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A Comprehensive Review of Literature on Application of Distribution Generation in Smart Grid Application

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***Abstract* - Smart Grid is future of the mankind. Embedded Applications, Power Generation and Distribution are integral part of smart grid application, and plays vital role in proficiency, performance, efficiency and stability of the system. Wide area distribution of embedded application in smart grid; demands critical focus on each integral part of Smart Grid System. Distributed Generation is most important part of any smart system. Application of Distributed Generation enhances efficiency, stability and profile of Smart Grid. This research article investigates the technique used in distributed generation in smart grid system. A comprehensive investigation is presented which includes key issues in the DG integrations; various DG technologies used so far, advantages and disadvantages of penetration of DG in smart grid application and research gap in the respective field. The article also discusses the penetration of DGs in the Indian power system in multidisciplinary context.**
***Keywords:* Distribution Generation, Smart Grid, Power System Profile, Stability, System Performance, Voltage Stability**

I. INTRODUCTION

Distributed Generations frequently represented as DGs is upcoming power injection technique which is gaining popularity among Industrial sector, Corporate Houses and research scholar across world with smart grid application system. In objective to exploit potential advantages of the DGs, this is mandatory to carry out further research in basic philosophy governing power distribution system. Smart Grid integrates efficiently and effectively small and medium size power generation utilities in to power application as per the demand and requirement of the power consumer. The prime objective of DG is to act as back-up power to improve the reliability of the system in case of break and also as a means of the deferring investment in the transmission & distribution networks. DG also avoiding the network charges in application, reducing the line losses, also deferring the construction of the large generation facilities. The DG also displaces the expensive grid supplied power, providing the alternative sources of the supply in the markets & provides the environmental benefits in comprehensive context. But depending upon system configuration and the management, above mentioned advantages can't be achieved. In the recent time, Distribution Generation has become very efficient & clean alternative to traditional electric power sources and advancement in the present technologies enhances capability of DGs economically feasible and profitable to the application. In recent time, DGs are the part of the distributed energy resources which also include the energy storage and the responsive loads.

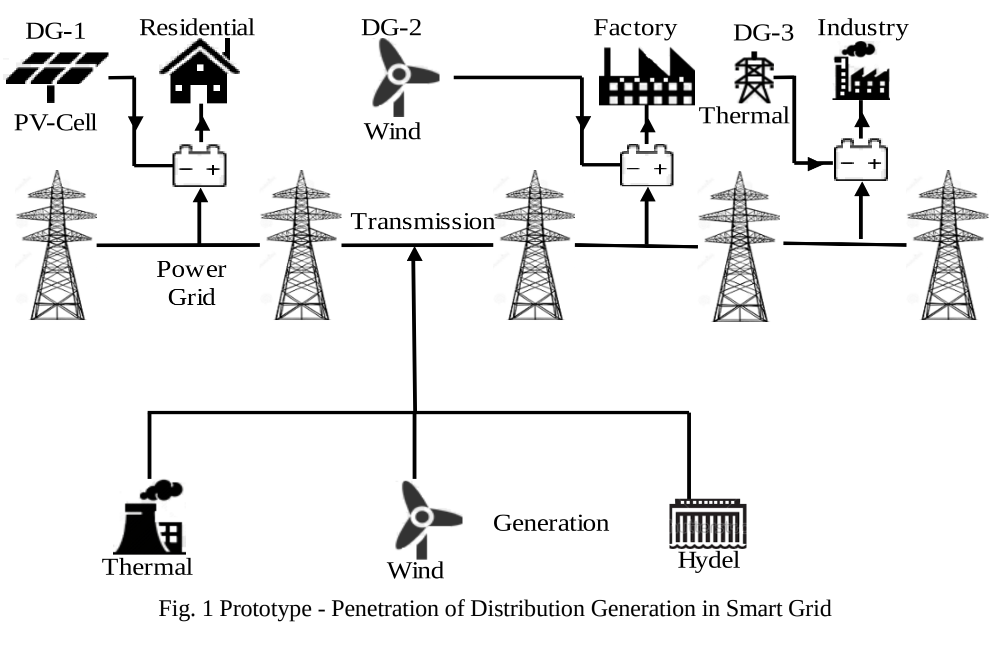
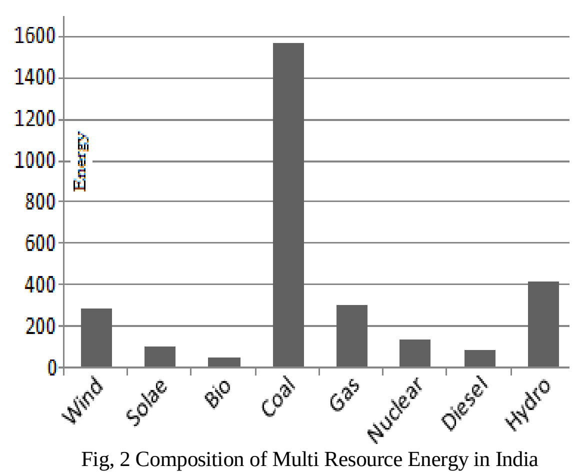


