybrid system consists of photovoltaic panels, wind turbines and storage batteries. Meta Particle Swarm Optimization (MPSO) is used to solve the problem. MPSO operation strategy, improves the global optimal searching ability of the proposed algorithm by avoiding the possibility of local minimum trap. They have proved that the method mentioned was effective and the total cost (devices, maintenance, installation costs) of the hybrid wind/PV system is lower than the total costs of the standalone wind and standalone PV systems. Finally, the optimal solution is received using proposed MPSO method.

Ali Kashefi Kaviani et al. [60] have proposed a methodology for designing a hybrid wind/photovoltaic generation system to supply power demand. The aim of this design is minimization of the overall cost of the generation scheme over 20 years of operation. Full demand supply is modelled as constraint for optimization problem. A Particle Swarm Optimization (PSO) algorithm is used to solve the optimization problem. The results are compared with those provided by the well-known GA. This comparison testifies that PSO has several advantages over GA, in terms of convergence to the global optimum solution, speed and accuracy, and computational complexity. PSO is quite capable of dealing with the optimal sizing of hybrid systems and provides satisfactory results.

Dipti Srinivasan et al. [61] have introduced the dispatch-coupled sizing methodology by integrating the battery into the operation of the generation units in the system, and formulates this application problem using optimal control. The two major renewable energy sources, solar photovoltaic panels and wind turbines are considered, together with traditional diesel generators. The Minimisation of dispatch cost and LCOE for each SAHPS is used as the objective of the optimal control. An improved particle swarm optimisation (MD-PSO) algorithm was applied for this specific problem. The numeric results of the system planning are benchmarked using an economic indicator, the levelized cost of electricity, to address the real-world system. The result has shown that the suggested improvements were shown to be more effective than the standard algorithm in both the benchmarking test functions and the optimal dispatch problem.

Yang H. et al. [27] have proposed a new methodology for optimal sizing for configurations of hybrid wind/PV system with battery banks. They have employed the popular optimization technique called genetic algorithm (GA) as optimal sizing method. This method was developed to calculate the optimum system configuration of the system in order to achieve the customers need by considering loss of power supply probability (LPSP) with a minimum annualized cost of system (ACS). The authors have been taken those components as decision variables like the PV module number, wind turbine number, battery number, PV module slope angle and wind turbine installation height in the optimization process. They have shown as the applied method for the analysis of a hybrid system to supply power for a telecommunication relay station and optimization performance has been found to be good. Additionally, they have reached at the conclusion that the relationships between system power reliability and system configurations.

Motaz Amer et al. [10] have presented a method for the optimization of the power generated from a Hybrid Renewable Energy Systems (HRES) in order to achieve the load demand. They have employed Particle Swarm Optimization (PSO) technique as searching algorithm to optimize the system, due to its advantages over the other techniques for reducing the Levelized Cost of Energy (LCE) with affordable range of the production by considering the losses between production and demand sides. They have the defined problem and the objective function is introduced taking in consideration fitness values sensitivity in particle swarm process. The algorithm structure was built using MATLAB software. At which the PSO proved its high intensity and sensitivity in solving such optimization problems. Beside the availability of the approach to control the production of the power generated using the load demand as the main input with both the total power losses of the whole system and the availability of the power stored in the both cases stand alone with battery storage or stand alone with grid storage.

A. H. Hameed et al. [62] have presented a novel technique to extract the optimum sizing of hybrid renewable energy generation system (HRES) with storage system via open space particle swarm optimization (OSPSO). The simulation using this technique is shown. The authors used the total system cost as the objective function and the technical sizing as a constraint. By using the proposed technique, the optimum number of PV modules, wind turbines, and batteries are determined, and a reliable and cost-effective generation system is achieved. Power supply reliability (LPSP) is treated as a constraint. Other design constraints are also located. Numerical example is given to demonstrate the applicability and usefulness of the proposed method.

Jose L. et al. [26] have presented the application of the strength Pareto evolutionary algorithm to the multi-objective design of isolated hybrid systems. Their aim was to minimize both the total cost throughout the useful life of the installation and the unmet load. They have used the techniques that Multi-objective evolutionary algorithm (MOEA) and a genetic algorithm (GA) to find the best combinations of components for the hybrid system and control strategy. The best tool currently available (HOMER), creates a design that only minimises the cost of the system, although it allows to study sensitivity by modifying other parameters, such as, for example, unmet load data. Also, a novel control strategy has been developed. An application example has been expounded, a design of a PV– wind–diesel system. The achieved results have established the practical value that the method has shown the designer that the method was appropriate.

