ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 6, June 2012

Environmental and Economic Aspects of Hybrid Distributed Generation in an Electrical Distribution System

J.A.Baskar, R.Hariprakash, M.Vijayakumar

Abstract-The increasing interest in Distributed Generation (DG) is driven by political, environmental, economical and technical developments in the recent times due to existing electrical distribution system now facing great challenges in several areas depending on the market economy, extensive global integration and constant need for more electrical power, which is forcing the system to operate much closer to its stability limits. An economic and environmental study is carried out on Fuel cell-PV-Wind (hybrid DG) energy and micro turbine-PV-Wind DG installations connected to the electrical grid system. Initially, an economical study is performed, proposing different scenarios where different values of interest rate and energy tariffs are considered. The parameters used to determine the profitability of a Fuel cell-HybridDG installation are determined. Further the environmental benefits of the proposed Fuel cell-PV-Wind systems connected to the grid have been evaluated compared with micro turbine cell-PV-Wind systems. This has been accomplished using HOMER (Hybrid Optimization Model for Electric Renewable) software. The contamination or emissions reduction and the externality costs are presented. The overall energy management strategy for coordinating the power flows among the different energy sources is presented with cost-effective approach.

Index Terms- **Distributed Generation, Hybrid DG, Emissions, Electrical Distribution System, HOMER.**

I. INTRODUCTION

Distributed generation (DG) can be defined as a source of small electric power connected to a distribution network or at a customer site, representing an innovative and efficient way to both generate and deliver electricity. Technological developments now allow power generation systems to be built in smaller sizes with high efficiency, low cost, and minimal environmental impact. Distributed generation can serve as a supplement to electricity generated by huge power plants and delivered through the electric grid [1]. Due to natural intermittent properties of wind and solar irradiation, standalone wind/PV renewable energy systems normally require energy storage devices or some other generation sources to form a hybrid system. Different renewable energy sources can complement each other, forms hybrid alternative energy systems with proper control have great potential to provide higher quality and more reliable power to customers than a system based on a single resource. There are many combinations of different alternative energy sources and storage devices to build hybrid systems that have been reported in paper [3]. The same authors presented the economic impact of hybrid DG in an electrical distribution system with cost effective approach [5]. Azmy A. M. and Erich I [6] presented the most economic operation regarding the operating costs of Fuel cells and micro turbines with AC Grid using genetic algorithms and neural networks. Cotrell, W. Pratt proposed the approach of feasibility of fuel cell and hydrogen internal combustion engines with remote DG systems [7].Milani, Neil Patrick presented the Performance Optimization of a Hybrid Wind Turbine-Diesel Micro grid Power system [9].However, the issues on optimal system configuration, power management and environmental aspects using fuel cell and micro turbines among different renewable energy sources with distribution system are not resolved yet. Therefore, more research work is needed on new alternative energy systems and their corresponding control strategies. Fuel cells are good energy sources to provide reliable power at steady state, but they cannot respond to electrical load transients as fast as desired and also costlier when compared with other DG sources. This problem is mainly due to their slow internal electrochemical and thermodynamic responses [5]. In this paper the proposed Fuel cell with wind and PV connected to electrical grid can complement each other, forms hybrid alternative energy systems with proper control have great potential to provide higher quality and more reliable power with cost effective to customers. There are many combinations of different alternative energy sources and storage devices to build a hybrid system. Among the list of some of the stand-alone or grid-connected hybrid systems that have been reported in paper [5] by the same authors, Fuel cell based DG (Wind-PV) and micro turbines based DG (Wind-PV) with AC Grid model has been proposed in this paper. In the proposed systems, the economic and environmental emissions using fuel cell and micro turbines with natural gas as fuel are presented. A hybrid alternative energy system can either be stand-alone or grid-connected if utility grid is available. For a stand-alone application, the system needs to have sufficient storage capacity to handle the power variations from the alternative energy sources involved. A system of this type can be considered as a micro-grid, which has its own generation sources and loads .For a grid-connected application, the alternative energy sources in the micro-grid can supply power both to the local loads and the utility grid [5]. In addition to real power, these DG sources can also be used to give reactive power and voltage support to the utility grid. The capacity of the storage device for these systems can be smaller if they are grid-connected since the grid can be used as system backup. However, when connected to a utility grid, important operation and performance requirements, such as voltage, frequency and harmonic regulations, are imposed on the system. This paper is set out as follows: Section II represents the distribution network connected with hybrid

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 6, June 2012

(Wind-PV) DG with fuel cell using natural gas as fuel was simulated and optimized results are analyzed and Section III represents the distribution network connected with hybrid (Wind-PV) DG with micro turbine using natural gas as fuel was analyzed. In Section IV results obtained with the simulation process using [10] in fuel cell hybrid DG and micro turbine based hybrid DG was analyzed and compared with the optimized categorized results based on both economical and environmental basis and the presence of fuel cell with DG using natural gas proved to be a economical and less pollutant based on CO_2 emissions.

