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Distributed generation deployment: State-of-the-art of distribution system planning in sustainable era

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ABSTRACT

One of the major consequences of evolutionary growth of industrial era is the continuously growing rate of energy consumption across the world. In the industrialized countries, the concern about economies accompanied by the environmental perspective is a significant driver for inventions of efficient and cost effective modular energy delivering structures. DGs with their heterogeneous forms are likely to be increased in utilization as an outstanding alternative solution to the prevailing energy crises. The advent of DG penetration is leading to fundamental changes in distribution network exploitation and exploration. Nonetheless the DG installation and exploitation has been debated in distribution networks, the fact is that, practically the Distribution Network Operators (DNOs) has limited control or influence over DG allocation and design. Their owners and investors depending on site and fuel availability finalize DG placement. The prime objective to achieve the most from DG installation, owes special attention of DNOs towards DG placement and sizing. This objective encompasses two major sub problems: which may be the optimal location for DG installation and with which capacity? Enormous quality literature is available enlightening this area. This paper presents a state of art of DG deployment techniques and their influence on the ongoing research efforts in this field. To relieve the imminent researchers from the difficulties of availing appropriate guidance, an elfin attempt has put forward through this paper by presenting significant information of research work done in this field.

1. Introduction

The striking rate of burning up of fossil fuel has drag the world in the crucial phase from which it is fast approaching the peak of fuel expenditure especially oil and gas. This impulsive stage has begun the turning up of researcher's efforts towards investigation of alternatives for endangered conventional energy resources. However, DG deployment, considered as part of the solution to the world's energy crises is changing the context in which electric power systems conventionally operated and regulated. The successful and beneficial DG deployment apprehension leads to an obligation of reexamination of both. These tiny technologies, which were previously been overlooked by governments and power system operators due to limited energy extracting methodologies are now coming back into craze. Tremendous growth in population and available conventional energy sources shows inversely proportional ratio. This adverse circumstance provides a vent for the search of new energy sources. A distributed energy source is the most suitable option to comply this inverse ratio [1]. Governments are incentivizing environment friendly technologies for achieving environmental targets with enhanced global energy security. DNOs are working hard to harness this thrust to bring network operational benefit of enhanced efficiency through improved voltage stability, system reliability, loadability and lower losses attained through investments in fruitful DG deployment. The main hurdles are implementation, installation, and reliability of the DG insertion strategies as well as techniques. Thus, the researchers are trying hard to establish better and revenue worthy techniques to exploit all possible benefits of DG [2]. The significant surge in distributed energy resources (DER), urges some utilities for modifying their business prototypes to reflect the increasing use of DER. Although numerous technologies are available focusing the execution of successful DG penetration in the system, none of the literature has presented their detailed analysis, specifically the relevant scope in DG designing and installation. Thus, the focus of this paper is study and collection of informative bits and pieces of the

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Nomenclature

DG	distributed generation
DNOs	distribution network operators
MW	mega watt
PV	photo voltaic
CHP	combined heat and power
kVAr	reactive kilovolt-amperes
AI	artificial intelligence
EA	evolutionary algorithm
PSO	particle swarm optimization
FS	fuzzy systems
HR	hereford ranch
TS	tabu search
ACS	ant colony system
DER	distributed energy resources
ABC	artificial bee colony
FA	firefly algorithm
kV	kilo volt
MVA	mega volt amp
MVAr	mega volt amp reactive
kW	kilo watt
pu	per unit
DISCO	distribution system company
GA	genetic algorithm
OPF	optimal power flow
CPU	central processing unit
DS	distribution system
FZ	fuzzy

techniques of fruitful DG deployment in optimum way. It attempts to present the state-of-art of the DG deployment planning in distribution system to endure the emerging growth of sustainable energy requirements.

