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Use of a Distributed Generation Source Independent of the National Network in Order to Supply a Part of Electric Energy Required by Ngl Project in Khark Island and Its Island-Wise Impacts on Reduction of Greenhouse Gases as Well as Reliability of the System

Milad Karimi[1*], Abbas Harifi[2], Alireza Sheikhi Finee[3]

[1]Department of Electrical eng.; Khomeini Shahr Branch; Islamic Azad University; Isfahan; Iran
[2,3]Faculty member of Hormozgan University - Faculty of Engineering and Technology - Department of Electrical & Electronics - Bandar Abbas – Iran

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ABSTRACT

This paper deals with analysis and evaluation of delivery of a part of electric energy to NGL plants on Khark Island. To describe the operation, a composite system consisted of renewable energies in the context of Distributed Generation (DG) was calculated by Homet software to obtain an economically ideal and optimal result. Homer is an advanced computerized model about renewable energies developed by NREL, which can execute a variety of economic and comparative processes for options of power generation systems. Here, the system includes a wind turbine, a solar panel, a diesel generator, an internal combustion engine and a DC/AC convertor. Also, sensitivity analysis was carried out for parameters such as wind velocity and solar radiation levels leading to identification of all economic and optimal priorities from Homer, which wind turbine, solar panel, diesel generator, internal combustion engine and DC/AC convertor were found to be the most optimal and sustainable options. In this paper, with regard to the capacity of utilized generators Loss of Load Expectation (LOLE) was computed by MATLAB.

KEYWORDS: Distributed Generation-Khark Island-N.G.L Project-Wind turbine-Solar Array-HOMER software.

1- INTRODUCTION

Text of the introduction. In this paper, renewable energy systems were analyzed by Homer to provide an optimal composite system meet a part of plant load. Homer is a computerized model developed by NREL to make a desirable economic-comparative analysis on proposed power generation systems. For a certain scenario, Homer inputs including load information, renewable resources, specifications and costs of systems components, and diverse information for system optimization. Homer is also capable of conducting sensitivity analysis on values of a paramenter (e.g. price of a wind turbine).

In addition, Homer has been used to present a more realistic picture of the system by modeling the effects of values varying over time such as electric charge, wind velocity and solar radiation. Economic analyses have to be conducted prior to installation of a renewable energy system. Homer carries out the economic analysis and categorizes the systems based on their current value. In the beginning, a system may demand further investments but it may become more cost effective.

2- Advantagesof dispersed generation and their evaluation, analysis andeconomic comparison

Dispersed generation is called by a variety of names such as Distributed Generation, Embedded Generation, and Dispersed GenerationDistributed Resources [1]. It is also called DG. In most cases, DG is placed in distribution networks. Imputing DG machines has some advantages and disadvantages. The most important advantages are:

- Improvement of generation quality
- Improvement of reliability
- Reduction of losses
- Increase of confidence level

There are also disadvantages, for examples:
Complexity of network and necessity of developing a network protection syste
Complexity of utilization and control of network

DG machines are classified to three major groups:

*Corresponding Author: Milad Karimi, Sama technical and vocational training college, Islamic Azad University, Bandar Abbas Branch, Bandar abbas, Iran milad.karimi@bndsama.ir (phone: +98-761-435-7080; fax: +98-761-435-7090)

- Novel energy technologies
- Gaseous technologies
- Energy storage devices

Gaseous technologies include gaseous combustion turbines, small turbines, internal combustion engines and fuel cells. Novel energy technologies involve natural latent energy, small wind turbine and photovoltaic cells. Energy storage devices are batteries, SMES, super-capacitors, water storage dams and CAES. The most important of which are internal combustion engines, wind turbines, biomass energy, fuel cells and solar cells [2].

Details of technical and economical assessment of DG utilization depend on type and properties of DG source, type of application, requirements and characteristics of consumer.

In these assessments, the planner should identify all technically feasible options and designs, and evaluate the projects in terms of viability.

For economic analysis of projects, at first a suited comparative technique is applied to existing solutions, then decision and selection are made among those solutions based on comparison results. economic analysis suggest that use of DG devices is mostly dependent on costs of system including cost for repair and utilization, fuel and accessories [3].

