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Technical and Economic Studies of Energy Supply Small Consumers away from Networks using Hybrid Systems with Energy Storage

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Abstract— ***Owing to acute energy crisis that most developing countries including Iran are facing today, the interest in alternative energy sources has increased manifolds in the recent past. Wind being a non-polluting and nontoxic energy source, will go a long way in solving our energy requirements. Wind energy can be utilized to windmills, which in turn drive a generator to produce electricity. Wind can also be used for water pumping. Solar and Wind resources are the hybrid options for the Island. HOMER, a software for optimization of renewable based hybrid systems, has been used to find out the best technically viable renewable based energy efficient system for different numbers of households. This study investigates the possibility of using and developing electritic power to supply reliable, affordable and sustainable electricity to rural, remote and isolated loads in rural South Khorasan. Simulations are performed using the Hybrid Optimization Model for Electric Renewable (HOMER) and the results are compared to those from other supply options such as standalone Photovoltaic system (PV), wind, diesel generator (DSL) and grid extension. Finally the paper points out some major challenges that are facing the development of this technology in South Khorasan.***

Keywords— HOMER, wind turbine, Photovoltaic, Deym

I. INTRODUCTION

Use the new generating plants cause depletion of fossil fuels, global warming, and pollution. This diverts researchers attention towards renewable energy resources. The renewable energy sources such as wind, Photovoltaic system, small-hydro, biomass, geothermal are inexhaustible in nature and easily available in our country. Also remotely located villages, islands, hills, military equipment, and so forth are some of the areas which are mainly isolated from the power system grid and in these areas wind and hydro-energy are available abundantly. Thus for supplying energy in such areas, isolated system, micro or minigrid system, is an emerging concept and draws the attention of many researchers. Micro grid is the small scale energy system equipped with distributed energy resources, electronic equipments, loads, ancillary facilities, and so forth. A number of new technologies and innovative ideas are proposed till now[1-3].

Deym Village is Located on the south Khorasan of Iran, roughly between 32° , 56' N and 58° , 25' E and 88 kilometers of Birjand. The Island is flat and just only about 1125m high from the sea level. The island is very beautiful but the people there are very poor. Fig.1. shows the location of Diem village at NASA.

Fig. 1.The location of Deym village at NASA.

Recently Government has taken decision to formulate a master plan for development and protection of this village. Village weather in the spring is very nice, summer is warm and in the winter weather be cool and dry.

The village has a good potential of solar and wind energy resources. But till now there has no such activity to use these resources. Therefore HOMER (Hybrid optimization Model for Electric Renewables), a software developed by National Renewable Energy Laboratory (NREL), USA for micro-power optimization model, has been used to find out the best energy efficient renewable based hybrid system options for the Island. It contains a number of energy component models and evaluates suitable technology options based on cost and availability of resources.

II. SYSTEM DESCRIPTION AND WORKING

Load profiles of the Deym

According to the load data, the peak load and aver-age daily load demand of the Deym are 5.3 kW/h and 50 kW/day,respectively. The daily load distribution profile of the Deym is indicated in fig.2.

