A Review on Integration of Renewable Energy - Based Distributed Generation in Deregulated Power Systems

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Abstract—For **developing as well as under developed countries, the deregulation of power sector becomes a new and prosperous challenge. As in developed countries utility market makes for the use of distributed generators (DG) a viable solution for managing energy cost. Earlier stand by generators installed only to handle outages, but now a days due to power shortage, power cut, slower restructuring process DG's can serve as a means of shaving load peaks. Recent development in DG technology brings extra flexibility into existing demand management system.**

This gives the utility a generation resources close to their loads that can be dissipated during peak time. Many utilities have implemented various demand management programs to help them in problematic times of power system.

Use of renewable source on distributed generators, which are rated at around 1-2 MW is getting popular. Electrical generation from renewable energy sources considered as a solution for environmental pollution, global warming and rapid depletion of fossil fuels. Government thorough the world has generated number of incentives to motivate development of renewable energy source. Generation units such as hydro-turbine, gas-turbine, micro-turbine, solar PV, fuel cell and wind generation and last but not the least micro-turbine will be part of this mix.

It is an increasing acceptance for the use of renewable energy source to attain a sustainable power supply. This paper discusses a new structure which addresses the integration of renewable energy source (REs) and distributed generators (DGs) into electricity grid. A simple scheme is also suggested for the connection of the distributed generators to the power distribution network.

An example is given using averaged load curve data. The major simplifying assumption is that load curve is known. This is appropriate for planning purpose, but extension will be necessary for operation.

Index Terms—Deregulated Power, Distributed Generators, Distributed Generators Resources, Load Management.

I. INTRODUCTION

Since Independence India has made significant achievement in developing power sector, but as a country we are facing major challenges in providing electricity access to all the household and also improving reliability and quality in power system. The most important input could be infrastructure development in which power is the most important and critical sector. It is in this context that reforms in power sector assume importance. Regional Grid has been established and a national grid is in the process of evaluation. Despite these efforts the country continuous to face power shortage (7.3% energy shortage and 11.7 % peaking shortage in 2004-2005) and the access remain low (Overall 55 % and rural 43.5 %) System losses are over 32 % and most of the state electricity board (SEBs) is incurring huge commercial losses.

Per Capita consumption of India is still very small compared to other countries as shown in fig.1.

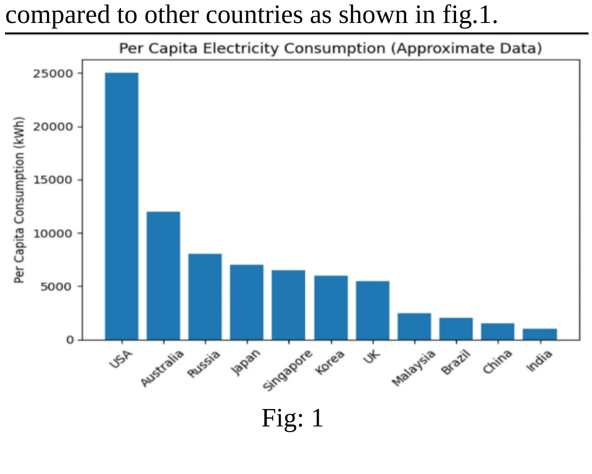


Fig: 1

Given this contextual background, government's goal to provide affordable and quality power for all by 2012 presents many challenges as well as opportunities to all those concerned with the development of the sector; the government, utilities, regulators, manufacturers and research and consultancy organization. A clear appreciation of the on-going development and future needs assumes importance in this context.

Power sector in most part of the world has been going through a process of reform for the past 15 years, In India the process started in 1991.The accelerated power development programmers (APDRP) launches by the government of India in 2001, is a landmark initiative to address this issue.

Energy demand of the country is increasing day by day and to meet this required demand. The conventional source is depleting at a faster rate. The use of conventional source at its extent result in pollutes the environment such as acid rain, greenhouse effect, pollution etc. Electricity generation from renewable energy sources is considered as a solution for environmental pollution, global warming and the rapid depletion of fossils fuels.

Government thought the world has generated a number of incentives to motivate development of renewable energy resources. Generation unit such as hydro-turbine, gas turbine, micro-turbine, solar PV, fuel cell and wind generation will be part of this mix.

A typical example is the UK where the Renewable obligation set a target that by 2010.10% of total electricity supplies should be from renewable energy plant.[1].

