The Payback Period Influence from Electricity Price of Photovoltaic Energy Systems for Local Customers in the Presence of Electricity Complications and Incentive Tariffs to Reduce Gas Emissions

Ali Bashiri, Pooya Najafi , Sasan Hosseinalizadeh and Mojgan Bashiri

Abstract— Use of solar energy is still required to spend much money. But the financial resources foreseen in clause "v" of note 11 in the 1393 budget law through the resources of electricity complications for installing small photovoltaic power plants and solar pre-heaters to home subscribers has been smooth the way to use them. In the beginning, each domestic subscriber pays approximately 40.000.000 Rials to use the electricity subsidy for purchasing and installing the 1 kW photovoltaic power plant. The power generation of the 1 kW photovoltaic power plant, in Tehran, will be equal to 1568 Kwh in a year and will lead to a reduction of 1.081 tons/year in carbon dioxide emissions. Use of the photovoltaic power plant, with the current price of electricity and this initial cost and without guaranteed sales of electricity to the network, has no economic justification. So to develop the culture of using renewable energy and reduce greenhouse gas emissions, a solution should be considered. In this paper, the incentive tariff to reduce the greenhouse gases has been defined and its value has been obtained at least 6,409,451 Rials per tons of reduction in greenhouse gas. This amount should be paid with a fixed rate to domestic subscribers over 25 years to the project would be economically feasible. This fee can be paid annually through domestic subscribers' Energy card from the resources of clause "Q" of note 2 in the 1393 budget law.

Keywords— Photovoltaic Solar Energy, Electricity Price, the Payback Period, Domestic Subscriber, Incentive Tariff to Reduce Greenhouse Gas Emissions.

I. Introduction

According to an estimation that has been published about global energy consumption in 2016, 78.4% of the total energy consumption of the world still comes from fossil fuels, 19% arises from the renewable energy and 2.6% originates from nuclear energy [1]. Less than 1.2% of the renewable energy share is provided by solar (photovoltaic) energy and wind power plants. With regards to the availability to renewable energies, particularly solar energy, and their cleanness and to reduce greenhouse gases, advanced countries' policy has been focused on the significant increase the solar clean energy share and decrease the fossil energy share or other energy sources. In Iran, due to the solar radiation in most parts and over whole year, there is a considerable potential to use solar energy to reduce emissions and fossil fuel consumption. On the one hand, load factor of about 65% of Iran electrical network implies that the annual growth of thermal power plants capacity is mostly due to the target of crossing from the maximum demand (peak load) of the summer. On the other hand, in recent years, the peak load of electricity network has been shifted from night to day due to the cooling load effects of gas coolers. This issue, in spite of creating problems to lead the power grid, has provided an opportunity for electricity distribution companies to pass the peak times through solar energy.

Due to the suitable capacity of solar radiation in many parts of Iran, most of the solar radiation also occurs at peak hours of electricity consumption. In recent years, by advancement of technology, the cost of solar cells has decreased significantly. But the use of solar energy to generate electricity still requires a high cost. According to the statistical report from the Ministry Energy America in 2013 [2], the construction of a photovoltaic solar power plant with a capacity up to 20 MW has the cost of $ 4,183 per kW (equivalent to 148,914,800 rials per kW). In Iran, due to the relatively low labor cost, the construction cost of the 1 kW photovoltaic power plant in 1393, taking into account the overhead expenses, has been reported to be approximately 85,000,000 rials. In the following, the finance flow of using the solar power plant is studied by considering the administrative cost, the electricity price, and the environmental impact of solar energy. Then, a strategy to reduce the payback period of the project is presented.