II. FUEL CELL HYBRID DG CONFIGURATION WITH GRID

Figure 1 shows the system configuration for the proposed hybrid alternative energy system connected to electrical grid. In the system, the renewable wind-fuel cell-PVsystem can be considered as a complete "green" power generation system because the main energy sources are all environmentally friendly. With HOMER software, proposed DG System combination of photovoltaic (PV) modules, wind turbines and fuel cells was modeled with distribution systems serving electric and thermal loads.

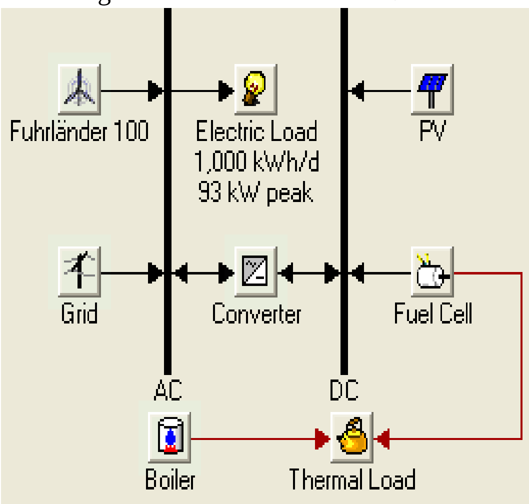


Fig.1.Block Diagram of Hybrid (Wind-PV-Fuel Cell) DG with AC Grid

The analysis and design of distribution systems can be challenging, due to the large number of design options and the uncertainty in key parameters, such as load size and future fuel price. Renewable power sources add further complexity because their power output may be intermittent, seasonal, and non-dispatchable, and the availability of renewable resources may be uncertain. This software was designed to overcome these challenges. The Proposed system configuration has been performed by three principal tasks namely simulation, optimization, and sensitivity analysis.

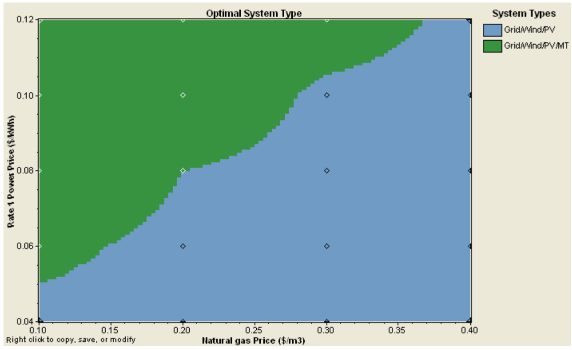


Fig2.Portion Of Simulation Results For The Proposed Wind-PV-Fuel Cell Hybrid DG System Connected to AC Grid.

This analysis represents an estimation of the potential CO_2 emission reductions, in that it focuses solely on technical capabilities assuming no economic or policy constraints. This analysis assumes successful achievement of performance and deployment targets associated with several advanced technologies as a basis for estimating CO_2 emissions reduction potential mentioned below:

- End-use energy efficiency
- Renewable energy
- Advanced light water nuclear reactors
- Advanced coal power plants
- CO_2 capture and storage
- Plug-in hybrid electric vehicles
- Distributed energy resources

To estimate potential CO_2 emissions reductions, this analysis calculated a different electricity generation mix based upon the technical targets, and then calculated the change in CO_2 emissions[15].The emissions reduction is calculated for each technology separately over time and graphed relative to the emissions indicated in appendix.

A. Simulation

The simulation process determines how a particular system configuration, a combination of system components of specific sizes, and an operating strategy that defines how those components work together, would behave in a given setting over a long period of time. This software can simulate a wide variety of micro power system configurations that generates electricity, to serve a nearby load. Such a system may employ any combination of electrical generation and storage technologies and may be grid-connected or autonomous, meaning separate from any transmission grid. Comprising combination of a PV array, wind turbines, an ac–dc converter and fuel cell system can be useful for grid-connected or autonomous loads. This software models a particular system configuration by performing an hourly time series simulation of its operation over one year and also steps through the year one hour at a time, calculating the available renewable power, comparing it to the electric load, and deciding what to do with surplus renewable power in times of excess, or how best to generate additional power in times of deficit. When it has completed one year's worth of calculations, it determines whether the system satisfies the constraints imposed by the user on such

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 6, June 2012

quantities as the fraction of the total electrical demand served, the proportion of power generated by renewable sources, or the emissions of certain pollutants. Achieving the indicated emission reductions requires deployment of a diverse set of new and existing technologies, none of which will provide the majority of potential reductions. In other words, there is no method that represents the bulk of emissions-reducing potential. Consequently, if one or more of these technology options are not available, even more aggressive levels of technology performance and deployment would be necessary in the remaining technology areas to achieve the estimated emissions-reduction potential. Key enabling grid-related technologies are needed to fully realize the emissions – reduction potential associated with end-use efficiency, renewables, plug-in hybrid electric vehicles, and distributed energy resources. In this paper distribution network connected with hybrid (Wind-PV) DG with fuel cell and microturbines was simulated.