Fig. 1 Prototype - Penetration of Distribution Generation in Smart Grid

The encouraging forces behind increased penetration of the distribution generation can be categorized multiple sector like Environmental Commercial and Regulatory factors. Numbers of small DGs are available now a day equipped with sophisticated and advance technology which produce very small or almost no greenhouse gas emissions. Other factor which encourage for DG application is that DGs reduce the transmission & distribution expansion along with avoidance of the large power plants. The uncertainty in the present electricity markets also encourages small generation schemes for personnel applications. As now a day's the DGs are cost effective to enhance the power quality and reliability so these qualities of DGs had provides an effective alternative. The major regulatory drivers for utilization of the DGs are diversification of energy sources which in result enhance the energy security and stability. As DGs are distributed along the smart grid; this propositions make DGs as very effective utility for profile management of power system in segments. There has been much research work in areas of the DG technologies application, positioning and sizing of DG, impact studies of increased penetration of DG on power application in multi dimension, economic & financial analysis coupled with the DG integration. Owing to wide scopes, this is bit difficult for the researchers, policy makers, and also for academicians to read all the related materials at once as the integration and penetration of DG is multi-dimensional phenomenon. Various research conclusions related to DGs technology and integration are presented in this article. This is very important for researcher to understand key issue of large penetration of the distributed generation in power application. This aspect had also been addressed in the research presented.



Fig, 2 Composition of Multi Resource Energy in India

II. LITERATURE SURVEY

A number of publications have looked at optimizing the placement and sizing of DG based on various criteria. In Wallace and Harrison (2003), the authors employ an optimal power flow (OPF) technique to maximize DG capacity with respect to voltage and thermal constraints. Short circuit levels, short circuit ratio, equipment ratings and losses are not considered. The effect of network sterilisation is clearly demonstrated by comparison between allocating generation to buses individually rather than as a group. In Vovos *et al*., (2005), a method is presented utilizing OPF for the allocation of generation capacity, which includes a detailed fault level constraint. In Kuri *et al*., (2004) genetic algorithms were used to place generation such that losses, costs and network disruption were minimized and the rating of the generator maximized.

The constraints considered were voltage, thermal, short circuit and generator active and reactive power capabilities. Generation is placed in single units at individual buses, while ignoring the interdependence of the buses and the network sterilisation that can result from improper DG placement. In El-Khattam *et al*., (2004) the authors use a heuristic approach to determine the optimal DG size and site from an investment point of view. Once again short circuit constraints are not considered and the focus of the objective function is on optimal investment rather than maximizing renewable energy. It uses a cost benefit analysis to evaluate various placements of DG. In Dugan et al. (2001), a planning process that considers DG as well as more conventional options is presented. DG investment in considered under a number of load growth scenarios, with its benefit found to vary between each scenario. However, it is still found to be a useful factor to be considered in the distribution planning process along with other more conventional options such as network reinforcement.

M.Gandomkar, M.Vakilin and M.Ehsan [1] have studied on "A combination of genetic algorithm and simulated annealing for optimal DG allocation in distribution networks". Their Paper presents a new algorithm based on integrating the use of genetic algorithm and simulated annealing methods to optimal allocation of distributed generation resources in distribution networks. Through this algorithm a significant improvement in the optimization goal is achieved. With a numerical example the superiority of the proposed algorithm is demonstrated in comparison with the simple algorithm.

Other publications have focused on reliability aspects of DG. In Celli *et al*., (2005), a multi objective planning strategy is presented using a genetic algorithm to identify the best compromise DG sizing and sitting. In Chowdhury *et al*., (2003), a probabilistic reliability model is presented to determine the impact of DG for use in distribution planning studies. In McDermott and Dugan (2003), the impact of DG on reliability and power quality is measured. Reliability and power quality indices were applied to a sample feeder to assess the impact. Work has also been done evaluating the contribution of wind generation, in particular, to reliability (Clark and Miller, 2006; Karki *et al*., 2006).The issues of load growth and load patterns in distribution planning are discussed in Willis (2004) and a multi stage approach to planning is described in Kuwubara and Nara (1997). In Quezada *et al*., (2006), the amount of losses incurred with increasing penetrations of various DG sources is examined. In Wang and Nehrir (2004), the authors propose a method which places DG at the optimal place along feeders and within networked systems with respect to losses. The allocation of losses to distributed generators in the network has been addressed in Costa and Matos (2004). Previous work has attempted to quantify the net benefits of DG (Chiradeja and Ramakumar, 2004), where a number of benefits such as reduced losses and voltage profile was assessed.

