Protagonist of renewable energy in distributed generation: a review

Protagonista de las energías renovables en la generación distribuida: una revisión

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Fecha de recepción: 5 de octubre de 2020
Fecha de aprobación: 9 de febrero de 2021

Saxena, V; Kumar, N; Nangia, U. Protagonist of renewable energy in distributed generation: a review. *Tecnología en Marcha*. Vol. 34-4 Octubre-Diciembre 2021. Pág 3-15.

https://doi.org/10.18845/tm.v34i4.5404

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Keywords

Battery storage; demand response; distributed generation; renewable energy resources; optimization approach.

Abstract

In the present scenario, world is progressing in the direction of energy crisis and severe ecological concerns due to the excessive utilization of non-renewable resources. Fossil fuel reserves are inadequate and produce hazardous geological contamination throughout the energy extraction. To meet such challenges, active amalgamation of renewable energy resources (RER) with distributed generation (DG) is the only way to progressing in future. Demand response scheme and battery storage is also essential for the reliable and consistent energy generation and efficient utilization. The role of RER in the evolution of DG is presented in this paper. The objective of this paper is to evaluate the barricades, reimbursements and influence of renewable energy based DG planning and framework. Moreover, a comparative assessment of renewable DG optimization based on optimization criteria and enhanced outcomes are evaluated for this futuristic atmospheric friendly approach.

Palabras clave

Almacenamiento de la batería; Respuesta de la demanda; Generación distribuida; Recursos energéticos renovables; Enfoque de optimización.

Resumen

En el escenario actual, el mundo está avanzando en la dirección de la crisis energética y graves preocupaciones ecológicas debido a la utilización excesiva de recursos no renovables. Las reservas de combustibles fósiles son insuficientes y producen una contaminación geológica peligrosa a lo largo de la extracción de energía. Para hacer frente a tales desafíos, la fusión activa de recursos de energía renovable con generación distribuida es la única forma de progresar en el futuro. El esquema de respuesta a la demanda y el almacenamiento de baterías también son esenciales para la generación de energía confiable y constante y para un uso eficiente. En este artículo se presenta el papel de la generación de energía renovable en la evolución de la generación distribuida. El objetivo de este trabajo es evaluar las barricadas, los reembolsos y la influencia de la planificación y el marco de generación distribuida basada en energías renovables. Además, se evalúa una evaluación comparativa de la optimización de la generación distribuida renovable basada en criterios de optimización y resultados mejorados para este enfoque futurista amigable con la atmósfera.

Introduction

Distributed Generation (DG) is an imperative phase of modern power electrification with the usage of comprehensively acknowledged renewable energy resources (RER). The exhaustion of traditional remnant energy sources, cognizance on biological contamination and augmented price of fuel drive its admiration in the existing scenario. DG is depleting the enslavement tenure of centralized generation. It involves smaller tools for the utilization hydro power, wind power, solar power, fuel cell power, ocean energy, geothermal biomass electrification) as well as non RER [1].

Fossil fuel based traditional power plants are fulfilling the major portion of the energy demand in various countries and emanate the contaminated pollutant in environment which may cause of danger for several organism and human being on earth. Global warming, Ozone depletion, natural disaster, species extinction, health hazardous, polluted atmosphere, novel decease generation and many more are severe effects due to acceptance of non-renewable fuels.

DG has the potential for the successful integration of natural resources into advanced power system framework to facilitate the better healthy atmospheric green energy generation.

The main challenge for the amalgamation of RER in the DG planning is the intermittent nature of natural resources specifically for the major contributors: wind and solar power generation. These sources are dependent on the weather and geographical conditions. Consequently, the manifestation of demand response program and energy storage devices are also essential for the efficacious incorporation of DG and sustainable energy sources [2].

Renewable DG planning

A renewable DG based modern power system structure consist various segments for the planning and implementations. These segments can be further subdivided into; DG system design, assessment of RER, load survey, drafting of energy storage model, optimization technique and elucidation of optimization results. The key segments of renewable DG planning are shown in a progressive manner in figure 1.