B. Optimization Results

In the optimization process, the proposed system was simulated with many different system configurations in search of the one that satisfies the technical constraints at the lowest life-cycle cost. In the sensitivity analysis process, it was performed with multiple optimizations under a range of input assumptions to gauge the effects of uncertainty or changes in the model inputs. The analysis assesses the economic and environmental impact of the technologies tied to a specific CO_2, Carbon monoxide, unburned hydrocarbons, particulate matter, Sulfur dioxide and Nitrogen oxides emissions constraint. It is a general equilibrium economic model that has been used to analyze the cost of CO_2 emissions mitigation as a function of technology cost, availability, and performance. Using technology descriptions and policy constraints as inputs, the model outputs not only energy production by technology, but also prices for wholesale electricity and carbon emissions. Optimization determines the optimal value of the variables over which the system designer has control such as the mix of components that make up the system and the size or quantity of each. Sensitivity analysis helps assess the effects of uncertainty or changes in the variables over which the designer has no control, such as the average wind speed or the future fuel price. The simulation process determines how a particular system configuration, a combination of system components of specific sizes, and an operating strategy that defines how those components work together, would behave in a given setting over a long period of time. The life-cycle cost is a convenient metric for comparing the economics of various system configurations. Such comparisons are the basis of optimization process, described in the table1 below gives the overall optimized results of a proposed hybrid system in the overall optimization results. They are listed in order (from top to bottom) of most cost-effective to least cost-effective. CO_2 emissions reductions policies will create a cost to the economy. Reducing CO_2emissions will require fundamental changes in how we produce, transform and use energy. The costs of emissions abatement will be determined through a combination of making investments today to ensure ample supplies of low cost, low emissions intensity energy alternatives in the future and reliance on higher cost substitutes in the interim. This analysis shows the implications of different paths. The extent of advanced technology development and deployment also influences natural gas usage and pricing in the context of meeting policy constraints. In the optimization results it gives us economic details about each system configuration. Table1 displays only the most cost effective configuration of each system design in which the most economical categorized result gives the least operating cost. It has been displayed in highlighted row in table2 which indicates the proposed hybrid DG system gives less operating cost of $34008 per year with 56% of utilization of renewable sources. The emission particulars of different pollutants are simulated and shown in table3.

Table1: Important Overall Optimization Results For The Proposed Fuel Cell Based Hybrid DG (Wind-PV) System Connected To AC Grid.

