A Review: Integration of Distributed Generation in Distribution System

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***Abstract*—Electrical energy plays a vital role for the evolvement of human race. As an increase of rapid development of developing countries, the demand of electrical energy is also increasing quickly for domestic, agriculture and industrial purposes. The conventional energy mostly uses fossil fuel, and fast consumption of conventional energy re-sources is depleting and likely not to be available for the next generations. Also the conventional energy producing a large amount of greenhouse gases, which is abolishing the environment. To overcome, the degradation of the environment, distributed energy sources must be used. But the continuing availability of energy is a major problems associated with non-conventional energy, because of that, many authors involve in design, planning and implement various types of optimization techniques or methods to overcome above optimization problem. Continuous evolution of computer hardware and software helps the researchers develop different type of optimization problem in the renewable energy field. This paper deals with the latest research on optimization technique and development of renewable energy.**

1. INTRODUCTION

According to law of Thermodynamics "Energy cannot be destroyed or created, it can be transformed from one form to another". This paper discusses various optimization techniques by which different renewable energy efficiently integrated and utilized by the distribution system. Energy consumption is an important parameter to indicate the standard of living of society. The developing countries have very high demand of energy which is required for overall development of industrial, agricultural purposes [1]. The resources of conventional energy are scared and have been over exploited at the cost of environmental degradation. According to the latest research if the above situation continues, then after some time the present conventional energy resources are not available on earth. The conventional energy sources are emitting greenhouse gasses that degrade the environment [2]. Natural balance has been adversely affected by this degradation like melting of ice in polar regions and water level increases gradually.

To protect the environment for next generation, it is important to develop distributed energy sources, so that dependence on conventional energy is reduced [3]. There are two ways of generating distributed energy sources as an integrated system with large existing power system or stand-alone system. The government decisions are important to reduce installation and integration cost as compared to conventional method to enhance the penetration of renewable in energy sector. So that setting of a renewable energy plant will be more acceptable than conventional sources [4]. It's important to decide the type of energy generation system at a particular place because of the factors where the place having sufficient availability of this energy. Many authors evaluated many distributed energy sources for sustainable development such as Wind, Hydro, Geothermal, Solar, Bio-energy etc [5]. Also mentioned many merits to use this energy such as price of generating electricity, greenhouse gas emission, land requirement, availability of resources, efficiency. Evans et. al.

[6] determines that wind power has a good social impact and emitted lowest amount of greenhouse gasses, but it involves a high amount of land. Lund et. al. [7] investigated a strategy to improve the sustainable development of the country by three major factors, i.e. energy saving technique, energy efficiency improvement and replacement of fossil fuel. The modern technological development of renewable energy had a great impact on sustainable development and has given a solution to the common environmental problem faced by the human being. The Various suitable optimization algorithms has been developed for solving complex situation arise while investigating the system of renewable energy. Some of the investigator has reviewed different type of modeling structure of renewable energy, problem of harmful emission and model for energy supply Vs demand for forecasting and control of optimization technique, also many researchers suggesting many new methods in distribution system [8]. This paper shows the update information on optimization method that is a apt subject for future researchers.