In most countries a great amount of this new generation (especially RE) is typically found in remote rural area where the loads are low. The distributed network (DN) is medium or even low voltage and designed for a unidirectional downstream flow of energy. As an alternative a utility as a customer can install distributed generation units at the customer site. This gives both the utility and customer additional flexibility during critical condition. for the utility it provides a mean for fast load reduction, while for the customers it can become a source of revenue or a tool for keeping critical load online.[2].

This is an increasing acceptance for the use of renewable energy source to achieve a sustainable power supply. This provides a vision of new energy supply structure, the integration of renewable energy source (REs) and distributed generation (DGs) into electricity grid.[3].

So, to fulfill that the new term emerges that is deregulation. In the process of deregulation entire power system is coming across the major changes in respect of generation, transmission and distribution with an objective of reliable, economic and quality power delivery to consumers. Deregulation has given rise the innovative ideas for connecting the power system components. Use of renewable energy source which are termed as distributed generators is one of them.

II. DEREGULATION OF POWER SYSTEM

In the earlier times there had been a vertical operation of the power system. The functions generation, transmission and distribution were been performed in regulated manner. In the old setup the generating unit is far away from the load centers. As the demand from consumers rapidly increases it becomes a difficult job for transmission and distribution to bridge the supply demand gap [4].

Deregulation is the process of power system restructuring in which laws and the policies of the power generation, transmission and distribution are reframed. Entire power industries are undergoing this process. This process of deregulation mainly involves unbundling of electric utilities into generation, transmission and distribution companies. With the deregulation it could be possible to divide the entire power industries into different parts such as generation, transmission and distribution companies. Main objective of deregulation is to provide electricity to consumers which will be qualitative, quantities and economics. It also to provide the competitive market to different entities in the restructured model of power system.[5].as shown in fig 2.

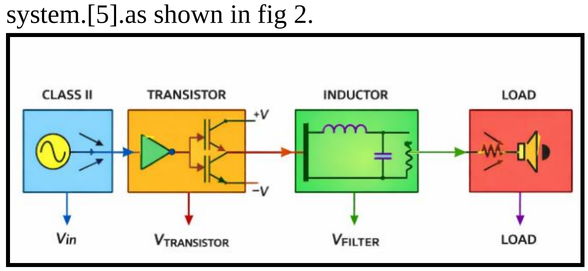


Fig: 2

Because of the restructuring and deregulation of power utilities, the power industries are going through turbulent, competitive, technological and regulatory changes, which affects its planning, operation, control, cost and reliability of power system.[6].

As earlier discussed, restructuring mainly involves unbundling of electric utilities into generation, transmission and distribution companies and permitting private industries to enter into generation, transmission and distribution. it further gives rise the concept of distributed

generators, micro-grid and utilization of independent regulatory authority.[7].

In the overall process of deregulation, an attention is needed to be given for improvement in transmission infrastructure, to make it possible to handle the power with free access. A new infrastructure is required to build up. It further requires a large investment. However, as an earlier step towards deregulation, small generators with renewable energy sources can be connected to power distribution network, thereby serving the objective of economic and reliable power delivery to customers. [8,9].

III. DISTRIBUTED GENERATORS

Electricity generation from renewable energy sources is considered as a solution for environmental pollution, global warming and the rapid depletion of fossil fuel.

Government thought the world have generated a number of incentives to motivate development of renewable energy sources (REs). A typical example is the UK where the Renewable obligation set a target that by 2010, 10% of total electricity supplied should be from renewable energy plant. In absolute terms this implies connections of around 200 MW of new distributed generators (DG) plant every year. By the year 2000, 20 % of California's electrical demand will be met by distributed energy resources. The decentralized energy generation will be continually integrated into the existing power network.

The deregulated environment will see energy produced locally, close to the load centers and the power ratings of these many generators will be in the hundreds of kilowatts to the tens of megawatt range. In most countries, a great amount of this new generation (especially DG) is typically found in remote rural areas where loads are low.

Distributed generation (DG) systems with generators installed in the medium or low voltage networks have becomes popular in distribution systems. The energy market is going to be restructured into a significantly more competitive market many companies is going to be restructured into a significantly more competitive industry. Many energy companies are containing to install distributed generations in medium or low voltage distribution system as a part of new customer-focused corporate strategy. The unit installed on distribution system will typically be no larger than 1 to 2 MW. This would be installed mostly by the utility itself or by the end users. This method of generation commonly referred to as Distributed Generators (DG).as shown in FIG 3.