M. Sedighizadeh and A. Rezazadehhave proposed a methodology in which genetic algorithm has been used for distributed generation allocation targeting losses and voltage profile. Their paper presents a method for the optimal allocation of distributed generation in distribution systems. In their paper their aim was to allocate the distributed generation for voltage profile improvement and loss reduction in distribution network. Genetic algorithm was used as the solving tool, which referring two determined aim; the problem is defined and objective function is introduced. Considering to fitness values sensitivity in genetic algorithm process, there is needed to apply load flow for decision-making. Load flow algorithm is combined appropriately with GA, till access to acceptable results of this operation. They used programming under MATLAB software and applied ETAP software for evaluating of result correctness. They implemented on part of Tehran electricity distribution grid. The resulting operation of this method on some testing system is illuminated improvement of voltage profile and loss reduction indexes.

Hasan Doagou and G.B. Gharehpetiana mentioned in their paper entitled “Optimal placement and sizing of DG (distributed generation) units in distribution networks by novel hybrid evolutionary algorithm” published in Elsevier presents an interactive fuzzy satisfying method, which is based on Hybrid Modified Shuffled Frog Leaping Algorithm, and should solve the problem of the Multi-objective optimal placement and sizing of DG (distributed generation) units in the distribution network. Minimizing total electrical energy losses, total electrical energy cost and total pollutant emissions produced are the objective functions in this problem. Also, the improvement of the voltage profile is considered as a constraint in determining the optimal placement. In the proposed method, the objective functions are modeled with fuzzy sets. The multi-objective problem is transformed into a mini–max problem, which is then handled by the proposed evolutionary algorithm.

III. RESEARCH GAP

After investigating numbers of research articles on respective field, we have concluded few of the important outcomes and conclusion from important issue in previous paragraph. In the table below, a research gap in the field of the distribution generator has been presents.

TABLE I RESEARCH GAP IN DISTRIBUTION GENERATOR IN THE CONTEXT OF SMART GRID

Title and Authors	Finding	Research Gap
“Impact of multi Distributed generation on key parameter in Distribution system” S. Anawatanaporn; A. Ngaopitkkul IEEE, Advances in Power System Control, Operation & Management, Year: 2015	a control scheme that implements a smart and simple strategy to support the fault: the maximum voltage support for the lowest phase voltage	Did not discuss about injects maximum rated current of the inverter, and balances the active and reactive power references to deal with resistive and inductive grids
"Distributed generation planning considering voltage stability: A literature study" W. T. Liang; Y. Xu; Z. Y. Dong IEEE Conference on Advances in Power System Control, Oprtion & Mmgmnt, Year: 2015	Multistage dynamic expansion planning problem is solved by Quantum Particle Swarm Optimization. The proposed algorithm is paralleled with the standard Particle Swarm Optimization.	Stability, profile and efficiency issue did not discuss. Also economic aspect of investment and revenue generation is totally ignored.
"Optimal placement of Distribution Generation in weakly meshed Distribution Network for energy efficient operation" B. Chalapathi, V V S N Murty IEEE Conference on Power, Control & Communication, Year: 2015	Power electronics based smart transformer has been proposed for profile improvement in Smart Grid System. Ancillary services also discussed. Principal of working with effect on system is briefed.	Effect on embedded system due to penetration of smart transformer in smart grid is ignored which is demand of tie with the growth of expansion of power system.
"Review of methods for optimal sizing and siting of Distributed Generation" Prem Prakash; Dheeraj K. Khatod 2015 Annual IEEE Conference on Power system, Year: 2015	Method for optimal placement of wind DG suggested. Objective function includes static voltage stability index, three-phase unbalance index, system reliability index, and DG investment cost.	Only Wind DG is discussed, other DG options like solar and photovoltaic techniques are totally ignored. The phenomenon under contingencies is not covered.
"A planning method for sitting and sizing of distributed generation based on chance-constrained programming" Zhaoxia Sun; Weiwei Li; Jinfeng Zhu; Qiangmin Liu; Tianci Liu IEEE Conferences, International Conference on Electric Deregulation Power Technologies Year: 2015	Multi objective minimum optimization framework on distribution network maintenance scheduling for total outage capacity, total switching times, as well as total network loss is presented.	Effect on profile and performance of integration of DG is omitted.