PV (kW)	FL 100	FC (kW)	Converter (kW)	Grid (kW)	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Renewable fraction	Natural gas (m3)	FC (hrs)
1	10	20	20	100	$342,000	36,771	$734,517	0.176	0.57	38,480	6,001
1	10	20	20	80	$342,000	36,771	$734,517	0.176	0.57	38,480	6,001
1	10	40	40	100	$387,000	34,008	$750,028	0.18	0.56	44,902	3,816
1	10	40	40	80	$387,000	34,008	$750,028	0.18	0.56	44,902	3,816
1	10	40	40	60	$387,000	34,009	$750,039	0.18	0.56	44,912	3,819
1	10	20	40	100	$357,000	36,918	$751,093	0.18	0.57	38,480	6,001
1	10	20	40	80	$357,000	36,918	$751,093	0.18	0.57	38,480	6,001
1	10	40	60	100	$402,000	34,156	$766,603	0.184	0.56	44,902	3,816
1	10	40	60	80	$402,000	34,156	$766,603	0.184	0.56	44,902	3,816
1	10	40	60	60	$402,000	34,157	$766,615	0.184	0.56	44,912	3,819
1	10	20	60	100	$372,000	37,066	$767,668	0.184	0.57	38,480	6,001
1	10	20	60	80	$372,000	37,066	$767,668	0.184	0.57	38,480	6,001
1	10	40	20	60	$372,000	38,289	$780,723	0.188	0.58	25,225	759
1	10	40	80	100	$417,000	34,303	$783,179	0.188	0.56	44,902	3,816
1	10	40	80	80	$417,000	34,303	$783,179	0.188	0.56	44,902	3,816
1	10	40	80	60	$417,000	34,304	$783,190	0.188	0.56	44,912	3,819
1	10	20	80	100	$387,000	37,213	$784,244	0.189	0.57	38,480	6,001
1	10	20	80	80	$387,000	37,213	$784,244	0.189	0.57	38,480	6,001
1	10	60	40	40	$417,000	35,287	$793,678	0.191	0.56	42,781	3,175
1	10	60	60	40	$432,000	34,117	$796,194	0.192	0.55	46,615	3,175
1	10	40	20	80	$372,000	39,948	$798,431	0.192	0.58	23,249	53
1	10	40	100	100	$432,000	34,451	$799,754	0.193	0.56	44,902	3,816
1	10	40	100	80	$432,000	34,451	$799,754	0.193	0.56	44,902	3,816
1	10	40	100	60	$432,000	34,452	$799,766	0.193	0.56	44,912	3,819
1	10	20	100	100	$402,000	37,361	$800,819	0.193	0.57	38,480	6,001
1	10	20	100	80	$402,000	37,361	$800,819	0.193	0.57	38,480	6,001
1	10	60	60	60	$432,000	35,532	$811,296	0.196	0.56	34,655	1,243
1	10	60	60	100	$432,000	35,591	$811,925	0.196	0.56	34,178	1,185
1	10	60	60	80	$432,000	35,591	$811,925	0.196	0.56	34,178	1,185
1	10	60	20	60	$402,000	38,412	$812,045	0.196	0.58	25,225	759
1	10	60	80	40	$447,000	34,265	$812,770	0.196	0.55	46,615	3,175
1	10	60	40	60	$417,000	37,146	$813,525	0.196	0.57	28,415	759
1	10	60	20	80	$402,000	39,638	$825,128	0.199	0.58	23,249	53
1	10	60	80	60	$447,000	35,680	$827,871	0.2	0.56	34,655	1,243
1	10	60	80	100	$447,000	35,738	$828,500	0.2	0.56	34,178	1,185
1	10	60	80	80	$447,000	35,738	$828,500	0.2	0.56	34,178	1,185
1	10	60	100	40	$462,000	34,412	$829,345	0.2	0.55	46,615	3,175
1	10	60	20	100	$402,000	40,827	$837,824	0.202	0.58	23,101	0
1	10	60	40	80	$417,000	39,724	$841,043	0.203	0.58	23,470	53
1	10	80	20	60	$432,000	38,536	$843,367	0.204	0.58	25,225	759
1	10	60	100	60	$462,000	35,827	$844,447	0.204	0.56	34,655	1,243
1	10	80	40	60	$447,000	37,270	$844,847	0.204	0.57	28,415	759
1	10	60	100	100	$462,000	35,886	$845,076	0.204	0.56	34,178	1,185
1	10	60	100	80	$462,000	35,886	$845,076	0.204	0.56	34,178	1,185
1	10	80	40	40	$447,000	37,440	$846,659	0.205	0.56	42,781	3,175
1	10	80	60	40	$462,000	36,153	$847,927	0.205	0.55	47,106	3,175
1	10	80	20	80	$432,000	39,329	$851,825	0.206	0.58	23,249	53
1	10	80	60	60	$462,000	36,716	$853,940	0.207	0.56	31,328	759
1	10	60	40	100	$417,000	40,975	$854,400	0.207	0.58	23,101	0
1	10	80	80	40	$477,000	36,186	$863,281	0.209	0.55	47,587	3,175
1	10	80	20	100	$432,000	40,494	$864,265	0.209	0.58	23,101	0
1	10	80	40	80	$447,000	39,414	$867,740	0.21	0.58	23,470	53
1	10	80	80	60	$477,000	36,750	$869,294	0.21	0.56	31,808	759
1	10	100	20	60	$462,000	38,660	$874,689	0.212	0.58	25,225	759
1	10	100	40	60	$477,000	37,394	$876,169	0.212	0.57	28,415	759
1	10	100	20	80	$462,000	39,019	$878,522	0.213	0.58	23,249	53
1	10	80	100	40	$492,000	36,334	$879,856	0.213	0.55	47,587	3,175
1	10	100	60	40	$492,000	38,306	$900,907	0.219	0.55	47,106	3,175
1	10	80	60	20	$462,000	42,503	$915,707	0.222	0.54	59,095	6,536
1	10	100	80	40	$507,000	38,331	$916,175	0.222	0.55	47,621	3,175
1	10	100	100	60	$522,000	37,011	$917,080	0.223	0.56	31,852	759
1	10	80	80	20	$477,000	42,127	$926,698	0.225	0.54	59,576	6,536
1	10	100	100	40	$522,000	38,476	$932,726	0.227	0.55	47,631	3,175
1	10	80	100	20	$492,000	42,275	$943,273	0.229	0.54	59,576	6,536
1	10	100	60	20	$492,000	48,106	$1,005,516	0.245	0.54	59,095	6,536
1	10	100	80	20	$507,000	47,722	$1,016,419	0.248	0.54	59,610	6,536
1	10	100	100	20	$522,000	47,867	$1,032,971	0.252	0.54	59,620	6,536

Table2: Results of Emissions of Proposed Fuel Cell Based Hybrid DG (Wind-PV) With AC Grid System.

Pollutant	Emissions (kg/yr)
Carbon dioxide	171,066
Carbon monoxide	201
Unburned hydrocarbons	22.3
Particulate matter	15.2
Sulfur dioxide	464
Nitrogen oxides	1910

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 6, June 2012

The table3 below gives the categorized economical results of a proposed fuel cell based hybrid DG (Wind-PV) with AC Grid system. The parameters used in this study of various renewable energy resources have shown in appendix.

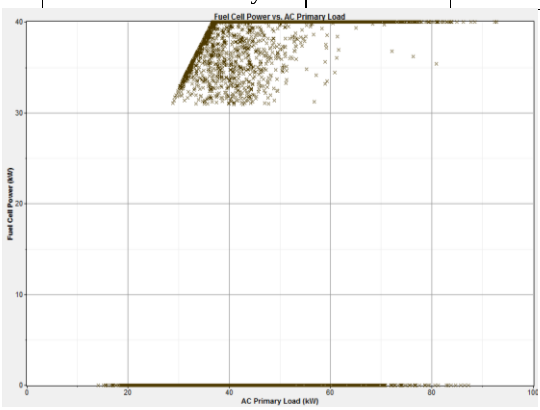
Table3: Categorized Economical Results of Proposed Fuel Cell Based Hybrid DG (Wind-PV) With AC Grid System.