Table 1. *Conditions of any DG technology*

Type of technology	Investment cost (S/KW)	Operating costs, maintenance (S/Mwh)	Emission NO_x (Kg/Mwh)	Emission CO_X (Kg/Mwh)	Efficiency	Life (Year)	Capacity range available	Start time	Type of network connection
(ICE) Diesel	350-500	5-10	10	650	36-43	20	From a few kW to 30 MW	10 sec to 15 min	Synchronous generator converter AC/AC
(ICE) Gaslight	100-600	7-15	0.2-1	500-620	28-42	20	From a few kW to 30 MW	10 sec to 15 min	Synchronous generator converter AC/AC
Combustion turbines	650-900	4-5	0.3-0.5	580-680	20-45	20	From 50 kW to 265 MW	2 to 10 min	Synchronous generator
Fuel Cells (PAFC)	4000-5500	5-10	0.005-0.01	430-490	36-42	10	From 5 to 250 kW	1 to 4 hours	converter DC/AC
Micro	700-1100	5-16	0.1	720	20-30	20	From 250 to 500 kW	About 120 sec	converter AC/AC
Photovoltaic	4444.5	0.0056	0	0	15-20	20	Depending on local conditions and the angle of radiation	-	Converter DC/AC
Wind turbine	1111.2	0.0023	0	0	40-45	20	Depending on local conditions , wind	-	Asynchronous Generator

3- Characteristics of Khark Island

Khark Island or as Jalal Al e Ahamad denotes ‘Pearl of Persian Gulf’ lies between $29° 15'25''$ northern latitude and $50° 20'29''$ longitude from Greenwich Meridian, 46km southwest Booshehr. This coral island of Parisians Gulf with a relative surface area 8 by 4 km is a subsidiary of Booshehr County and Booshehr Province. Freshwater has historically been provided through natural depressions, digging tens of wells and qanats and diversion of storm waters to small reservoirs and natural depressions.

Khark Island is a critical port for exporting Iranian crude oil. At present, containing large quays for exporting crude oil, sulfur and methanol, it is considered as one of the biggest ports for oil export.

4- NGL project in Khark Island

NGL, developed in 2012 in Khark Island, was an ideal project in terms of national economy. In this project, additional gases are ignited within oil fields, collected by pipelines from the sea and Khark, sent to purification plant (removal of acrid acid) and finally processed in NGL plant to be prepared for sale. As

NGL becomes fully operational, all flares of the area will be terminated. This project is under way, with a progress of 56% on land and 35% on sea. Collection of 600 million cubic feet of natural gases and extraction of gaseous fluids were planned to be executed each day avoiding from burning of 400 million cubic feet of gas a day in Bahregan and Khark to be transferred to NGL unit based in Khark Island. Other NGL units including the Power Plant and Utility will be operational on a phased basis until the end of 1391 (winter of 2013).

NGL is consisted of 7 packages, of which 5 packages were fully accomplished and the 6^{th} package is underway.

5- Technical and economic analysis of a DG project [4]

First phase of economic analysis in a DG project is to determine how much equipment should be installed and how much is saved each year due to use of DG.

Users should undertake additional functioning costs including costs for fuel and Operation and Maintenance.

Utilization costs = fuel costs + O&M costs

Fuel costs are a function of DG efficiency and fuel price.

6- Renewable resources of the region

6-1- Solar radiation

Booshehr Province, particularly Khark Island, is one of the best recipients for solar radiation throughout the country. Monthly solar radiation values of the region used by Homer software are derived from [5]. For this purpose, from 29° latitude and 50° longitude, the profile is as shown in Fig.1.

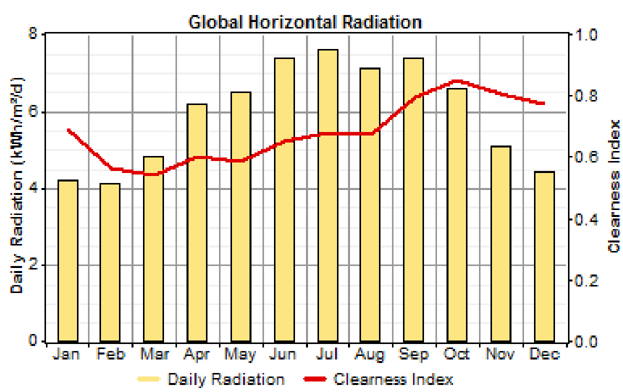


Figure 1. *Mean monthly solar radiation*

A point to taken into consideration in working with Homer is that for PV array, it only uses their nominal potential (kw) not their surface area (m^2) [6].