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II. INTRODUCTION TO PHOTOVOLTAIC SYSTEMS

A photovoltaic system is composed of solar panels, voltage converters (DC/AC), batteries, and charge controllers. There are generally two types of voltage inverter available: off grid and on-grid. Energy converters constitute the main part of the photovoltaic system. A large number of these small solar cells are put together to form a module and several panel modules placed adjacent to each other to create a panel. The combination of solar panels constitutes a solar array. The energy produced by each panel is quantified in terms of the vertical radiation angle in the summer afternoon. In general, the solar radiation power per square meter of the Earth's surface is estimated to be equal to 1000 W. Depending on the geographical location of each point on the Earth and the remoteness and nearness to/from the equator, the Sun's radiation is different. The sunlight varies with the change of seasons and the distance of the Earth from the Sun. The efficiency of photovoltaic panels, with current technology on the market, have an efficiency of about 15% to 18%. Photovoltaic systems are generally divided into two categories: systems connected to the network (on-grid) and independent of the network (off-grid). In on-grid systems, photovoltaic systems inject power into the grid along with the network. In these systems, the power control unit is used to convert Dc to Ac with the same amount of voltage and power as the electrical network and control the power distribution in the system, automatically. If the power produced by the PV system is more than the power required, additional power is injected into the power grid and if power consumption is higher than power product, the extra power needed is received from the electricity grid and sent to the load. The block diagram of the on-grid photovoltaic system is shown in Figure 1. In the off-grid photovoltaic system, the battery is used as an energy storage source. Therefore solar panels, in addition to supplying loads, should provide the current required to charge the batteries. The block diagram of the off-grid photovoltaic system can be seen in Figure 2.

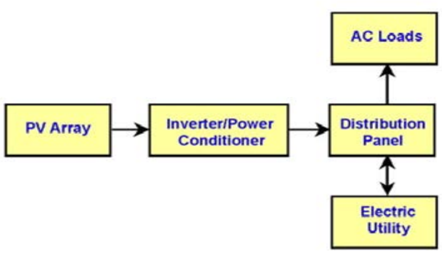

Figure 1. The block diagram of the on-grid photovoltaic system

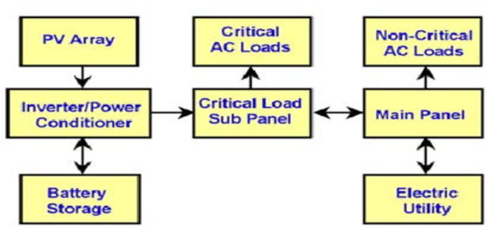

Figure 2. The block diagram of the off-grid photovoltaic system

III. CALCULATION OF THE FINANCE FLOW FOR THE 1 KW PHOTOVPLTAIC POWERPLANT PPROJECT USING ELECTRICITY COMPLICATIONS

Based on the clause "v" of note 11 in the 1393 budget law regarding to the development of renewable energy and with the aim of giving security to country's energy and reducing pollution, the government is authorized to execute the installation project of small solar pre-heaters and small power plants over the rooftops, parks, and pedestrians in 1393. So the objective of this article is to evaluate the payback period of the 1 kW solar power plant for domestic subscribers, in Tehran. According to the electricity tariff and its general conditions [4], in Table 1, electricity tariff of domestic consumption in the common areas and in non-heating months of tropical regions (subject to subscribers in Tehran) is displayed. Diagram 1 indicates the stepped mutation of the electricity price.

Table 1. Electricity tariff in common areas

The average monthly energy consumption (kWh)	The base price per kWh (rials)
0 to 100	372
More than 100 to 200	434
More than 200 to 300	930
More than 300 to 400	1674
More than 400 to 500	1922
More than 500 to 600	2418
More than 600	2666