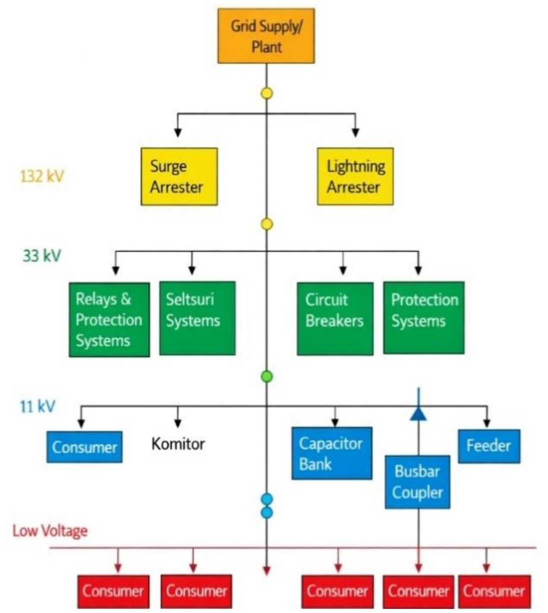


Fig:3 Distributed Generators

Distributed generations (DG) are small-scale generation that is usually connected to the medium or low voltage system. It could be wind turbine, photovoltaic generation, micro-turbines, fuel cells, battery storage, combustion engine, small hydro are coming into load side.

As a new power delivery system with such generation flexible, reliable and intelligent electrical supply delivery system (FRIENDS) is proposed. For utility DG can help to maintain system stability, provide the spinning reserve and reduce the transmission and distribution cost. For end users DG can provide power supply flexibility and improve power quality. For the society, the renewable energy can reduce the emission from traditional power plant. As per the various studies by the year 2010 approximately 20 % of all the power generation is predicated to come from distributed generators. [10]

Business today is depended on global consumers and requires 100% power reliability 7days a week,24 hours a day, many businesses provide 2 or 3 shifts and 5 to 7 days a week depending on their customer demand. Also, they rely on non-manufacturing hours to process orders, back up computer networks and up-date manufacturing information. Business today demands premier power services that guarantee 100% power availability.

Many uncontrollable circumstances can affect power availability. Some of these include hurricanes, ice and snowstorms, lightning etc. weather information services give the public advanced warning of upcoming storms so that preventive measures can be taken. Automobile accidents cannot be predicated but the impact of the power outage can be minimized with the right type of equipment.

A specific example is when a server lightning storm is moving through an area. A local manufacturing facility could transfer to its own generation without interruption of power. When a storm passes the load can be transferred back to the utility again without interrupting the load. This is a common case in the deregulated power environment. DG would be better solution to deal such and similar cased.

Distributed generation refer to the production at or near the place of consumption. Example of distributed generation include backup generators at hospital, solar photovoltaic system on residential rooftops and combined heat and power CHP system (also known as cogeneration)

In industrial plant and university campus. These applications differ from the infrastructure for supplying electricity that utilities in the United States have built over the past decades. These basic characteristics differentiate most distributed generation from traditional electricity supply location capacity and grid connections. Distributed generators are located at or near the point at which the power is used. They are typically on-site generators owned and operated by retail customers that are used to meet a portion of the customers demand or to provide backup service for customers that need highly r4eliable power. Application of distributed generators would include combined heat and power operation for examples the cold weather territory and institute could use CHP to generate electricity on campus and then use waste steam from boiler toe heat buildings.

Electric utilities can also install their own generators near customers. Such installations reserve congestion in power line during periods of peak demand, helping to defer investment in additional transmission and distribution capacity.

They may also be used to most the quality and reliability of local electricity service by providing voltage control and backup power to customers who require such premium service.