Efficinecy of PV panels decreases with temperature increase and the generated power varies highly with nonlinear increase in panel temperature. The manufacturers allocate a value to this property, which is expressed as total power variations per each centigrade increase. For example, if the panel produces 0.5% less energy for each centigrade, thermal coefficient is -0.5%. PV panels are exposed to sunlight, absorb infrared beams and are heated. They are dark and tend to increase to increase temperature. Sometimes, due to lack of wind, the temperature reaches 80°C.

$$P_{PV} = Y_{PV} F_{PV} \left(\frac{\bar{G}}{\bar{G}_{T,stc}}\right).[1+\alpha_p(T_C - T_{C,stc})] \quad (2)$$

where

Y_{PV} =nominal power of PV arrays under standard test conditions

F_{PV}= PV correction factor (%)

G= radiation levels on a PV array at current period (Kw/m^2)

α_p=thermal coefficient (%℃)

T_c= PV cell temperature at current period (℃)

$T_{C,STC}$= = PV cell temperature under standard test conditions (25 ℃) [7].

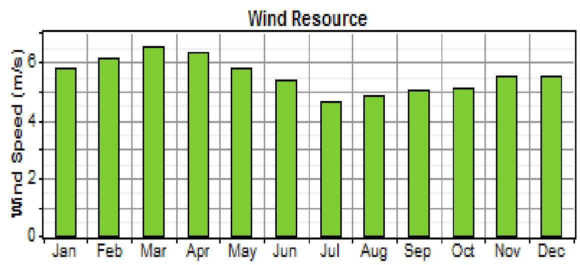
And, PV efficiency under standard test conditions is

$$\eta_{stc} = \frac{Y_{PV}}{A_{PV}\,\bar{G}_{C,stc}} \quad (3)$$

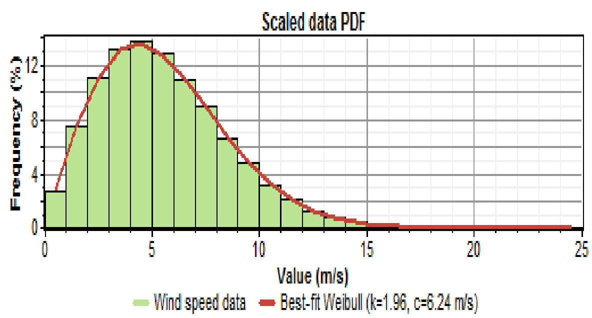
where
η_{stc}= PV efficiency under standard test conditions
Y_{PV}= intensity of radiation under PV standard test conditions
A_{PV}= nominal power of an array [7].
The battery used is a Surrette 6CS25P introduced to Homer database. (For further information, see [8].

6-2- Wind

The effect of wind is an important feature of coastal and insular cities. In this paper, the parameters measured in Khark Airport station are used. Wind velocity is adopted form the statistics of wind atlas stations of New Energy Organization measured for 8760 hours of a year separately resulting in increased accuracy and precision. Figure 4 shows diagram of probability distribution function of wind velocity and average wind velocity in months of a year for Khark Special Economic Zone [9].



(a)



(b)

Figure 2. *a) Average wind velocity in months of a year. b) Probability distribution function of wind velocity*

7- Introduction of wind turbines used

For this simulation, EG 1.5SL wind turbines were used, as this turbine is currently being used in many countries such as Turkey and it has already been defined in Homer database. Details of this turbine are presented in table1 [10-11]. Also, it is assumed that the turbine is installed 80m above the ground. Maximum capacity of the turbine is shown in Fig.3.