M.S. Ismail et al. [63] have proposed a method for optimal sizing of a hybrid system consisting of photovoltaic (PV) panels, a backup source (micro turbine or diesel) and a battery system minimizes the cost of energy production (COE) and a complete design of this optimized system. Their aim was to supply a small community with power in the Palestinian Territories. Genetic Algorithm was applied to the system for optimizing the objective function while covering the load demand with a specified value for the loss of load probability (LLP). They have concluded that electrifying such rural areas by using this hybrid system was cost-effective and more beneficial when compared to extending the utility grid to supply these remote areas due to the hybrid system decreases both operating costs and the emission of pollutants.

Hongxing Yang et al. [64] have presented an optimal sizing method to optimize the configurations of a hybrid solar–wind system employing battery backup. They have employed genetic algorithm (GA) Optimization techniques, which has the ability to attain the global optimum with relative computational simplicity. The authors take those components of the system as decision variables of the system are PV module number, wind turbine number, battery number, PV module slope angle and wind turbine installation height. The designed objective function has been optimized and the required loss of power supply probability (LPSP) with a minimum annualized cost of system (ACS) was obtained. Good optimal sizing performance of the algorithms has been found, and the optimal solution is a hybrid solar–wind system. Although a solar or a wind turbine only solution can also achieve the same desired LPSP, it represents a higher cost.

A. Benatiallah et al. [65] have presented the methodology for calculation the optimum size of a Wind system to satisfy the load demand of a typical house in south of Algeria (desert area). For a given load and a mixed multiple-criteria integer programming problem, the types and sizes of wind turbine generators (WTG) was calculated based on the minimum cost of system. They have employed the nature inspired algorithms, genetic algorithm (GA) for optimally sizing a wind power system. The authors have defined that the objective function is the total cost, where the total cost is the sum of initial cost, an operation cost, and a maintenance cost and have determined an optimal configuration of wind generating systems, where total cost is more optimal using GA. In order to match the load of the site, a computer program has been developed to size system components. A cost of electricity, an overall system cost is also calculated for each configuration. The study was performed using a graphical user interface programmed in MATLAB.

Roy et al. [18] estimated the optimal sizing for a hybrid solar - wind system for distributed generation for utilization of resources available at Sugar, a remote off-grid Island. They optimized the feasibility and size of the generation units and evaluated them using Hybrid Optimization of Multiple Energy Resources (HOMER) software. Sensitivity analysis was performed on the optimal configuration obtained. A comparison between the different modes of the hybrid system was also studied. It was estimated that the solar PV -Wind Hybrid system provided lesser cost per unit of electricity. The capital investment cost was also observed to be less when the system ran with wind DG compared to solar PV DG.

Rachid B. et al. [66] have introduced a new methodology of sizing optimization of a stand-alone hybrid renewable energy system. They have applied a deterministic algorithm to minimize the life cycle cost of the system while guaranteeing the availability of the energy. The deterministic algorithm is presented and implemented to minimize the objective function which is equal to the life cycle cost of the hybrid system and finally, the result has shown optimum numbers of wind turbines, PV panels and batteries depend on the particular site, load profile and the specifications and the related cost of each component of the hybrid system.

Riad Chedid and Saifur Rahman [67] have proposed the tool that can help designers determine the optimal design of a hybrid wind-solar power system for either autonomous or grid-linked applications. The proposed analysis employs linear programming techniques to minimize the average production cost of electricity while meeting the load requirements in a reliable manner, and takes environmental factors into consideration both in the design and operation phases. The authors designed a controller that monitors the operation of the autonomous grid-linked system. Such a controller determines the energy available from each of the system components and the environmental credit of the system. It then gives details related to cost, unmet arid spilled energies, and battery charge and discharge losses.

Akbar Maleki and Fathollah Pourfayaz [68] have proposed a methodology for optimizing Hybrid photovoltaic (PV)–wind turbine (WT) systems with battery storage as a green and reliable power system for remote areas. Their aim was to increase the steady in usage of hybrid energy system (HES) and consequently optimum sizing is the main issue for having a cost-effective system. They have employed three different evolutionary algorithms, namely, particle swarm optimization (PSO), tabu search (TS) and simulated annealing (SA), and four recently invented metaheuristic algorithms, namely, improved particle swarm optimization (IPSO), improved harmony search (IHS), improved harmony search-based simulated annealing (IHSBSA), and artificial bee swarm optimization (ABSO), are applied to the system and the results are compared in terms of the TAC for optimum sizing of a PV/ WT/battery hybrid system to continuously satisfy the load demand with the minimal total annual cost (TAC). The proposed methods are applied to a real case study and the results are discussed. The result has shown that not only average results produced by ABSO are more promising than those of the other algorithms but also ABSO has the most robustness. Also considering LPSPmax set to 5%, the PV/battery is the most cost-effective hybrid system, and in other LPSPmax values, the PV/WT/battery is the most cost-effective systems.

