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Feasibility Study of Using Renewable Energy Sources for a University Campus in Smart Grid Using Fuzzy Method

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Abstract

In this paper, the electrical consumption of Hamedan University is derived of the bills, and then with defining of fuzzy Bus Thermal Coefficient objective function for heating, the amount of available heat selling to university consumer that is produced by Biomass CHP plant is calculated. With the capacity determination of Biomass CHP plant to provide Thermal and electrical energy of university and calculation of photovoltaic systems to supplying electrical energy, each technical calculation is presented. Then, Economic Calculation of each project will be addressed separately. The Economic optimization in designing and operation of electrical systems is usually done through a review of investment criteria, that in this study, are include: Net present value (NPV), Internal Rate of Return (IRR) and Return period (PP) that with regard to the economic evaluation methods, the economic evaluation of project is doing. The economic calculations show that the use of biomass CHP plant is adequate but using of photovoltaic system is not adequate.

Keywords: Biomass CHP plant, Photovoltaic systems, Technical and economic feasibility

1. Introduction

With increasing the demand for electrical energy and electrical energy efficiency of small units, these units are more likely to utilize in the distribution system and near the consumers. These small units that are connected to the distribution system are called "distributed generation" (DG). The privatization of electricity industry, less environmental pollution, high efficiency and developing methods of electricity generating through the renewable energy are important factors for the development of these generator types. The use of distributed generation units has significant impact on the power systems technical and economic issues [1]. One type of theses power plants is electricity and heat co-generation unit (CHP) which supplies the heating or cooling needed by consumers through its waste heat output and increases the whole power plant efficiency up to 75% and above it. As the fuel gas is available in our country, these power plants are good substitute for the electricity and heat generation.

Biomass is one of the new energy. Millions of tons of waste and sewage sludge produced and are destroyed in worldwide annually and each country and even each city will manage the matter differently [2].

Biomass energy can be achieved from the waste. Biogas is the gas that produced in the fermentation and decomposition of organic matter by anaerobic bacteria, especially methane from anaerobic fermentation arise in a chamber. Feasibility studies for biogas pilot project with the input of organic waste, sewage sludge, slaughterhouse and the plasma of Saveh city shows that this system is economically justified [3].

In the present paper the technical and economic feasibility of biomass CHP plant to provide electrical and heating energy and the technical and economic study of the use of photovoltaic systems for the supplying the electrical energy of Azad University of Hamedan has been integrated.

In the first part of this paper, electrical and thermal consumption of Azad University of Hamadan is given. To obtain the thermal energy that can by supply of biomass power plants, the fuzzy objective function of heat selling is defined. At the second part of this paper, the technical feasibility study of using biomass CHP plant to provide electricity and thermal energy and photovoltaic system to supply electrical energy of Azad University of Hamedan has shown. To the economic study, despite more investment criteria and additional information that provided from these criteria, only one of the criteria of NPV, IRR or PP is used to reject or accept of this project [5].

2. Consumption of Electrical And Thermal Energy Of University(Fuzzy Method)

In this section, to determine the capacity of CHP and photovoltaic plant with respect to information that extracted from the receipt of the University, determined the amount of electrical and thermal energy of university.

2.1. Electrical Consumption of the University

The electrical consumption Curve of the university in various month is as follows:

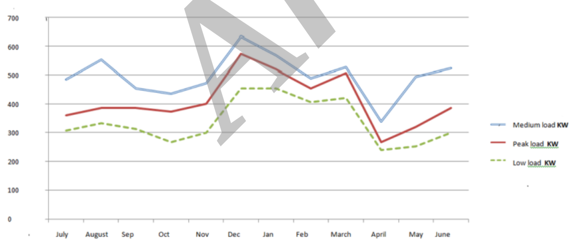

Fig.1. Monthly electrical consumption Curve of the university

According to electricity tariff in 2011 [6], the price of electricity per kilowatt hour is as follows: The medium time : 190 riyals, the peak time: 380 riyals, and minimum time: 95 rials.

