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Future Scope Analysis of Distributed Generation in Deregulated Indian Power Market

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Abstract:- Till date, greater chunk of electricity is generated in conventional way at large generating stations, after that electricity is transmitted at high voltages to the load centres and then it is distributed among consumers at distribution level voltage through distribution systems. Whereas Distributed Generation is defined as generation located at or near the load centres.The liberalization of the electricity market and the separation between electricity supplier and network operator in India have gained attention to the subject of connecting generated power by distributed generation plants directly to grids. There are many reasons why a customer may choose to install a distributed generator, as it can be used to generate a customer's entire electricity supply or for peak shaving or for standby or emergency generation or as a green power source (using renewable technology). In some remote locations, DG can be less costly as it eliminates the need for expensive construction of distribution and/or transmission lines. The objective of this paper is to assess the impact and study the future scope of Distributed Generation on the deregulated power market scenario in India using Herfindahl Index.

Keywords:- Carbon Footprint, Deregulated Power Market, Distributed Generation (DG), Herfindahl Index(HI), Renewable Energy.

I. INTRODUCTION

A. Distributed Generation

Distributed Generation is described as the generation located at or near the load centres. In this scheme electricity is generated through various small scale power generation technologies. It has no stringent definition of DG available but all the definitions are more or less similar in nature. Let us show some light on some of the existing definitions:

According to *DPCA (Distributed Power Coalition of America)* [1] defines that Distributed Generation is any small scale power generation technology that provides electric power at a site closer to customer than central station generation. A distributed power unit can be connected directly to the consumer or to a utility's transmission or distribution system.

IEA (International Energy Agency) [2] says that the Distributed Generation is generating plant serving a customer on site, or providing support to a distribution network and connected to the grid at distribution level voltages.

CIGRE (International Council on Large Electric Systems) [3] Distributed Generation is not centrally planned, usually connected to the distribution network, smaller than 50 or 100 Megawatt.

According to *Ministry of New and Renewable Energy, Government of India,* [4] Distributed Generation is defined as**: -** Installation and operation of electric power generation units connected to the local network or off-grid generation characterized by

- Generation capacity ranging from Kilowatt to Megawatt level.
- Generation at distribution voltages (11kV or below).
- Grid interconnected at distribution line side.
- Interconnected to a local grid or totally off-grid, including captive.

The energy resources for Distributed Generation can be classified into renewable and non-renewable. The Distributed Generation technologies based on renewable source of energy are Wind, Photo-voltaic & Solar thermal, Ocean (Tidal and Marine current), Small Hydro. The Distributed Generation technologies based on non-renewable source of energy are Micro Turbine, Industrial Combustion Turbine, Combined Cycle Gas Turbine and Reciprocating engines (Internal Combustion Engine) [5, 18, 19]. Again Fuel Cells can be classified as renewable (using Hydrogen) or nonrenewable (using Natural gas or Petrol). Depending upon the different sources of generation, range of Distributed generation differs. Usually Distributed Generation is classified as [5]**:-**

- Micro Distributed Generation (From 1 W to < 5 KW)
- Small Distributed Generation (From 5 kW to < 5 MW)
- Medium Distributed Generation (From 5 MW to < 50 MW)
- Large Distributed Generation (From 50 MW to < 300 MW)

B. Deregulation

By the term Deregulation in power sector describes a process by which government removes or reduces restriction on power industry and invite private sector to invest in power industry.

There are handful reasons [6] which led to deregulation of power sector in India. Traditionally electric utility systems developed as the central station concept for economic consideration. Large generator units produce power at less cost per Kilowatt than small generator units. But now-a-days due to technical innovation efficiency of small units for combined cycle, hydro and fuel cell is improved over larger units. Moreover computerised control systems, data communications, off-site monitoring systems, improvement in materials like new high temperature metals, special lubricants, ceramics, carbon fibres permits stronger and less expensive small machinery to build. These makes it possible to build economically viable small plants that could provide energy at a lower price than what consumers are paying for, which is coming from the traditional giant power plants.

Here goes some of the major reasons [6] for going into deregulated power market,

1. Deregulation brings an end to the need of providing risk free finance to build infrastructure; as it is a proven technology, the risk involved in investing money is cancelled out.
2. Existing monopoly utilities have an obligation to serve all consumers but they does not promote the pro-active attention to consumer needs, whereas a competitive electric service company predicts consumer's needs and responds in advance; competition brings innovation, efficiency and lowers the cost [7].