Bashir and Sadeh [69] considered a hybrid system of wind, PV and tidal energy with battery storage. In this paper they highlight the benefits of tidal energy which is energy harnessed from rising and falling of ocean water levels as being highly predictable compared to wind and solar. They consider a 20 years plant life and optimize the design with the objective of minimizing the annualized cost of generated energy of the life of the plant, with the constraint of having a specific reliability index. They use PSO algorithm for optimization. They carried out the process of Simulation in MATLAB environment revealed that in comparison to stand alone hybrid wind solar and the new system was more economical.

Sharmistha Sharma et al. [70] have introduced a new methodology for optimal sizing of battery energy storage device to minimise operation cost of micro grid optimal operational planning of micro-grid (MG) with regard to energy costs minimisation. Their objective was to formulate a cost-based and to determine the optimal size of battery energy storage (BES) in the operation cost minimisation problem of MG under various constraints, such as power capacity of distributed generators (DGs), power and energy capacity of BES, charge/discharge efficiency of BES, operating reserve and load demand satisfaction. They have used the optimisation technique known as grey wolf optimisation (GWO) to solve the problem. They have tested the proposed algorithm on a typical MG. Simulation results have shown that the proposed approach outperforms several existing optimisation techniques such as genetic algorithm, particle swarm optimisation, tabu search, differential evolution, biogeography-based optimisation, teaching–learning based optimisation, bat algorithm (BA) and improved BA in terms of quality of solution obtained and computational efficiency.

Abdolvahhab Fetanat and Ehsan Khorasaninejad [71] have used ant Colony optimization for continuous domains (ACOR) based integer programming is employed for size optimization in a hybrid photovoltaic (PV) and wind energy system. ACOR is a direct extension of ant colony optimization (ACO). Here the objective function of the PV and wind system design is the total design cost which is the sum of total capital Cost and total maintenance cost that should be minimized. The optimization is separately performed for three renewable energy systems including hybrid systems, solar stand alone and wind stand alone. The main features of the authors for a complete data set are regular optimization formulation and ACOR based integer programming. The optimization results have shown that this method gives the best results just in few seconds. The comparative analysis is made between artificial intelligent (AI) approaches and a conventional optimization method. Moreover, the results are very promising and prove that the authors' proposed approach outperforms them in terms of an optimal solution and speed.

Ryohei Yokoyama et al. [56] have introduced a deterministic approach technique to optimal unit sizing for hybrid power generation systems utilizing photovoltaic and wind energy. The optimization problem is considered as a multi objective one, and a discrete set of Pareto optimal solutions is derived numerically by using the weighting method. To test the validity and effectiveness of the method and to evaluate the system performance, a numerical study on an on-site system has been carried out by using data on natural energy obtained through real measurement. They conclude from these as: relationships between economy and energy savings or environmental protection have been clarified, as it is use full for large investment due to its economic capacity demand of electricity satisfied.
Andrea G. Kraj et al. [72] have introduced the simulation of Multi-Renewable Energy Systems (MRESs) with the aim to facilitate the optimization of multi-functional power systems for remote autonomous power generation. They have employed an evolutionary algorithm technique, to evaluate objectives within the geographical and economic constraints of the simulated MRES configuration. The objectives are to maximize renewable energy generation, minimize costs, and maximize system reliability to meet a given demand load. The simulated MRES implements real resource data for wind and solar energy and model biomass resources in combination with diesel backup and storage systems for electrical energy generation. They conclude that multi-hybridization of renewable energy systems can stabilize the electricity supply of remote locations through complimentary combinations of energy systems and contribute to the most economical solution. The model demonstrates the application of the simulated MRES for remote and isolated energy systems, and provides a tool for economic planning prior to system implementation.

Tina et al. [73] presented a probabilistic approach based on the convolution technique to incorporate the fluctuating nature of the resources and the load, thus eliminating the need for time-series data, to assess the long-term performance of a hybrid solar–wind system for both stand-alone and grid-connected applications. Analytical expressions have been developed to obtain the power generated. They have performed the analysis the Reliability by the use of the energy index of reliability (EIR) directly related to energy expected not supplied (EENS) and drawing the inclusion of the time-value of energy as appropriate in economic assessments of the system. They have proved the result by taking numerical example application to illustrate the validity of the developed probabilistic model: the results are compared to those resulting from time domain simulations.