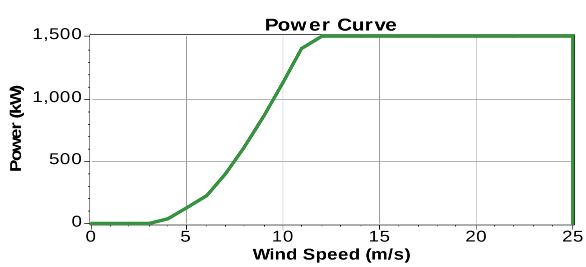


Figure 3. *Maximum capacity of EG 1.5SL wind turbine relative to wind velocity variations*

Table 2. *Specifications of EG 1.5SL wind turbines*

Nominal capacity	1500 KW
Minimum wind speed	3.5 m/s
Maximum wind speed	20 m/s
Nominal Average wind speed	14 m/s
Number of rotor vanes	3
Rotor diameter	77 m
Brooms surfaces of	4657 m^2
Rotor speed	11-20.4 r.p.m
Power Control Type	Active control blades
Turbine height (from center)	61.4-100 m

8- Economic analysis and savings [7]

8-1- Total interest rate

Total interest rate as a function of yearly nominal interest rate and inflation rate is an input to Homer software. It is the interest considered for bank deposits of any country, i.e. equating the amount we pay in cash at present to the payment we make annually during certain number of years, which is calculated as follows:

$$i = \frac{i' - f}{1 + f} \qquad (4)$$

where
i= real annual interest rate
I'= nominal annual interest rate
f= inflation rate
N= number of years
CFR function, updated to present time for calculating interest rate, is a series of annual payments calculated as (assuming constant inflation rate):

$$CRF(i,n) = \frac{(1+i)^N * i}{(1+i)^N - 1} \qquad (5)$$

8-2- Average energy cost (COE)

Average energy cost is defined by Homer as average cost of each kWh of useful energy generated by the system. To calculate average energy cost, Homer divides cost of electricity generation in a year (total annual cost – cost of heat provision) by total useful energy. COE equation is as follows:

$$COE = \frac{C_{ann,tot}}{E_{served,tot}} \qquad (6)$$

where
$C_{ann.,toto}$= annual total cost of system ($/yr)
E_{served}= total energy applied, which is obtained from

$$E_{served,tot} = E_{prim,AC} + E_{prim,DC} + E_{gride,sales} \qquad (7)$$

where
$E_{prim,AC}$= supplied AC charge (yr/kwh)
$E_{prim,DC}$= supplied DC charge (yr/kwh)
$E_{gride,sales}$= total energy sold to grid

9- Effect of reduction of environmental pollution on dispersed resources throughout the island

Based on tables and reports presented in energy balance sheet of Ministry of Energy (2007), it can be concluded that for each kWh of energy generated by all power plants in the country, 0.973g, 2.694g and 643.872g of NO_X, SO_X and CO_2 are produced, respectively. On the other hand, emission of greenhouse gases by wind turbines and photovoltaic cells is almost zero. Therefore, if DG resources are used to provide energy, each kWh of energy generated by them, emission of 0.973g NO_X, 2.694g SO_X and 179.392g CO_2 is prevented.

10- Numerical studies and simulation results

10-1- Composite system

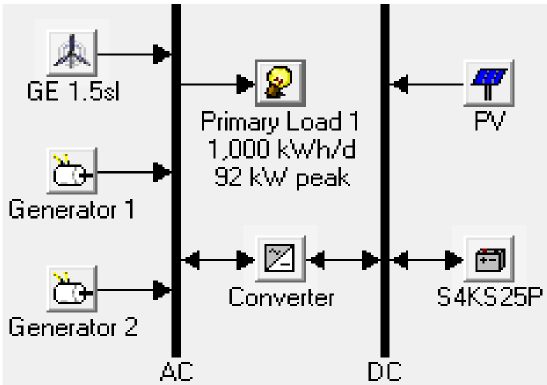
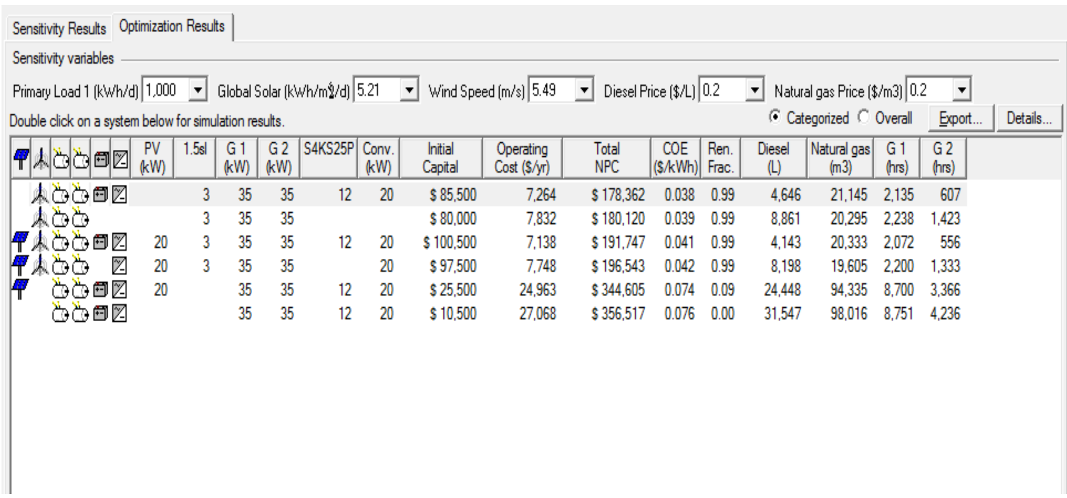