IV. DISTRIBUTED GENERATION TECHNOLOGIES

Distribution Generation are also commonly known as embedded generations or dispersed generations. Numbers of research scholar had defined the DG application in power system. Increasing size and numbers of DG embedded in the smart grid plays an important role in the power system profile and stability. Current definition of DG is very diverse and range from 1kW PV installation, 1 MW engine generators to 1000 MW offshore wind farms or more. Few popular DG technologies are listed below:

1. Reciprocating Diesel or Natural Gas Engines
2. Micro-Turbines
3. Combustion Gas Turbines
4. Fuel Cells
5. Photovoltaic (PV) system
6. Wind Turbines

Table 1 provides a brief overview of the most commonly used DG technologies and their typical module size.

TABLE II BRIEF INFO ABOUT THE TYPES OF DG TECHNIQUE AND RESPECTIVE CAPACITY

S. No.	Technology	Capacity (KW)
1	Combined Cycle Gas Turbine	35
2	Internal Combustion Engines	5
3	Combustion Turbine	1
4	Micro -Turbines	35
5	Fuel Cells - Phosphoric Acid	200
6	Fuel Cells - Molten Carbonate	250
7	Fuel Cells - Proton Exchange	1
8	Fuel Cells - Solid Oxide	250
9	Battery Storage	0.5
10	Small Hydro	1
11	Micro Hydro	25
12	Wind Turbine	0.20
13	Photovoltaic Arrays	0.02
14	Solar Thermal - Central Receiver	1
15	Solar Thermal - Lutz System	10
16	Biomass Gasification	100
17	Geothermal	5
18	Ocean Energy	0.1

The technologies Small Hydro, Micro Hydro, Wind Turbine, Photovoltaic Arrays, Solar Thermal, Lutz System, Biomass Gasification, Geothermal and Ocean Energy are considered as renewable DGs. In the centralized generation, following three technologies are normally used for distributed generation that is synchronous generator asynchronous generator and power electronic converter interface. It has been forecasted that by year 2025, 32% of the newly installed generation will be DGs, and a similar study predict that the share of DG in new generation will be 40% till 2030.

V. PENETRATION OF DGS IN THE POWER SYSTEMS

Numbers of the DG facilities are available now a day. These DG facilities are differ in term of capacity, mode of operation and the technique these DGs uses for power generation and the way these embedded in the smart grid power system application. Small Range, Medium Range and Mega range DG do have their own advantages and disadvantages. The size and the location coordinate plays an important role on how effective is the DG integration in smart grid application. These factors also affect the influence of DG set on static stability, transient stability, profile of the smart grid under normal and contingencies. DG integration also affects the economic aspect, commercial aspect and environmental issues related with the power generation. Different types of the Distributed Generations facility is expected to grow in the future years. DG includes application of the small generators, which are scattered throughout a power system application, to provide electric power needed by the electrical customers. This type of locally distributed generation integrated to the power system has several merits from the view point of environmental restriction and the location limitations, along with the transient and voltage stability in the power system.

Numbers of research scholar work has been reported in the literature for optimal location and size of DGs integrated in distribution power network. Suitable size of DGs and location point for efficient and reliable supply is one major concern. The size of the DGs depends on several factors like availability of the type of input energy, space for commissioning, economic & environmental concerns. An overview of the control and the grid synchronization for the distributed power generation systems is also addressed in article. Research article also discuss a robust stability analysis of the voltage and the current control for the distributed generation systems along with the value based methods which try to find best option for costs and advantages of DG placement and at later stage optimal types of DG’s and corresponding locations with sizes in distribution feeders is also included.

In the article we have also covers the loss allocation technique, the derivative based technique, circuit’s based technique and tracing method for smart grid optimization in the context of DG. A methodology for planning of DG in Smart Grid using the safety index as per norms that is the ratio of the reserve power to its standard deviation had also been presented. The Multi objective performance index which is based on the size and the location determination of the distributed generation in distribution power systems application with multiple load models had been proposed and concluded the load models can significantly affect optimal location & sizing of distributed generation resources in the distribution systems. Below presented table shows various methods used for the DGs location and integration in smart grid power systems application. As the inclusion of smart grid technology in power system application, power system is becoming more and extremely complex equation in the structure, analysis, operation, system control, overall management and the ownership of the system. The power system analysis including DGs are required to solve multiple existing objectives of the power systems application and will be useful in the future for ancillary services and aggregation technology.