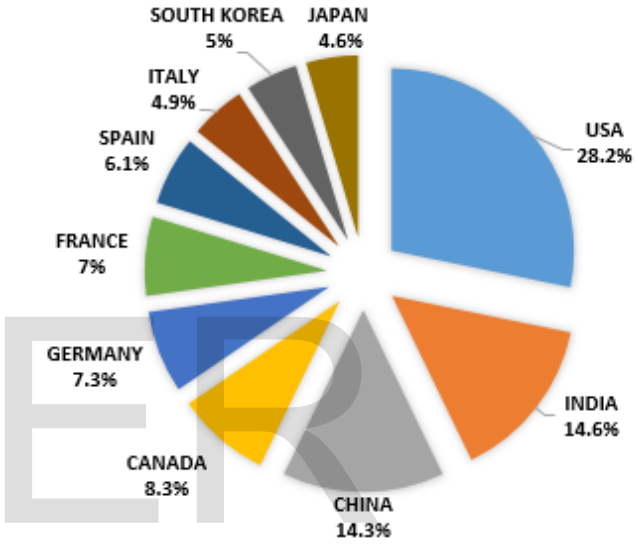
2. OPTIMIZATION TECHNIQUES

Optimization is a tool which needed in every small/large organization for taking hard decision and solving different type of problems. Mathematical optimization [9] is a process to find minimum and maximum value of real function by choosing inputs within range. Combinational optimization [10] is an important field of optimization where it deals with the various algorithms that should be solved many discrete and combinational problems. The combinational optimization problem associated in various fields such as VLSI technology, corporate planning etc. computational optimization is a type of optimization

technique where it developed efficient and correct algorithm to solve different optimization problem such as unconstraint, constraint, network optimization. Computational algorithm also used in the industry to give the maximum profit and reduce the cost of the product. It helps to design a computational model based on a mathematical formula and implement the model by software engineering. Some optimization problems come up in mathematics and computer science which is inherent intractability means complex in nature, so it's very difficult to find algorithm for the optimal solution, this problem is called NP-Complete problem [11]. The optimal feasible solution is not found in this type of problem and it takes lots of time to find the optimum solution. To overcome this type problem various approximate methods (ANN, heuristic approaches) are used but previously traditional optimization methods are used. Traditional optimization techniques are linear programming (LP), Lagrangian relaxation (LR) etc. Heuristic methods are simple procedure which gives satisfactory solution but not give necessarily optimum for large scale complex optimization problem. Meta-heuristic methods are the generalized form of heuristic method, that also applied in various type of problems [12]. Some case complexity of the problem is very difficult that heuristic and meta- heuristic technique does not give the optimal solution in specific runtime. Some cases parallel processing technique is used to get a good and optimal solution in reduced run time [13]. Commonly used method for characteristic meta-heuristic algorithm is dependent on trajectory method vs. population based method while various available methods are nature inspired vs. non nature inspired method. Trajectory heuristics are a type of meta-heuristics process where outcome is a single solution when it use single function during the search process and. The main trajectory heuristics methods are Taboo search (TS), Hill Climbing (HC), Iterated Local Search (ILS), Variable Neighbourhood Search (VNS) And Simulated Annealing (SA) etc [93-95]. Population heuristics technique are a type of meta-heuristics process that uses a more than one no of solution which change after every iterations and outcome is a huge no of solutions at the end. The main population heuristics methods are ACO, PSO, ABCO, Memetic Algorithm (MA), GA, scatter search (SS) etc[12-14].

It is seen that most of the computational optimization method concentrated on solving single objective function, but there exist a large number of applications on optimization problem where more than one objective function is present. Some author proposed multi objective algorithm to reduce the clash between the objective function at the time of an optimum solution. Multi-objective algorithm can be divided into two categories that are aggregate-weight function and Pareto-based optimization methods. Aggregate-weight functions are the combination of all the objective functions to a single objective function mathematically [15]. This single objective function describes the weight codes that relate all the combined objective function respectively. The limitation of this method is to adjust the weight of all objective functions in a single objective function. This objective function gives us a particular solution in search process which helps the decision maker to take the decision. Some drawbacks of aggregating functions can be resolved by Pareto-based optimization technique [16]. Multi objective meta-heuristics classified into trajectory method and population based method.

The below figure shows that paper submitted by the different country on optimization technique applied to renewable energy, figure only cover data from 10 countries.