PV (kW)	FL 100	FC (kW)	Converter (kW)	Grid (kW)	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Renewable fraction	Natural gas (m3)	FC (hrs)
1	10	20	20	100	$342,000	36,771	$734,517	0.176	0.57	38,480	6,001
1	10	20	20	80	$342,000	36,771	$734,517	0.176	0.57	38,480	6,001
1	**10**	**40**	**40**	**100**	**$387,000**	**34,008**	**$750,028**	**0.18**	**0.56**	**44,902**	**3,816**
1	10	40	40	80	$387,000	34,008	$750,028	0.18	0.56	44,902	3,816
1	10	40	40	60	$387,000	34,009	$750,039	0.18	0.56	44,912	3,819
1	10	20	40	100	$357,000	36,918	$751,093	0.18	0.57	38,480	6,001
1	10	20	40	80	$357,000	36,918	$751,093	0.18	0.57	38,480	6,001
1	10	40	60	100	$402,000	34,156	$766,603	0.184	0.56	44,902	3,816
1	10	40	60	80	$402,000	34,156	$766,603	0.184	0.56	44,902	3,816
1	10	40	60	60	$402,000	34,157	$766,615	0.184	0.56	44,912	3,819
1	10	20	60	100	$372,000	37,066	$767,668	0.184	0.57	38,480	6,001
1	10	20	60	80	$372,000	37,066	$767,668	0.184	0.57	38,480	6,001

Table 4: Results Of Fuel Cell Based On Electrical Output, Thermal Output And Total Efficiency With Hybrid DG (Wind-PV) Connected To AC Grid System.

FUEL CELL PARAMETERS

Quantity	Value	Units
Hours of operation	3,816	hr/yr
Number of starts	730	starts/yr
Operational life	10.5	yr
Capacity factor	42.1	%
Fixed generation cost	2.05	$/hr
Marginal generation cost	0.0420	$/kWhyr
Electrical production	147,470	kWh/yr
Mean electrical output	38.6	kW
Min. electrical output	30.9	kW
Max. electrical output	40.0	kW
Thermal production	95,010	kWh/yr
Mean thermal output	24.9	kW
Min. thermal output	19.9	kW
Max. thermal output	25.8	kW
Fuel consumption	30,969	m3/yr
Specific fuel consumption	0.210	m3/kWh
Fuel energy input	305,823	kWh/yr
Mean electrical efficiency	48.2	%
Mean total efficiency	79.3	%



.

Fig 4: Variation of Fuel Cell Power in KW versus the AC Primary Load in KW.

III. SYSTEM CONFIGURATION WITH MICROTURBINE BASED DG (WIND-PV) CONNECTED TO AC GRID

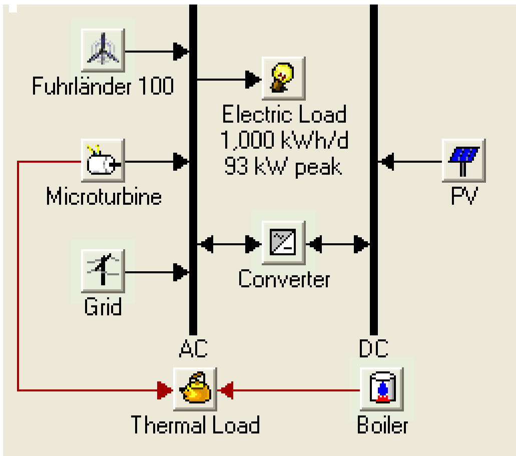


Fig.5: Block diagram of micro turbine based hybrid (Wind-PV-) DG with AC Grid.

Except the fuel cell the configuration is unchanged and simulated in the aspects of economical and environmental way. Table 5 gives the important economical results of the proposed microturbine based hybrid DG (Wind-PV) with AC Grid. Table 6 gives the important environmental results of the proposed microturbine based hybrid DG (Wind-PV) with AC Grid system. Table 7: Results of Fuel cell based on electrical output, thermal output and electrical and total efficiency with hybrid DG (Wind-PV) connected to AC Grid system.

Table 5: Important Economical Results of the Proposed Micro turbine Based Hybrid DG (Wind-PV) With AC Grid System.