2.2. Heating Consumption of the University

To obtain the heat consumption, at first define the Bus Thermal Coefficient. Bus Thermal Coefficient (BTC), indicates the possibility of selling steam and warm water to each bus, and with regard to the consumers around the bus is calculated as follows:

$$BTC_i = \frac{P_{h_i}}{1MW} \ , \ BTC_i \geq 0.1 \qquad (1)$$

The thermal coefficient of bus will be achieved by normalization the possibility of heat selling to 1MW.Finally, the buses with higher amount of BTC are eligible for CHP installation that will be considered in the calculations of objective function optimization.

Ph_i is the function of effective coefficients phase sharing (minimum) of heat selling and will be expressed by equation (2) :

$$P_{h_i} = \sum_{j=1}^{n} P_{h_{ij}} = \sum Q_{h_{ij}} \times f_{ij}(\beta \cap d \cap x \cap \Psi) \qquad (2)$$

Where:

P_{e_i} : Active power consumption at bus "i".

P_{h_i}: The electrical equivalent of heat selling possibility at buses" i".

P_{T_i}: The total power

$P_{h_{ij}}$: The possibility of heat selling (equivalent to electric power) to the consumer "j" at bus "i.

N: Total number of consumers around each bus.

BTC_i : Bus thermal coefficient of bus "i".

$Q_{h_{ij}}$: The heat consumption (equivalent to electric power) of consumer "j" at bus" i".

β : Type of consumer.

d: The distance between the heat consumer and power plant.

x: Coefficient of CHP technology that depends on the conditions that heat be generated by CHP.

C_H: saving the thermal cost after CHP installation, $\frac{\$}{\text{year}}$

λ_H : The cost of per "MWh" heating, is equal to7.2 $, since the project of "targeted subsidies" is executed.

Δt_i : 8760 hour for a year.

Finally by determination of bus thermal coefficient, the amount of saving the thermal cost of each bus (with regard to government support in this area) will be obtained after CHP installation as follows :

$$C_{H_i} = BTC_i \times \Delta t_i \times \lambda_H \qquad (3)$$

2.2.1. Calculation of β

According to the National Building Regulations in Iran (National Building Regulations In Iran 2009) , there are four groups of building types, A to D. This grouping is based on the following three factors :

- Continuation the using of building during the day and the year.
- The temperature difference between the interior and exterior of the building.
- The significance of stabilization the temperature of indoor spaces.

β is determined based on the user type in Table II. Higher β indicates more possibility of heat selling to the consumer.

Table.1.
Buildings classification according to the National Building Regulations

Warm and humid	High cooling required	High heating required	The energy required	City name	row
		×	high	Hamadan	211
×	×		high	Bandar abbas	48
			low	Rasht	112
		×	medium	Tehran	71

2.2.2. Amount of heat consumption (equivalent to electrical power) Qhij

Amount of each user consumption depends on its location, (table 1). Based on Standard National Regulations, buildings in various parts of the country are divided into three groups, based on the need for the annual heating- cooling energy:

- The need for low annual heating-cooling energy
- The need for medium annual heating-cooling energy
- The need for high annual heating-cooling energy

Some examples are given in Table 2.

Table.2.
Need to heating &cooling energy in different locations in Iran

Sample	β	User type
Hospitals, hotels(4 and 5stars), industries with the heating consumption for the generation process (cement, steel, meltedmetals, sugar, food, greenhouseTown)	1	A
Integrated academic and large schools (with dormitory), skyscrapers, large residential complexes (with central heating systems).	0.75	B
Stores, factories (heating and sanitary use only), international airport	0.5	C
Places of business (shopping centers), offices	0.25	D
spread consumers can not using of central heating systems	0	All cases

According to Table 2, it can be seen that Hamadan city requires large amount of heating energy. The calculation of the energy needed for different loads (various applications) according to references (ASHREA handbook of fundamental 2005)[8] , (Tabatabaie, Seyed Mojtaba 2008)[9], has been done to 1000 m2 infrastructure, and this point is considered that, Hamadan city uses from natural gas of the main pipeline with special heating value of 9434Kcal/m3 or 1060 Btu / ft^3. For example, in multi-unit residential building that use the central heating systems (for 1000 m^2 infrastructure)

A) The warm water consumption : 231.84 (KW)
B) The heat consumption for heating : 117.16 (KW)
Total heating and warm water consumption of different buildings is shown in Fig.2.