II. DEREGULATION IN INDIAN POWER MARKET

Many electric utilities and power network companies around the globe, during the decade of nineties [6], have been forced to change their way of operation and business. The shift is seen from the vertically integrated structure to the unbundled formation i.e. the former vertically integrated utility which performed all the functions involved in power generation, transmission and distribution is disaggregated into separate companies devoted to each function. In India, The Electricity Act 2003 addressed certain issues [8] that have prevented or slowed down the reform process and did not adequately encourage private investment in the electricity sector. The act moves towards creating a market based regime in the power sector. The act focuses on creating a competition in the industry, ensuring supply of electricity to all areas within the country, protecting consumer's interest etc. The Act, in addition to grid extension as a mode for rural electrification, specifies distributed generation and supply through stand-alone conventional and renewable energy systems [8]. Among few major provisions of the Electricity Act 2003 [8], unbundling of the State Electricity Boards (SEB) on the basis of function (Generation, Transmission, Distribution), provision of issuing more than one license for transmission and distribution in the same geographical area, elimination of licensing for setting up a generating station, subject to compliance with technical standards (excluding hydroelectric power station), removing captive power plants from the bound of licensing and other permissions, provision of open access with respect to transmission, introduction of a spot market for bulk electricity are notable in this context.

III. EFFECT OF DISTRIBUTED GENERATION IN DEREGULATED POWER MARKET SCENARIO

A. Herfindahl Index (HI)

For the assessment of the effect of Distributed Generation we introduce a popular economical index called Herfindahl Index [9].By using this we can measure and understand the level of competition that exists within a market or industry. Moreover it gives an indication of how the distribution of market share occurs across the companies included in the index. Understanding the level of market competition can be important for strategic planning as well as when trying to establish pricing for a company's products or services, in this case the company is any power generating company and their product is power. The calculation of the HI differs from the standard Concentration Ratio in that it squares each market share value which places a higher importance on those top companies that have a larger market share. The formula used for determining the Herfindahl Index (HI) is as follows:

$$H = \sum_{i=1}^{N} s_i^2$$

Where s_i is the market share of company i in the market and N is the number of companies.

The HI can have a theoretical value ranging from close to zero to 10,000. If there exists only a single market participant having 100% of the market share the HI would be 10,000. If there were a great number of market participants with each company having a market share of almost 0% then the HI could be close to zero.

- When the HI value is less than 100, the market is *Highly Competitive.*
- When the HI value is in between 100 – 1000, the market is *Reasonably Competitive or Not Concentrated.*
- When the HI value is in between 1000 – 1800, the market is said to be *Moderately Concentrated.*
- When the HI value is above 1800, the market is said to be *Highly Concentrated.*

A simple example will be very helpful to understand how HI can be determined. Suppose there are 5 firms producing 12% of goods each and the rest is equally produced by 10 firms. So, last 10 firms their share of producing goods is 4% for each of them. So, the HI becomes,

$$H = 5*12^2 + 10*4^2 = 880$$

Therefore the conclusion is that, the market for the particular good is not concentrated or reasonably competitive.

B. Case Studies

Now we have to shift our focus on the using of HI index in different power scenario. Let us assume that load demand of 500 MW prevailing at certain geographical area. If we neglect the losses then at least 500 MW of power is to be generated there to meet the total load. Now we consider some scenarios where in steps of 20% we inject renewable distributed generation along with conventional non-renewable power sources.

i) *Case-1***:** All the demand is met by conventional power plants, each having equal capacity of 100 MW. So, there will be 5 plants.

Table I: Generation Break-up for Case-1

CAPACITY(MW)	NO.OF PLANTS	TOTAL(MW)
100	**5**	**500**

So, the share of each plant is = (100/500)*100 % = 20 %

Therefore, $H = 5*20^2 = 2000$

ii) *Case-2***:** 20% of the total demand is met from renewable distributed generation energy, and the rest is met by conventional plants. The numbers of renewable distributed generation energy plants are taken arbitrarily and they are of the range 20 MW, 10 MW, 5 MW, 2 MW as they are available in the Indian market as per the different sources like Wind energy, Solar PV cells, Micro Hydro units etc.