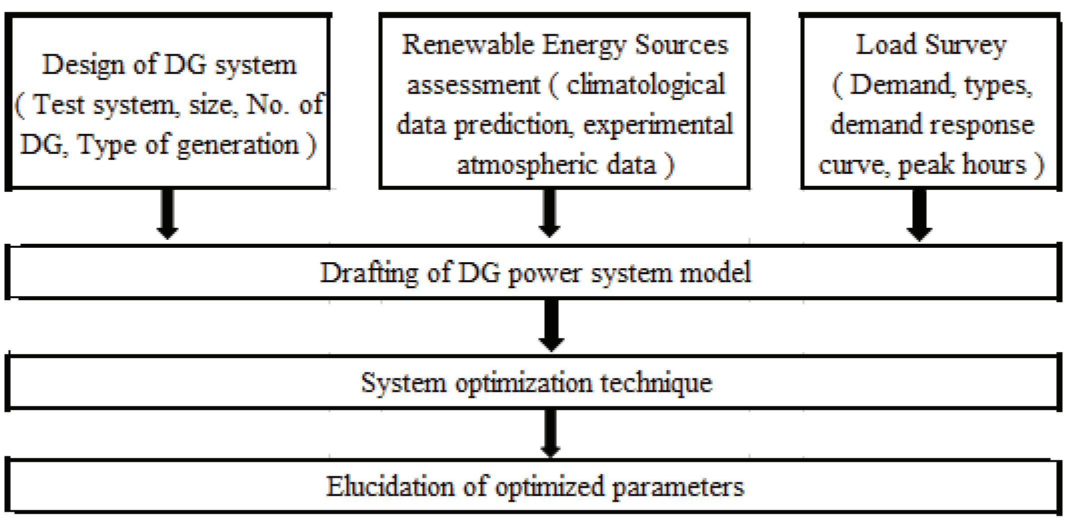

Figure 1. Key segments of renewable DG planning.

DG system design

DG system designs exhibits the types of energy generation, methodologies of battery storage and bus planning in several arrangements. The generation of energy may be based on renewable or non-RER. Renewable sources consist of solar photovoltaic (SPV) system, wind power generation, crops based generation, biomass generation and fuel cells while various types of combustion engines are incorporated with fossil fuel based generation [3].

There are several possible reliable amalgamations of renewable energy generation, utilization and energy storage although such sources have intermittent nature. Harvesting of energy from biomass and biogas could also be utilized in amalgam DG system. The low emission of pollutant based DG technologies are given in table 1.

The description and merits of various types of bus planning are as follows:

- DC-bus architecture: Easy to implement and generated energy is supplied to DC bus to deliver the supply DC load while AC supply could be given by using inverter devices.
- AC-bus architecture: Generated energy is provided to AC bus to carry forward for AC demand although DC supply is available with the help of converter devices.
- Hybrid AC-DC bus architecture: Better efficiency and such type of system can deliver the AC and DC power simultaneously. Inverters and rectifiers could also be used for AC-DC energy storage.

Table 1. Samples of low pollutant based DG technologies [4].

Methodologies	Explanation
Dispersed Heat Methodologies	
Solar heating of water	Solar thermal collector is used to convert sunlight into boiled water.
Heat pump	Water heating by using the temperateness deposited for a thermal reservoir.
Biomass	Water and surface heating by burning the biomass ingredients.
Dispersed Energy generation Methodologies	
SPV array	Designed to convert solar heat into electricity.
Wind mills	Designed to transform wind energy into electricity.
Micro-wind	Small-scale windmill up to 100 kW.
Micro-hydro	Designed to covert kinetic energy of water into electricity.
Biomass	Designed to extract electricity via landfill gas production and upto 40 MW.
Hybrid Heat and Power Methodologies	
Biomass	Energy generation from 100 kW biomass to 85 MWth /20 Mwe.
Upto 1 MW	Small-scale energy distribution for residential and commercial purpose.
1 MWe-10 MWe	Mid-level energy distribution for community and industry.
>10 MWe	High-level energy distribution for industries.