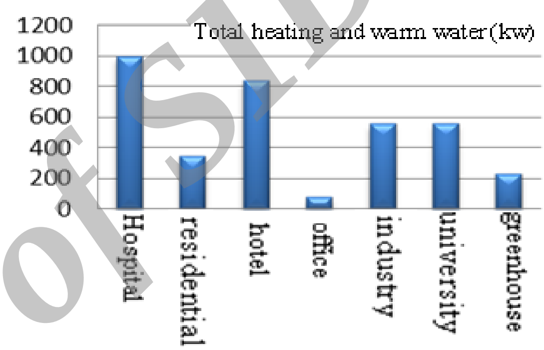

Fig.2. Q_{hij} for different consumers, with infrastructure of 1000 m^2

2.2.3. Determination of Technology Coefficient (x)

This ratio expresses which technology is used to generate electricity and heat in the CHP (Table 3). Coefficients x_1 to x_5 can be determined according to the CHP thermal output. For example, gas turbine technology, which provides heat, warm water, LP and HP steam, has highest coefficient of x.

2.2.4 The distance between heating consumer and power plant (d)

The other issue that should be considered at heating distribution is the distance between heating consumer and power plant, so that by increasing the distance, heat selling possibility will be reduced while the transport cost will be increased. In other words, the bus thermal coefficient (fitness) is proportional to the inverse distance:

$$f(d) \approx \frac{k}{d} \quad (4)$$

That, d is the difference between heating consumer and power plant and coefficient **k** is depends on the heat transferring system that achieved based on the practical results.

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Table.3.
Various CHP technologies(x)

Technology	steam turbine	reciprocating engine	gas turbine	micro turbines	Fuel cell
Typical ratio of heat to power	0.1-0.3	0.5-1	0.5-2	0.4-0.7	1-2
The Power electrical efficiency (HHV)	15-38%	22-40%	22-36%	18-27%	30-63%
Total efficiency(HHV)	80%	70-80%	70-75%	65-75%	55-80%
Using of output heat	LP-HP steam	LP-HP steam	Warm water , LP steam	Heating, warm water, LP steam	Warm water, LP-HP steam
x	0.25	0.5	1	0.5	0.75

The possibility of heat and warm water transferring to the different distances expressed by following fuzzy membership function (Fig.3):

$$\overline{f(d)} = \begin{cases} 1 & d < 333 \\ \dfrac{1050-d}{717} & 333 \le d \le 1050 \\ 0 & d \ge 1050 \end{cases} \quad (5)$$

Fuzzy membership function: fuzzy digit $f(d)$ in parametric mode is the regular pair of ($\overline{f(d)}, \underline{f(d)}$) which must satisfy the following requirements:

1. $\underline{f(d)}$ Continuous boundary function from left.
2. $\overline{f(d)}$ Continuous boundary function from right.

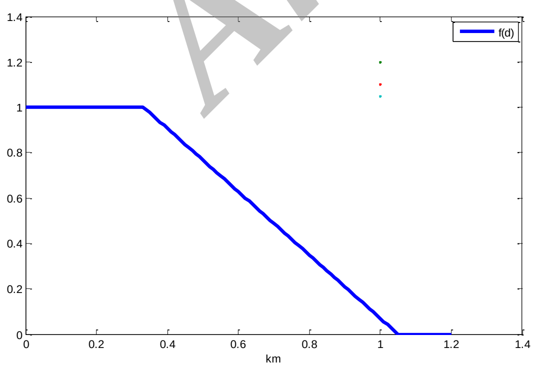

Fig.3. The fuzzy digit corresponding f(d)

In the table 4 calculating the Consumer heat of biogas CHP plant is shown:

Table.4
Calculation of the objective function for the heat selling

Bus Thermal Coefficient $P_{Sij} = P_{is} \times f(\beta \cap d \cap x)$	Heat and hot water consumption per KW	Type of bus consumer and infrastructure	20 kv Bus No#
$4175 \times (0.75 \cap 0.25 \cap 1) = 1043KW = 1.043MW$	4175	university	33, 34, 35

3. The Technical Feasibility of Biomass CHP Plant And Photovoltaic System

In this section, according to consumption of electrical and thermal energy at university, technical calculations of photovoltaic systems and the CHP biogas plant has been shown.