TABLE III OPTIMIZATION TECHNIQUES USED IN DG LOCATION AND INTEGRATION

S. No.	Technique	Scholarly Article Reference
1	Genetic Algorithm GA	"A genetic algorithm for the non parametric inversion of strong lensing systems" by J. Liesenborgs; S. De Rijcke; H. Dejonghe, IEEE, Monthly Notices of the Royal Astronomical Society, Volume: 367, Issue: 3, IEEE, Year: 2006
2	Ant Colony ACO	"A new Ant colony optimization algorithm based band selection method" Xu Sun; Lina Yang; Qian Shen; Li Ni; Bing Zhang, Workshop on Evolution in Remote Sensing (WHISPERS), IEEE, Year: 2014
3	Tabu Search TSO	"Tabu search optimization in translucent network regenerator allocation" by Zhaoyi Pan; Benoit Chatelain; David V. Plant; Francois Gagnon; Christine Tremblay; Eric Bernier,Conference on Networks Systems, IEEE, Year: 2008
4	Analytical expression AEO	"Closed-form optimization of multi-transmitter wireless power transfer systems" by Dieter Lang; Alon Ludwig; Costas D. Sarris, International Conference on Numerical Modeling and Optimization (NEMO), IEEE, Year: 2015
5	Particle Swarm PSO	"Optimization of the Xin'anjiang hydropower station using particle swarm optimization and genetic algorithm" by Guohua Fang; Xianfeng Huang, International Conference on Natural Computation, IEEE, Year: 2014

VI. DISTRIBUTED GENERATIONS IN INDIA

In the Indian context, the availability of renewable energy sources is very aspiring. Solar power is easily available across India. In a year, nearly about 300 days, the availability of solar power is good enough for production of considerable amount of electrical power. Indian Government has taken several initiatives like fiscal and financial incentives, preferential tariff for promotion use of renewable energy systems, devices in India. Significant achievements have been made by the initiative of Indian Government in the field of generation of electrical energy from renewable energy alternatives.

TABLE IV SUMMARY OF DG OPTIONS IN INDIA

S. No.	DG options	Type	Technology Status	Capacity Factor
1	Diesel	Non Renewable	Commercially Available Technology, Indigenous	Not constrained
2	Gas engine	Non Renewable	Commercially Available Technology	Not constrained
3	Micro turbine fuelled by natural gas	Non Renewable	Demonstration	Not constrained
4	Fuel cell fuelled by natural Gas	Non Renewable	Demonstration	Not constrained
5	Wind turbines	Renewable	Commercially Available Technology, Indigenous	13% Average
6	PV	Renewable	Commercially Available Technology, Indigenous	Max 25%
7	Biomass gasifier	Renewable	Commercially Available Technology	Not constrained
8	Gas Engine	Renewable	Gasifier, Indigenous	-
9	Biomass Cogen	Renewable	Commercially Available Technology, Indigenous	50%

Lots of difficulties exist in exploration of the renewable energy sources in country. The major limitation faced are inherent intermittent nature of renewable energy sources which lead to low capacity utilization factors ranging from about 17% to 70% which depend on the resource and location, grid synchronization limitations on account of intermittent nature of supply, relatively higher capital investment requirement in comparison to the conventional power projects; also the requirement of the preferential tariffs apart from the other fiscal and financial concessions to make investment in renewable power attractive proposition. Table III represents the various DGs options in India. Following are the alternative available in renewable form of energy in India is brief below

A. Wind Energy

India ranks fifth in the world amongst wind energy producing countries of world after Germany, Spain, USA and China. Indian Government has taken initiative to install Wind farms in more than 9 States. Interestingly near about more than 95% of the installed capacity belongs to the private sector in seven States. The wind power generation capacity in the India has significantly increased recent years. The total installed wind power capacity of India was 32.72 GW at the end of 2015 which is mainly spread across South Indian Territory, West and the North regions. By the end of 2017, India will became fourth largest installed wind power capacity in world. The tariff of wind power reached on the record low of 2.43 per kWh and which is without any direct or indirect subsidies during auctions for the wind projects. The Union Government announced that the applicable guidelines for the tariff based wind power auctions to bring more minimum level to render the risk of investors in the wind power project. In India handsome numbers of the wind turbine manufacturers are present and are manufacturing Wind Electric Generators of rating ranging from 225 kW to 2100 kW. Also very large numbers of water pumping mills and small aero generators had commissioned across country. Wind solar & wind diesel hybrid systems is also installed at many location. The Ministry of New & Renewable Energy of India has established centers for wind energy technology at Chennai to act as technical focal point in country. Financial assistance for the renewable source of energy is also available by Indian Renewable Energy Development Agency which is a supporting arm of Ministry. Table below shows wind power potential and power generated till March 2015.

