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A Distinctive Analysis between Distributed and Centralized Power Generation

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Abstract: **The role of Distributed Generation (DG) is ever increasingly being recognized as a supplement and an alternative to large conventional Centralized Generation (CG). Besides, there is also a debate regarding the genuine prospects of DG; always prevailed between industry stakeholders and other interest groups. Within the scope of this review, a comparative study of CG and DG has been presented. In this report, a broad spectrum of issues is being considered to depict the paradigm, drives, shortcomings and future challenges for CG and DG.**

Keywords: **Centralized Generation (CG), Distributed Generation (DG), DG technologies, drives for DG mix, and challenges for DG mix.**

I. INTRODUCTION

Distributed Generation (DG), for the moment loosely defined as small-scale electricity generation near to the point of use, is not an entirely new concept. In the early days of electricity generation, power plants supplied electricity to the customers of close vicinity, connected with a direct current (DC) based ‘microgrid’. Then the emergence of alternating current (AC) grids made long distance electricity transmission viable. Besides, large-scale steam turbines enabled better economies of scale in electricity generation with higher power output. Gradually the power systems converged around CG, burning cheap fossil fuels, situating far from urban centers, with high-voltage transmission and low-voltage distribution lines carrying electricity to every business, facility and home. But in 1960s, when thermal efficiency of turbines was pushed to the furthest and metallurgical fatigue became apparent, then CG reached to its saturation and utilities could no longer expect to see significant cost declines. On the other hand, throughout the last decade, technological innovations such as improved materials and engineering designs for photovoltaic systems, wind turbines, micro turbines, fuel cells, internal combustion engines and other emerging technologies along with changing economic and regulatory environment have resulted in a renewed interest for DG. Still, the efficiencies of different DG technologies are less, compared to CG technologies. But the comparative efficiency for DG looks better when the transmission and distribution losses of CG are counted. For optimal use of DG, the waste heat can be used for cogeneration. This approach of DG usage makes it economically attractive. The interconnection of DG with the electric grid can pose genuine safety and reliability risks for the utility if not properly tied. But, distributed nature of DG reduces transmission and distribution losses by robust terms based upon the very large numbers of individual generators and statistical robustness of such a collection is compared in [1] to CG.

It is now more than a decade since DG has drawn major attention amongst electric power system planners and operators, energy policy makers and regulators as well as developers [2]. Now, the penetration of DG into CG is well-established as policy in many countries.

II. CG AND DG PARADIGM

A. Centralized Generation:

CG is the bulk electric power generating system with central power plants. It includes large fossil-fired (gas or coal) boilers or nuclear boilers to produce steam that drives turbine generators. In some cases, large hydro is also used. The widespread concentration of CG for power generation was driven by several factors [3]:

1) Economies of scale: With the advent of steam turbines, it was possible to increase the size of the turbines while decreasing the marginal cost of electricity production.

2) The search for high energy efficiency: Efficiency gains were achieved through handling higher pressures and temperatures of steam used in electricity generation.

3) Innovation in electricity transmission: Using AC instead of DC, it was possible to transmit electricity over long distances with a significant loss reduction.

4) Environmental constraints: It was possible to relocate the generation facilities outside the city centers thus replacing the exhaust from plants.

5) The search for reliability: Reliability of supply was increased as the failure of one plant was compensated by the other plants in the interconnected system.

III. DRIVERS FOR DG MIX WITH CG

A. Disadvantages of CG:

1) Transmission and distribution costs: In CG, transmission and distribution costs amount for up to 30% of the cost of delivered electricity on average [5]. These costs are mainly made up of line losses, unaccounted for electricity losses and conversion losses. In table I, percentage of transmission and distribution losses in US is represented. In addition to the cash cost, these billions of KWh losses have an implicit cost in terms of greenhouse gas emissions.

TABLE I: TRANSMISSION AND DISTRIBUTION LOSS IN US [10]

Year	2001	2002	2003	2004	2005	2006	2007	2008
Loss-%	5.4%	6.4%	5.9%	6.7%	6.6%	6,5%	6.4%	5.9%

2) Rural electrification: In CG, rural electrification covering long distance to serve small consumption becomes uneconomical.

3) Investment in transmission and distribution networks: Significant investment is required to upgrade the transmission and distribution networks to meet the ever-growing energy demand by CG. It is estimated that the total amount to be invested in generation, transmission and distribution up to 2030 for the OECD countries stands between 3,000 and 3,500 billion dollars [11].

4) Thermal efficiency: According to [3], from 1900 to 1960, utilities continuously increased the thermal efficiency in steam turbines and theoretically reached up to 40% to squeeze more kilowatt-hours from each unit of fossil fuel. This scenario is graphed in fig. 1. But at a certain level, when super-heated pressurized steam pressed against the turbine blades and boiler tubes, metallurgical fatigue increased substantially, decreasing the reliability of huge power plants and increasing maintenance costs. The decision to stop pushing thermal efficiencies meant that utilities could no longer expect to see significant cost declines from this aspect of their industry's technological progress.