Figure 4. *Establishment of Homer model*

10-2- Optimisation Results

For optimization, the best composition is selected among possible options. The best composition will be one which can fulfill all constraints pre-determined by the user, with least net pure cost (NPC). Then, after the results of Homer simulation were obtained, all possible states will be sorted by NPC and a composition with least NPC will be introduced as the optimal option (Fig.5).

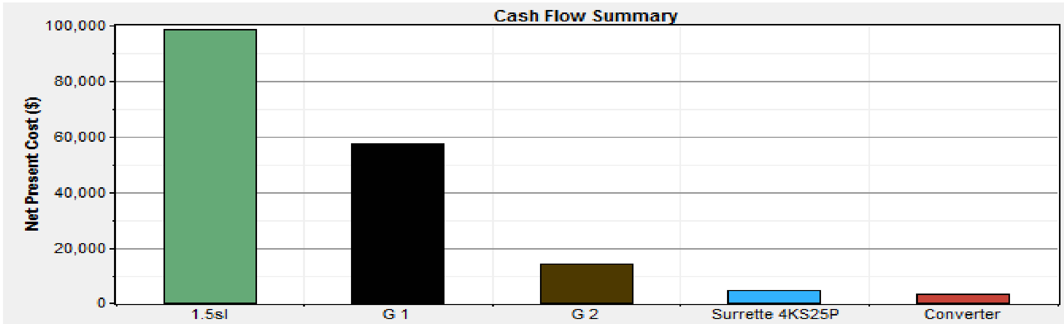


PV (kW)	1.5sl	G 1 (kW)	G 2 (kW)	S4KS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Natural gas (m3)	G 1 (hrs)	G 2 (hrs)
	3	35	35	12	20	$ 85,500	7,264	$ 178,362	0.038	0.99	4,646	21,145	2,135	607
	3	35	35			$ 80,000	7,832	$ 180,120	0.039	0.99	8,861	20,295	2,238	1,423
20	3	35	35	12	20	$ 100,500	7,138	$ 191,747	0.041	0.99	4,143	20,333	2,072	556
20	3	35	35		20	$ 97,500	7,748	$ 196,543	0.042	0.99	8,198	19,605	2,200	1,333
20		35	35	12	20	$ 25,500	24,963	$ 344,605	0.074	0.09	24,448	94,335	8,700	3,366
		35	35	12	20	$ 10,500	27,068	$ 356,517	0.076	0.00	31,547	98,016	8,751	4,236

Figure 5. *Software output based on NPC*

Sensitivity analysis simulation considering a constant load (1000 kwh/d) was conducted for three parameters: wind velocity, solar radiation, diesel and liquefied gas costs. Having wind velocity (5.21 kwh/m^2/d), solar radiation (5.49 m/s) and fuel cost (0.2$/l), the best optimal arrangement is a composition of a EG 1.5SL wind turbine, two diesel generators, a battery bank and a convertor. NPC of this optimal arrangement is $178362, which is best for 1000kwh/d consumption.

