Off-Grid and On-Grid Connected Power Generation: A Review

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ABSTRACT
Off-grid has several complimentary functional applications and succinctly it has been regarded to be important technology to realize as its reliability, sustainability and techno-economic solution of energy. Among various decentralized generation techniques, hybrid renewable energy source (HRES) is one of the promising techniques in terms of sustainability, simplicity of operation and commissioning. The most common hybrid systems preferably used are PV/Wind/Battery and PV/Diesel/Battery according to feasibility of these sources. In the recent years, HRES have been developed as new age technology for the faster meeting the load demand for the remote area with superior combinations. For all experimental investigations done by the researchers using hybrid optimization model for electric renewable (HOMER) involved (a) study area characterization (b) resource assessment (c) load demand for the domestic, agricultural, community and commercial (d) expected different combination of RES and (e) optimization analyses in order to achieve objective function by attempting a number of combination of RES. Based on the optimization technique the result have been evaluated by the help of different parameters as decision variables, sensitivity variable. The optimization aim was carried out in different cases regarding minimization of per unit energy cost (PUEC) and emission of greenhouse gases (GHGs).

Keywords
PUEC, HRES, DE, CHP (Combined Heat and Power), GHGs, HOMER

1. INTRODUCTION
India has been pursuing non-conventional sources of energy for various applications for a longtime. Several technologies—solar heating, solar photovoltaic, biomass, wind—have been demonstrated over the years. Currently, renewable sources of energy make up for about 5% of grid electricity produced in the country. This is impressive growth compared to 2.7% that is contributed by nuclear energy despite huge investments made in that sector. Despite the growing contribution of renewables to the national power kitty, about 125,000 or 21% villages remain in dark and not all households have power in the villages electrified. While the government efforts continue to spread solar and biomass based lighting, heating and power systems in villages, efforts in the non-governmental sector have shown that decentralized, off-grid power generation through biomass based gasifiers and solar photovoltaic offers a viable, long-term solution to rural electrification.

Distributed generation, also distributed energy, on-site generation (OSG) or district/decentralized energy is defined by Ackermann et al., 2003 as Electric power generation source directly connected to the distribution network or on the customer side of the meter using a variety of small, grid-connected devices referred to as distributed energy resources (DER) or distributed energy resource systems. This system can provide several benefits to the consumers such as higher energy efficiency, reduced CO_2 emission, flexibility of generation as per the requirements resulting in better energy service and saving and optimal use of resources thus decreasing the Power System Vulnerability. There are different methods of decentralized power generation.

1.1 Cogeneration
Cogeneration through combined heat and power (CHP) is the simultaneous production of electricity with the recovery and utilization of heat. Cogeneration is a highly efficient form of energy conversion and it can achieve primary energy savings of approximately 40% compared to the separate purchase of electricity from the national electricity grid and a gas boiler for onsite heating. Combined heat and power plants are typically embedded close to the end user and therefore help reduce transportation and distribution losses, improving the overall performance of the electricity transmission and distribution network. For power users where security of supply is an important factor for their selection of power production equipment and gas is abundant, gas-based cogeneration systems are ideally suited as captive power plants[1].

1.2 Solar Power
The energy received by the earth from the sun (with a rate of 174 PW in the upper atmosphere) is by far larger than the current world energy consumption. In view of the present crisis of the dominant energy resources and the raising concern about environment, solar power emerges as a concrete alternative for a sustainable and environmental-friendly growth of the world energy supply[2].

India is densely populated and has high solar insolation, an ideal combination for using solar power in India. Some large projects have been proposed, and a 35,000 km² area of the Thar Desert has been set aside for solar power projects. The government has targeted to produce 20,000 MW of solar power by 2020.

1.3 Wind Power
Wind energy technologies use the energy in wind for practical purposes such as generating electricity, charging batteries, pumping water, and grinding grain. Wind energy is a result of the sun's uneven heating of the atmosphere, the earth's irregular surfaces (mountains and valleys), and the planet's revolution around the sun, which all combine to create wind

[3].Wind energy is a clean and eco-friendly energy source and increasingly accepted as a major complementary energy source for securing a sustainable and clean energy future in India. The Indian government has aimed to fully utilize the abundant resources of this energy, which India has. The official assessment shows this country has potential to generate over 100,000 MW of wind energy[4].

1.4 Hydro Power

Hydroelectric power captures the energy released from falling water. In the most simplistic terms, water falls due to gravity, which causes kinetic energy to be converted into mechanical energy, which in turn can be converted into a useable form of electrical energy. India has vast hydropower potential of over 84,000 MW at 60% load factor, out of which, Brahamaputra, Indus and Ganges basins contributing about 80%. Out of this total, India has harnessed only about 15% so far, another 7% under various stages of development and the balance 78% remains unharnessed due to many issues and barriers. Hydropower has immense benefits and has been brought forward as a favored option for power generation over the last decade as it involves no extra foreign exchange outgo[5].