Renewable energy resource assessment

For renewable DG planning and implementation, it is necessary to prepare a complete framework of natural resources of energy generation as the reliability of such sources are less as compared to fossil fuel based energy generation. To meet the new environmental challenges, distributors are required to increase the effectiveness of green energy generation though misery from intermittency. Natural resources are dependent on the local atmospheric condition, seasonal changes, soil fertility, geographical dimensions and observational forecasting.

Moreover, energy generation of solar and wind power are more intermittent in nature and an accurate assessment model is not easy to prepare for this futuristic approach. Biomass based energy generation is also reliant on weather condition but feedstock storage can ensure the uninterrupted energy generation.

Authors presented the effects of geographical conditions and ecological changes on the dispersed energy generation by natural energy sources simulated in Visayas, Philippines. Solar PV and wind power generation has been used and for investigating the annual energy generation, the relevant ecological parameters can be elaborated as monthly PV panel position optimization, mean irradiance level of solar energy and monthly average of wind speed [5].

A new indexing system has been proposed for the reliability of renewable distributed energy sources with the help of traditional fault consequence assessment approach and the minimum path technique. Moreover, a two state model and three state model has been developed for the stability enhancement, which is mainly dependent on the sensible entrance of distribution network. The outcomes has been compared with the absence of DG [6].

Consequently, higher intermittency of wind and solar power generation could be minimized by using experimental atmospheric data and climatological data prediction and these approaches are elaborated further [7]:

Experimental Atmospheric Data

Atmospheric data of intermittent type natural energy sources could be collected through on-site readings, published research, experimental atmospheric observatories, self-sponsored firms and governmental authorities. Solar energy parameters can be abbreviated as; Global solar radiation data, SPV array power output, average and seasonal annual solar irradiation, daily horizontal solar irradiance, solar intensity, hourly solar radiation and relative frequency of global solar radiation. In continuation, wind speed data characterization as; hourly mean wind speed data, monthly average wind speed data, daily wind energy data and relative frequency of wind speed.

Climatological Data Prediction

Climatological data forecasting is necessary to avoid the limitations of renewable energy generation and to estimate the reserved fuel calculations:

- Partial accessibility of services and proficiency for meteorological statistics dimension in convinced segments;
- Economic restriction that confines comprehensive climate data dimension with great persistence; and
- Failure of measuring association that intrudes the continual data apprehending for a long period.

Table 2. Cataloguing of RES forecast boundaries with outcomes [8].

Group	Dimension of forecast boundary	Outcomes
Extreme short period	Seconds to hour	Clearance cost of energy production
		Real time monitoring of grid operation and optimization
Diminutive period	Hour to hours	Fund arrangement of load scheduling
		Reliable of with justified load announcements
Intermediary period	Hours to week	Unit assurance conclusions
		Reserve precondition verdicts
		Generation dynamic / inert mode pronouncements
Prolonged period	Week to year and above	Operational budget optimization
		Forecasting and supervision of processes
		Prospective observations on wind power project

Demand response

Demand response scheme is a mandatory program for DG framework in which users change their energy utilization pattern from high load hours to low load hours to get the benefits of reduced electricity charges. Most of the countries, renewable dispersed energy sources are utilized only at small-scale energy generation in modern power grid. Consequently, the need of demand response scheme as an ancillary support is highlighted for the intermittent renewable energy generation [2].

Previously, people do not know about the cost tariff and incentive schemes related to demand response in conventional power system then there is the domination of utility side to control the energy utilization of end users. Now the circumstances are different and prosumers are the stakeholders for planning and execution of energy disbursement. In continuation, three categories have been suggested for consumers' classification: industrial, commercial and residential. Moreover, the consumers can shift their load from crest load period to bottom one or they can reduce their load during peak pricing hours or use indigenous generation for the demand contentment. The benefits of above-mentioned scheme summarized in terms of: financial, risk assessment, stability, efficient commercialization, user facilities, low pricing and ecological. Numerous types of cost factors are also involved in demand response scheme namely: empowering machinery, reaction strategy, troublesomeness, missing commercial, deferment, communiqué, tariff arrangement, supervision, enticement expenditures, assessment and client edification [9, 10]. The classification of demand response scheme is shown in figure 2.