TABLE V ESTIMATE WIND POWER POTENTIAL AND ACTUAL GENERATION IN INDIA

S. No.	Indian State	Gross Potential(MW)	Million Units
1	Andhra Pradesh	8285	2020
2	Gujarat	9685	3924
3	Karnataka	6630	6581
4	Kerala	885	n/a
5	Madhya Pradesh	5600	569
6	Maharashtra	3750	7958
7	Orissa	1800	2235
8	Rajasthan	5500	n/a
9	Tamil Nadu	3150	27748
10	West Bengal	460	n/a
11	Total	46195	46827

Table presents saving in the coal & reduction in the pollutant because of wind power generation till March 2008 in India.

TABLE VI EQUIVALENT SAVING OF COAL & OTHER POLLUTANTS BY USE OF WIND POWER GENERATION

S. No.	Description	Total Saving in k'tons
1	Substitution of Coal	1,83,30,800
2	Sulphur di-Oxide	2,97,896
3	Nitrogen Oxides	2,06,222
4	Carbon di-Oxide	4,58,27,000
5	Particulates	24,632

The renewable energy is ultimate answer to climate change & the global warming challenge. The carbon free energy is assumed to be energy of future whose development & deployment requires all the possible encouragement. This had come in focus in international deliberations on future of planet in context of climate change.

B. Solar Energy

As an approximate estimation, total area India receives nearly about solar energy which is equivalent to 5,000 trillion kWh per year. Daily average solar energy in India varies from 4 - 7 kWh per square meter of which is a significant and impressive amount of energy. India had set a target of 50 MW for solar power generation during next five year plan and this is seems that this is likely to be achieved.

33 grid solar photovoltaic power plants had been installed in across the country with financial support of Government. Including these plants with aggregate capacity of 2.12 MW nearly about 2.55×106 kWh of electricity in one year can be expected. Around 1.45×106 decentralized off-grid solar photovoltaic systems of about 125 MW capacities had been installed in the country, which is capable of generating 150×106 kWh per year. A collector area of about 2.15×106 square meters has been installed for the solar water heating applications. A solar water heating system with 2 sq. m of collector area can generate energy equivalent to 1500 kWh of electricity when system is in operation about 300 days in a year.

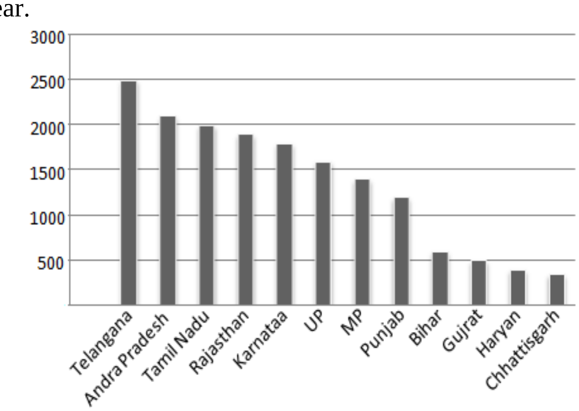


Fig. 3 State wise Status of Solar Energy Utilization in India

C. Biomass

In India the biogas Production is equivalent to near about 5% of the total LPG consumption across nation. Biogas is one of the viable alternatives to burning energy question. In 2014-15, about 30,700 lakh cubic meters of the Biogas are produced India which is equivalent to 7% of total LPG consumption of nation. New target for addition of 1700 MW capacity which consisting of 500 MW biomass power projects & 1200 MW of bagasse cogeneration project had been proposed during next plan period. Cumulative biomass powers of about 18,000 MW from surplus of the agro residues have been estimated.

The States of the Assam, Andhra Pradesh, Chhattisgarh, Bihar, Gujarat, Haryana, Kerala, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh & West Bengal are having potential for setting up biomass based power projects of 100 MW.

Biomass power potential in identified districts of above States ranges between 10 MW to 100 MW. Sugar mills which have crushing capacity of 2500 tons per day in the States have an estimated potential of 5000 MW surplus power generation through optimum bio gas based cogeneration

D. Small Hydro Power

Six hundred eight small hydro power projects with an aggregate capacity of 2015 MW have been set up in country. Annual estimated generation project is 4028×106 kWh year. Target of adding 1400 MW from small hydro power had been planned during the next Plan. It can be observed from Table below that India has tapped a very small fraction of the available renewable energy sources. Government is positively promoting with different policies to enhance utilization of alternative sources of energy.