Borowy and Salameh [16] have developed a methodology for calculation of the optimum size of a battery bank and the PV array for a standalone hybrid Wind/PV system. A graphical construction technique for figuring the optimum combination of battery and PV array in a hybrid solar/wind system has been utilized. The designed system components are simulated for various combinations of PV array and battery sizes and the loss of power supply probability (LPSP). Then, this LPSP, the PV array versus battery size is plotted and the optimum solution, which minimizes the total system cost has been calculated.

Kellogg et al. [74] have used the deterministic Optimization method called an iterative optimization method to select the wind turbine size and PV module number needed to make the difference of generated. In this paper was to determine the optimum generation capacity and storage needed for a stand-alone, wind, PV, and hybrid wind/PV system for an experimental site in a remote area in Montana with a typical residential load. The total annual cost for each configuration is then calculated and the combination with the lowest cost is selected to represent the optimal mixture, an economic analysis has been performed for the above three scenarios and is used to justify the use of renewable energy versus constructing a line extension from the nearest existing power line to supply the load with conventional power. Annual average data for hourly values for load, wind speed, and insulation have been used in order to determine the optimal value.

## VIII. VIII. Gap Analysis

Different methodologies have been employed for optimum sizing of a standalone HES consisting of PV arrays, wind turbines, battery banks and diesel generator by a number of scholars at different time. The purpose of Optimizing hybrid renewable energy system was to satisfy the load demand of the society with minimum possible cost by considering the concern of environmental protection as needed. Nowadays, implementation of nature inspired techniques is getting attention and used to optimizing hard Optimization for which conventional solving algorithms are failed due to number of reasons. The results obtained from these optimization methodologies depend on the number, dimension and size of decision variables and parameters involved in the problem to solve hybrid system.

After an intensive review of literatures, on Optimizing Hybrid Renewable Energy System by Techniques of Nature Inspired Computational Intelligences, it is observed that the modelling of hybrid energy system and their application are not specifically mentioned for the rural areas by considering all the parameters of the components and decision variables at one time. The models developed so far mainly focus on rural areas generally and not individual sites, cluster of villages or particular district. Very limited efforts are reported on comparison of simulation tools. Comparative analysis didn’t compose on many literatures. Even though, there is no specific nature inspired technique for the real problem at hand the effort made to apply two or more techniques to optimize the designed problem and comparing the result to show why the applied technique was prefer in the reviewed papers are much less or else under what condition the involved technique is important.

Despite the large number of researchers have been done in Optimizing Hybrid Energy Systems by using different computational intelligence techniques weather deterministic or stochastic approaches, comparisons made among simulation tools and with nature inspired techniques was less. Further, attempts for developing a hybrid technique for optimizing renewable energy system of different resources for meeting the energy needs of the rural society are also limited. So, we encourage research of this field to give their attention in addition to identifying the variables and parameterise suitable for a specific problem, they have to look the direction of using hybrid nature inspired technologies to improve the quality of the solution and coat of computation.

## IX. CONCLUSION AND FUTURE SCOPE

Due to fast reducing conventional energy sources and a continuously increasing energy demand in the context of environmental issues, scholars have been encouraged intensive research for new, more efficient, and green power plants with advanced technology. Nowadays, an environmental protection concerns are increasing in the whole world, which was the cause for both new energy and clean fuel technologies are being intensively pursued and investigated. Most of the renewable energy from wind, micro-hydro, tidal, geothermal, biomass, and solar are converted into electrical energy to be delivered either to the utility grid directly or isolated loads.

There is also high imbalance of electricity distribution among countries and within the country everywhere. The magnitude of this imbalance distribution was wide in developing countries. For instance, in Ethiopia only 27% of about 105.57 million of total population has got the chance of accessing electricity. Among these about 85% of the population lives in the rural with the access to electricity less than 5% [75, 76]. Here in addition to low coverage there is imbalance distribution and needs great attention to compromise the gap observed. This survey paper compiled brief summary of renewable energies focusing on wind energy and solar energy with their advantages and disadvantages when employed to balance power demand and different papers are reviewed. All scholars agreed that to full fill the exponentially increasing energy demand all over the world, hybrid renewable energy systems are the most technologies to be encouraged.

In order to get sufficient energy with affordable project through the life time of the system, proper sizing and optimising all the component system is important. These involved wind and solar hybrid renewable energy system components are explained, Optimization problem contains the net present cost (the initial or capital investments, the replacement costs of the system components, the yearly operation and maintenance costs, cost of diesel generator) with those conditions affect the energy demand was discussed. Lastly simulation tools which are used to simulation, optimization and sensitivity analysis based on the raw of input data inserted by user are compiled.