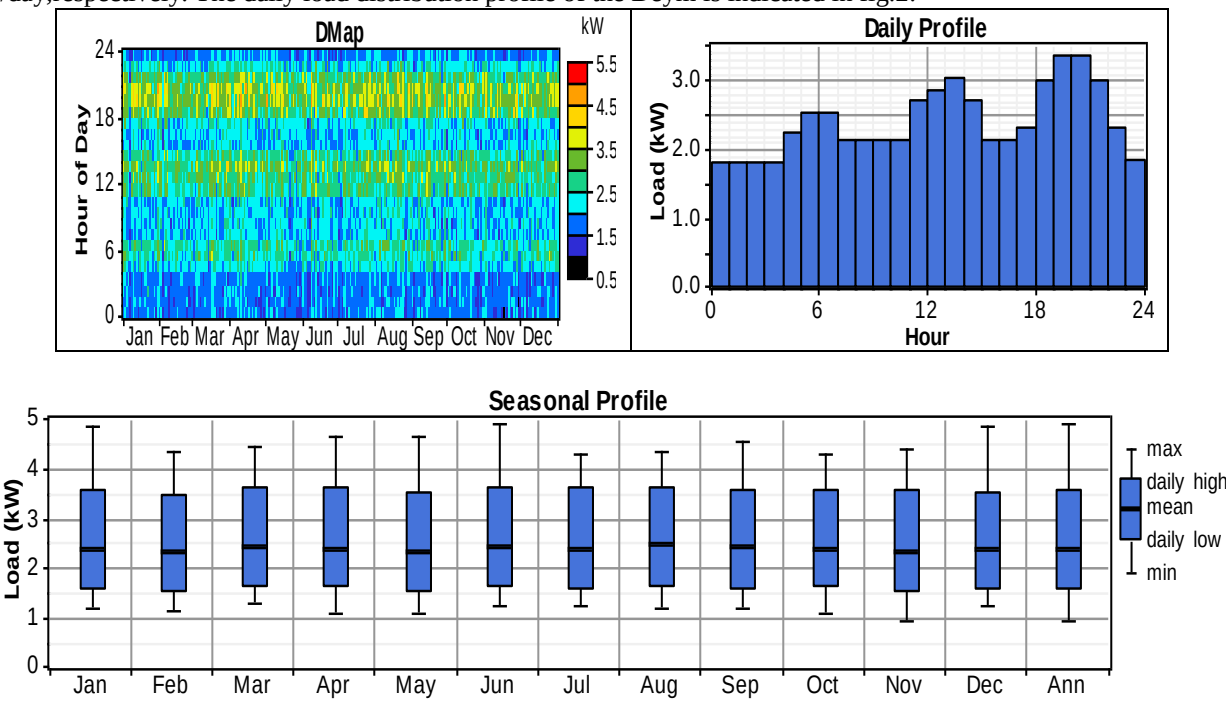

Fig.2. The daily load distribution profile of the Deym

HOMER makes energy balance calculations for each hour in a year to simulate the operation of a system. HOMER can provide assistance to synthesize the load profiles (with randomness) by entering the values for a typical day when the hourly load profiles do not exist for a whole year.

According to the table.1, the minimum load demand occurs between 23:00 and 04:00 O'clock while the maximum value of the load demand with 3.35kW/h occurs between 19:00 and 21:00 .

Table.1. Value of the load demand of the day

Load (Kw)	The Hours of the Day	Load (Kw)	The Hours of the Day	Load (Kw)	The Hours of the Day	Load (Kw)	The Hours of the Day
3/000	- 18:00 19:00	**2/850**	- 12:00 13:00	**2/535**	07:00 - 06:00	**1/800**	01:00 - 00:00
3/350	- 19:00 20:00	**3/035**	- 13:00 14:00	**2/125**	08:00 - 07:00	**1/800**	02:00 - 01:00
3/350	- 20:00 21:00	**2/700**	- 14:00 15:00	**2/125**	09:00 - 08:00	**1/800**	03:00 - 02:00
3/000	- 21:00 22:00	**2/125**	- 15:00 16:00	**2/125**	10:00 - 09:00	**1/800**	04:00 - 03:00
2/300	- 22:00 23:00	**2/125**	- 16:00 17:00	**2/125**	11:00 - 10:00	**2/242**	05:00 - 04:00
1/850	- 23:00 00:00	**2/300**	- 17:00 18:00	**2/700**	12:00 - 11:00	**2/535**	06:00 - 05:00

Photovoltaic system

Photovoltaic (PV) cells are semi-conductor devices that convert sunlight energy directly to electrical energy. The PV array is an interconnection of PV modules or panels that produces direct current (DC) electricity in direct proportion to solar radiation.

To evaluate and design solar energy systems, knowledge of the availability and quality of sunlight is required. The solar radiation cycle changes daily and may be affected by meteorological conditions such as clouds and fog. The altitude angle of the sun radiation at the solar panel, the solar position at any time of day, the temperature, etc, should be considered in the solar radiation measurement. The scaled monthly averaged solar radiation for Deym, shown in Fig. 3, was measured by NASA[4]. The scaled annual average solar radiation has been evaluated to be 5.17 kWh/m2/day. Table.2. shown the costs of photovoltaic system.