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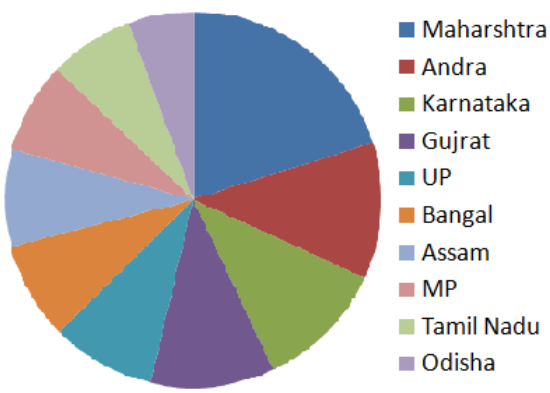

Fig. 4 State wise Status of Biomass Energy Utilization in India

TABLE VII RENEWABLE ENERGY IN INDIA

S. No.	Source/System	Estimated potential	Installed capacity/nos
1	Wind power	45 000 MW	3595 MW
2	Biomass power	16 000 MW	302.53 MW
3	Bagasse Cogeneration	3500 MW	447.00 MW
4	Small Hydro	15 000 MW	1705.63 MW
5	Industrial & Municipal waste	1700 MW 1000 MW	17 MW 29.50 MW
6	Family-size biogas plants	12 Million	3.71 Million
7	Solar street lighting systems	-	54 795
8	Home lighting systems	-	342 607
9	Solar lanterns	-	1566 kWp
10	Solar photovoltaic plants	-	1566 KWp
11	Solar water heating systems	140 M-m2 of collector area	1 M- m2 of collector area
12	Solar photovoltaic pumps	-	6818
13	Wind pumps	-	1087
14	Biomass gasifiers	-	66.35 W

VII. KEY ISSUES IN DGS INTEGRATION TO POWER SYSTEMS

Application of Distributed Generation offers numbers of advantages in multiple aspects. These advantages can be summarized as below:

1. Increased Voltage Support
2. Reliability
3. Price Elasticity
4. Efficiency
5. Ancillary Service Provisions
6. Reduced Emission, Security Risk
7. Market Power
8. Cost Of Electricity
9. System Energy Loss

There are several important and key issues, and challenges in integration of DGs in the power systems. These factors are as listed below:

1. Operation and Control of Smart Grid
2. Optimal Location of Distribution Generation Instigation
3. Modeling Issues of Power System
4. Protection System Add On
5. Change of Short Circuit Capacity
6. Power Quality Profile of Smart Grid
7. Stability issues related with Smart Grid
8. Commercial Issues of System
9. Economic Factors related with Installation and Commissioning
10. Unbalancing Issues in case of contingencies
11. Demand Response Effect

Below is the brief about above mentioned issues in short:

A. Operation and Control of Smart Grid

The outcome energy of Distributed Generation varied according to need and variation in local load. Also the power output of a DG system is controlled independently of local loading of area. Independent control mode is implemented if the DG operation follows the price signal, which may or might not related to local load variations, or else the DG follows availability of natural resources, such as solar or wind power in nearby vicinity. In this condition, the DG might adversely affect voltage control of the network by increasing variations between maximum and minimum voltage level, compared to condition when DG is not available. As the minimum voltage level could remain but maximum voltage level may increase, that is in low load situations with the DG operating at the maximum production and at unity power factor. Distribution Generation can provide some challenges in the traditional voltage, frequency and power control or system profile.

Because of the large penetration of DG system in power application, there is risk of the control and stability of overall system. In case if circuit break occurred in distribution system, this can propagate to the main system and can cause Catastrophic Failure in complete application. If the loss-of-mains is not detected by DG assemble itself, DG unit will continue to operate. In case if DG unit is able to match active and reactive power of load in islanded system precisely, then islanded system could continue to operate without any problem. But, very unrealistic that DG will exactly match load in system during time circuit breaker opens, hence large frequency or voltage variations will occur when DG unit tries to supply load. Most interconnection rules require a loss of main detection system which automatically disconnects DG unit in case of loss of main and unit remains disconnect until grid is restored.

B. Optimal Location of Distribution Generation Integration

Location of installation of Dg is one of the important factors which need to be addresses, as location affects overall profile of the system. Researchers had suggested numbers of technique to find the optimal location of the DG location coordinates. Each technique had different approach and uses different technique for optimization. These techniques are heuristic search technique and are capable of incorporating multiple objectives with multiple parameters. Based on priorities of objectives, analytical hierarchical process can be chosen to suggest the best location of DGs and capacity of DGs. The suggested methods are good enough for present condition of the power system which is keep on changing due to various reasons like expansion of network, load concentration, structural & regulatory changes. This is to be noted that suggested optimal location may change as per time and demand. Growing penetration level of DGs, optimal locations keep on changing & new coordinated planning study is needed to find optimal location. Availability of the fuel supply and type of fuel in future will surely affects optimal location of DGs