PV (kW)	FL 100	MT (kW)	Converter(KW)	Grid (kW)	Initial cost	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Renewable fraction	Natural gas (m3)	MT (hours)
1	10		40	80	$65,167	50,872	$608,215	0.103	0.42	65,227	
1	10		40	100	$65,167	51,048	$610,092	0.103	0.42	65,227	
1	10	30	40	60	$92,667	49,068	$616,455	0.105	0.42	71,282	759
1	10	30	40	80	$92,667	50,133	$627,826	0.108	0.42	65,625	53
1	10	30	40	100	$92,667	50,748	$634,389	0.109	0.42	65,227	0
1	10	60	40	60	$120,167	49,824	$652,023	0.114	0.41	80,578	759
1	10	60	40	80	$120,167	49,904	$652,876	0.114	0.42	66,332	53
1	10		80	80	$94,333	52,811	$658,074	0.115	0.42	65,227	
1	10	60	40	100	$120,167	50,448	$658,686	0.115	0.42	65,227	0
1	10		80	100	$94,333	52,986	$659,951	0.116	0.42	65,227	
1	10	30	80	60	$121,833	51,006	$666,314	0.117	0.42	71,282	759
1	10	30	80	80	$121,833	52,072	$677,685	0.12	0.42	65,625	53
1	10	60	40	40	$120,167	52,711	$682,841	0.122	0.39	115,792	3,175
1	10		100	80	$108,917	53,780	$683,003	0.122	0.42	65,227	
1	10	30	80	100	$121,833	52,686	$684,248	0.122	0.42	65,227	0
1	10		100	100	$108,917	53,956	$684,881	0.122	0.42	65,227	
1	10	30	100	60	$136,417	51,976	$691,243	0.124	0.42	71,282	759
1	10	60	80	60	$149,333	51,762	$701,882	0.127	0.41	80,578	759
1	10	30	100	80	$136,417	53,041	$702,615	0.127	0.42	65,625	53
1	10	60	80	80	$149,333	51,842	$702,735	0.127	0.42	66,332	53
1	10	60	80	100	$149,333	52,386	$708,545	0.128	0.42	65,227	0
1	10	30	100	100	$136,417	53,656	$709,177	0.128	0.42	65,227	0
1	10	60	100	60	$163,917	52,731	$726,812	0.133	0.41	80,578	759
1	10	60	100	80	$163,917	52,811	$727,664	0.133	0.42	66,332	53
1	10	60	80	40	$149,333	54,649	$732,700	0.134	0.39	115,792	3,175
1	10	60	100	100	$163,917	53,355	$733,474	0.135	0.42	65,227	0
1	10	60	100	40	$163,917	55,618	$757,630	0.141	0.39	115,792	3,175
1	10	60	40	20	$120,167	63,637	$799,477	0.152	0.35	163,870	6,536
1	10	60	80	20	$149,333	65,575	$849,336	0.164	0.35	163,870	6,536
1	10	60	100	20	$163,917	66,545	$874,266	0.171	0.35	163,870	6,536

From the above results it is observed that the third row gives us the lowest operating cost of $49068 per year using microturbine based HG system with 42% of utilization of renewable sources.Figure6 gives the variation of cash flow versus net present cost in $.

Table 6: Environmental Results of the Proposed Micro turbine Based Hybrid DG (Wind-PV) With AC Grid System.

Pollutant	Emissions (kg/yr)
Carbon dioxide	334,323

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 6, June 2012

Carbon monoxide	66.6
Unburned hydrocarbons	7.37
Particulate matter	5.02
Sulfur dioxide	913
Nitrogen oxides	859

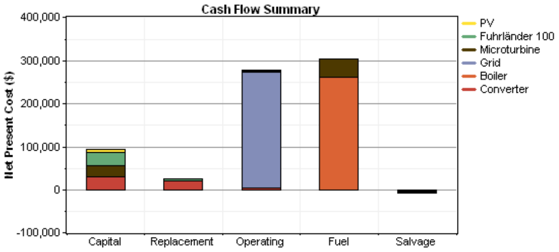


Fig 6: Variation Of Cash Flow In $ Versus Net Present Cost Of Micro turbine Based Hybrid (Wind-PV) DG

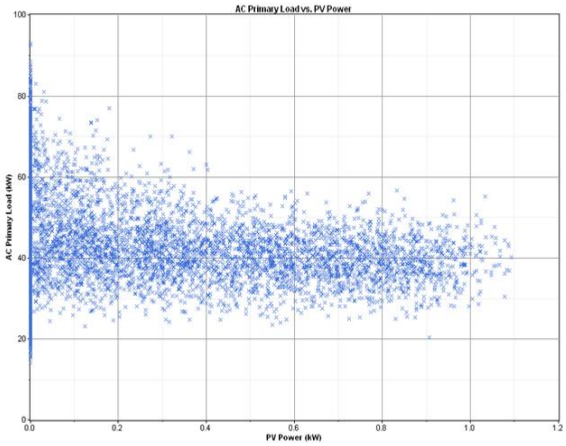


Fig 7: Variation of PV Power in KW versus the AC Primary Load in KW.

Table 7: Results of Micro Turbine Based Hybrid DG (Wind-PV) Connected To AC Grid on Electrical Output, Thermal Output and Total Efficiency.