The second defining characteristics of distributed generation are its size. Generation capacities of customer-owned units used primarily to meet on-site requirements. Typically range from a few kilowatts to several hundred kilowatts. Generators in this range are typically best suited to applications that meet the energy demand of individual homes and business. Very few customers require generator larger than 1 MW to serve only their on-site need. -The level of third connection with the load or regional grid is the third characteristics that distinguish distributed generation (1-2 MW) from traditional supplies. Traditional supplies are connected to the grid at the transmission level (the high voltage portion of the delivery network)

If distributed generators came into widespread use, most distributed generators would be connected to the grid at the distribution level. Which is the portion of the delivery network, built with limited capacity, that transport electricity at low voltage for the final few miles to the customer (This is also the portion of the network that is owned and operated by local retail utilities, most of which are regulated by state agencies. Most of the policy debate surrounding distributed generation concerns small (Less than 2 MW) customer-owned system that primarily serve on site loads and are connected to the utility network at the distribution level. The debate has arisen in part because of technical issues surrounding distribution level connections to the grid and possible conflicts between local utilities and generators that are both produce of electricity and detail utility customers.

IV DISTRIBUTED GENERATORS RESOURCES

Several technologies are frequently mentioned as well that suited to small and medium-sized distributed generation applications. Among the technologies fueled by fossil energy are conventional steam turbines, combustion turbines, internal combustion engine generators, and micro turbines and fuel cells. The renewable technologies are photovoltaic cells, wind-powered generators and biomass-fueled generators. Amongst these, fuel cells and renewable technologies are proved to be the most suitable for low powered distributed generators.

Fuel cells use an advanced electrochemical process to generate electricity. The process is comparable to that used in conventional batteries, except that the reactant material in fuel cells can be replenished so that the units will not run down. Fuel cells produce virtually no emissions of air pollutants or greenhouse gases. Because their costs per installed kilowatt are still high relative to those of conventional technologies, commercially available fuel cells currently suit only very specialized applications. But some companies have developed new fuel cell technologies that they project will lower costs significantly [11].

Photovoltaic cells convert sunlight directly into an electric current. A panel of semiconductor material sandwiched between two conducting layers absorbs solar energy and releases electrons to produce the current. Photovoltaic systems can be small, which is why they are widely used in residential settings, particularly in the Southwest and California. Since photovoltaic systems, by their nature, produce electricity intermittently, they require battery storage or a supplemental power source to provide continuous electricity service. Photovoltaic cells produce no direct emissions, and they have low maintenance requirements. Improvements in manufacturing processes have reduced the costs of photovoltaic systems significantly in the past decade. [11]

Wind generators are turbines powered by windmills. A mature technology, wind turbines have been widely used in California and Europe by utilities and independent power producers to generate electricity to be sold over the grid. In California, wind farms have total generating capacities ranging from 15 megawatts to more than 600 megawatts (individual turbines at those sites have capacities of more than 1 megawatt). Most analysts would not consider large wind turbines to be a type of distributed generation because they are not typically located near customers. As with photovoltaic cells, the potential of wind generators is limited by available wind resources and by issues related to the sitting of these large towers with their rotating wind blades (including noise and threats to migrating birds). Silent rooftop wind energy system is latest development in the technology of wind generators. These turbines are vibration free and can be installed on the buildings. These are designed for as low as 1.5 kW power outputs [12].

Small wind turbines designed for residential and rural applications to date account for only a limited share of the market. For residential and small commercial distributed generation applications, suitable wind turbine capacities are 5 kilowatts to 50 kilowatts. The installed costs per kilowatt for those smaller systems are much higher than for the large systems. Because of the large amount of space they require, small wind generators are generally appropriate for applications in rural areas with good wind resources.

Biomass refers to a renewable fuel rather than to a particular technology. The EIA defines biomass as "organic non-fossil material of biological origin constituting a renewable energy source." Wood products, animal and plant agricultural waste, and municipal solid waste are all examples of biomass. Electric generators use biomass as fuel, often mixed with other fossil fuels. The most common use of biomass is to heat a conventional boiler directly. Another possible application is biomass gasification, in which the product would be used in place of natural gas. Although biomass may provide environmental benefits by displacing coal-fired generation, the burning of biomass and the production of animal wastes (as two examples) can create air and water quality problems of their own. The financial attractiveness of biomass depends on such factors as the availability and cost of the organic material, the avoided cost of alternative disposal of the material, and the need for residual heat to warrant cogeneration [13].

V CASE STUDY

Demographic Details

Indala comes under Gadchirolli District. It is 15 km from Gadchirolli According to sensex in 1996 the village is 306.29 Hector & population is near about

1207.Total agricultural land according to 96-97 is 426 square meter. Total agricultural land having irrigation is 101.00 Hector and diesel pump for this area is 10 nos and electric pump is 1 no. Total animals in this village according to sensex is 225 including cow, ox, Buffalos, etc. The population to animal ratio is consider to be 5/1. According to sensex in Indala the energy used pattern are simply agricultural as well as domestic

Substation Details

The substation is located at Gadchirolli (indala) It is about 80 km from main substation of Wirur & 8 km from the main city.