3.1. Biomass CHP plants

The situation of Hamedan Azad University in the region outside the city, Possibility of using waste Hamadan city, waste production at the University and close to Industrial area of Bu Ali Sina, The use of biogas power plant systems is possible in this place.

Combined Heat and Power plant (CHP) used in this project can provide heating, hot water and electrical energy required in Azad University of Hamedan. In this project, be used the plant that is capable of supplying 0 / 6 MW of electricity and 1 / 13 MW of heating and hot water that its efficiency is 81 / 5 % , Efficiency of electrical power is equal to 25 , and power to heat ratio is 42 (OPET Report 12)[7] .

The most important parts of this CHP plant are: The gas plant, a gas engine with a heat recovery unit and a separate gas boiler has been established, that is shown in Fig 4.

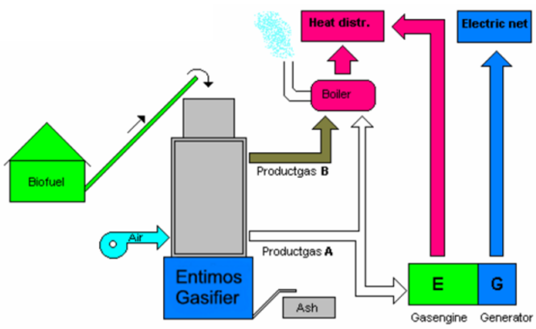

Fig.4. Diagram of University Biomass CHP plant process

3.1.1 Fuel power plant

The results of qualitative and quantitative studies of environmental pollutants as well as the performance of these pollutants in the process of energy production in anaerobic reactors is shown in Table 5.

3.1.2. Performance and production of the biogas CHP plant

Daily, materials that shown in Table 6 as the combination of anaerobic digesters can be entered in the power plant. Production of biogas plant is shown in Table 7.

Table. 5
Profile of the quality and quantity of feed fed power plant

Quantity	Parameter
6930	Gas production (m^3 /day)
606.3	Electrical Power (KW)
1130	Thermal power (KW)
43400	Liquid fertilizer (produced water) /year m^3
4,850,400	The amount of electrical energy per year (kwh) - Gross
6,236,800	The amount of thermal energy per year (kwh)
6290	The amount of organic fertilizer,50% humidity (ton/year)

Table. 6
Profile of material that input to power plant

%TS	Daily Qty (tons)	Inputs
12.2	146	Waste solution
8.33	70	Sludge treatment plant in Hamadan
0.5	21	Slaughterhouse wastewater
10	237	Total feed input

Table. 7
Production of biogas plants

Percent of total	Quantity (kg/day)	Parameter
Municipal waste		
100	185000	The average municipal solid waste (garbage) in 2016
75	138750	The average household wastes
48.786	90254	The average organic
9.635	17825	The average total solids (TS)
7.418	13720	The average total volatile solids (VS)
Sludge treatment plant		
100	70000	The average sludge treatment plant in Hamadan
8.33	5831	The average total solids (TS)
Slaughterhouse wastewater		
100	21000	The average slaughterhouse wastewater
0.508	106.68	The average total solids (TS)
0.428	89.88	The average total volatile solids (VS)

3.1.3 Photovoltaic Systems

Photovoltaic systems can also be used to supply electricity of the university. Hamadan University is located in latitude and longitude '36 ◦ 46 and '48 ◦ 34 East that located in a good region of the solar radiation intensity (the average radiation intensity in this region is about 4.85 KWh/m^2) (New Energy Organization of Iran) [4].

Fig.5. Supply of electrical energy by similar photovoltaic concentrator systems in Massachusetts

3.1.4 Calculations and Equipment Selection

The following table is shown the details and cost of required photovoltaic systems.