Table II: Generation Break-up for Case-2

CAPACITY(MW)	NO.OF PLANTS	TOTAL(MW)
100	**4**	**400**
20	**2**	**40**
10	**3**	**30**
5	**4**	**20**
2	**5**	**10**

So, for each conventional plant the share is 20% and for each renewable distributed generation energy plants those are 4%, 2%, 1% and 0.4% respectively and the total number of plants is 18.

Therefore, $H = 4*20^2 + 2*4^2 + 3*2^2 + 4*1^2 + 5*0.4^2 = 1648.8$

iii) *Case-3***:** 40% of the total demand is met from renewable distributed generation energy, and the rest is met by conventional plants. Renewable distributed generation energy plants are of the range of 20 MW, 10 MW, 5 MW, 2 MW, 1 MW, 0.5 MW.

Table III: Generation Break-up for Case-3

CAPACITY(MW)	NO.OF PLANTS	TOTAL(MW)
100	3	300
20	5	100
10	5	50
5	4	20
2	5	10
1	10	10
0.5	20	10

Here, for each conventional plant the share is 20% and for each renewable distributed generation energy plants those are 4%, 2%, 1%, 0.4%, 0.2% and 0.1% respectively and the total number of plants is 52.

Therefore, $H = 3*20^2 + 5*4^2 + 5*2^2 + 4*1^2 + 5*0.4^2 + 10*0.2^2 + 20*0.1^2 = 1305.4$

iv) *Case-4*: 60% of the total demand is met from renewable distributed generation energy, and the rest is met by conventional plants. Renewable distributed generation energy plants are of the range of 20 MW, 10 MW, 5 MW, 2 MW, 1 MW, 0.5 MW.

Table IV: Generation Break-up for Case-4

CAPACITY(MW)	NO.OF PLANTS	TOTAL(MW)
100	2	200
20	5	100
10	10	100
5	10	50
2	10	20
1	20	20
0.5	20	10

Here, for each conventional plant the share is 20% and for each renewable distributed generation energy plants those are 4%, 2%, 1%, 0.4%, 0.2% and 0.1% respectively and the total number of plants is 77.

Therefore, $H = 2*20^2 + 5*4^2 + 10*2^2 + 10*1^2 + 10*0.4^2 + 20*0.2^2 + 20*0.1^2 = 932.6$

Next case must contain 80% of renewable distributed generation energy share, and 20% of conventional plants share. With this scheme considering total no. of plants in the vicinity of 100, HI value comes in the range of 100 – 1000 which comes in the same category as the following case, so skipping detailed tabulation.

v) *Case-5*: In this case total demand is met by renewable distributed generation energy plants having the range of 20 MW, 10 MW, 5 MW, 2 MW, 1 MW, 0.5 MW.

Table V: Generation Break-up for Case-5

CAPACITY(MW)	NO.OF PLANTS	TOTAL(MW)
20	10	200
10	10	100
5	20	100
2	25	50
1	30	30
0.5	40	20

So, for each renewable distributed generation energy plants those are 4%, 2%, 1%, 0.4%, 0.2% and 0.1% respectively and the total number of plants is 135.

Therefore, $H = 10*4^2 + 10*2^2 + 20*1^2 + 25*0.4^2 + 30*0.2^2 + 40*0.1^2 = 225.6$

From the aforesaid case studies we can draw a bar chart clearly showing effect of penetration of renewable distributed generation (*Green Power*) in the present energy generating market scenario.

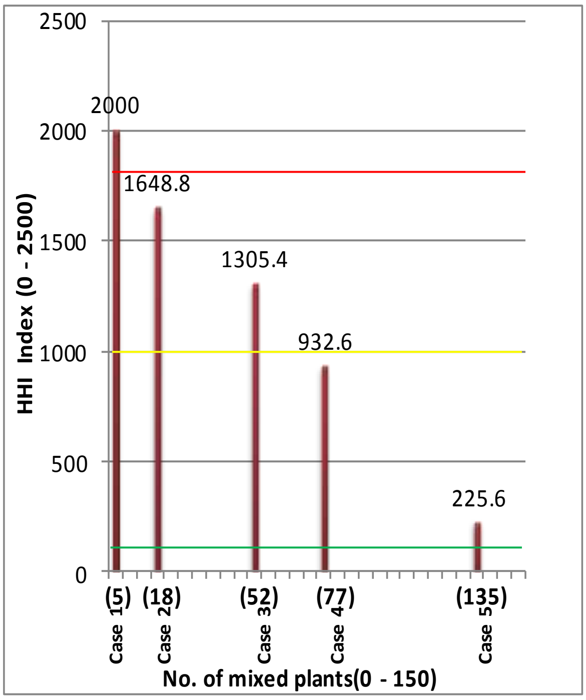

Fig.1: Variation of Herfindahl Index with the number of mixed (Conventional and Renewable Distributed Generation) generating plants

