A Review on Optimal and Sustainable Approaches for Decentralized Power Generation Using Renewable Energy Sources in Remote Areas

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Abstract

With environment change, declining fossil reserve, extreme integration, the chances of disorder and higher cost of energy supply, centralized system may be replaced by decentralized power- generation system especially in urban and rural areas. Now-a days, many researchers proposed and found the various merits of decentralized system using renewable energy sources over the centralized generation system. The cost of energy (COE) is usually low for stand-alone hybrid renewable energy source (HRES) systems with higher reliability than single renewable energy source like solar photo-voltaic (SPV), wind energy, biomass, biogas, and micro-hydro as well as grid-connected system. PV/wind/battery and PV/diesel/battery are the most preferred hybrid systems in distributed power generation according to resource feasibility. The optimization aims to carry out by the researchers in terms of minimization of the per-unit energy cost (PUEC) and greenhouse gases (GHGs) emissions (CO_2, NO_x and particles) for the various cases using mathematical modeling and hybrid optimization model of electric renewable (HOMER) software. They also compared the results which are favorable in the decentralized power generation system, especially used in remote areas. In this article, a review of the techno-economical analysis of modular energy system with regards to comparison of both the systems has been done. Moreover, the optimization of the system is obtained using different types of parameters as wind speed, solar radiation, diesel consumption, type, and quantity of different biomass feedstock of the particular site.

Keywords: Cost of electricity, Distributed generation, EENS, Energy index ratio, Greenhouse gases, HOMER, Hybrid renewable energy sources, Per unit electricity cost, Solar photo-voltaic, Wind generating system.

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Introduction

Centralized energy generation model is planned with consideration of high-load centers located at urban areas as well as densely populated areas and it has not considered the rural needs of energy as well as their living concerns. These conventional strategies have led to the nature degradation as well as poor rural livelihood practices. The energy needs of rural and distant-located population are still being fulfilled by inefficient energy sources in spite of some steps having been taken by the government in this direction but proving insufficient. The complete energy needs can only be met by reaching the energy utilities to the distantly located villages which are devoid of efficient as well as required energy supply [9].

The small-scale energy generation using renewable sources of energy can meet the load demands at the consumer premises without requiring much future expenses. Some low level of integration of energy generation techniques may lead to higher level of power continuity of supply than a mere alone centralized energy generation as centralized planning has very high level of integration and hence is on higher risks for discontinuity of supply.

In this aspect, it has been revealed that energy generation could be optimum when distributed generation (DG) is adopted along with the interconnection of centralized. It will definitely help the nation to become an optimum energy supplier and in turn will help in nation building by improving the daily practices of energy utilization by privileged as well as underprivileged population of the country. The country adopting these integrated techniques for energy generation in sustainable way may only become an energy-sufficient nation [10].

Survey on Decentralized Power Generation

It is being discussed nowadays on promoting the establishment of additional decentralized energy systems that are identified by the nearness and connectivity of the generation and consumption areas. These systems are comparatively more sovereign of the main electrical energy supply systems and may utilize some different sources of energy. Hence, these are merely sensitive as compared to the centralized systems and of transmission networks [8]. Mainly these systems are advantageous in respect of nearly free availability; less carbon emission and vicinity available renewable energy sources like solar, wind power, biomass, biogas, mini hydro, etc., and an important tribulation of wind energy with respect to organizational integration is its irregular power yield in Belgium. The power of a wind turbine in a fussy location changes with wind speed at center height that also can be mentioned as a dependent of wind speed at 10 m above ground level. This irregular response requires additional salt away power capacity, which would not be required if the wind turbine had not been used. The installations of wind turbines lead the centralized power system to drive less competently [11]. The scope, relevance and applications of renewable energy sources of different categories like biomass, solar PV, wind turbines, etc., in various decentralized modes at various distant locations including villages and cluster of villages in India is discussed and observed that the cost of electricity generation from the biomass gasifier duel fuel-diesel (70% biomass+30% diesel) hybrid system (5 units of 100 kW) at Gosaba island, Sunderbans, West Bengal, India is Rs. 1.39/kWh which is lower as compared to Rs. 5.02/kWh with grid power, providing its feasibility. The village electrification at Hoshalli and Hanumantha nagar, Karnataka, India by 20 kW woody biomass gasifier for home lighting, street lighting, pumping water for drinking and ploughing and operation of a flour mill at a cost of Rs. 3.34/kWh by Centre for Sustainable Technologies (CST), Indian Institute of Science, Bangalore, India. The economic viability of biomass-power systems is yet to be justified more in India. The installation of SPV systems with total power of 300 kWp at Sagar Island, Sundarban region, West Bengal by Ministry of New and Renewable Energy (MNRE) via WBREDA in 1996 has facilitated the electricity and drinking water to the hefty inhabitants of around 2000 families in the isolated island with serving around 50% of the total electricity needs. Micro-hydro and wind are the other renewables to harness with large possibilities for DG systems in India with 84,044 MW at 60% load factor from hydro power plants and 45000 MW from wind power with 1% land requirement as depicted by Central Electricity Authority (CEA). Sagar island wind-diesel hybrid system was first of its kind in Asia to get operational in 2002 by WBREDA with two units of 50 kW each generating power to harness the local grid and supplying electrical power to 861 consumers including commercial loads in the dusk hours along with the integration with the already operational 500 kW biomass gasifier diesel system to meet the demanding increase in loads at the distantly located island [9]. Compared to the cost of grid-connected electricity with the cost of supplying electricity by DG technologies to different kinds of villages in India (like for a single, isolated village and a cluster of villages) and integrated the location-specific kind of cost by empirically using a comprehensive cost function for the distribution network with considerations of 5, 10, 15, 20 and 25 km distances from the 33 kV nearby grids as shown in Table 1.