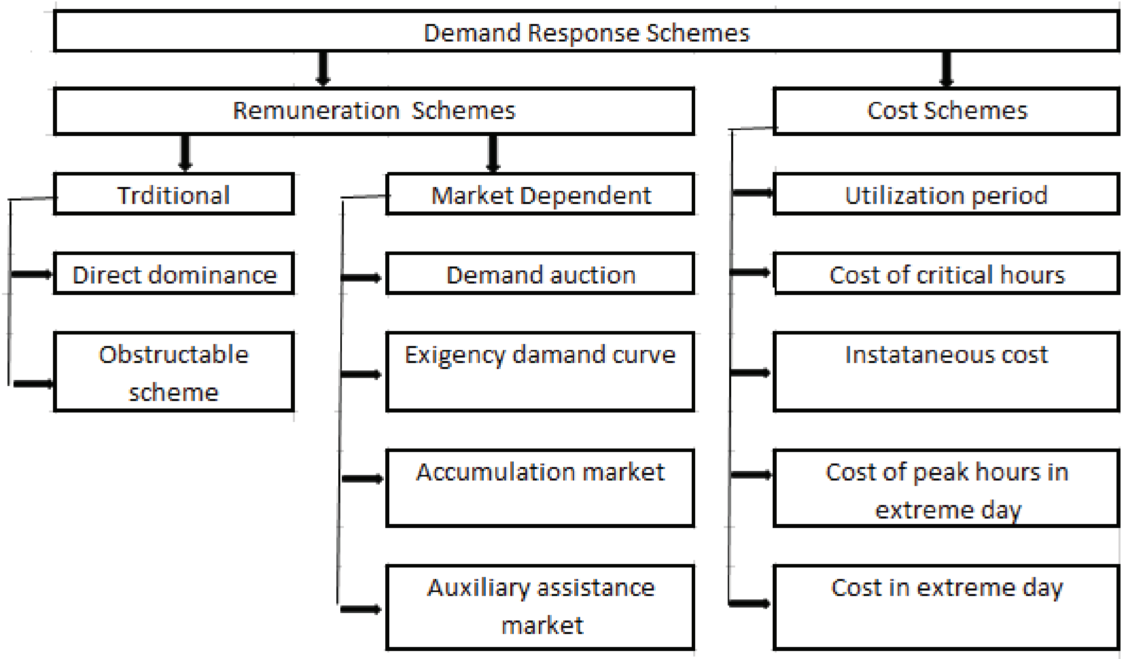

Figure 2. Classification of demand response schemes.

Energy Storage

For maximizing the level of DG penetration, energy storage is an essential part of renewable DG planning and execution. The charge storage is the key element to square up the challenges of solar and wind power generation for facilitating the futuristic opportunities of green environment. Energy storage system broadly classified in different form of energy namely; electrical, mechanical, chemical and thermal. Moreover, these methodologies have been compared in terms of technology, charge density, efficacy of retrieval, pricing, merits, demerits and applications.

The barriers for the effective implementation of battery storage are:

- Guidelines and practices adopted by distribution companies that disservices the energy storage.
- Capital cost, operating cost and maintenance cost for large-scale storage.
- Ignorance of battery storage merits.

Electricity pricing controlled by the administration normally do not facilitate the proper guidelines for saving of energy via energy storage. Moreover, the stockholders are not very much interested due to higher cost of the storage framework. In addition, the absence of remuneration for energy saving and less availability of justified literature are also affects the assimilation of such structure [11]. The cataloguing of energy storage system is shown in figure 3.