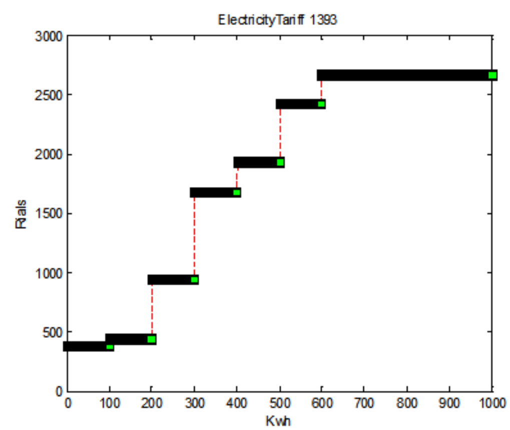

Diagram 1. The stepped mutation of the electricity price

The implementation plan of the clause "v" of note 11 in the 2014 budget law is executed as 50% of applicants' contribution and through the resources of the clause "z" of note 11 in the 1393 budget law. According to records of past performance, installing and running the 1 kW on-grid photovoltaic system has the cost of 85,000,000 Rials. Moreover, given that the guidelines issued by the New Energy Organization of Iran, Tavanir Company pays up to 45,000,000 Rials per 1 kW from solar power plant to the executive system (power distribution companies) after the system startup. Therefore, construction of a 1 kW on-grid solar power plant, using electricity complications, will cost about 40.000.000 Rials for a common domestic customer. The value and the price of the electricity produced in a year should be considered to evaluate the financial flow of the project. Four 260 W solar modules (model YL260C-30b) Manufactured by YINGLI Company with the dimensions of 40*990*1640 mm3 and specifications listed in Table 2 at standard test conditions are used to calculate the electric power generated by the 1 kW photovoltaic power plant [5].

Table 2. Technical Specifications of 260 W solar module manufactured by YINGLI Company [5]

Electrical parameters at Standard Test Conditions (STC)							
Module type			YLxxxC-30b (xxx=P_{max})				
Power output	P_{max}	W	280	275	270	265	260
Power output tolerances	ΔP_{max}	W	0/+5				
Module efficiency	η_m	%	17.2	16.9	16.6	16.3	16.0
Voltage at P_{max}	V_{mpp}	V	31.3	30.9	30.5	30.1	29.7
Current at P_{max}	I_{mpp}	A	8.96	8.91	8.85	8.79	8.74
Open-circuit voltage	V_{os}	V	39.1	38.8	38.6	38.3	38.1
Short-circuit current	I_{sc}	A	9.50	9.47	9.43	9.37	9.35

STC: 1000 W/m² irradiance, 25˚C cell temperature, AMI .5g spectrum according to EN 60904-3.

Average relative efficiency reduction of 1.9% at 200W/m² according to EN 60904-1.

To calculate the annual power production, the monthly and yearly average of radiation intensity have been obtained using Homer V2.81 Software for Tehran with the latitude of 35.749095° and the longitude of 51.391715° [6]. The results are shown in Diagram 2.

By examining the monthly solar radiation data which is displayed in Diagram 2, the average solar radiation throughout a year is calculated 4.9 kWh per square meter per day. Since the effective solar radiation occurs within 6 hours from 9 am to 3 pm over a year, the average solar irradiation is estimated to be 817 W. According to Figure 1, an on-grid inverter, with the ability of providing the necessary power, should be used to connect photovoltaic power plants to the grid. In this paper, the inverter (model SB1300TL) Manufactured by SMA is studied. The efficiency in terms of output power and inverter's input voltage are shown in Diagram 3 [7]. Maximum efficiency of the inverter, with 40% more output load, has been reported to be 96% for the voltage of 400 v and 95% for the voltage of 200 v. Equation (1) is used to calculate the AC electric power generated from the 1 kW photovoltaic system [8].

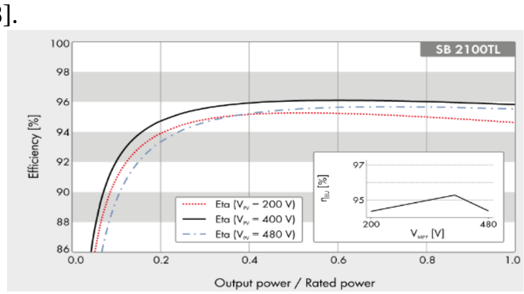

Diagram 2. Monthly average solar radiation in Tehran

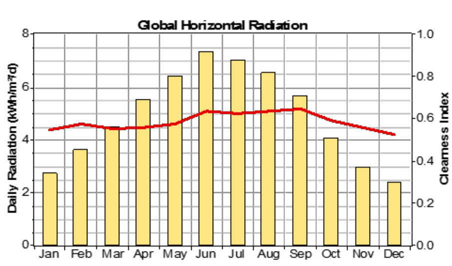

Diagram 3. The output efficiency of the solar inverter (model SB1300TL, SB2100TL)

$$P_{AC} = ((P_{No\min al} \times (1 + (T_{Cell} - 25°C) \times \frac{\gamma \,\%/°C}{100} \times \frac{s}{1000\,W/m^2}) - P_{Cable}) \times \eta_{inv} \quad (1)$$

