Fuzzy Method in Feasibility Study of Using Biomass Solar Hybrid Source and Photovoltaic system for Designing a Research Center Building in Smart Grid of Hamedan

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Abstract

In this paper, the electrical consumption of a Research Center Building is derived of the bills, Then with defining of fuzzy Bus Thermal Coefficient objective function for heating, the amount of available heat selling to Research Center Building consumer that is produced by Biomass Solar Hybrid Source is calculated. With the capacity determination of Biomass Solar Hybrid Source to provide Thermal and electrical energy of Research Center Building 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 calculation shows that the use of Biomass Solar Hybrid Source is adequate but using of photovoltaic system is not adequate.

Keywords: Biomass Solar Hybrid Source, 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 countries and even each cities 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 Research Center Building in Hamedan has been integrated.

In the first part of this paper, electrical and thermal consumption of a Research Center Building in Hamadan is given. To obtain the thermal energy that can by supply of biomass power plants, the fuzzy objective function of heat salling 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 a Research Center Building in 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].

1. Consumption of Electrical And Thermal Energy Of Research Center Building (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 Research Center Building, determined the amount of electrical and thermal energy of Research Center Building.

A. *Electrical Consumption of The Research Center Building*

The electrical consumption Curve of the musem in various time of a day is as follows:

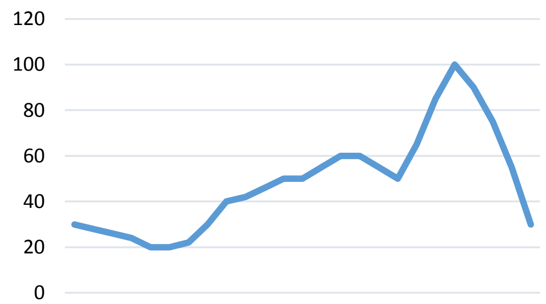

Fig. 1. Load profile of the musem

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.

B. *Heating Consumption of the Research Center Building*

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:

$$BTC_i = \frac{P_{h_i}}{1MW} \quad , \quad BTC_i \geq 0.1 \tag{1}$$

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) :

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

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 :

$$C_{H_i} = BTC_i \times \Delta t_i \times \lambda_H \tag{3}$$

2. 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 2. Higher β indicates more possibility of heat selling to the consumer.

Table.1.
Building classifications according to the National Building Regulations

Row	City name	The required energy	High heating	High cooling	Warm & Humid
211	Hamadan	high	×		
48	Bandar abbas	high		×	×
112	Rasht	low			
71	Tehran	medium	×		

A. Amount of heat consumption (equivalent to electrical power) Q_{hij}

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.

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 [8] , [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/m^3 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)

B. 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.

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

User Type	β	Sample
A	1	Hospitals, hotels(4 and 5stars), industries with the heating consumption for the generation process (cement, steel, meltedmetals, sugar, food, greenhouseTown)
B	0.8	Integrated academic and large schools (with dormitory), skyscrapers, large residential complexes (with central heating systems).
C	0.5	Stores, factories (heating and sanitary use only), international airport
D	0.3	Places of business (shopping centers), offices
All cases	0	spread consumers can not using of central heating systems

Table.3.
Various CHP technologies(x)

Technology	F.C	M.T..	G.T	R.E.	S.T
Typical ratio of heat to power	1-2	0.4-.7	0.5-2	0.5-1	0.1-0.3
The power electrical efficiency (HHV)(%)	30-63	18-27	22-36	22-40	15-38
Total efficiency(HHV)(%)	55-80	65-75	70-75	70-80	80
Using of warm water	*	*	*		
Using of LP-HP steam				*	*
Using of heating		*			
Using of LP steam		*	*		
x	0.75	0.5	1	0.5	0.25

C. 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:

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

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.