There is one 220 kV incoming feeder from Wirur. This 220kv is step down by main transformer the rating of the transformer is 220/33 kV, 25 MVA supplied power to (33kV) Gadchirolli, chamorshi, Dhanora & Armori.

This 33 KV step down voltage is again fed to two transformers having rating 33/11 KV 5 MVA.

1) 33/11KV, 5 MVA T.F.1 Fed power to 11KV Dhanora & 11KV Armori feeder.
2) 33/11KV, 5 MVA T.F.2 Fed power to 11KV Gadchiroli &11KV Charmoshi.

In Indala the energy used pattern are simply agricultural as well as domestic which shown in FIG 4.

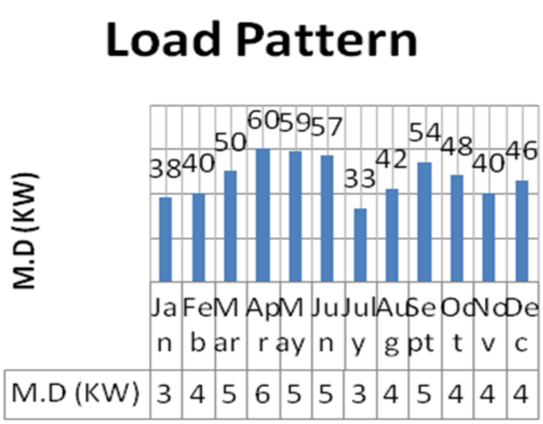


Fig: 4

The monthly average energy consumption per day is given in Table .1

Month	Average Load (kWh/d)
Jan	12.0
Feb	12.0
Mar	16.5
Apr	19.3
May	19.0
Jun	18.2
Jul	10.0
Aug	13.7
Sep	17.0
Oct	15.2
Nov	12.2
Dec	14.7

VI SIMULATION RESULT

The single line diagram representing the generating sources main source utility and two distributed generators DG1 and DG2 connected to the distribution. As shown in FIG.5.

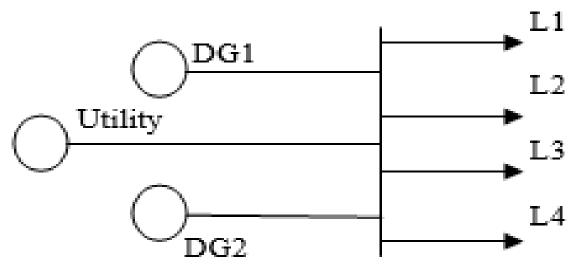


Fig: 5

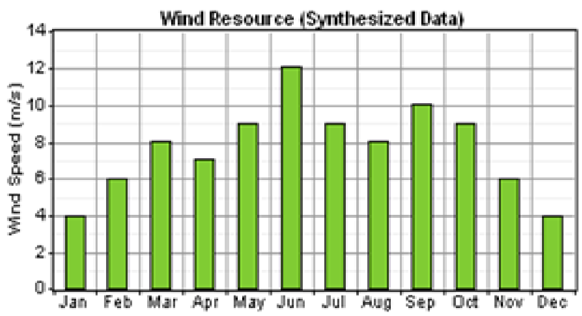
Load is varying from 33 KW to 60 KW is connected to the distribution feeder. The load mainly consists of domestic and agricultural load of Indala according to Sub-station information. The load is supplied from continuously operating basic source from utility grid, along with two distributors generators DG1of 1KW operated using wind energy and DG2 0f 5 KW operated using solar energy. Connected in parallel with battery and converter to the feeder.