1.5 Waste-to-energy

Waste-to-energy (WtE) or energy-from-waste (EfW) is the process of generating energy in the form of electricity and/or heat from the primary treatment of waste. WtE is a form of energy recovery.

Waste is the unwanted by-product of industrial, commercial and domestic activities or anything otherwise discarded. It can be gaseous, liquid or solid. In Britain it has grown dramatically in volume and complexity over the last 50 years. Priority is now being given to the reduction of waste at source, its re-use, its recovery by recycling and to the use of waste as a source of energy (the glossary defines words shown in italics). Treatment and disposal of that which remains should be carried out in a safe and environmentally acceptable manner. All these activities need to be carried out in a manner consistent with the principle of sustainable development and without imposing an unnecessary burden on industry.

2. LITERATURE REVIEW

[Dinesh C. Sharma, et-al, 2007] discussed transforming rural lives through decentralized green power. Technology has shown the way to lighting up rural India, now it is up to government to enable an environment policy that can ensure that the lights do not go off. The access to electric power remains a distant dream for majority of the poor living in developing countries. Per capita electricity consumption in developing countries is far lower than the developed countries. It is not sufficient due to per capita electricity consumption in developing countries was 1155 kWh, compared to 10,262 kWh for high-income OECD countries. The technologically available options for decentralized power generation are mainly biomass, solar and mini hydro. Statistics shows that local ownership of a power plant can go a long way in ensuring sustainability. Electricity in rural homes should be viewed as an extension of an urban facility in rural areas. A policy paradigm shift is needed to make electrification integral to all rural development plans.

[Sanjoy Kumar Nandi, et-al, 2010] presented Prospect of wind PV–battery hybrid power system as an alternative to grid extension in Bangladesh where only 20% of the population is connected to grid electricity, with the vast majority being deprived of conventional supplies. It is clear that the optimized wind PV-battery hybrid system is more cost effective compared to wind-alone, PV- alone system and wind-PV hybrid system for the load with 10% annual capacity of shortage for this hypothetical system in the proposed site that is greater than 10 km from the grid. In Bangladesh, interest in small scale renewable energy (especially solar energy) based power system for rural electrification has grown enormously among energy planners. Nandi and Ghosh showed that wind -PV-diesel is the best option with 5% annual capacity of shortage for all the potential sites of the Kutubdia island Bangladesh. It is not sufficient, Bangladesh mobilization of heavy equipment for installation and servicing of mid-size to large wind turbines is critical to the economic viability of a wind project. The proposed solutions are: Solar and wind energy are the most readily available source of energy. It is non-conventional sources of energy because it is non-polluting. Through Solar Photovoltaic (SPV) cells, solar radiation gets converted into DC electricity directly. New ideas is install large capacity of wind &solar power plants and main problem is sun light is available in night only and its capital cost is very high. More data are required to improve the analysis such as a description of the loads, including how they vary over the day and through the seasons and wind speed. Never the less, the initial analysis is of the hybrid system is promising enough that further effort can be justified to collect the additional data to perform a more detailed analysis.

[A.B. Kanase-Patil,et-al,2011] has presented sizing of integrated renewable energy system based on load profiles and reliability index for the state of Uttarakhand in India. The idea is sizing of integrated renewable energy system based on load profiles. The technique used is energy balance techniques, "Binary Search Optimization Technique". The proof is renewable energy resources such as micro hydropower (MHP), biomass, biogas, wind and solar energy in decentralized mode for the electricity supply has received considerable attention in recent years due to adverse environmental impacts and fuel cost escalation associated with conventional energy generation. The result is proposed system totally depends on the renewable energy systems and eliminates the use of conventional energy systems. The related work integrated wind/hydro approach has been used for operational optimization of system components and reduction of electricity cost for a remote island. It is not sufficient due to adverse environmental impacts and fuel cost escalation associated with conventional energy generation. The study analyzes the different load profiles and gives different choices to select the best option out of the proposed optimized solutions. In order to assess the potential of renewable energy resources, an extensive survey was conducted and data about the availability of biomass, intensity of solar radiation (insolation), hydropower and wind speed was collected. The potential assessment has been carried out as per the methodology adopted in the earlier study carried out by the authors. New ideas is install large capacity of renewable energy system and main problem is mainly solar heating, solar photovoltaic, micro hydropower (MHP), biomass, biogas, wind available in all time and its capital cost is very high. An optimization model consisting of MHP, biomass, biogas, wind and solar energy has been developed and simulated for the study area. The model developed has been found to be very useful for cluster of villages in the hilly state of Uttarakhand, India as it offers a designer a variety of options that can be useful for selection of renewable systems sizes for the similar area. The proposed system totally depends on the renewable energy systems and eliminates the use of conventional energy systems.