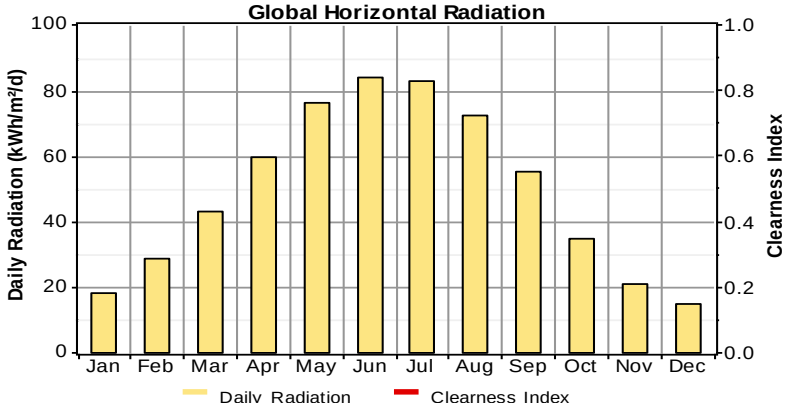

Fig. 3. Daily radiation with the clearness index.

Table.2. The costs of photovoltaic system

The cost of repair and maintenance($)	The cost of the replacement($)	The cost of the system ($)	Size (Kw)
100	1350	1350	1

Wind system

The wind speed variations are of great impact on the energy availability produced by the system. Thus, wind turbine rating is usually much higher compared to the average electrical power demand. For our study, we have considered the Generic turbine and rated at 3 kW/DC. The cost of the system is 27,000$, the replacement and maintenance costs are taken as 27,000$ and 2000$/year. The lifetime of the wind turbine is taken as 20 year.

Wind data at Deym:

Wind is used as wind energy which is extracted with wind machines like wind turbines. To install a wind turbine we need sufficient wind velocity so that we get maximum of power density. Site selection is necessary in this case. For this we need to collect wind data. After collection of wind data, the compilation of that wind data is very important as it decides the type, design, and location of wind turbine[5].

Wind data were collected at Khur, which is situated in western part of Birjand, a backward place of East region of Iran. The data collected were compiled using the HOMER. Data recorded for the last three years and the sample data were depicted in Fig.4. After the analysis various graphs in HOMER for that particular data, we observed that wind velocity is nice. The maximum wind velocity is obtained in summer.

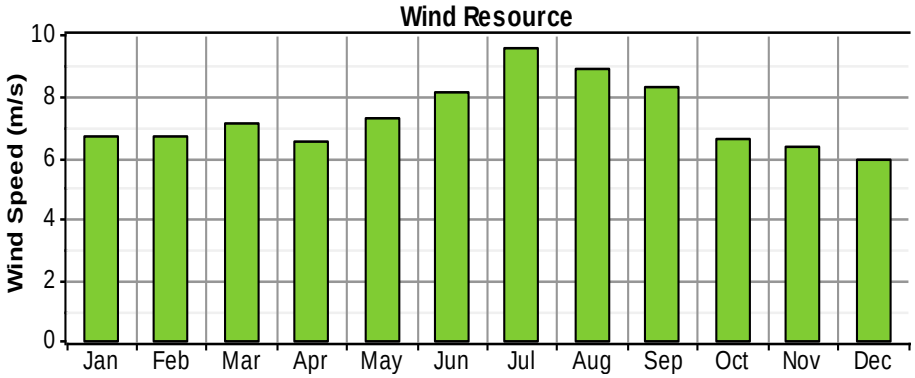

Fig.4. Annually wind speed distribution of the region.

Diesel generators

In the total energy supply of the village of a diesel generator AC in the proposed model has been used in addition to the backup role will increase the reliability of the system [6]. The price of fuel for each liter of 0/116$/L has been considered but the fuel cost, doses up to 0/116$/L to 0/3$/L also for variables is considered sensitive. The initial cost of diesel generator is considered to be 1000$.

Battery

The battery bank used in this hybrid system is VTM 200-12. The chosen battery has a 2-V, 150-Ah capacity with bus nominal voltage of 12 V. The battery's lifetime is estimated between 3 to 5 years. HOMER assumes that the properties of the battery remain constant throughout the battery's lifetime and are not affected by external factors such as temperature. The cost of a single battery is 200$, and the replacement cost is 200$ with operating and maintenance costs of 0$. Fig.5. shows the specification of battery used in project.