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## XI. REFERENCES

[1] Fetanat Abdolvahhab and Ehsan Khorasaninejad. Size optimization for hybrid photovoltaic–wind energy system using ant colony optimization for continuous domains based integer programming, *Applied Soft Computing, Vol.* 31, pp. 196-209 (2015).

[2] Antonio Luque and Steven Hegedus. Handbook of photovoltaic science and engineering., West Sussex, England: John Wiley & Sons (2011)

[3] "Convert News, 2015. [Online]. Available: http://convertnews.com/1827-photovoltaic-panel-how-it-work-buy.

[4] N. Alrikabi. Renewable Energy Types, *Journal of Clean Energy Technologies,* vol. 2, no. 1, pp. 61-4, (2014) .

[5] Godson J., M. Karthick, T. Muthukrishnan and M. S. Sivagamasundari. Solar PV-wind hybrid power generation system, *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering,* Vol. 2, no. 11, pp. 5350-5354 (2013).

[6] Dresselhaus, M. S., and I. L. Thomas. Alternative energy technologies, *Nature,* Vol.414, no. 6861, pp. 332-337 (2001).

[7] N. Alrikabi. Renewable Energy Types, *Journal of Clean Energy Technologies,* vol. 2, no. 1, pp. 61-4 (2014).

[8] Niven Robert K. Ethanol in gasoline: environmental impacts and sustainability review article, *Renewable and Sustainable Energy Reviews, Vol.* 9, no. 6, pp. 535-555 (2005).

[9] Muselli L. A., G. Notton, and A. Louche. Design of hybrid-photovoltaic power generator, with optimization of energy management, *Solar energy, Vol.* 65, no. 3, pp. 143-157 (1999).

[10] Amer, Motaz, A. Namaane, and N. K. M'sirdi. Optimization of hybrid renewable energy systems (HRES) using PSO for cost reduction, *Energy Procedia, Vol.* 42, pp. 318-327(2013).

[11] Muselli, M. N. G. L. A., G. Notton, and A. Louche. Design of hybrid-photovoltaic power generator, with optimization of energy

management, *Solar energy*, *Vol.* 65, no. 3, pp. 143-157 (1999).

[12] Billinton Roy. Evaluation of different operating strategies in small stand-alone power systems, *IEEE Transactions on energy conversion*, *Vol.* 20, no. 3, pp. 654-660 (2005).

[13] Elhadidy, M. A., and S. M. Shaahid. Parametric study of hybrid (wind+ solar+ diesel) power generating systems, *Renewable energy*, Elhadidy, M. A., and S. M. Shaahid. "Parametric study of hybrid (wind+ solar+ diesel) power generating systems." *Renewable energy*, *Vol.* 21, no. 2, pp. 129-139 (2000).

[14] G. T. Getachew Bekele, Feasibility study of small Hydro/PV/Wind hybrid system for off-grid rural electrification in Ethiopia, *Applied Energy* , vol. 97, pp. 5-15, (2012).

[15] A. Z. Kamaruzzaman Sopian1, Optimal Operational Strategy for Hybrid Renewable Energy System Using Genetic Algorithms, *Wseas Transactions on Mathematics*, ISSN: pp. 1109-2769 (2008).

[16] Borowy, Bogdan S., and Ziyad M. Salameh. Methodology for optimally sizing the combination of a battery bank and PV array in a wind/PV hybrid system, *IEEE Transactions on energy conversion*, *Vol.* 11, no. 2, pp. 367-375 (1996).

[17] Diaf Said, Djamila Diaf, Mayouf Belhamel, Mourad Haddadi and Alain Louche. A methodology for optimal sizing of autonomous hybrid PV/wind system, *Energy Policy*, *Vol.* 35, no. 11, pp. 5708-5718 (2007).

[18] Roy, P. C., A. Majumder, and N. Chakraborty. Optimization of a stand-alone Solar PV-Wind-DG Hybrid System for Distributed Power Generation at Sagar Island, In *AIP Conference Proceedings*, vol. 1298, no. 1, pp. 260-265 (2010).

[19] Gupta Ajai, R. P. Saini and M. P. Sharma. Design of an optimal hybrid energy system model for remote rural area power generation, In *Electrical Engineering, 2007. ICEE'07. International Conference on*, pp. 1-6. IEEE (2007).

[20] Ramoji Satish Kumar, Bibhuti Bhusan Rath and D. Vijay Kumar. Optimization of hybrid PV/wind energy system using genetic algorithm (GA), *Journal of Engineering Research and Applications*, Vol.4, pp. 29-37 (2014).