[P. Raman, et-al, 2012] has developed Opportunities and challenges in setting up solar photo voltaic based micro grids for electrification in rural areas of India. The government of India provided subsidies worth of around Rs.500 million for projects aimed at promoting the use of solar energy in rural areas. These subsidies are directly spent to the project related to solar home lighting and street lamps in villages across country. It is not sufficient, Erratic voltage levels and unreliable power supply are major problems, due to the inadequate generation and ageing transmission system leading to frequent power cuts. To solve this problem, many wind - PV–battery hybrid power system and solar photo voltaic plants will be installed of large capacity to continue the generation of power. The proposed solutions are Solar energy is the most readily available source of energy. It is non-conventional sources of energy because it is non-polluting and it helps in lessening the greenhouse effect. Through Solar Photovoltaic (SPV) cells, solar radiation gets converted into DC electricity directly. Various applications of solar energy are Residential Application, Industrial Application, Remote Application and Transportation. New ideas is install large capacity of solar power plants and main problem is sun light is available in night only and its capital cost is very high. In the long term, there can be a high return on investment due to the amount of free energy a solar panel can produce and it is most important source of energy. The photovoltaic cell installed on the roof of the house collects the solar energy and is used to warm the water and charge the battery etc.

[Diego Silva Herran, et-al, 2012] has presented Design of decentralized energy systems for rural electrification in developing countries considering regional disparity. The idea is developed in order to design decentralized energy systems for rural electrification using local biomass resources, considering disparity in energy consumption between urban and rural areas. The techniques used are Inadequate planning techniques and linear programming technique. The surprising result is improvements of the model are needed in order to internalize benefits of decentralized electrification using local biomass in terms of increased local income and CO2 emissions reduction. The related work is access and quality of energy supply, as well as the consumption patterns of household's present considerable differences between these regions. It is not sufficient due to urbanized countries rates of electrification in urban areas are close to 100%, other countries access to electricity is small in both urban and rural areas. This paper describes an attempt to incorporate regional disparity into an optimization model describing a developing country's energy system. Energy conversion technologies included in the system are diesel generation with diesel fuel, and biomass conversion technologies based on direct combustion, and gasification. The Base scenario is used as the reference for comparison. In this scenario electricity supply gives positive profits in urban areas, where unit net cost and unit total cost are 0.2 cents/MJ and 1.7 cents/MJ, respectively. The applicability of these technologies is limited by high maintenance needs and fuel homogeneity requirements. The application of an optimization model for the design of decentralized energy systems for electrification using biomass for Meta department in Colombia results in the following outcomes: The least-cost energy system design suggests the replacement of diesel generators using diesel fuel with gasification plants using sugarcane and planted forest waste in remote areas. All agricultural wastes are used in rural areas, except rice husk and bagasse produced in remote areas. Biomass-based electricity supplies all the demand in rural areas, with wastes contributing 62% of resource supply. In urban areas, 60% of electricity is supplied by gasifiers using forest waste.

[Abolfazl Shiroudi,et-al,2013] has presented Stand-alone PV-hydrogen energy system in Taleghan-Iran using HOMER software: optimization and techno economic analysis. The idea is RE sources can open new ways to solve this environmental issue. The simulation results demonstrate that energy system is composed of 10-kW PV array, 3.5-kW electrolyzer, 0.4-kW proton exchange membrane fuel cell, 2.5-kW inverter, and 60 batteries (100 Ah and 12 V). The related work is integrated and worked at the Taleghan renewable energies' site in Iran. The hydrogen produced by the electrolyzer is compressed and stored in hydrogen vessel and provides energy for the fuel cell to meet the load when the solar energy is insufficient. There is one year gap. Renewable energy (RE) sources are attracting more attention as alternative energy sources nowadays. Depletion of energy sources and global warming plays a big role in this movement. RE sources can open new ways to solve this environmental issue. They are free of pollution during operation might be enough.PV systems have the advantage of minimum maintenance and easy expansion (up sizing) to meet growing energy needs. Hydrogen storage has an economic advantage over lead-acid batteries for long-term storage.