MICROTURBINE PARAMETERS

Quantity	Value	Units
Hours of operation	759	hr/yr
Number of starts	308	starts/yr
Operational life	59.3	yr
Capacity factor	8.66	%
Fixed generation cost	3.20	$/hr
Marginal generation cost	0.1	$/kWhyr
Electrical production	22,751	kWh/yr
Mean electrical output	30	kW
Min. electrical output	21.8	kW
Max. electrical output	30	kW
Thermal production	39193	kWh/yr
Fuel energy input	101138	kWh/yr
Min. thermal output	45.7	kW
Max. thermal output	51.7	kW
Fuel consumption	10242	m3/yr
Specific fuel consumption	0.45	m3/kWh
Mean total efficiency	61.2	%
Mean electrical efficiency	22.5	%

IV. OPTIMISATION RESULTS OF FUEL CELL HYBRID DG AND MICROTURBINE HYBRID DG WITH GRID–A COMPARISON

Comparing the economic values in table3 and table5 the operating cost of the fuel cell is $34008 per year with 56% of utilization of renewable sources, whereas the operating cost of microturbine based HG system is $49068 per year with 42% of utilization of renewable sources. it clearly indicates that under certain combinations with cost effective constraints fuel cell is economical. Comparing the environmental emissions in table2 and table4, using fuel cell based hybrid HG, Carbon dioxide emissions are 171,066 kg/year and Sulfur dioxide emissions are 464 kg/year with Carbon dioxide emissions are 334,323 kg/year and Sulfur dioxide emissions are 913 kg/year. Therefore both in economical and environmental comparisons fuel cell based hybrid DG with ac grid are better than microturbine based hybrid DG with ac grid.

V. CONCLUSIONS AND RECOMMENDATIONS

The simulation and optimized results presented in this paper suggest the Fuel cell hybrid DG system is economical(less operating cost of $34008 per year with 56% of utilization of renewable sources) and environmentally less pollutant(Carbon dioxide emissions are 171,066 kg/year and Sulfur dioxide emissions are 464 kg/year) compared with microturbine based hybrid DG with ac grid(operating cost of $49068 per year with 42% of utilization of renewable sources and Carbon dioxide emissions are 334,323 kg/year and Sulfur dioxide emissions are 913kg/year). A reliable power source and the suitability of developed model for energy management studies of hybrid distributed generation systems with electrical distribution systems is presented in this paper. Further the total efficiency of the Fuel cell hybrid DG system is more (79.3%) when compared with micro hybrid DG system turbine hybrid DG system (61.2%). For economical reasons the technical challenges of interconnecting the distributed generation units with the distribution lines are ignored and the results are analyzed based on cost and emission factors.

VI. ACKNOWLEDGEMENTS

The authors would like to thank the Research Committee of the NREL and the HOMER software for submitting this paper.

REFERENCES

[1] Thomos Ackermann, Goran Andersosn, Lennart Soder, “Distributed generation: a definition” Elsevier Electric Power Systems Research Vol.57, 2001, pp. 195-204.

[2] W. EI-Khattan, M.M.A. Salama, “Distributed generation technologies, definitions and benefits” Elsevier Electric Power Systems Research Vol.71, pp. 119-128, 2004.

[3] Modeling and Control of Hybrid Wind/ PV/ Fuel Cell Distributed Generation Systems by Caisheng Wang,

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 6, June 2012

MONTANA STATE NIVERSITY Bozeman, Montana July 2006.

[4] Micro power System Modeling with Homer by Tom Lambert Mistaya Engineering Inc & PAUL GILMAN and PETER LILIENTHAL National Renewable Energy Laboratory.

[5] Economic Impact of Hybrid Distributed Generation in an Electrical Distribution System by J.A.Baskar, R.Hariprakash, M.Vijayakumar in "Journal of Theoretical and Applied Information Technology"15th January 2012. Vol. 35 No.1.

[6] Intelligent operation management of fuel cells and micro turbines using genetic algorithm and neural networks by Azmy A. M. and Erich I.

[7] Modeling the Feasibility of Using Fuel Cells and Hydrogen Internal Combustion Engines in Remote Renewable Energy Systems September 2003 J. Cottrell W. Pratt.

[8] K. Sedghisigarchi and A. Feliachi, "Dynamic and Transient Analysis of Power Distribution Systems with Fuel Cells—Part I: Fuel-Cell Dynamic Model," IEEE.

[9] Performance Optimization of a Hybrid Wind Turbine-Diesel Micro grid Power System by MILANI, NEIL PATRICK.

[10] HOMER Software from NREL.

[11] E. G. Potamianakis, C. D. Vournas, "Modeling and Simulation of Small Hybrid Power Systems", to appear in IEEE Power Tech, Bologna Italy, June 2003.

[12] Wind Energy and Production of Hydrogen and Electricity - Opportunities for Renewable Hydrogen Preprint J. Levene, B. Kroposki, and G. Sverdrup.

[13] Getting Started Guide for HOMER Version 2.1, April 2005.

[14] HOMER Software from NREL.

[15] Design of Isolated Hybrid Systems Minimizing.

[16] Costs and Pollutant Emissions José L. Bernal-Agustín*, Rodolfo Dufo-López and David M. Rivas-Ascaso.