Where P_{AC} is the output AC power deliverable to the power grid in W. $P_{No\min al}$ is the total power of solar modules and in this paper, it is considered to be equal to 1040 W. $\gamma[\%/°C]$ is the negative thermal constant of the module which according to the data of ref. [5] is equal to 0.42 $\%/°C$. s is the radiation value on the surface of the solar module and according to the calculations, it is 817 W/m2 for Tehran. P_{Cable} is transmission line loss which is less than 1% in this paper. η_{inv} is the inverter efficiency and is considered up to 95%, in accordance with the ref. [7]. T_{Cell} is the surface temperature of the photovoltaic cell. To calculate T_{Cell}, first the average annual temperature is considered to be 23°C in Tehran using weather data contained in reference [9], then the temperature of photovoltaic cells is calculated by using equation (2) [10].

$$T_{\text{Cell}} = (T_{amb} + (\frac{NOCT - 20°C}{80\,W/m^2})) \times S \quad (2)$$

In equation (2), T_{amb} is considered to be 23°C. $NOCT$ (Nominal Operating Cell Temperature) is assumed to be 46°C according to the ref. [5]. S, in accordance with the ref. [11], is intended to be 800 W/m2. By placing these values in relation (2), T_{Cell} is calculated to be 49°C. Then by putting the cell temperature and other values in equation (1), P_{AC} will be equal to 723.5 W. Given that the effective radiation of sunlight is during 6 hours, the total power delivered at 365 days of the year is 1568 kWh per year. So without considering environmental and social aspects of the plan and only from economic point of view to domestic subscribers, the advantages of the project can be seen in the reducing stepped tariffs of the plan. It should be noted that this project is not currently include guaranteed sales of electricity. According to Diagram 4, maximum advantage will be for consumers whose monthly average electricity consumption is between 300 kWh to 330 kWh and use the gas coolers at 9 am to 3 pm in summer. 130 kWh electricity generation per month by the 1 kW on-grid photovoltaic power plant allows to domestic customers, with monthly average consumption of 330-300 kWh, to pay 930 dollars per kW, instead of paying the tariff of 1674 dollars per kWh, and enjoy cheaper rates.

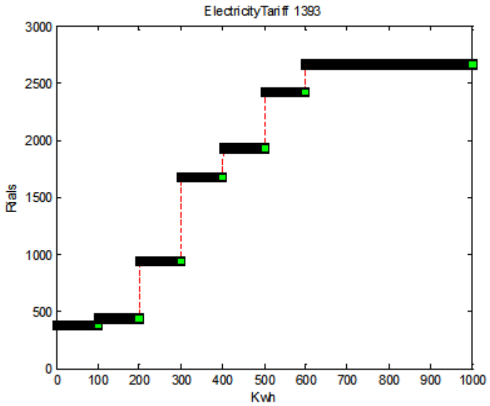

DIAGRAM 4. Electricity tariff reduction from the range of 300-400 kWh to the range of 100-200 kWh per month by using the 1 kW photovoltaic power plant

Given the above conditions, the maximum financial efficiency of the photovoltaic power plant to domestic subscribers, through electricity tariff reduction, will be 744 R ials per kWh of electricity generated from photovoltaic plants. In order to evaluate the financial flow of the project, net present value (NPV), net future worth (NFW), and internal rate of return (IRR) are calculated by using the equations (3), (4), and (5), respectively [12].

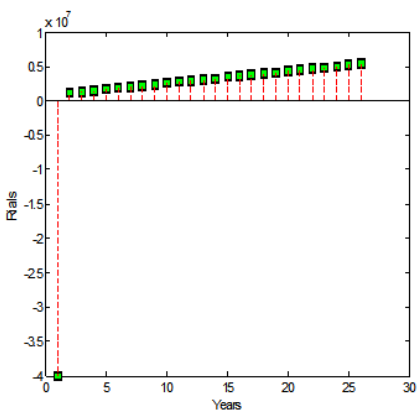

Diagram 5. The financial flow of the 1 kW photovoltaic power plant in the domestic sector by saving in the electricity tariff