1. Wind Source: -Monthly average wind speed in m/s is shown in Table.2

Data source: Synthetic

Month	Wind Speed (m/s)
Jan	4.0
Feb	6.0
Mar	8.0
Apr	7.0
May	9.0
Jun	12.0
Jul	9.0
Aug	8.0
Sep	10.0
Oct	9.0
Nov	6.0
Dec	4.0

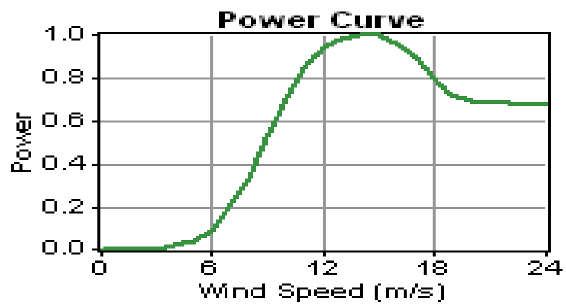
And graphical representation of wind data is shown infig.6



DC Wind Turbine: Generic 1kW

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	15,000	10,000	500

Quantities to consider:	0, 1
Lifetime:	15 yr
Hub height:	25 m



Weibull k:	2.00
Autocorrelation factor:	0.850
Diurnal pattern strength:	0.250
Hour of peak wind speed:	15
Scaled annual average:	7.67 m/s
Anemometer height:	25 m
Altitude:	0 m
Wind shear profile:	Logarithmic
Surface roughness length:	0.01 m

2. PV Source: -Solar Resource

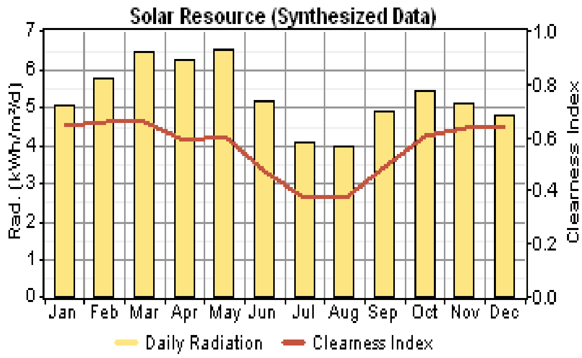
Latitude:	18 degrees 4 minutes North
Longitude:	78 degrees 5 minutes East
Time zone:	GMT +5:30

The monthly average radiation and clearness index is shown in fig 7.

Data source: Synthetic

Month	Clearness Index	Average Radiation (kWh/m^2/day)
Jan	0.647	5.031
Feb	0.661	5.755
Mar	0.659	6.448
Apr	0.591	6.233
May	0.603	6.534
Jun	0.477	5.177
Jul	0.376	4.061
Aug	0.375	3.976
Sep	0.488	4.876
Oct	0.606	5.443
Nov	0.638	5.074
Dec	0.643	4.794

Scaled annual average: 5.28 kWh/m²/d and graphical representation in fig 8.



PV System

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
5.000	15,000	10,000	0

Sizes to consider:	5 kW
Lifetime:	20 yr
Derating factor:	80%
Tracking system:	No Tracking
Slope:	18.1 deg
Azimuth:	0 deg
Ground reflectance:	20%

3. Battery: Trojan L16P

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	300	300	20.00

Quantities to consider:	12, 18, 24
Voltage:	6 V
Nominal capacity:	360 Ah
Lifetime throughput:	1,075 kWh

4. Converter

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
1.000	1,000	1,000	100

Sizes to consider	0, 6, 12, 18 kW
Lifetime	15 yrs
Inverter efficiency	90%
Rectifier relative capacity	100%
Rectifier efficiency	85%

5. Economics

Annual real interest rate:	6%
Project lifetime:	25 yr

Output Result

The simulation is carried using simu link software Homer 2.68 beta. The Overall combination of Sources is shown in fig.9

PV (kW)	G1	L16P	Converter (kW)	Initial capital
5	1	12	6	$ 39,600
5	1	18	6	$ 41,400
5	1	24	6	$ 43,200
5	1	12	12	$ 45,600
5	1	18	12	$ 47,400
5	1	24	12	$ 49,200
5	1	12	18	$ 51,600
5	1	18	18	$ 53,400
5	1	24	18	$ 55,200

Operating cost ($/yr)	Total NPC	COE($/kWh)
2,085	$ 66,247	0.947
2,311	$ 70,938	1.014
2,537	$ 75,628	1.081
2,844	$ 81,955	1.171
3,070	$ 86,645	1.238
3,296	$ 91,336	1.305
3,603	$ 97,662	1.396
3,829	$ 102,353	1.463
4,056	$ 107,044	1.530