Table. 8
Technical equipment for photovoltaic stations (Faran Electronic Industries)[10]

Number needed for each station	Current (A)	Voltage (V)	Power (W)	Name
2667	5.13	46.8	240	Solar Panel
194	140	24	-	Controller
232	230 AH	12	-	Battery
80	0 - 1200	48	8000	Inverter

Table .9
Cost of purchase and installation of photovoltaic equipment (Faran Electronic Industries)[10]

Purchase and installation Costs (US $)	Number	Name
2,688,336	2667	Solar Panel
93,120	194	Controller
197,200	232	Battery
600,000	80	Inverter
Total cost : 3, 578,656		

4. The Economic Approach

Analysis of industry project, prior to the assessment, design and feasibility study of various aspects of the plan is assessed. The estimate was calculated from the plan should be considered time value of money. The typical steps of an economic evaluation of a project are:

1. Define a set of investment projects for consideration.
2. Establish the analysis period for economic study. There are three different situations to be considered: The useful life of each alternative equals the analysis period; the alternatives have useful lives which are different from each analysis period and there is an infinite analysis period.
3. Estimate the cash flow profile for each project.
4. Specify the Minimum Attractive Rate of Return (MARR) denoted by k.

5. Compare each project proposal for preliminary acceptance or rejection.
6. Accept or reject a proposal on the basis of the established Criteria [11, 12].

Biezma and San Cristo´bal [13] categorized many various methods of project evaluation into four basic types: NPV methods, rate of return methods, ratio methods and payback methods. The NPV criterion method can be divided into four subtopics or time analysis periods: present worth (PW) method, future worth (FW) method, annual worth (AW) and capitalized worth (CW) method. Each of the four NPV methods provides the same results [14].

In this paper, we used The NPV method. In this method, all costs and revenues during the period studied are transferred to the first investment by a coefficient called P / A, Then initial investment costs with the negative sign and revenues resulting with the positive sign then we gathered them together. If the number is positive, calculated the rate of returned plan for further evaluation and investigation.

4.1. Economic Evaluation of Photovoltaic Systems

Calculations show that during the project life (20 years), With rates of electricity in Iran, The number of NPV method is negative then design of photovoltaic systems for supplying the electrical energy are not economically justified.

4.2. Economic Evaluation of Biogas CHP Plant

Economic feasibility made by using of computer modelling software COMFAR and the input is as follows:
- The cost of initial investment: 2 million $
- Time of construction and the life: 2 years and 20 years
- Interest rates are 14%
- Share of the income tax: 25%
- Discount rate and $ exchange rates: 12% and 13 $
- Annual operating and maintenance costs: 15% of initial investment
- The net amount of electricity produced and electricity prices: 4 million KWH and 61/7 $/ MWH
Price and level of Fertilizer production: 6 / 2 and 0/05 $/kg
- Thermal power plant capacity (net) and annual operating hours: 1,130 kilowatt hours of heating and 8,000 hours.
- Registration fee of CDM and the price of CER: 40 thousand $ and 6 $ per ton equivalent to CO2
- Recycled materials and the sale price: 3,000 tonnes and 100 $/Ton
- Input materials and gate fee: on average the equivalent of 50,000 tons and 7 $/Ton.

Results of Economic Analysis

- The total net present value discount rate of 12%: 21031/6 Thousand $.
- Internal Rate of Return Investment with 12% discount rate: 22 / 64 %
- The net present value discount rate of 20%: 3843/5 Thousand $.
- Internal Rate of Return Investment with 20% discount rate: 26 / 19 %
- Interest during construction: 5707/44 Thousand $.
- Working capital: 1012/5 Thousand $.
- Annual revenue: 12517/8 Thousand $.

The economic evaluation will be made clear that the project is economic justification for implemented.

5. Conclusion

This paper studies the economic and technical feasibility of using photovoltaic systems to supply electric energy to be paid Azad University of Hamedan. Also possibility of using of biogas CHP plant to provide electrical and heating energy of the university has been studied. Technical analysis shows the possibility of using these systems in these places. Economic analysis conducted according to the present cost of electricity represents no economic justification for the use of photovoltaic systems on the supply of electrical energy. The economic evaluation of biogas CHP plant to provide electrical and thermal energy of the university indication that economically justifiable of these system.

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