AUTHOR BIOGRAPHY

J.A.Baskar received B.Tech degree in Electrical and Electronics Engineering from JNT University, Hyderabad India in1993, and M.Tech in Energy Management from S.V. University, Tirupathi, India in2005, India. He worked with Andhra Pradesh Dairy Dev Co-op federation Ltd., Chittoor, for 17 years. At present he is pursuing PhD in Electrical Engineering at JNTU, Anantapur, India. He is working as Associate Professor and HOD of EEE Dept. at Siddhartha Educational Academy group of institutions, Tirupathi. He has published 2 research papers in international journals. His research areas include power systems, Electrical Machines, Distributed generation system and energy management.

Dr.R.HariPrakash received B.Tech & M.Tech with distinction from Birla Institute of Technology Ranchi. He Obtained PhD from Indian Institute of Technology, Chennai. He has 35 years of Industry/Research/Teaching at various levels. He worked as senior lecturer at Nanyang University, Singapore. He worked in NBKR Institute of Science & Technology Vidyanagar as Assistant professor and became Professor and Head of the Department. He is a Member of Board of Studies at JNTU Anantapur, S.V.University, Anna University, and Vellore Institute of Technology. He has published seven papers in National & four papers in International Journals. He worked as Principal of Gokula Krishna College of Engineering, Sullurpet, and Sri Venkateswara College of Engineering Chittoor. Currently he is the Principal of Brahmaiah College of Engineering, North Rajupalem, Nellore-524 366. He has authored the book "Operations Research" published by SCITECH publishers, Hyderabad. He is a Member of Indian Society for Technical Education, Indian Society for Non-Destructive Testing, Indian society for Automobile Engineering and American society of Mechanical Engineering, Fellow of Institute of Engineers. His areas of research specialization are Energy Management, Energy Distribution, Alternate source of Energy, Eco-fuels.

Prof. M. Vijaya Kumar graduated from S.V. University, Tirupathi A.P India in 1988. He obtained M.Tech degree from Regional Engineering College, Warangal, India in 1990. He received Doctoral degree from Jawaharlal Nehru Technological University, Hyderabad, India in 2000. Currently he is working as Professor in Electrical and Electronics Engineering Department, JNTU College of Engineering, Anantapur, A.P, India. He is a member of Board of studies of few Universities in A.P., India. He has published 87 research papers in national and inter-national conferences and journals. Six PhDs were awarded under his guidance. He received two research awards from the Institution of Engineers (India). He served as Director, AICTE, and New Delhi for a short period. He was Head of the Department during 2006 to 2008. He also served as Founder Registrar of JNTUniversity, Anantapur during 2008 to 2010. His areas of interests include Electrical Machines, Electrical Drives, Microprocessors and Power Electronics.

APPENDIX

The machine and controller parameters that have been used in this paper during the simulations are given below.

System Report GridConnectedFuelCell-pv-wind

Sensitivity case:

Fuel Cell Capital Cost Multiplier	0.5
Fuel Cell Replacement Cost Multiplier	0.5
Rate 1 Power Price	0.1$/KWH
Rate 1 Demand Rate	0.1$/KW/mo

System architecture

Fuel Cell	40KW
PV array	1KW
Wind turbine	10*100KW
Grid	100KW
Inverter	40KW
Rectifier	40KW

System Report Grid Connected Micro-PV-Wind

Sensitivity case:

Natural gas price	0.3 $/m3
Rate 1 Power Price	0.1$/KWH

System architecture

1.

Micro turbine	30KW
PV array	1KW
Wind turbine	10*100KW
Grid	60KW
Inverter	40KW
Rectifier	30KW

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 1, Issue 6, June 2012

Wind Data

Description; Fuhrlander 100 (FL)

Rated Power: 100kW AC

S.No.	Wind Speed (m/s)	Power Output (kW)
1	0.00	0.000
2	1.00	0.000
3	2.00	0.000
4	3.00	1.000
5	4.00	2.000
6	5.00	8.000
7	6.00	17.000
8	7.00	30.000
9	8.00	45.000
10	9.00	63.000
11	10.00	79.000
12	11.00	94.000
13	12.00	108.000
14	13.00	119.000
15	14.00	125.000
16	15.00	122.000
17	16.00	120.000
18	17.00	112.000
19	18.00	107.000
20	19.00	101.000
21	20.00	97.000
22	21.00	96.000
23	22.00	95.000
24	23.00	94.000
25	24.00	97.000
26	25.00	101.000

4. Primary Load

Hour	Load (kW)
00:00 - 01:00	10.000
01:00 - 02:00	6.000
02:00 - 03:00	6.000
03:00 - 04:00	6.000
04:00 - 05:00	6.000
05:00 - 06:00	12.500
06:00 - 07:00	20.000
07:00 - 08:00	22.500
08:00 - 09:00	18.750
09:00 - 10:00	12.000
10:00 - 11:00	12.000
11:00 - 12:00	17.500
12:00 - 13:00	17.500
13:00 - 14:00	11.000
14:00 - 15:00	11.000
15:00 - 16:00	11.000
16:00 - 17:00	11.000
17:00 - 18:00	17.500
18:00 - 19:00	27.000
19:00 - 20:00	29.000
20:00 - 21:00	40.000
21:00 - 22:00	29.750
22:00 - 23:00	22.750
23:00 - 00:00	12.750