The most suitable configuration the homer can select is shown in fig.10

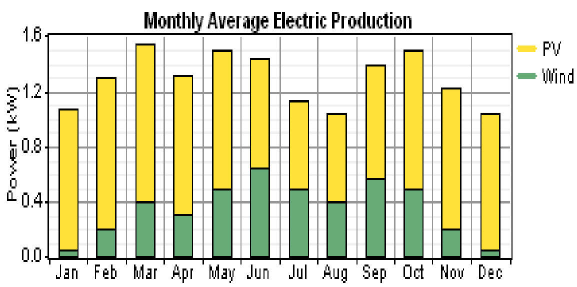
PV (kW)	G1	L16P	Converter (kW)	Initial capital
5	1	12	6	$ 39,600

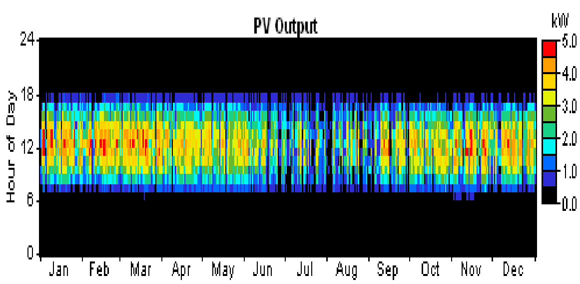
Operating cost ($/yr)	Total NPC	COE ($/kWh)	Renewable fraction
2,085	$ 66,247	0.947	1.00

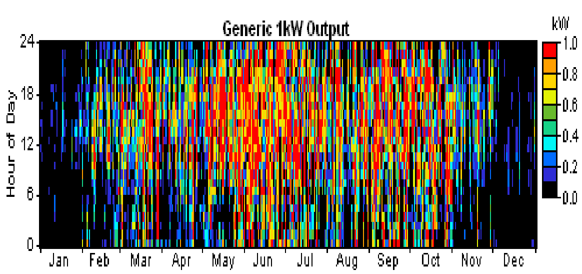
Electrical Output of the source is shown in fig no.11

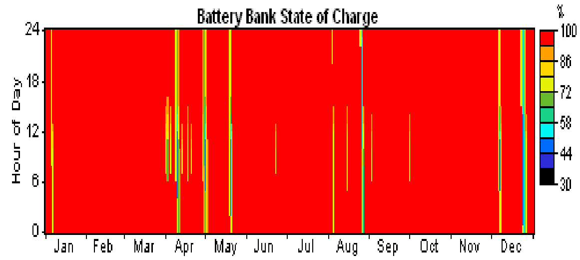
Component	Production (kWh/yr)	Fraction
PV array	8,153	72%
Wind turbine	3,110	28%
Total	11,263	100%

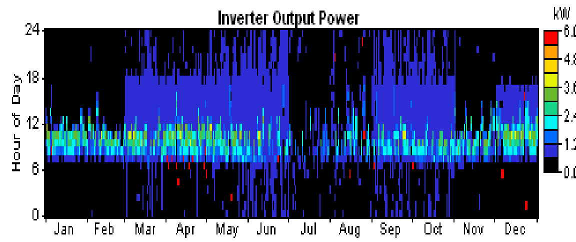
The graphical representation of output is shown in fig.12











With Utility source the PV array shares about 72% of load whereas wind turbine shares about 28%.

VII CONCLUSION

It was discussed that the renewable resources such as photovoltaic and wind power could be the best options for distributed generators. However, the use of renewable sources in DGs is not the only factor that decides the successful operation of DG system. It is decided by providing switching control mechanism according to the load variation at the distribution feeder.

As a sample the load variation for 1 year of Indala distribution feeder of 11 KV is taken. And simulation carried out by using Homer 2.68 beta.

Finally, it can be concluded that in deregulated environment DGs with proper renewable sources, power crises in the smaller load distribution area can be solved up to greater extent. Instead of overloading the main grid system.

VIII DISCUSSION

There is need for DGs to be able to operate to meet the peak demand. So that the main grid can't not be over loaded DG can be used to make the weak grid stronger because according to Indian contexts due to environmental changes high terrain, population and lack of investment and we know that Infrastructural development is demanding huge investment. So Private sector participation/slauding for generation, transmission and distribution is offered. Already DGs are in operation such as in multiplex, in hospital in society and institutes for back power but they didn't control and monitored by any authorities to ensure load dispatch scheduled as well as environmental impacts.

From the data shown in fig. shows that due to lack of infrastructural development to meet out the demand the distributed generators (DG) are needful. So that it saves the transmission cost or we say that DG is cost effective.

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