$$NPW = \sum_{t=0}^{N} (\frac{R_t}{(1+i)^n}) \quad (3)$$

$$NFW = \sum_{t=0}^{N} (R_r \times (1+i)^n) \quad (4)$$

$$NPW = \sum_{n=0}^{N} (\frac{C_t}{(1+r)^n}) = 0 \quad (5)$$

According to the 25 years lifetime and the Regardless maintenance cost of the photovoltaic power plant, the financial flow has been defined as the linear plot for the next 25 years by taking into account the 22% bank interest and the 15% average annual increase in electricity prices, as shown in Diagram 5. In the financial flow shown, the initial purchase cost of the system and the benefits of solar electricity generation have been shown as negative and positive values. This financial flow has been analyzed and the net present value, the net future value, and the internal rate of return value have been calculated using the equations (3) and (4) and (5), respectively. The results have been indicated in Table 3.

Table 3. Economic analysis of financial flow shown in the diagram 5

NPW	-31281569
NFW	-4511119096
IRR	0.0498%

The results show that installation of 1 kW photovoltaic systems to domestic customers, with discounts of 50% through electricity complications and without guaranteed purchase of electricity and no incentive award for greenhouse gas reduction, is totally uneconomical. Also,

Diagram 5. The financial flow of the 1 kW photovoltaic power plant in the domestic sector by saving in the electricity tariff

The reduction of 744 dollars per kWh of solar electricity production cannot supply their initial investment cost of 40.000.000 Rials over 25 years. Bank's annual high profit, low price of electricity, and high initial investment cost are the reasons which have led to be uneconomical of this project. To develop the use of renewable energy and to be economical of the investment on solar electricity systems to domestic subscribers, an indicator has been defined as the incentive tariff to reduce greenhouse gases and using the software program method, the incentive tariff value has been determined. According to the Department of Environment America [13], the emission factor of carbon dioxide, as the main greenhouse gas, has been determined per kWh by the equation (6). The calculation of the factor value has been done according to the carbon dioxide produced by power plants that have been used at peak load times to provide non-basic electricity.

$$CO_{EF}^{2} = 6.89551 \times 10^{-4}\ tons/_{kWh} \quad (6)$$

According to the production of 1568 Kwh by the 1 kW PV system over a year and the use of equation (6), the annual reduction of carbon dioxide emissions is estimated to be 1.081 tons.

The internal rate of return is one of the standard methods to evaluate economic plans in engineering economics. In this method, the cash flow is discounted to the current rate with an unknown return rate, in such that the net present value will be equal to zero. In other words, the discounted revenue during the payback period is equal to the discounted costs over the same period and accordingly, the unknown return rate will be determined. If this rate of return is higher than the real interest rate, the project will be profitable and feasible, otherwise the plan will be detrimental and non-applicable. Therefore in this paper, in order to support the economy and increase at least 22% the internal rate of return, an index (g) is defined as reduction tariff in greenhouse gas emissions. As an incentive, g is annually added to the financial flow of the plan in return for savings and greenhouse gases reduction. The fee can be paid yearly in domestic subscribers' energy card. A software program has been designed in MATLAB R2014a to calculate the incentive tariff.

In this program, the incentive tariff value is defined from 1 to 10,000,000 Rials with steps of 100 riyals. Outputs of the program is displayed in Figure 3.