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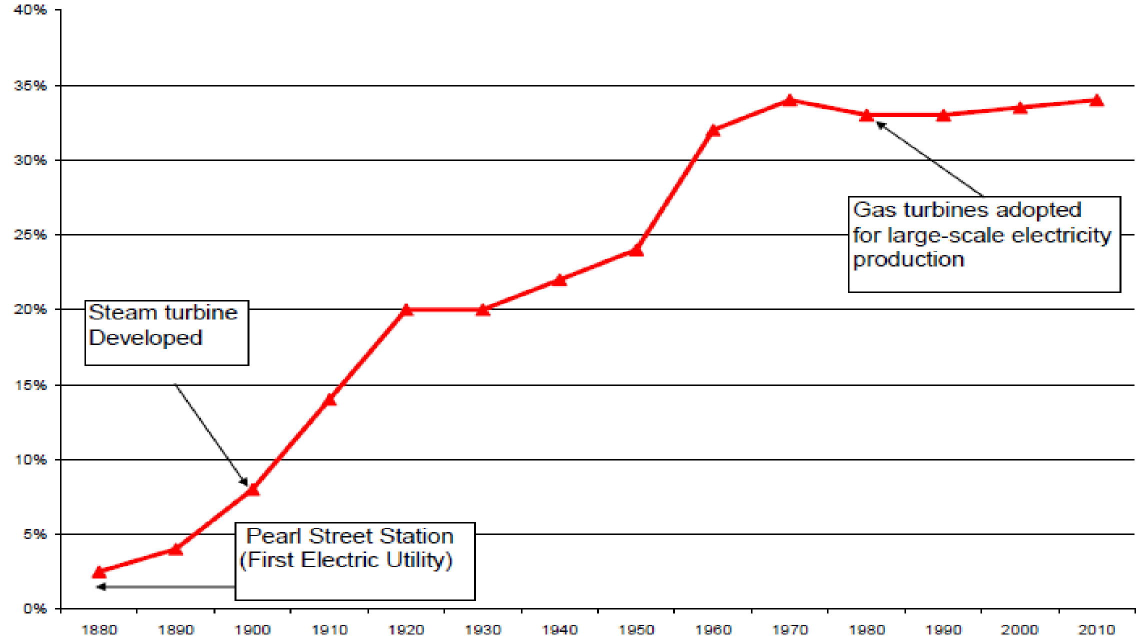

Fig. 1. Average U.S. Fossil Power Plant (Fleet) Efficiencies [3]

5) *Cogeneration:* By reusing waste heat for cogeneration, total thermal energy efficiency can be increased up to 90% [12]. But cogeneration becomes improbable in case of CG as it is far away from the load center.

IV. LIBERALIZATION OF ELECTRICITY MARKETS

1) Standby Capacity or Peak Use Capacity (Peak Shaving): To support the "needle peaks" of short duration (such as air conditioning at hot afternoon) on the grid, CG utilities get forced to expand electricity distribution capacity. But that expanded capacity comes with a very poor "load factor,"– there are very few hours each day in which those kilowatt-hours of electricity are being purchased, to pay for the additional wire, transformer and substation capacity [3]. On the other hand, in a deregulated electricity market, the diminution of reserve margins or the failure of generators to supply the network can lead to capacity shortfalls. Both of the cases result in high electricity prices to the consumers [9]. Being standby capacity or peak use capacity, DG can serve as a hedge against these price fluctuations.

2) Power Quality: In CG, due to grid failures and switching operations, insufficient power quality can be caused resulting in voltage dips, interruptions, transients, network disturbances from loads yielding flicker (fast voltage variations), harmonics, and phase imbalance. However, having a reliable power supply is very important for society as a whole, and industry in specific. Companies may find the grid reliability of a too low level and decide to invest in DG units in order to increase overall reliability of supply to the desired level [13].

3) Energy Security: DG can contribute to energy security through two effects:

a) Fuel diversity: As DG technologies can accommodate a larger range of fuel than CG; DG has been used to diversify away from coal, fuel, natural gas and nuclear fuel [5].

b) Back up generation: DG can be prominently used for back up capacities to prevent operational failures in case of network problems.

V. ENVIRONMENTAL CONCERNS

At present, environmental policies are the major driving force for DG in Europe [13]. Due to the heavy reliance on fossil fuel, coal and to a lesser extent natural gas, the environmental negative impact of the CG is significant. The electricity sector is responsible for 25% of the NOx emissions, 33% of the CO2 emissions and 66% of the SO2 emissions in the United States [14]. Though DG is not solely renewables but renewables, except for large hydro and off-shore wind parks, have a decentralized nature. DG can be used to mitigate the impact in terms of emissions associated with transmission and distribution losses and to increase efficiency through cogeneration and renewable energy.

VI. THE TREND AND CHALLENGES OF DG MIX WITH CG

Due to the definition variance of DG, the estimation of DG penetration also becomes complicated. In fig. 2, certain estimation is given which shows positive trends.