3. OPTIMIZATION METHOD IN DISTRIBUTED GENERATION

Energy is an important and basic foundation of economic development and sustainable growth of a country. Researchers have carried out for different technologies in the energy system and also they propose many optimization methods and technique to deal with the problems of distributed generation [17]. In the recent scenario the demand for energy is increasing rapidly due to improvement of state of living, as major problem is distribution of this energy. Designer has a dual responsibility to overcome the problem presently faced in each type of renewable energy and to make them cost effective and long-lasting for the future generation. Community scale point of view there are different problems, i.e. allocation of energy resources, policies and also another point of discussion is the energy security, energy structure and economic cost. This complex problems are solved by ILP technique or MILP technique. Some author uses this technology to get the maximum energy security with a

minimum investment cost and increases the reliability of the system [18]. Kahraman et. al. [19] applied fuzzy based multi criteria, procedure to choose the best alternative among distributed energy sources.

Connolly et. al. [20] integrates the distributed energy sources to the various energy system and analysis the data with computer tools in different circumstances. Some author uses MIP, GA, SA and TS for solving different problems related to the distribution of energy in a transmission line [21,22]. According to Zangeneh et. al. [23] research few renewable energy has the ability to work successfully in this competitive market and it has limited resources in some region of the world. The author suggested Pareto-based multi-objective algorithm for optimal design of some distributed energy sources such that wind, biomass, solar, etc. Cai et. al. [24] combines ILP method and Fuzzy logic for generating long term distributed generation source management plan, it helps to identify the different policy under different system constraints. AIRashidi and EL-Naggar et. al. [25] suggested a PSO algorithm with the goal for minimizing the error in model parameter. Decorato et. al. [26] applied LP procedure in the optimization technique to determine the production of primary energy sources, also determine the power or heat generation and emission of different gases.

Now a day different optimization methods are used for the small period energy plan due to the uncertainty of supply [27,28]. More important things in the present scenario are to generate large scale production of distributed energy sources and connect it to the electric power system. Some author uses ANN technique to determine the energy demand[29]. Mitchell et. al. [30] developed a simulator of distributed energy sources to determine the energy flows and scheduling of power in grid connection or in stand-alone system. According to some researcher problem associated with energy are complex and it requires a multiple decision making method and multiple criteria for optimum solutions [31-33].

The electric power generation by renewable energy is difficult to control and storage. The best solution for the above problem is that to produce the required amount of power and distribute it to the consumers via the system to ensure that the need of the power and generation of power should be balanced. Franco and Salza [34] mentioned various types of optimization method for solving different problem on new distributed energy sources. Niknam et. al. [35] derived an excellent algorithm in which base was made on fuzzy adaptive PSO. This algorithm has given optimal solution of the electric supply distribution system to obtain a comparable solution with GA, PSO, DE, ACO and TS. The system has further improved the energy using energy storage technology. Some of the Author suggested method to derive the strategy of a combine power system having renewable power and storage power. One main advantage of renewable energy has an unlimited resource for multi operation purposes such as water pumping, water distribution, etc. some authors use photovoltaic cell, windmill, biogas for direct water pumping [36]. Other authors use indirect pumping the water by generating electricity [37]. Presently a high amount of energy is consumed for water supply system. Vieira and Ramos suggested wind-hydro hybrid system for water supply system.

4. DISTRIBUTED ENERGY

Distribution generation refers to smaller scale type generating plant which is present at the load centre or near the load centre. This type of generation minimize the transmission and distribution loss and increased the voltage stability of the system. Also due to this type of generation reliability of the supply system is increased. Different type of distributed energy sources are given below-

4.1 WIND ENERGY

Wind energy is an important source of distributed energy. A wind farm/wind turbine can harness the power from the wind and use it for generating electricity. According to Hernandez et. al.[38] wind is periodic in nature. The population of the earth gradually increasing hence it is necessary to develop optimal design of small scale grid connected wind power station at the geographical position to fulfil the demand [39]. It is not possible to get wind power at every place because of the geographical structure of the earth. It is unpredictable as compared to other distributed energy sources. Wind farm are situated in the offshore, high altitude, position and open plain based on technical data of wind [40]. Wind farms are designed based on topological location, wind speed data, potential of wind energy and location of load centres to wind energy generated farms. Zhao et. al. [41] design GA where input is component of wind plant and key specification, then design an optimal wind station where system reliability and production cost will be optimized.