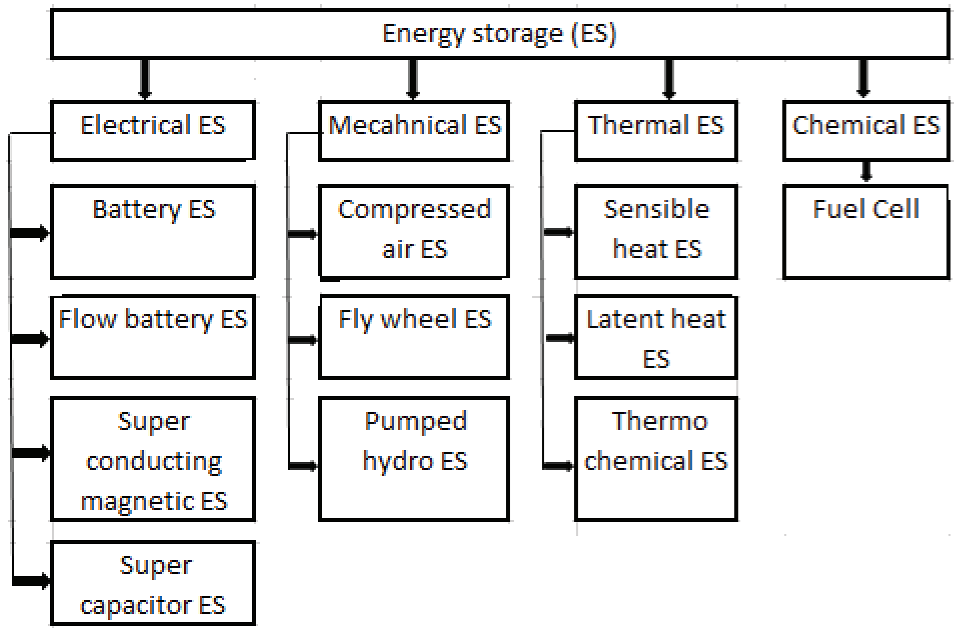

Figure 3. Cataloguing of energy storage system.

Renewable DG optimization

The frequency regulation of a DG has been carried out with the help of Moth Swarm technique of optimization, in which series of PI-PD controller is used through the incorporation of renewable energy based sources (like SPV and wind power) and energy storage devices along with electric vehicle. PI works in the primary stage while PD is in secondary and such a cascaded operation reduced the steady state error of the system in comparison of conventional PID controller, which directed to unstable transient response. For the MATLAB and SIMULINK realization, the gain and time constant parameters of SPV, wind power generator, fuel cell, fuel cell, diesel engine generator, electric vehicle and battery storage have been taken as the nominal parameter of DG [12].

An architecture of battery storage for the effective integration of distributed SPV system to avoid the circumstances of intermittent RER. Simultaneously the flexibility of grid irrespective of faults (circuit scale fault, substation scale fault and generation pant scale factor) is also comprehended that may cause of disturbance. Numerous type of battery storage architecture have been identified based on different type of working principle namely: In building distributed storage architecture, circuit / distribution storage architecture, substation / micro grid storage architecture, generation plant storage architecture and utility / grid storage architecture. The outcomes consisted the grid resilience maximization via optimizing the combination of battery storage system to increase the penetration level of renewable energy [13].

Authors proposed a technique mathematical apprehension of power and voltage quality enhancement by the amalgamation of DG in power distribution and this operation was carried out with the help of flexible multi-level switch. Loading frequency and power handling capability of feeder considered for the effective assimilation of DG with the feeder equalization. Moreover, a control framework of PI controller and a steady state converse model has been fabricated to optimize the different mode of flexible multi-level switch with the shortcomings [14]

Coordinated scheduling of renewable DG with the constraints of futuristic smart grid has been presented and such a combination is focused to sort out the disturbance due intermittency of RER. Firstly, renewable virtual sources are taken for the procedural implementation and then the obtained characteristics are simulated for designing the strategy framework. The recommended model has shown the potential to use the pumped storage energy to vanish the intermittency of renewable energy generation and got the effective forecasting with source shedding in view of profit maximization [15].

A Novel Filter is used for the prediction of distributed solar power generation, in which geographical propinquity of energy system affects the observations. Moreover, the intermittency in cloud formation and propagation have been considered for such model at a resolution of 1 minute. This bi-level methodology consist the estimation of PV power and lower frequency measurements of sampled data [16].

Authors presented a dumping cost to evaluate the soil contamination and new framework for delivering the electrical energy at unity power factor level to minimize the distribution energy losses. Consequently, the cost required for the power congestion management also reduced and it will enhance the level of futuristic smart city power project [17].

The voltage regulation of a distribution system has been improved with the use of solar PV DG as reactive elements and independent from the information exchange and feedback assessment. The backward / forward sweep algorithm has been used for the demonstrated methodology with the consideration of irradiance level of solar energy and ambient temperature [18].