Variation of Herfindahl Index (HI) with the number of mixed (Conventional and Renewable Distributed Generation) generating plants signifies that as the number of renewable distributed generation plants are increased the Herfindahl Index value is decreasing, thus showing more and more competition in the power industry. In the first case HI is 2000 which clearly shows the monopoly nature of the power industry. Now in subsequent cases as penetration of renewable distributed generation increases HI value falls, indicating towards increasing competition level in the power industry.

IV. ANALYSIS

Recently electricity suppliers are showing increased interest in distributed generation as it acts as a tool which can help them to fill in niches in a liberalised market. In that type of market, customers seeks the electricity service best suited for them. In short, distributed generation empowers suppliers in the electricity sector to respond flexibly to the changing market conditions because of their small sizes and the short construction lead times compared to most types of larger central power plants.

Aforesaid case studies and the figure derived from that study reveal a sense of growth in competition level in Indian power market in the deregulated scenario. Under deregulated environment, electric utilities will always try to innovate something for the betterment of service and in turn save its costs to maximize the profit. By means of these utilities will try to ensure that they maintain their consumer base in spite of competition. So, in this scenario most effective solution is to introduce Renewable Distributed Generation technologies (*Green Power*) along with conventional power plants (*Dirty Power*). A chart is given below for understanding the relative costs of investment in conventional power plants and non-conventional i.e. renewable distributed generation energy plants [11],[12],[13],[20],[21],[22],[23].