Many researchers are doing research to design wind turbine and wind farm layout to get optimum output, output of a wind turbine is the function of air density and the wind speed at that position [42]. Power quality of wind turbine can be easily calculated by numerous matrices i.e. power factor, active power, reactive power, etc. Some Author design a multi-objective evolutionary algorithm (MOEA) to configure the rotor of a horizontal axis wind turbine with only one aim to get the maximum output [43,44]. Maalawi and Negm [45] developed an optimization model to design the blade structure of horizontal wind turbine where the variables are cross-sectional area, length of section and radius of gyration. Li et. al. [46] optimizes gearbox ratio of wind generator using GA. Roy et. al. [47] determines a methodology to optimize

the rotor and other component of stand-alone wind-battery hybrid system. Fuglsang and Thompson [48] design a numerical algorithm with the help of an aero elastic load prediction code. . It is not possible to get power at every speed of wind, there is some cut in and cut out speed of wind so that some author proposed mixed-integer nonlinear programming (MINLP) to determine the optimal capacity of the wind taking account the speed of the wind [49]. Hameed et. al. [50] presented an algorithm to monitor the performance of wind turbine. Several researchers are determining that data using fuzzy logic and power curve estimation [51]. Another important parameter of a wind power station is the layout of the wind farm. Author Grady et. al. [52] suggested GA to estimate the optimal position of wind turbine in a wind firm. Herbert et. al. [53] uses Pareto-based analysis to determine the performance, reliability of wind firm. Mustakerov and borisson [54] proposed a MINLP optimization algorithm to dcalculate the number and type of wind turbine in a firm.

One major problem of wind generation is the uncertainty of power supply. Some author proposed fuzzy technology to get the maximum profit with minimum risk of uncertainty [55]. kusiak and li [56] suggested a methodology to determine the wind speed of any position by analyse the wind speed of neighbour location. Zhang and Wirth [57] proposed a planning upon the wind power plant for short term energy management, in which external battery storage should be present to supply the power of the external grid at the time of energy shortage or absorbed the power from the sources at the time when demand is low. Kuo [58] proposed a multi-objective energy dispatch, which consider two components, i.e. environment and fuel cost

4.2 SOLAR ENERGY

Solar energy is the most convenient, clean, universally available source of renewable energy. In many places it is the most dependable source of energy. This energy is available in the day time and almost full year. It is more predictable than other source of renewable energy. Mainly two types of designs are used to convert solar energy. In passive solar design the optimal building captures the sun radiation and use it for artificial lights or heating of buildings (which is called solar homes) in low temperature zones [59]. Now a day energy efficient building is the main priority in the world wide [60]. Active solar design is used for heating water where solar energy is converted into heat energy and electrical energy using PV cells. Hence the radiation data are needed for optimum design of active and passive solar energy systems. The radiation data of location are found out by radiometric stations with a low spatial resolution. The interpolation and extrapolation techniques are applicable where the spatial variability is not accurate. Bosch et. al. [61] proposed an artificial technique based on ANN for calculating the solar radiation data over the mountain area; also Neuro-fuzzy technique is used for forecasting the solar radiation.