Figure 6 illustrates costs of all these components, among which wind turbine is the highest, and since Khark is a major oil and gas export terminal in the world, fuel cost is most reasonable.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
GE 1.5sl	75,000	28,791	384	0	-5,359	98,816
Generator 1	2,500	882	409	54,062	-103	57,750
Generator 2	2,500	0	116	11,879	-230	14,265
Surrette 4KS25P	3,000	1,860	26	0	-534	4,351
Converter	2,500	835	0	0	-155	3,179
System	85,500	32,368	935	65,941	-6,381	178,362

Figure 6. *Simulation results for using all DG devices (best option)*

Sensitivity analysis diagram for wind and sunlight variables against constant diesel price (Fig.7) provides possibility of finding optimal arrangement for various point the site.

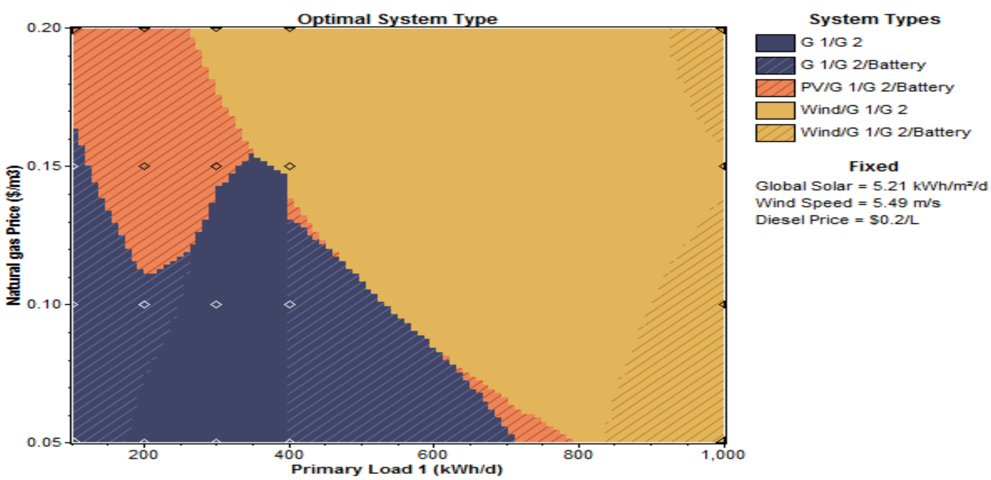


Figure 7 (a). *Type of optimal system against solar radiation, wind velocity, fixed diesel fuel price vs natural gas price, and maximum variable capacity.*

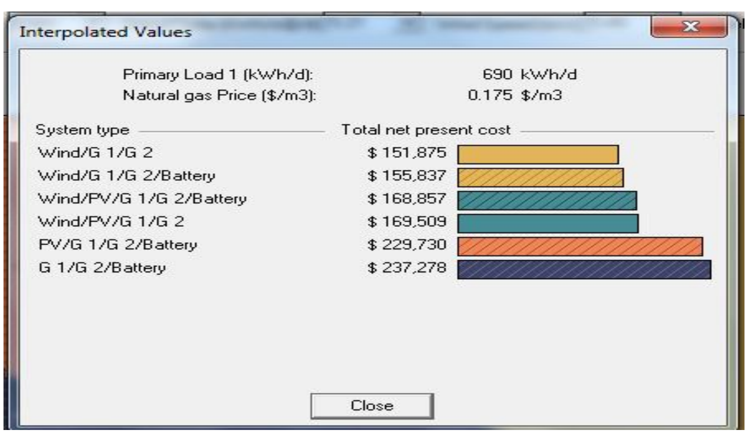


Figure 7 (b). *NPC of the optimal composition*

A characteristic of DG resources is their effects on greenhouse gases such as SO_2, NO_x, CO_2 and other harmful gases for environmental health. Homer is also able to calculate effects of these gases on a composite system. As a result, wind turbine and solar arrays partly do not produce any of these gases.

Figure 8 shows sensitivity analysis of maximum number of solar arrays capacity against defined load, which decreases CO_2 significantly by more solar radiation and wind velocity.