Table 1.Cost of Delivered Power for Different Generating Systems according to Distance for the Years 1999, 2005 and 2010 [3]

Type of Generating System	Cost (in Rs.) of Delivered Power on the Basis of Distance (Km) from 33 KV Grid Point				
	5	10	15	20	25
1999					
Thermal	9.39	14.38	20.27	25.71	31.15
Diesel	14.12	19.56	25.00	30.44	35.88
SPV	26.10	26.10	26.10	26.10	26.10
2005					
Thermal	9.55	14.69	19.64	25.45	29.69
Diesel	14.85	19.90	24.94	30.75	34.99
SPV	15.18	15.18	15.18	15.18	15.18
2010					
Thermal	9.67	14.45	19.15	28.83	28.59
Diesel	15.76	20.43	25.15	29.83	34.54
SPV	9.67	9.67	9.67	9.67	9.67

The cost of delivering power is drastically reduced with the use of SPV from Rs. 26.10 in 1999 to mere Rs. 9.67 in 2010 as compared to the thermal and diesel generation systems and hence making DG technology an economic sense. So, it is important to create criterion and recognize ecological factors that need to be implemented while DG scheduling [1]. Due to the complex incorporation, centralized energy systems are prone to instability in the network and hence losing their demand. Some other factors which diminish its demand are the exhaustion of fossil fuels and their environment-degrading influence and the aspiration of investors to reduce the challenges via operation of smaller-scale, modular generation and transmission systems. Small-scale DG systems, where generation and utilization are generally firmly bounded, are rising as a possible substitute. They are less susceptible to the vague accessibility of distant principal energy and hauling networks. Also the closeness of generation and consumption makes DG systems cleaner as they generally use renewable sources or combined heat and power (CHP). Completely DG is not inevitably enviable but it is an ingredient of a more universal solution. Decentralized energy generation, especially electricity generation, is a distributed way of energy generation. It is a practice that may fulfill the energy needs of the underprivileged areas in a sustainable way with clean energy generation efforts. The safe and uncontaminated energy systems of the upcoming era will be those stretchy enough to permit for a variety of hybrid modes of operation and asset, including the best characteristics of both technologies. The best quality of CHP is the valuable decrease in losses during transmission, as electrical energy is generated near the load, and during conversion, because dissipated heat in the generation course is reused for space and water heating, for cooling and for manufacturing process heat. Also, CHP units can amplify the security of supply during the period when grid is occupied, and allows selling spare energy into the main grid. The limitation with CHP-produced electricity is its reliance on the central contribution of the main fuel, mostly natural gas. The possible choices for CHP units are allowing flexible multi-fuel operation, mainly those which can be driven from locally accessible waste products or bio-energy such as landfill gas, manure, agricultural waste [8]. For conciseness, micro grid is considered as one of the promising network designs and operational technique for DG supply systems. Its attracting cause is its ability to function either coupled to a wider network or as an island to eliminate technical hurdles to flawless system integration and flexible active system supervision [7]. There has been developed an optimized model for different energy index ratio (EIR) and expected energy not supplied in kWh (EENS) using HOMER software, for seven un-electrified villages (namely Naula, Paparha, Lod Bagar, Kotli gatoliya, Obari, Sangura) and Kharkhet) in Almora district, Uttarakhand, India to satisfy the electrical and household requirements via off-grid electrification by utilizing Integrated renewable energy systems [10]. The model is prepared for the cost of energy (COE) with EIR for the four conditions namely: (i) only solar potential (ii) wind and solar potential (iii) energy plantation and solar potential and (iv) combination of wind, energy plantation and solar potential and mathematically calculated as shown in Eqs. (1) and (2).

$$EENS = L*D/3600 \quad (1)$$

Where, L is the average annual power load (kW); D is the duration of unavailability of load (seconds).

$$EIR = 1-EENS/E_0 \quad (2)$$

Where, EIR is yearly; E_0 is the total Energy demand of the system (kWh) [2, 4, 5].

Proposed the best system for Almora is the system that achieves higher reliability with optimum total system cost. The above condition (iv) is also considered and analyzed that reduces the total system cost and offers highest reliability and the COE obtained with reliability of 0.95 EIR is found to be Rs 3.36 per kWh and is least whereas COE for conditions (i), (ii) and (iii) are Rs 4.81, Rs 4.65 and Rs 3.43 per kWh respectively for the same reliability [6].

Conclusion

Due to huge potential of renewable energy sources, current research trends to decentralization of electricity generation to meet the load demand at remote areas due to its sources availability, flexible infrastructure, sustainability of possible hybrid combinations, extent of security of supply, reduced energy losses and emissions. Advantages of the biomass-based hybrid DG systems to the consumers are: (a) a level of energy sovereignty (b) same or better power quality (c) local control for power supply security (d) a greener environment although at some locations fluctuating weather conditions and insufficient feedstock leads to inefficient operation of decentralized systems. Moreover, techno-economic feasibility is obtained by HOMER in terms of COE and finally concluded that decentralized power generation could become more economic, reliable and sustainable as compared to centralized generation system especially in urban and distant rural areas.

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