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

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

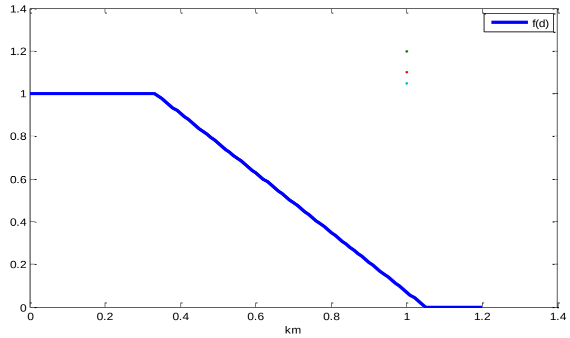

Fig. 2. The fuzzy digit corresponding f(d)

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:

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

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

$$P_{Sij} = P_{is} \times f(\beta \cap d \cap x) =$$
$$4175 \times (0.75 \cap 0.25 \cap 1) = 1.043MW \qquad (6)$$

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

20kVBus number	Type of bus consumer and infrastructure	Heat and hot water consumption (Pis)per KW	Bus Thermal Coefficient(MW)
33,34,35	Research Center Building	4175	1.043

3. The Technical Feasibility of Biomass Solar Hybrid Source and Photovoltaic System

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

A. Biomass Solar Hybrid Source

The situation of the Research Center Building in the region outside the city, Possibility of using waste Hamadan city, waste production at the Research Center Building 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 Research Center Building in 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 3.

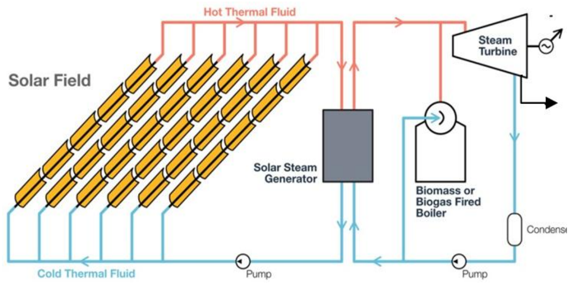

Fig. 3. Diagram of Biomass Solar Hybrid

B. 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 as follows (table 5). (Design basis is assumed 2016 (5 years after commissioning)). Performance and production of the biogas CHP plant

Materials which have been 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.Production of biogas plant is shown in Table 7.

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

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

Table.6.
Profile of material that input to power plant

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

Table.7.
Production of biogas plants

Parameter	Quantity
Gas production (m3/day)	6930
Electrical Power(kW)	606.3
Thermal power(kW)	1130
Produced Water(m3/year)	43400
The amount of electrical energy per year (kwh) - Gross	4,850,400
The amount of thermal energy per year (kwh)	6,236,800
The amount of organic fertilizer (ton/year)with 50% humidity	6290

C. Photovoltaic Systems

Photovoltaic systems can also be used to supply electricity of the Research Center Building. Hamadan Research Center Building 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) [4].

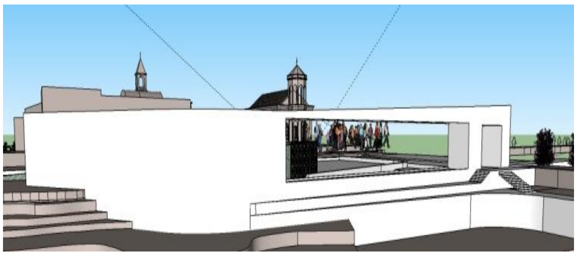

Fig. 4. Research Center Building and Supply of electrical energy by installation of photovoltaic panels on the roof of the Building

D. 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]

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

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

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

– Define a set of investment projects for consideration.

- 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.
- Estimate the cash flow profile for each project.
- Specify the Minimum Attractive Rate of Return (MARR) denoted by k.
- 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 return of the plan for further evaluation and investigation.

A. 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.

B. Economic Evaluation of Biogas CHP Plant

Economic feasibility made by using of computer modeling 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 Gatefee: on average the equivalent of 50,000 tons and 7 $/Ton.

C. Results of Economic Analysis

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

- 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 $.

5. Conclusion

This paper studies the economic and technical feasibility of using photovoltaic systems to supply electric energy to be paid the Research Center Building in Hamedan. Also possibility of using of Biomass Solar Hybrid Source to provide electrical and heating energy of the Research Center Building 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 Biomass Solar Hybrid Source is shown that it provide electrical and thermal energy of the Research Center Building by an economically justifiable way.

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