The stand-alone photovoltaic system is needed Energy storage facility for continuous power supply to the grid. The effective technology of storage must be developed and implement for large scale utilization with suitable initial and running cost [62]. The industry of grid connected photovoltaic power has been attention to price declines that's why many projects are developed in this market [42]. Kalogirou [63] uses ANN and GA for solving the problem of maximum economic benefits of solar energy system. Aronova et. al. [64] presented an optimization method to estimate the energy generated by photoelectric power modules, also estimate the different management of modules at different location where the area required for single module is fixed. Szargut and Stanek [65] solve the problem with the performance of a solar collector by correctly measure the collector area per unit of heat demand, the distance of the pipe axes in the collector plate and the diameter of collector pipes. Varun [66] presented a GA model for maximizing the performance of the flat plate solar heater with the help of different system and different operating parameters. Chang and Ko [67] presented a hybrid technique which combines nonlinear evaluation with PSO for deciding the tilt angle of solar module to get the maximum output from them. A complex problem to design a stand-alone photovoltaic system is sizing of the system. The goal of optimum sizing is to get the acceptable energy, power quality improvement and supply the customer at economic cost. Mellit et. al. [68] analysed the performance of different solar system and presented ANN and GA for sizing photovoltaic systems. Li et. al. [69] uses hybrid energy storage technology to solve the problem of sizing of a stand-alone photovoltaic system. Kornelakis and Marinakis [70] have also appliedthe PSO technique to this problem. To get the maximum energy output from Solar PV cells, they must be operating at maximum power point to get the maximum efficiency according to irradiation and cell temperature. Fong et. al. [71] presented EA to maximize the energy saving in solar heating respect to conventional energy heating.

4.3 BIO ENERGY

It's been estimated that just one-eighth of the total biomass can fulfil the demand for energy of total humanity. The meaning of biomass in this context is living things like plants, animals, fungi, bacteria etc. Biomass energy is an essential sources of distributed energy. Easiest way to get Bio-energy from biomass is direct combustion or anaerobic digestion process. In these processes a huge amount of heat is generated which is used for generating electricity or used for various purposes like water heating, water pumping etc. Biomass also produces different types of bye-product like bio-

diesel, ethanol, producer gas and biogas (methane, carbon-dioxide). Around the world total 50 countries generate electricity from biomass. European countries are generating a percentage of demanded power from biomass such as Austria (7%), Finland (20%), and Germany (5%). In some places biogas is generated from waste material and uses it for several purposes like IC engine, household etc. According to a survey it is seen that India's potential for power generation from biomass is 5200 MW by 2017. Sustainable power can be generated from biomass [72], According to price, efficiency, availability, social impacts and greenhouse gas emission it is more sustainable. Reche et. al. [73] suggest a PSO algorithm that can determine the optimal location for distributed power generator when uses forest residue as an input fuel. A huge number of authors uses PSO algorithm to get the optimal location and supply area from which generates maximum power from bio-energy plant [74, 75]. In recent scenario vegetable oil fuel is a primary interest for generating bio-diesel [76] because of the oil crisis and this is a clean and environmental friendly fuel. Sharma and Singh [77] introduced a report where investigation about various ways to produce bio-diesel is carried out. Alfenso et. al. [78] evolves a technique to estimate energy produce from biomass resources with some constraints such as Co2 emission balance, plant size, heat generation and demand of consumers. Presently electricity is generated by the gasification of biomass. Due to the increasing demand of bio energy by gasification some model have been designed to explain the process, design and optimization of gasifiers based on kinetics [79].

4.4 SMALL HYDRO POWER

Hydropower is the power harnessed from the water for useful purpose. It is ultimately derived from the sun, which drives the water cycle. Kinetic energy is embodied in the flow of water. It is an important source of energy for mankind through the ages. It can be used for various purposes like generating electricity, grind grain etc. small hydropower plants are an important sources distributed energy sources in hilly area. In future planning power is not generated from large hydro power plant because it has an adverse effect on the environment. Many countries are now generating electricity from small hydro power plant. Carbon emission is negligible in small hydro power plant. In addition to hydropower, ocean power is generated from ocean waves and tides. The present day thinking of planners is not to establish very large dams but to design appropriate size of a Run-of-river type small hydro power plant, According to cost effectiveness of investments. Agnostopoulos and papantonis [80] represented a EA for analysing the sizing of a small hydropower plant also it simulate the operation to get maximize the economic benefit. Pena et. al. [81] determines the capacity of small hydropower plant, according to time series forecasting. Yoo [82] proposed traditional LP method to generate the maximum energy in small hydropower plants from their optimal value calculation, also it analyze the model sensitivity and determine the reservoir capacity. Hongling et. al. [83] proposed a review on hydro power plant with the uncertainty in profit risk, also signifying the scope of research and give the direction. Ladurantaye et. al. [84] examined mathematical modeling technique at maximum profit, acquired the value by selling electricity in a relaxed market when it is generated from a cascade of dams and reservoirs. Finardi et. al. [85] completed the optimal scheduling of hydrothermal system by the use of linear programming. Liu et. al. [86] mentioned a LP program for small hydropower plant in portfolio problem with uncertainties in market prices. Author Khanmohammadi et. al. [87] solved the unit commitment problem using PSO algorithm, stochastic programming. Foong et. al. [88] applied a method which combines ACO and plant maintenance scheduling for solving maintenance scheduling problem in a hydropower plant. The operation of a reservoir in a hydropower plant is to continuously measure the water level of it and the volume of water released from it.