[21] Prasad A. Rajendra and E. Natarajan. Optimization of integrated photovoltaic–wind power generation systems with battery storage, *Energy*, *Vol.* 31, no. 12, pp. 1943-1954 (2006).

[22] Shaahid S. M. and M. A. Elhadidy. Economic analysis of hybrid photovoltaic–diesel–battery power systems for residential loads in hot regions—A step to clean future, *Renewable and Sustainable Energy Reviews*, *Vol.* 12, no. 2, pp. 488-503 (2008).

[23] Subrahmanyam J., P. K. Sahoo and Madhukar Reddy. Local PV-Wind hybrid systems development for supplying electricity to industry, *Acta Electro technical*, *Vol.* 53, no. 1, pp. 10-15 (2012).

[24] Khatib Tamer, Azah Mohamed and Kamaruzzaman Sopian. A software tool for optimal sizing of PV systems in Malaysia, *Modelling and Simulation in Engineering* 2012, Vol. 10 (2012).

[25] Benatiallah A., L. Kadia and B. Dakyob. Modelling and optimisation of wind energy systems, *JJMIE*, *Vol.* 4, no. 1 (2010).

[26] Bernal Agustín, José L. and Rodolfo Dufo-López. Multi-objective design and control of hybrid systems minimizing costs and unmet load, *Electric Power Systems Research*, *Vol.* 79, no. 1, pp. 170-180 (2009).

[27] Yang Hongxing, Wei Zhou, Lin Lu and Zhaohong Fang. Optimal sizing method for stand-alone hybrid solar–wind system with LPSP technology by using genetic algorithm, *Solar energy*, *Vol.* 82, no. 4, pp. 354-367 (2008).

[28] T., Markvard. Solar electricity, the second ed. USA. Willey, (2000).

[29] Habib M. A., S. A. M. Said, M. A. El-Hadidy and I. Al-Zaharna. Optimization procedure of a hybrid photovoltaic wind energy system, *Energy*, *Vol.* 24, no. 11, pp. 919-929 (1999).

[30] Duffie J. A. and W. A. Beckman. Solar engineering of thermal of thermal process, *Wiley, New York* (1991).

[31] Borowy Bogdan S. and Ziyad M. Salameh. Methodology for optimally sizing the combination of a battery bank and PV array in a wind/PV hybrid system, *IEEE Transactions on energy conversion*, *Vol.* 11, no. 2, pp. 367-375 (1996).

[32] Ilinca Adrian, Ed McCarthy, Jean-Louis Chaumel and Jean-Louis Rétiveau. Wind potential assessment of Quebec Province, *Renewable energy, V*ol. 28, no. 12, pp. 1881-1897(2003).

[33] GL. Johnson. Wind energy systems. Englewood Cliffs (NJ), *Prentice-Hall;* 1985.

[34] Sinha Sunanda and S. S. Chandel. Review of software tools for hybrid renewable energy systems, *Renewable and Sustainable Energy Reviews, Vol.* 32, pp. 192-205 (2014).

[35] Singh Shakti, Mukesh Singh and S. C. Kaushik. A review on optimization techniques for sizing of solar-wind hybrid energy systems, *International Journal of Green Energy, Vol.* 13, no. 15, pp. 1564-1578 (2016).

[36] Connolly David, Henrik Lund, Brian Vad Mathiesen and Martin Leahy. A review of computer tools for analysing the integration of renewable energy into various energy systems, *Applied Energy,* Vol. 87, no. 4, pp. 1059-1082 (2010).

[37] Afzal Anis, Mohibullah Mohibullah and Virendra Kumar Sharma. Optimal hybrid renewable energy systems for energy security: a comparative study, *International Journal of Sustainable Energy, Vol.* 29, no. 1, pp. 48-58 (2010).

[38] Z. S. Chong EK. An introduction to optimization., John Wiley & Sons, (2013).

[39] G. M., Heuristic and metaheuristic optimization techniques with application to power systems. In12 WSEAS International Conference on Mathemetical Methods and Computational Techniques in Electrical Engineering (MMACTEE'10), Selected Topics in Mathematics, *Selected Topics in Mathematical Methods and Computational Techniques in Electrical Engineering* , pp. 95-103 (2010).

[40] Box Frank. A heuristic technique for assigning frequencies to mobile radio nets. *IEEE Transactions on Vehicular Technology, Vol.* 27, no. 2, pp. 57-64 (1978).