Quick Details

Place of Origin:	Zhejiang China (Mainland)	Brand Name:	JUST	Model Number:	volta max battery
Usage:	UPS	Voltage:	12v	Sealed Type:	Sealed
Maintenance Type:	Free	Size:	483*170*241MM	Weight:	39KG
Nominal Capacity:	150AH	Model:	volta max battery	Voltage Range:	2V,6V,8V,12V
Capacity Range:	33AH-250AH	More use:	inverter, solar &wind, EPS, electric, vehicle	OEM:	OEM your brand freely
Certificate:	CE,ISO,TS16949,SGS,CE,RoHS	Warranty:	3-5years	Color:	Black, white, grey and colorful
Company Area:	100.000Square meters	Trade Value:	30.000.000USD		

Fig.5. specification of battery used in project

Inverter

In this system, because DC electric power should be converted to AC power to load, a set of inverter system is required. The sizing of the inverter is based on the rated PV and the wind turbine which is provided by optimizing with HOMER through sensitivity analysis. For all inverter sizes, the efficiency is assumed to be 90%. The estimated price of an inverter is 2500$, which is the same as the replacement cost and its lifetime is up to 15 years. Various sizes of inverters are considered for the optimization in the sensitivity analysis. The cost of a single inverter is 2500$, and the replacement cost is 2500$ with operating and maintenance costs of 0$.

Simulation software

To meet the renewable energy system analysis and optimization needs, we use HOMER, a computer model that simplifies the task of evaluating design options for both off-grid and grid-connected power systems for remote, stand-alone and distributed generation (DG) applications. HOMER's optimization and sensitivity analysis algorithms allow the user to evaluate the economic and technical feasibility of a large number of technology options and to account for uncertainties in technology costs, energy resource availability, and other variables [7-8].

Hybrid system modeling

The use of renewable energy sources has been developed recently and predictably Gets a significant contribution of electrical production coming to take over the world. Hybrid systems today, a special place in the basket of the world's energy. In low energy environments, combined with the existing energy resources, talent can be a good method for powering the area required. This article includes a hybrid energy system modeling, renewable energy sources for rural and remote areas of the network design. The purpose of this design is to optimize the total cost of production, increase reliability, reduce environmental pollution along with renewable energy sources and efficient use of local energy sources, is available in natural. Fig.6. shows all components of the hybrid system.

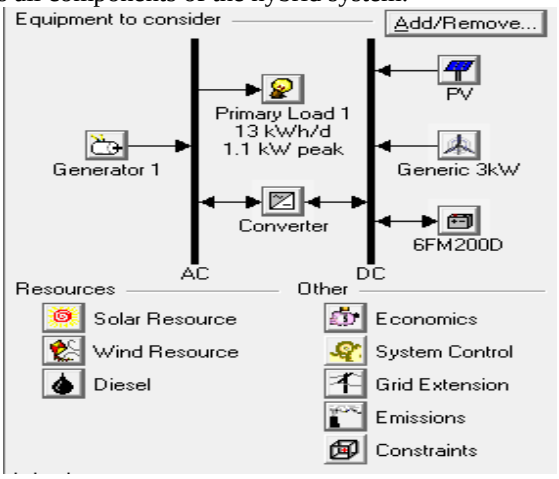

Fig.6. All components of the hybrid system.

III. RESULTS AND DISCUSSION

In this case, the average wind speed is equal to 8/13 m/s and output panel 5/5 Kwh/m^2/day and the price per liter of diesel generator fuel is the amount of 0/3$ and The amount of load is 8 kW.

HOMER simulates system configurations with all of the combinations of components that were specified in the component input. It discards from the results, all non-feasible system configurations, which are those that do not adequately meet the load, given either the available resource or constraints that were specified.

The simulation results will be analyzed and then compared to those acquired by the use of the PV, wind standalone, diesel generator as well as hybrid diesel-battery used to supply the same load. The comparison criteria will be the Initial Capital (IC), the Total Net Present Cost (NPC), the Cost of Energy (COE) as well as the system Capacity Shortage.

A summary of the technical and economical results obtained by Homer is displayed on Fig.7,8. From this Fig we can notice that based on the NPC, COE and the breakeven grid extension distance that the hydrokinetic is the best option to supply the load with electricity.