4.5 HYBRID POWER

It is experienced that single source of renewable energy is not reliable and stable. In such cases, planners are planning hybrid power plants having components of solar power, wind power etc. The efficiency of each system is harnessed to create a stand-alone hybrid power plant for a particular load centre [89]. Hybrid system is more cost efficient and more dependable than single distributed energy sources. Aim of hybrid energy system is to contribute the energy to the peak load at minimum cost. katsigiannis et. al. [90] design a multi-objective algorithm to minimize the energy cost and greenhouse gas emission. Some practical economic dispatch problem has non-linear and non-convex type objective function, so general optimization methods are not capable of solve such problems. Brini et. al.[91] and Bernal-Agustin et. al.[92] solved economic dispatch problem of a hybrid system with the help of MOEA that decreases the fuel cost and the greenhouse gas production. Ould [93] and Bilal et. al.[94] suggested multi-objective GA technique to design solar-wind-battery hybrid system to reduce the loss of supply. The Hybrid energy sources are more admired in remote areas due to advancement of Renewable energy techniques. Some paper discusses various techniques like LP, fuzzy logic to supervising the production system of hybrid system [95,96]. However, it is difficult to design a hybrid system because of uncertainty of load demand, basic sources and non-linear characteristics of some components. There is some conflict objective of combining conventional and renewable hybrid sources, but some author deal with this problem by combining two renewable sources technology

and cost etc. Author Giannakoudis et. al. [97] suggested an optimization method to design a hybrid system that consists of wind generator, accumulator, hydrogen storage tanks, photovoltaic panels, fuel cell etc.

In some remote villages energy is supplied from isolated electrical power units because the grid extension is impossible in this area. Bernal-Agustin et. al.[98] analyzed the strategy of a complex PV-wind-diesel-hydrogen hybrid system along with storage technology. Some author use GA for optimal configuration of a distributed energy sources on an island where the system consists of a wind turbine, batteries and photovoltaic cell [99]. Balamurugan et. al. [100] introduces a biomass-wind-solar-battery hybrid system to deliver peak load demand at the time night and low wind speed. Nema et. al. [101] evaluates to design a stand-alone PV- wind hybrid system with conventional backup sources and attention to the future developments.

5. CONCLUSION

This paper gives us a review of latest research on renewable energy also discusses many optimization methods to design, planning and controls the energy sources. Distributed energy sources are improve the reliability and stability of the system also efficiency of the system is increased. It is concluded that recently in the field of distributed energy many research paper is submitted mainly on solar and wind energy and increasing gradually. The reviews of two hundred journals/papers will be very useful for another designer to study the different method in distributed energy field. Many algorithm are based on general traditional method of research i.e. interval linear programming, mixes-integer, Lagrangian relaxation, etc. but in modern time, many researchers are not following traditional method and they are advising new methodology research work using heuristic methods which are very useful in planning, designing and optimum utilization of energy. Some of the designers have solved the multi-objective problems which are associated with renewable energy using Pareto optimization technique. In addition to the above these are other techniques which have been explored in solving the problems and encountered in technological development. Multi-objective optimization technique are futuristic research areas in the field of distributed energy.

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