[41] Nafeh Abd El-Shafy A. Optimal economical sizing of a PV-wind hybrid energy system using genetic algorithm, *International Journal of Green Energy, Vol.* 8, no. 1, pp. 25-43 (2011).

[42] Ko Myeong Jin, Yong Shik Kim, Min Hee Chung, and Hung Chan Jeon. Multi-objective optimization design for a hybrid energy system using the genetic algorithm, *Energies, Vol.* 8, no. 4, pp. 2924-2949 (2015).

[43] Koutroulis Eftichios, Dionissia K., A. Potirakis, and Kostas K. Methodology for optimal sizing of stand-alone photovoltaic/wind-generator systems using genetic algorithms, *Solar energy, Vol.* 80, no. 9, pp. 1072-1088 (2006).

[44] Mohamed, Mohamed A., Ali M. Eltamaly, and Abdulrahman I. Alolah. PSO-based smart grid application for sizing and optimization of hybrid renewable energy systems, *PloS one*, *Vol.*11, no. 8 (2016).

[45] Amer, Motaz, A. Namaane, and N. K. M'sirdi. Optimization of hybrid renewable energy systems (HRES) using PSO for cost reduction, *Energy Procedia, Vol.* 42, pp. 318-327 (2013).

[46] Abdelhak B. Jemaa, Abdelaziz H., Najib E., Faicel H. and Farouk Y. Optimum Sizing of Hybrid PV/Wind/Battery System Using Fuzzy-Adaptive Genetic Algorithm, *Proceedings of the 3rd International Conference on Systems and Control*, *(*2013).

[47] Sopian Kamaruzzaman, Azami Zaharim, Yusoff Ali, Zulkifli Mohd Nopiah, Juhari Ab Razak, and Nor Salim Muhammad. Optimal operational strategy for hybrid renewable energy system using genetic algorithms, *WSEAS Transactions on Mathematics, Vol.* 7, no. 4, pp. 130-140 (2008).

[48] Benatiallah A., L. Kadia, and B. Dakyob. Modelling and optimisation of wind energy systems, *JJMIE*, *Vol.* 4, no. 1 (2010).

[49] Koutroulis E., Dionissia K., Antonis P., and Kostas K. Methodology for optimal sizing of stand-alone photovoltaic/wind-generator systems using genetic algorithms." *Solar energy, Vol.* 80, no. 9, pp. 1072-1088 (2006).

[50] Al-Shamma'a, Abdullrahman A., and Khaled E. Addoweesh. Optimum sizing of hybrid PV/wind/battery/diesel system considering wind turbine parameters using Genetic Algorithm, In *Power and Energy, 2012 IEEE International Conference on*, pp. 121-126 (2012).

[51] K. S. Mellit A. Application of neural networks and genetic algorithms for predicting the optimal sizing coefficient of photovoltaic supply (PVS) systems, *Florence, Italy , (*2006).

[52] Heyrman B., Dupré L., Efficient Modeling, Control and Optimization of Hybrid Renewable-

Conventional Energy Systems., *International Journal of Renewable Energy Research (IJRER)*, vol. 3, no. 4, pp. 781-8 (2013) .

[53] Sopian K., Azami Z., Yusoff Ali, Zulkifli M., Juhari Ab R., and N. S. Muhammad. Optimal operational strategy for hybrid renewable energy system using genetic algorithms, *WSEAS Transactions on Mathematics, Vol.* 7, no. 4, pp. 130-140 (2008).

[54] K. B. Ramoji SK. Optimal economical sizing of a PV-wind hybrid energy system using genetic algorithm and teaching learning based optimization., *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 3, no. 3, (2014).

[55] Borhanazad Hanieh, Saad M., Velappa G. G., Mostafa M. D., and Ali Mirtaheri. Optimization of micro-grid system using MOPSO, *Renewable Energy, Vol.* 71, pp. 295-306 (2014).

[56] Lotfi Saeed, Farid L. T., and Mohammad Ghiamy. Optimal design of a hybrid solar-wind-diesel power system for rural electrification using imperialist competitive algorithm, *International Journal of Renewable Energy Research, Vol.* 3, no. 2, pp. 403-411 (2013).

[57] Tafreshi S. M. M., Zamani HA, Ezzati SM, Baghdadi M, Vahedi H., Optimal unit sizing of Distributed Energy Resources in MicroGrid using genetic algorithm., in *Renewable & Sustainable Energy Reviews*, (2010).

[58] Menniti Daniele, Anna Pinnarelli, and Nicola Sorrentino. A method to improve microgrid reliability by optimal sizing PV/Wind plants and storage systems." In *Electricity Distribution-Part 1, 2009. CIRED 2009. 20th International Conference and Exhibition on*, pp. 1-4 (2009).