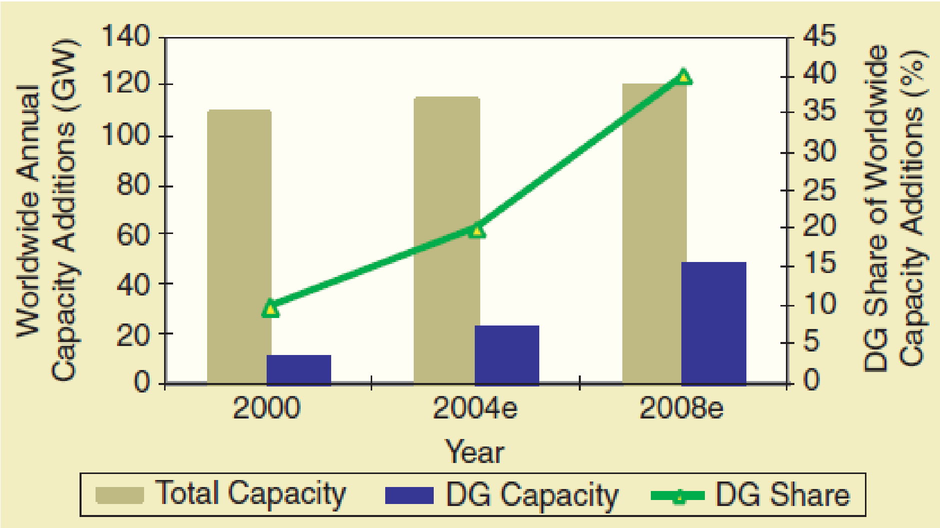

Fig. 2. DG market growth [20]

With this positive trend there are also many challenges that DG is facing to keep up the pace. Main challenges are:

A. Technical challenges:

1) Equipment capacity: Adding DG at distribution grid can significantly impact the amount of power to be handled by the equipments. As in case of excess power, especially the transformers should support the power to flow towards to the high voltage network to be directed to other consumption areas.

2) Voltage and current stability: As distributed generators will be switched on or off, short term abnormal voltage or current oscillation may occur and result to a destabilizing effect on the network. Besides, adding DG above a certain threshold at distribution grid might tend to increase grid voltage above the specifications.

3) Protection: Additional protection systems are required to avoid internal faults, defective distributed network and islanding [15]. It requires the distribution system to be upgraded, as protection systems may no longer operate as designed.

4) Ancillary Services: To adjust production in case of demand surge and to hold voltage control devices, ancillary services are still provided by CG. With the increment of share in the power, DG must also provide ancillary services.

5) Active Distribution Networks: The integration of DG on a large scale will require the distribution network to be active to manage the flow coming from CG, forecast the levels of output from distributed generators, collect information, devise start-up procedures in case of system failures and automate in real time. This increased level of complexity will require the development of management and control procedures necessary to ensure quick and safe operation [16].

6) Virtual power plant: DG require to adopt the concept of virtual power plant which is the coordination of several distributed generators with a strong integration of information, communication and management systems in order to act as an integrated plant [17].

B. Cost competitiveness:

On a pure cost per kilowatt basis, DG is clearly not the cheapest source of generation. But reduction of transmission loss and cogeneration opportunity makes it interesting. Besides some of the DG technologies are not matured enough to predict the real cost now. At the end, in a liberalized market, DG has to compete with well established CG technologies. Thus, cost competitiveness will be a major challenge for DG to overcome.

C. Regulatory barriers:

In a recent study of European regulation, the key factors were analyzed that might impede the spread of DG in Europe [18]:

1) Network tariffs: When getting connected to distribution network, DG has to pay physical connection charges and recurring use-of-system charges to the distribution network operator. Connection charge can be deep or shallow. The choice between deep and shallow connection charges is bound to have a major impact on the penetration rate of DG.

2) Distribution planning: Though in the long run DG defers investment in the network, reinforcement work has to be undertaken to accommodate this new form of generation. This additional distribution costs make operators less inclined to favor DG.

3) Energy Loss: The behavior towards energy losses varies greatly across countries. DG has a positive impact on these losses. Regulation on this specific point affects the profitability for DG.

D. Impact on climate change and global warming:

DG does not necessarily mean clean generation. In [19], there is an analysis on the performance with respect to emissions of DG operating either for only electricity or as cogeneration units. It appears that, DG is not always the best performer in terms emissions. To be used in the cleanest way possible, DG will thus have to use the less emitting technologies and favor cogeneration.

VII. CONCLUSION

The flaws of the CG paradigm led to look for a complement generation technique. Besides, the facts such as the wide range of potential applications for DG, liberalization of electricity market and the trend to use renewable energies in most developed countries may propel DG to have a large share of power generation in the future. However, more research and development is essential to overcome the barriers that DG systems are currently facing. In fact, DG systems need to accomplish higher efficiency, lower emissions and lower capital costs. Above all, if regulatory authorities and government policy makers continuously support DG systems and modify the structure, operation and pricing mechanisms of the open markets, only then DG systems can develop further in accordance with the estimations.

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