[Gianfranco Chicco, et-al, 2007] has identified that the idea of generation of electricity is primarily based on the conventional methods like a single centralized Thermal Power Station for the entire region but the recent developments in the fields of efficient generators, cogeneration enhancing the generation efficiency has shifted the research to develop more productive Distributed Multi-Generation System (DMG) focusing on smaller generation units distributed locally over the entire region. In this research paper, the author has suggested the possible framework for the DMG System outlining its structure, component and energy flow taking into account the various technical, economic and environmental aspects. This system can provide several benefits to the users such as higher energy efficiency, reduced CO_2 emission, flexibility of generation as per the requirements resulting in better energy service and saving and optimal use of resources thus decreasing the Power System Vulnerability. Due to the its huge complexity, this system have many challenges to overcome such as method to integrate various DER (Distributed Energy Resource) with the DMG System, development of inverter technology for network interfacing and power quality improvement. Hence the possible benefits of the DMG System paves the way to future scenarios focused on the development of multi-generation solutions.

[Buljit Buragohain, et-al, 2009] estimated that the total power potential of renewable energy resources in India is about 80GW among which the contribution of biomass based power is about 20 GW. This is because biomass gasification-based power plant in rural areas offers several advantages like easy availability of biomass, flexibility of installation and operation as well as other socio-environmental benefits like employment opportunities of local people and reduced CO_2 emission. The feasibly and operationally successful decentralized biomass based village electrification program in Karnataka, Tamil Nadu and West Bengal has already proved the accountability of this system.

[Sonaton Ghosh, et-al, 2001] has found that in order to have a long-term solution for rural electrification, the government of India installed an off-grid woodfuel-based 500 KW power plant at Gosaba island of West Bengal in July, 1997. The analysis of the plant revealed a moderate success in terms of

diesel replacement (59%) at optimum load condition of 64%. The COE for unit generation of reference year has been estimated at Rs 4.27/KWh. The system suffers 13 % of T&D loss which is very high considering a decentralized power plant. The plant was found to be self-sufficient in terms of fuel wood and local labors however ways for the fulfillment of future increase in demand needs to be addressed.

[Alam Hossain Mondal, et-al, 2010] In this research paper, various combinations of wind, photovoltaic (PV), diesel generator and battery has been analyzed using HOMER to find out the optimum size of system to fulfill the requirements of 50 households of three remote villages of Bangladesh namely; Cox's bazar, Sylhet and Dinajpur having 50 KWh per day primary load with 11KW peak load. It was found that the most economically feasible system would consist of PV (6 KW)-diesel Generator (10KW)-battery (2V, 800 Ah) having per unit cost of electricity 25.4 Tk/KWh. The system also offers many benefits such as local employment, reduction in diesel consumption and CO_2 emission.

[M. Hiloidhari, et-al, 2010] has presented the analysis of crop areas of Sonitpur District of Assam using the Indian remote sensing satellite estimates that the total crop residue biomass (CRB) available in the district is about 0.28 million tonnes out of which 0.17 million tonnes are practically available having the power potential of about 16.94 MW. The crop residue intensity (tonne km^{-2}) varies from village to village and it was found that out of 1223 villages, 453 villages comes under medium intensity CRB range while 439 and 331 villages comes under low and high intensity range respectively. The highest village level power potential of 71.86 KW was observed in No. 1 Charaibari of Pub-Choiduar DB followed by 65.55kW (Bengabari village) of Behali DB and 62.74kW (Keheru Khanda) village of Dhekiajuli DB

3. SOFTWARE DESCRIPTION

HOMER: HOMER is a software application developed by the National Renewable Energy Laboratory in the United States. This software application is used to design and evaluate technically and financially the options for off-grid and on-grid power systems for remote, stand-alone and distributed generation applications. It allows you to consider a large number of technology options to account for energy resource availability and other variables.

4. CONCLUSION

Decentralized power systems based on renewable sources of energy discussed are not only transformative but are actually 'disruptive' technologies (that go beyond and alter existing technological models). They do not fit into any existing models of regulation, finance and cost-benefit syndrome yet they have demonstrated their feasibility and acceptability in field experience in India. The emerging power policy framework supports decentralized power generation, but only as a last resort—in cases where it is technically and economically not feasible to extend gird connectivity. Decentralized power through renewables is not yet a preferred option for rural electrification. Moreover, the same incentives (in the form of assistance to state governments) are being offered for rural electrification through grid extension. So, rural electrification through grid extension is likely to be preferred by states over renewables about which public education and appreciation is poor. Moreover, grid electricity is politically a more attractive proposition than renewables because of their not-so-successful track record in the past. This poor image is likely to be reinforced because, in their zeal to meet the targets for electrification, subsidized solar lighting systems are being doled out without any programme whatsoever for their maintenance and upkeep. This is being done despite the fact that lack of maintenance service has been the bane of renewable sources in India, and their failure to make a dent.

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