



Grid-connected versus stand-alone energy systems for decentralized power—A review of literature

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ABSTRACT

The decentralized power is characterised by generation of power nearer to the demand centers, focusing mainly on meeting local energy needs. A decentralized power system can function either in the presence of grid, where it can feed the surplus power generated to the grid, or as an independent/stand-alone isolated system exclusively meeting the local demands of remote locations. Further, decentralized power is also classified on the basis of type of energy resources used—non-renewable and renewable. These classifications along with a plethora of technological alternatives have made the whole prioritization process of decentralized power quite complicated for decision making. There is abundant literature, which has discussed various approaches that have been used to support decision making under such complex situations. We envisage that summarizing such literature and coming out with a review paper would greatly help the policy/decision makers and researchers in arriving at effective solutions. With such a felt need 102 articles were reviewed and features of several technological alternatives available for decentralized power, the studies on modeling and analysis of economic, environmental and technological feasibilities of both grid-connected (GC) and stand-alone (SA) systems as decentralized power options are presented.

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1. Introduction

Electricity is accepted as one of the driving forces of the economic development of all the nations. The challenge of

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continuously generating electricity and meeting the growing demands is daunting for both developed and developing countries, exerting tremendous pressure on the energy infrastructure. In developing countries where more than 50% of the population resides in rural regions, cost of delivered electricity becomes very expensive and unaffordable to the rural poor giving rise to reduced standard of living and social inequity. For example, in India, a very high concentration of the population (more than 70%) is living in rural regions and around 40% of the total population lives without any access to modern energy services [1]. To keep pace with the current growth rate of demand for electric power, the primary energy supply has to be increased threefold and power generation has to be increased fivefold, for which 3% of the nation's GDP has to be invested annually [2,3].

The high costs of delivered electricity can be attributed to strong dependence on centralized energy systems which operate mostly on fossil fuels and require huge investments for establishing transmission and distribution grids that can penetrate remote regions [4]. Further more, the fossil fuel combustion results in the emission of obnoxious gases rising concerns about the climate change and other health hazards.

In order to counter these problems there is a strong need for alternative systems of power generation and distribution. Unlike the centralized energy systems, on the other hand, decentralized energy systems are mostly based on renewable energy sources, operate at lower scales (a few kWh scale) both in the presence and absence of grid, and easily accessible to remote locations because of generation of power in the propinquity of demand site. Therefore, implementation of decentralized energy systems can handle the rural electrification imbroglio effectively by providing environmentally benign, sustainable and reliable energy supply. Globally, the total share of decentralized power generation in the world market increased to 7.2% in 2004, up from 7% in 2002 [5]. In the case of new capacity addition for power generation, output from decentralized generation saw a tremendous growth from 13% in 2001 to 25% in 2005 [6]. In 2006, 36% of the electricity generated from capacity addition was of decentralized type. Considering the advantages decentralized systems offer, the forecasts have predicted a further increase in the share of decentralized power systems in the global energy scenario [7]. If decentralized energy strategy is adopted, total worldwide savings are estimated to reach 2.7 trillion dollars by 2030 [5,8].

2. Extent of decentralization

The implementation of decentralized energy systems depends upon the extent of decentralization. At village decentralization, the system is managed by local participation and energy is supplied to meet the local needs. In few cases, the excess power may be supplied to the grid. On the other hand it is also possible to have industry level decentralization, in which case the power generated as a by-product of industrial process (as in bagasse co-generation) is used mainly to cater to its own needs with any surplus being fed into the grid. The extent of decentralization also determines whether the system operates in either grid-connected (GC) or stand-alone (SA) mode.

2.1. Grid-connected systems

We can distinguish two types of grid-connected systems. In the first type, the GC system's main priority is to cater to the local needs for electricity and any surplus generation will be fed into the grid, and when there is shortage electricity is drawn from the grid. The other option is utility scale, wherein decentralized stations are managed by the utilities in the same way as large electric power

plants. Any output of the GC systems is fed into the central utility grid without paying heed to the local needs. Some of the important features of GC systems are as follows.

- A grid-connected energy system is an independent decentralized power system that is connected to an electricity transmission and distribution system (referred to as the electricity grid). They are ideal for locations close to grid.
- The operational capacity is determined by the supply source. The system functions only when the supply sources are available.
- Because of the supply driven operation, the system may have to ignore the local demand during times of unavailability of supply sources.
- The system could be either used to meet the local demand and surplus can be fed to the grid, or otherwise, the system may exist only to feed the grid.
- The connectivity to grid enables setting up relatively large-scale systems and hence they can operate at high plant load factors improving the economic viability of the operation.
- In a grid-connected power system the grid acts like a battery with an unlimited storage capacity. So it takes care of seasonal load variations. As a result of which the overall efficiency of a grid-connected system will be better than the efficiency of a stand-alone system, as there is virtually no limit to the storage capacity, the generated electricity can always be stored, and the additional generated electricity need not be "thrown away".
- In addition to the initial cost of the system, cost for interface of the system with grid is incurred.
- For systems operating on renewable sources like biomass, wind and solar PV, there will be a high pressure on these renewable sources, as the system usually operates at high scales and need more biomass for its operation [3,5].

2.2. Stand-alone systems

Stand-alone systems produce power independently of the utility grid; hence, they are said to stand-alone. These are more suitable for remotest locations where the grid cannot penetrate and there is no other source of energy. Stand-alone systems comprise the majority of photovoltaic installations in remote regions of the world because they are often the most cost-effective choice for applications far from the utility grid. Examples are lighthouses and other remote stations, auxiliary power units for emergency services or military applications, and manufacturing facilities using delicate electronics. The SA systems suffer from innate disadvantages like low capacity factor, excess battery costs and finite capacity to store electricity forcing to throw away the extra energy generated [10]. The important features of SA systems are as follows.

- In SA energy systems, the operational capacity is matched to the demand.
- The needs of the local region assume maximum priority.
- These systems are ideal for remote locations where the system is required to operate at low plant load factors.
- Operation is mostly seasonal, as the typical stand-alone systems are usually based on renewable energy technologies like solar PV, which is not available throughout the year.
- This does not exert pressure on biomass and other renewable energy sources as it requires fewer resources for small-scale applications.
- These systems are not connected to the utility grid as a result of which they need batteries for storage of electricity produced during off-peak demand periods, leading to extra battery and storage costs, or else the excess power generated has to be thrown away.

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