Sensitivity Results | Optimization Results

Sensitivity variables

Primary Load 1 (kWh/d) 8 | Global Solar (kWh/m²/d) 5.5 | Wind Speed (m/s) 8.13 | Diesel Price ($/L) 0.3

Double click on a system below for simulation results.

PV (kW)	G3	Label (kW)	6FM200D	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)	Batt. Lf. (yr)
3			20	5	$ 10,550	686	$ 19,315	0.517	1.00			9.1
3		1	20	5	$ 11,550	668	$ 20,088	0.538	1.00		0	9.1
1	1		4	5	$ 31,650	2,993	$ 69,914	1.873	1.00			6.2
1	1	1	8	5	$ 33,450	2,975	$ 71,477	1.915	1.00		0	10.0

Fig.7. Simulation results summary

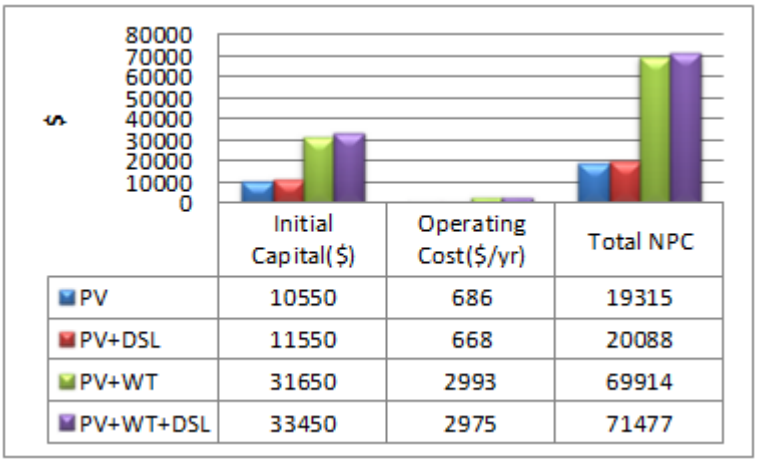

Fig.8. Combined of distributed generation

Fig. 7 gives the breakeven grid extension distance at 0/666 km. This means that the total cost of implementing the micro-hydro project for 20 years will be equivalent to the cost of installing a grid extension line of 0/666 km.

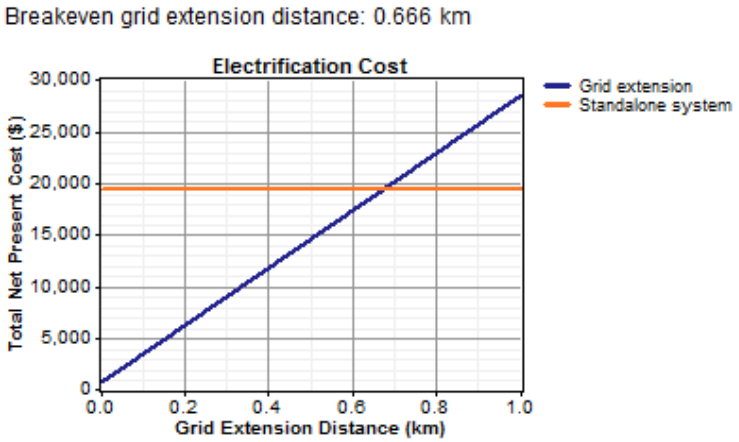

Fig. 7. Grid extension distance (km).

By comparing the cost of constructing the network diagram with alternative energies that is seen if the distance between the village up to the national electricity network will be less than the economic construction of the network is attained is kilometer but for distances of more than this amount is the best option for energy supply in this region is the use of alternative energies.

IV. CONCLUSIONS

Nowadays, renewable energy systems, with the lowest levels of pollutant gases, plus save energy, in terms of economic instrument to be able to compete with conventional energy production system of using fossil fuel independent or attached to cargo of the higher importance of long distance network and is very difficult. In this study, the different sources of energy (wind, Sun, and diesel generators) and storage system was examined and supplies using the optimized software for HOMER it became clear that for the domestic consumer is independent of the network in the region, taking into account wind speed and solar radiation data area and also the cost of various components of the system now, the system is the most economical combination of battery and photovoltaic converter in energy supply in Deym village.

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