2. DG definitions

Any electric power production technology that is integrated within distribution systems fits under the distributed generation umbrella [3]. Nonetheless Electric Power Research Institute (EPRI) defined DG as generation from 'a few kilowatts up to 50 MW' [4], nowadays much higher capacity units of DGs are active in the power network. The technologies adopted in DG encompass small gas turbines, micro-turbines, fuel cells, wind and solar energy, biomass, small hydropower etc. [5,6]. It is either isolated and supplying the local load, or integrated, supplying energy to the remaining of the electric system. In distribution systems, it can be beneficial to consumers as well as to the utilities, especially in sites where supply from the central generation is impracticable or if there are deficiencies in the transmission system. The IEEE defines distributed generation as the generation of electricity by facilities that are sufficiently smaller than central generating plants to allow interconnection at any point nearly the load in a power system [7]. Distributed generation takes place on two distinct levels [8,9].

(i) Local level and
(ii) End-point level

Local level DGs often comprise renewable energy technologies that are site specific, such as wind turbines, geothermal energy, solar systems (photovoltaic and combustion), and small scale hydro-thermal plants. These DGs tend to be smaller and less centralized than the conventional plants. They are often more energy and cost competent. Since these local level plants generally take into account the local circumstance, usually produce less environmentally destructive or distracting energy than the centrally controlled conventional plants. At the end-point level, the individual energy consumer can apply many of these technologies with similar effects. One DG technology normally employed by end-point users is the modular internal combustion engine. At this level DGs can function as isolated "islands" of electric energy production or they can operate as small contributors to the power grid [4,10–12].

However, in general terms the DGs can be assembled broadly under well-known distinguishing criteria i.e. dispatchable, non-dispatchable, or renewable, nonrenewable DGs. The DGs generally categorized under two key captions as mentioned in Fig. 1.

Most of the DGs utilize renewable energy resources. International Energy Agency (IEA), defines renewable energy resources as the sources that are generally not subject to exhaustion, such as the heat energy from the sun, the velocity of wind, organic energy of biomass, pressure of falling water, tidal energy and geothermal energy [13]. Nonetheless, their accessibility varies extensively according to geographic and climatic state of affairs and technology efficiency to exploit the renewable energy resources, their plentiful accessibility make them even more flourishing solution to the era of energy crises.

Other significant advantages [14–17], of these technologies are as mentioned below,

- Modular structure is possible: Mini-hydro turbines, PV systems, wind turbines, diesel engines, solar thermal systems, fuel cells and battery storage consist of a number of small modules, which are assembled in factories. This feature makes it flexible in terms of maintaining the continuity of supply even in case of failure of some units or maintenance.
- In case a module fails, the other modules remain unaffected by it. As each module is small as compared to the unit size of large centralized power stations, the effect of module failures on the total available power output is considerably smaller.
- Installation Time: The small installation time is one of the significant salient features of these modules at the final site. Manufacturing and erection on site require significantly less time than for centralized power stations.
- Furthermore, each modular unit can start to function as soon as it is installed on site, independent of the status of the other modules.
- Finally, these technologies allow cascading on modules later or move modules to another site, if required

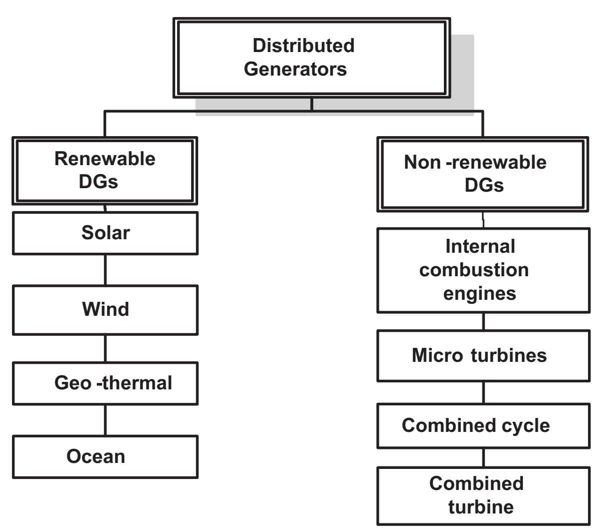

Fig. 1. Basic types of DG's.