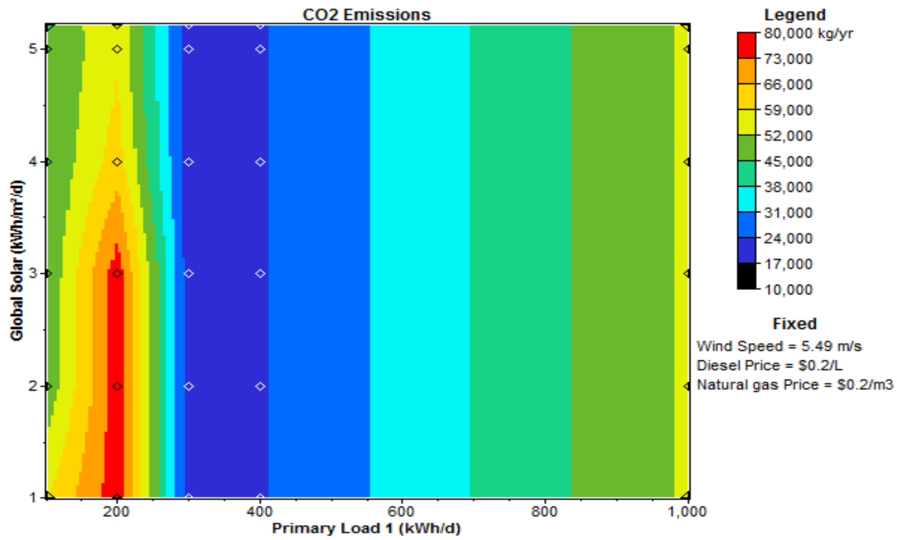


Figure 8. *Use of maximum number of solar arrays with regard to solar radiation in the region against defined load and their effects on reduction of greenhouse gases (CO_2)*

Figure 9 shows SO_2 analysis against maximum solar radiation and estimated loading capacity in the simulation.

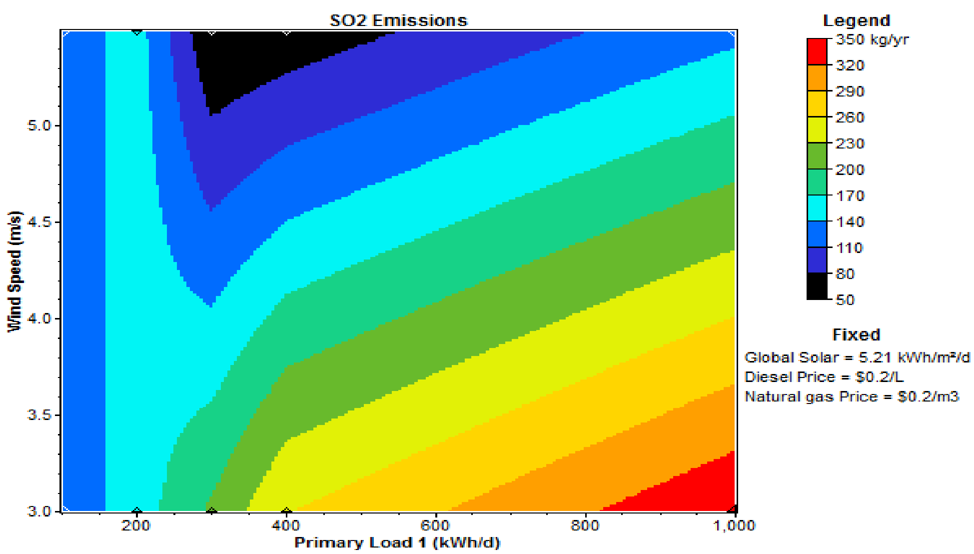


Figure 9. *Capacity of using maximum wind velocity in the area and its effects on reduction of greenhouse gases (SO_2)*

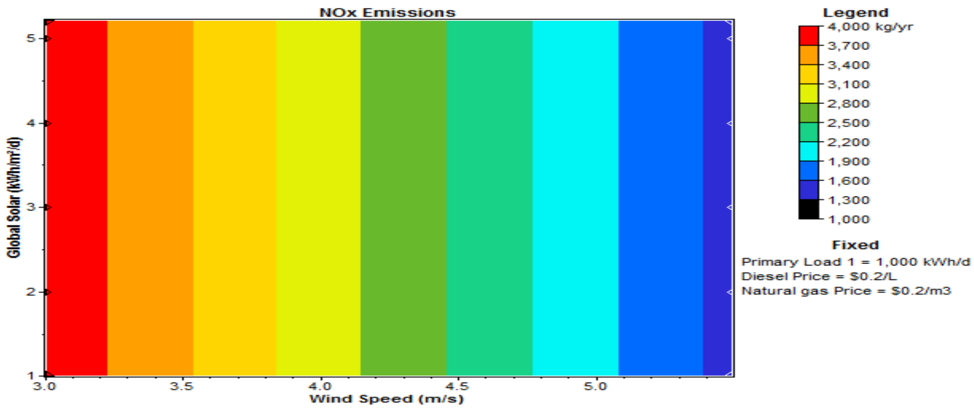


Figure 10. *Capacity of using solar arrays with regard to solar radiation and wind velocity in the region for reducing greenhouse gases (NOx)*