[59] Bansal Ajay Kumar, R. A. Gupta, and Rajesh Kumar. Optimization of hybrid PV/wind energy system using Meta Particle Swarm Optimization (MPSO), In *Power Electronics (IICPE), 2010 India International Conference on*, pp. 1-7 (2011).

[60] Kaviani, Ali Kashefi, Hamid Reza Baghaee and Gholam Hossein Riahy. Optimal sizing of a stand-alone wind/photovoltaic generation unit using particle swarm optimization, *Simulation, Vol.* 85, no. 2, pp. 89-99 (2009).

[61] Shang C., Dipti Srinivasan, and Thomas Reindl. An improved particle swarm optimisation algorithm applied to battery sizing for stand-alone hybrid power systems, *International Journal of Electrical Power & Energy Systems, Vol.* 74, pp. 104-117 (2016).

[62] Abdul M., H. Hameed, Mohsen T. E., Adel A. S. and Mohamed M. A. Optimum sizing of hybrid WT/PV systems via open-space particle swarm optimization, In *Renewable Energy and Distributed Generation (ICREDG), 2012 Second Iranian Conference on*, pp. 55-60 (2012).

[63] Ismail, M. S., M. Moghavvemi, and T. M. I. Mahlia. Genetic algorithm based optimization on modelling and design of hybrid renewable energy systems, *Energy Conversion and Management, Vol.* 85, pp. 120-130 (2014).

[64] Yang Hongxing, Wei Zhou, Lin Lu, and Zhaohong Fang. Optimal sizing method for stand-alone hybrid solar–wind system with LPSP technology by using genetic algorithm, *Solar energy, Vol.* 82, no. 4, pp. 354-367 (2008).

[65] Benatiallah A., L. Kadia, and B. Dakyob. Modelling and optimisation of wind energy systems, *JJMIE, Vol.* 4, no. 1 (2010).

[66] Belfkira Rachid, Cristian Nichita, Pascal Reghem, and Georges Barakat. Modelling and optimal sizing of hybrid renewable energy system, In *Power Electronics and Motion Control Conference, 2008. EPE-PEMC 2008. 13th*, pp. 1834-1839 (2008).

[67] R. S. Chedid R., Unit sizing and control of hybrid wind-solar power systems, *IEEE Transactions on energy conversion*, vol. 12, no. 1, pp. 79-85 (1997).

[68] P. F. Maleki A., Optimal sizing of autonomous hybrid photovoltaic/wind/battery power system with LPSP technology by using evolutionary algorithms, *Solar Energy*, vol. 115, pp. 471-83 (2015).

[69] S. J. Bashir M., Size optimization of new hybrid stand-alone renewable energy system considering a reliability index.," *InEnvironment and Electrical Engineering (EEEIC), 2012 11th International Conference*, no. IEEE, pp. 989-994 (2012).

[70] Sharma Sharmistha, Subhadeep Bhattacharjee, and Aniruddha Bhattacharya. Grey wolf optimisation for optimal sizing of battery energy storage device to minimise operation cost of

microgrid, *IET Generation, Transmission & Distribution, Vol.*10, no. 3, pp. 625-637 (2016).

[71] K. E. Fetanat A., Size optimization for hybrid photovoltaic–wind energy system using ant colony optimization for continuous domains based integer programming, *Applied Soft Computing* , vol. 31, pp. 196-209 (2015) .

[72] A. KRAJ, Intelligent computational infrastructures for optimized autonomous distributed energy generation in remote communities, *Brazil Wind Power, (*2015).

[73] Tina G., S. Gagliano, and S. Raiti. Hybrid solar/wind power system probabilistic modelling for long-term performance assessment, *Solar energy, Vol.* 80, no. 5, pp. 578-588 (2006).

[74] Kellogg W. D., M. H. Nehrir, G. Venkataramanan and V. Gerez, Generation unit sizing and cost analysis for stand-alone wind, photovoltaic, and hybrid wind/PV systems, *IEEE Transactions on energy conversion, Vol.* 13, no. 1, pp. 70-75 (1998).

[75] Tessema Zereay, Brijesh Mainali, and Semida Silveira. Mainstreaming and sector-wide approaches to sustainable energy access in Ethiopia, *Energy Strategy Reviews, Vol.* 2, no. 3, pp. 313-322 (2014).

[76] World Bank. 2008. The little data book on Africa 2008. *Africa Development Indicators.* Washington, DC: World Bank. http://documents.worldbank.org/curated/en/695421467990317712/The-little-data-book-on-Africa-2008.