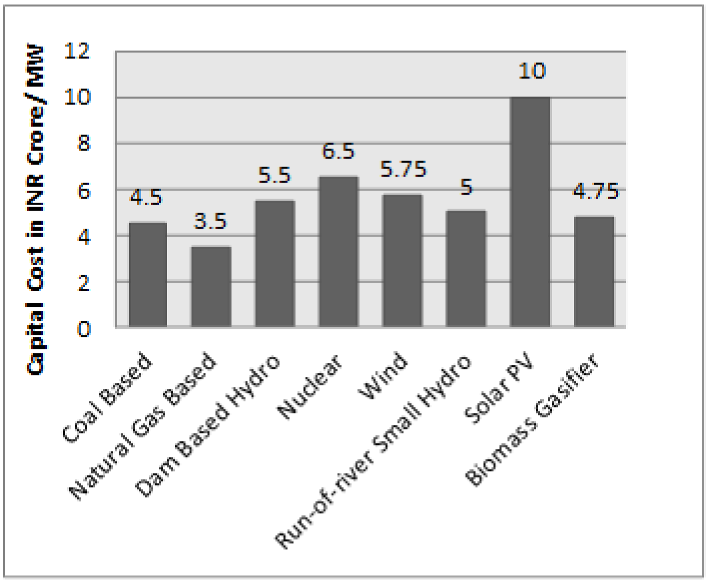

Fig.2: Capital cost in INR crore/ MW for different types of generating plants

The aforesaid chart clearly shows that present value of capital cost for different electricity generation technologies powered by conventional and non-conventional sources of energy is running almost side by side. Capital cost is decreasing day by day in case of renewable distributed generation energy plants due to scientific innovation and international energy policy towards *Green Power* and the same is increasing for the fossil fuel powered conventional power plants as fossil fuel price is increasing due to their limited availability. Economic efficiency refers to the principle that using valuable resources should be avoided. According to International Energy Agency (IEA), the increasing share of distributed generation in the installed capacity is likely to imply less choice for fossil fuels, leading to diversification of primary energy sources. Moreover the renewable sources of power merely produce Carbon-dioxide and other Green House Gases that is hugely responsible for global warming and other adverse climatic changes. On this context *Carbon Footprint* is an important index, which measures the total amount of Carbon-dioxide and other Green House Gases emitted by an organization [14]. Once the size of a carbon footprint is known, a strategy can be developed to minimise it. The mitigation of carbon footprints through the implement of alternative renewable sources of energy, such as solar, wind etc. represents one way of reducing a carbon footprint and is often known as Carbon offsetting. So, for Indian perspective, capacity addition in power sector is driven by the requirement to achieve energy stability, security of energy supply and energy independence combined with the requirements to minimize carbon footprints. This in turn directs its policy (National Electricity Policy) to encourage renewable power generating technologies under 10^{th}, 11^{th} and 12^{th} 5 year plans (FYP) [16]. The Government of India (GOI) has set a renewable energy capacity addition target of 29.8 GW for the 12^{th} FYP, taking the total renewable capacity to almost 55 GW by the end of financial year 2017 [24]. It is worthwhile to mention in this context that in 2009, the GOI launched the Jawaharlal Nehru National Solar Mission (JNNSM), one of the 8 key missions of the National Action Plan on Climate Change (NAPCC), to install 20 GW of Solar power by 2022 [24]. A chart is given below clearly showing the effect of deregulation which in turn brings competition among the market players to innovate newer technologies to reduce the capital cost [15],[21] and also the cost per unit of electricity [10],[17] (Here the example is given for Solar PV units only).

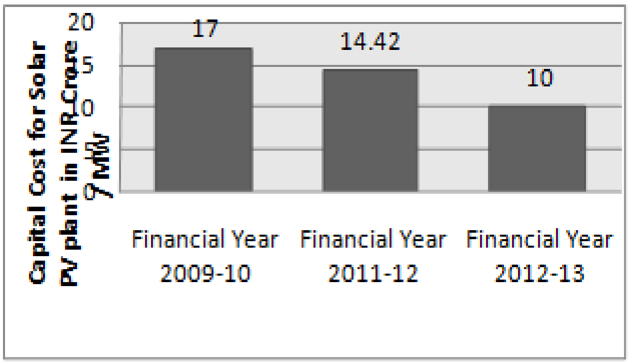

Fig.3: Variation of capital cost for Solar PV plants with respect to financial years

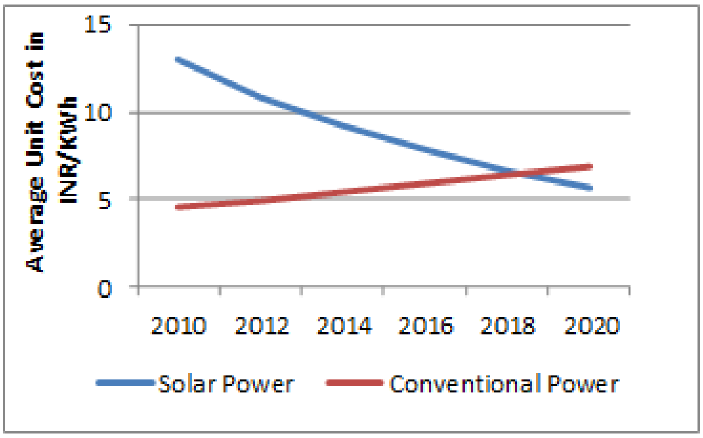

Fig.4: Variation of average unit cost in INR/KWh of Conventional Grid power and Solar power with respect to year

V. CONCLUSION

The effect of incorporating Distributed Generation in the prevailing deregulated power market scenario in India is clearly presented by the paper. With the help of a well-established economic index i.e. Herfindahl Index, this paper depicts the effect of competition in the present power market. The deregulation process in a power deficit country like India attracts new investors to come and generate electricity at cheaper rate than the others which is clearly depicted in fig. 4. As number of new players is increased, Herfindahl Index falls, showing the competitive nature of power market. To establish themselves in the market, they have to reduce the cost of electrical power which can be done by reducing transmission and distribution related losses (mainly by avoiding congestion in the transmission & distribution lines by reducing the amount of power flowing through them), reducing the use of costly imported fossil fuels, reducing emission of greenhouse gases etc. which in turn directs to the inevitable use of Distributed Generation technology. Reduction of emission of greenhouse gases using renewable distributed generation reduces carbon footprint directly which in turn is having a green impact on eco-system.

Therefore, our methodology not only suggests the mere competitions in the deregulated power market scenario but also suggests the most effective way to decrease a carbon footprint by decreasing the dependence on carbon emitting fuels.

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