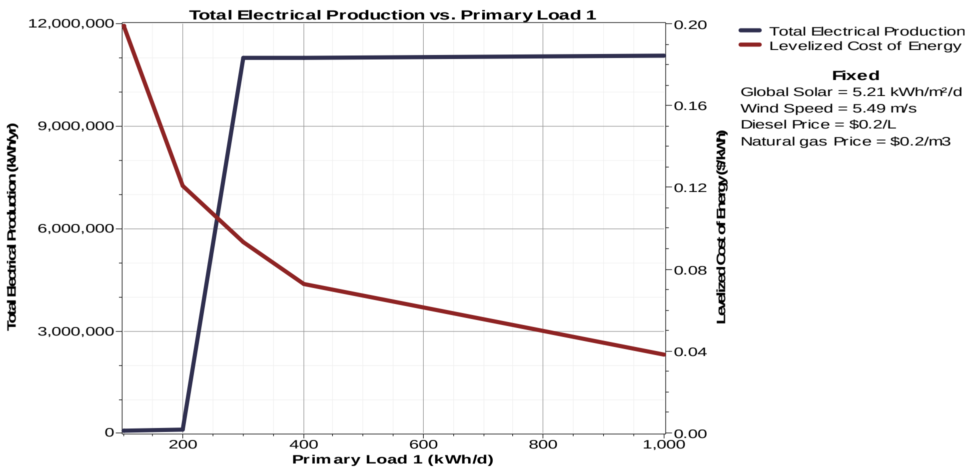


Figure 11. Diagram of variations of average energy cost, and percentage of renewable energy with load changes, when radiation and wind are maximum.

11- Analysis of LOLE in presence of generators used for desirable load

Analysis of LOLE in presence of generators used for desirable load

In this case, where four DG generators (solar panels, wind turbine, diesel generator and internal combustion engine) were used to provide a desirable load (92 Kw peak), LOLE was calculated by Homer. Regarding this arrangement and the results (Fig. 12), LOLE IS 0.1865 Days/Year.

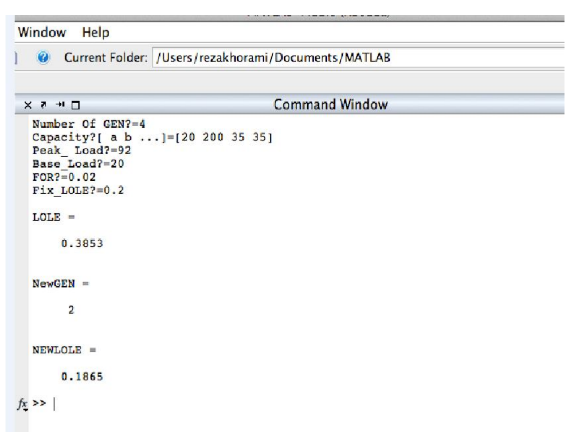


Figure 12. *LOLE in the system in presence of DG generators*

12- CONCLUSIONS

In this paper, economic assessment of DG sources was taken into consideration for satisfying a part of electric energy needs of NGL plant in Khark Island. For this purpose, all results were used by Homer software to analyze a composition of four main DG components (PV array, diesel generator, internal combustion engine and wind turbine) and a convertor. The results indicate that Homer has selected several optimal options, the best of which is a composition of PV array, diesel generator, internal combustion engine and wind turbine together with a convertor. Sensitivity analysis was conducted for wind velocity and solar radiation against variable and fixed values for diesel and liquefied gas prices, and the desirable load. Finally, after all economic and optimal priorities were identified by Homer during 25-year lifetime of the project; thermal power plants decrease environmental pollutions.

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