A right way off for land utilization has been recommended due to higher cost of acquiring the space for such infrastructure. The unusable land near to railway track area, water storage land and highway could be used while offers a remuneration to the owner. A geographic information system is also developed to get the details of such type of land sources [19].

The augmented risk of renewable DG due to intermittency of climatological and atmospheric condition have been highlighted with the proposal of adaptive forecaster subgroup assortment strategy for enhancing the forecast. In this two level approach binary genetic algorithm is used for the selecting the characteristic and backing of regression based vector is applied to calculate the suitability level of the estimator. The accuracy has been enhanced by 58.4% in comparison of real prediction method [20].

A case study of wind power generation as a DG to meet the demand of rural America has been analyzed and the time period till 2015 is called as pre wind era and after this post wind era. A graphical presentation has been demonstrated for the variation in the development of residential, commercial and industrial customers over the last five years of span. Along this wind speed, atmospheric temperature and load demand are also taken into account [21].

A simulation test has been done to investigate the survival of wind power generation as distributed energy sources during the abnormal condition of power failure. Seven-scenario system (Without DG, downstream, mid-way, upstream and four types of wind power generation) has been adopted to validate the results [22].

Table 3. Comparative assessment of renewable DG optimization.

Ref.	Optimization approach	Optimized parameters								
		DG Capacity / Size	DG location	System losses	Voltage profile	Cost	Calculation time	Fitness value	Power factor	Reliability
[26]	Particle Swarm Optimization	ü	ü	ü	ü					
[27]	Particle Swarm Optimization algorithm and Grey Wolf Optimization algorithm	ü	ü	ü	ü					
[28]	Coordinated optimization			ü	ü		ü			
[29]	Dragon fly-Partcle swarn optimization	ü	ü	ü	ü					
[30]	Coyote Optimization Algorithm			ü	ü		ü	ü		
[31]	Generalized Benders decomposition			ü	ü	ü			ü	
[32]	Distributed generation management algorithm			ü					ü	ü
[33]	Data-driven distributionally robust optimization					ü				
[34]	Particle Swarm Optimization			ü	ü					
[35]	General Algebraic Modeling System		ü	ü	ü					ü
[36]	Particle Swarm Optimization	ü	ü	ü	ü					
[37]	Corrected moth search optimization	ü	ü	ü	ü	ü				
[38]	Genetic ant colony optimization			ü	ü		ü			
[39]	Multi-objective modified symbiotic organisms search	ü	ü	ü	ü	ü				

Due to the progression in large heat pump projects, many countries are required to advancement in the traditional grid system, which offers the possibilities of RER. For the effective integration of heat pumps with the wind power generation in distribution network, a mathematical model has been presented with the objective of profit maximization and cost reduction [23].

Wind power generation as DG has been used for the voltage profile enhancement, loss reduction and ecological benefits in the distribution network. A power control curve optimization approach has adopted for the speed regulation of windmill rotor and the optimized parameters are energy losses and voltage quality [24].

Multi objective function of DG size and allocation optimization has been considered for the operating cost, capital cost, environmental cost, wind and light abandonment cost subjected to voltage, current, equation flow and DG capacity constraints. The realization has been done with the implementation of particle swarm optimization method in wind power turbine, solar PV and gas fueled micro turbine generator [25]. A comparative assessment of renewable DG optimization is given in table 3.

Conclusions

To meet the energy demand with atmospheric constraints, DG is one of the important aspect of energy contentment and assimilation of RER are essential. The effective execution of renewable energy based DG are obligatory the more precise model of weather forecasting to avoid the energy intermittency and ensure the continuous power flow. Demand response program enables the energy management from consumer's side, in which the requirement of the energy is optimized to face the challenges of expansion of power system or possibilities in terms of renewable DG implementation. Subsequently, an adequate energy storage system is also enhanced the probability of incessant energy availability. A comprehensive framework and planning of natural energy based dispersed generation and optimization processes are evaluated in this paper. The outcomes of this evaluation can be summarized as; for a new environmental friendly energy world, the forecasting of RER availability are necessary accompanied by demand management and energy storage system.

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