C. Modeling Issues of Power System

As penetration level of DGs in power application increases up to certain threshold, this will no longer be optimal to model the static loads characterized by amount of the active & reactive power being consumed. Importance of modeling of new DG technologies had already been realized by researchers & engineers; resulted in number of the scientific articles reporting the development of dynamic models of the fuel cell systems, doubly fed induction machines, and generic, loads micro turbines. Depending upon dynamical phenomena of system response, different models may be used in analysis & simulations. The dynamic or transient stability study is extremely important to models system which must reflecting main dynamical features of system with maximum accuracy. It indicates that owners of the DGs must make all relevant technical characteristics of the DG available. Not only static characteristics of DG units are important, also the characteristics of the main controls of governor, voltage regulator & excitation system of synchronous generator must be incorporated.

D. Protection System Add On

The presence of protection arrangement is also important feature, which need to be addressed in system design. Depending on characteristics of the DG, the location of DG and network configuration, impact of DG on over current protection may changes, which clearly indicate that the DG will certainly impact on protection scheme of distribution grid. The protection system of DG units must be able to detect fault and the rapidly disconnect from main network, DG will not interfere with normal operation of protection system. Most interconnection standard, require disconnection of DG as son a fault occurs. In practice, the distribution networks are automated and equipped with SCADA systems. Protection scheme should be properly coordinated & designed.

E. Change of Short Circuit Capacity

The installation of new distributed generators in distribution networks potentially increases level of short circuit capacity. This is desirable to have a high short circuit capacity that is at point of connection of inverter of line commutated with the HVDC station or in presence of the large loads with rapidly varying demand; in general increase of SCC potentially indicates a problem in the application.

F. Power Quality Profile of Smart Grid

Profile is the indicator of quality of power. DGs possess different characteristics & thus create different power quality issues. Effect of the increasing network fault level by adding generation often leads to an improved power quality of system. Excessive use of the power electronics devices & modern controls introduces power quality problems & moreover, these devices are extremely prone to power quality problems.

G. Stability issues related with Smart Grid

Distribution network design is not required to address issues of related with the stability as the network incorporated are passive & radial, remained stable under most circumstances provided transmission network is itself stable. But this is likely to change as penetration of schemes increases & their contribution to the network security becomes greater. Areas that need to be considered will include transient as well as long term dynamic stability & voltage collapse.

H. Commercial Issues of System

Commercial aspects are needs to be considered in DGs installation. As commissioning of DGs are very expensive and is long term investment. Companies and investors are supposed to be very careful while investing the project. In objective to support the development of active distribution networks & extract corresponding advantages associated with the connecting increased the amount of DG, new commercial arrangements required to be developed.

In general, three approaches are possible these are to recover cost of implementing active management directly through price control mechanism, to establish an incentive scheme which would reward companies for connecting DG and to establish market mechanism, outside of regulatory framework; this would create a commercial environment for development of the active networks

I. Economic Factors related with Installation and Commissioning

Due to developing technologies of distributed generators, major risk to existing & upcoming DGs is to economically embed in future application. The agreement for supply future load & government commitment for survival are major concerns. This is expected that DGs should get reasonable return from market such that more expansion can be sought

J. Unbalancing Issues in case of contingencies

Various DGs, which supply to network in single-phase, are available. If it exists, the unbalancing of the system will occur and it should not increase beyond the permissible limit. Moreover, operation of DGs suffers with unbalancing of loads in phases. Their performance of overall system may adversely affect due to unbalancing.

K. Demand Response Effect

Electricity market exists in several countries and demand response is encouraged for better economics of electricity market. The responses may not be very beneficial as DG may lose revenue because of demand response.

VIII. CONCLUSIONS

This paper addresses the distributed power generation technologies and their impacts on the future power system. The various DGs options incorporated in Indian power system are described along with future potential and options. Due to rising use of fossil fuels and environmental concerns, the penetration of distributed generation coming from the renewable energy sources, is increasing and expected to grow further in the future. This increasing penetration brings various technical and economic challenges in integrating the distributed generations in to existing power systems, which are critically examined.

IX. FUTURE SCOPE

Penetration of DG in smart grid power system application has huge opportunity and bright prospects with great potential. An appropriate regulatory policy of Government should be required for future growth of DGs to foster the required changes and to thrive the DG integration. There is an urgent need to articulate appropriate policies that support the integration of DG into distribution networks. DGs can play vital role in the electricity markets emerging all over the world. DG displaces energy produced by central generation and facilitated flexibility and capacity. Depending on market structure, where these are install, DGs participant in energy markets and may be used to provide ancillary services so as to improve the economic viability of some DG projects. Several technical and regulatory and policy constraints may be faced by the DGs.

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