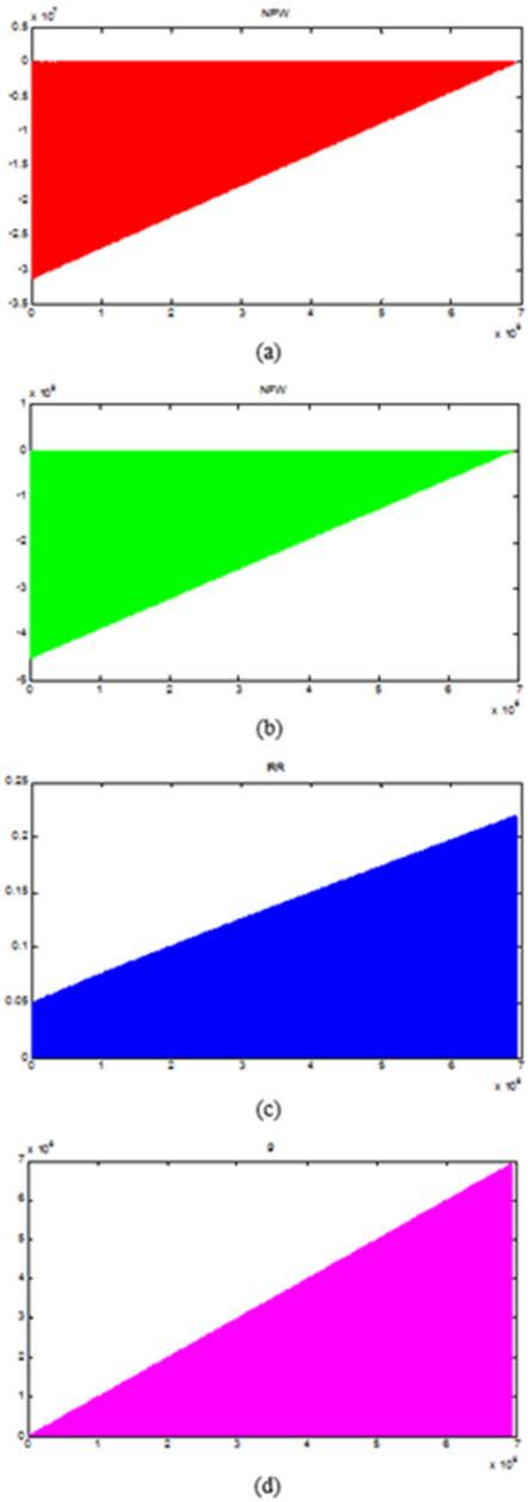

Figure 3. Software outputs related to the tariff incentive value for reducing greenhouse gases (a) Net present value (b) Net future value (c) Internal rate of return (d) Annual incentive tariff value

Investigating the graphs of Figure 3 shows that by increasing the incentive tariff value, greenhouse gases are reduced annually and with a constant amount during 25 years. Also net present and future values are changed from negative values to positive values and the internal rate of return is stopped at about 22%. So, at least 6,409,451 Rials should be paid annually to reduce greenhouse gas emissions over 25 years to the 1 kW photovoltaic system plan for domestic subscribers would be economical. The financial flow and the economic analysis of the reinforced project have been shown in Diagram 6 and Table 4, respectively.

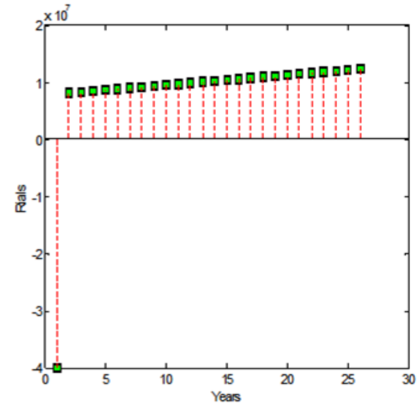

Diagram 6. Financial flow shown in the diagram 5 reinforced with the incentive tariff to reduce carbon dioxide

Table 4. Economic analysis of financial flow shown in the diagram 6

NPW	4.40
NFW	635
IRR	0.22%
g	6409451 Rials

IV. CONCLUSIONS

Increasing in greenhouse gas emissions and environmental pollution as well as decreasing in fossil fuel resources has driven human societies toward new energy sources. One of the renewable and clean energy is solar energy. Use of solar energy is still required to spend much money. But the financial resources foreseen in clause "v" of note 11 in the 1393 budget law through the resources of electricity complications for installing small photovoltaic power plants and solar pre-heaters to home subscribers has been smooth the way to use them. In this paper, the payback period of the 1 kW photovoltaic power plant project has been calculated through methods of engineering economics from the standpoint of domestic subscriber, with regarding to electricity tariff and its general condition, as well as the perspective of government, by taking into consideration the cost of electricity. Then the incentive tariff to reduce of greenhouse gas emissions has been defined by using the resources of clause "Q" of note 2 in the 1393 budget law to improve the process of being economical of these power plants.

REFERENCES

[1] A. Zervos, "RENEWABLES 2014 GLOBAL STATUS REPORT," REN21, Milan, 2014.

[2] U. D. o. Energy, "Updated Capital Cost Estimates," U.S. Energy Information Administration, Washington, 2013.
[3] P. Najafi, "solar energy system design of great Tehran electrical distribution company building to peak shaving and investigating parameters of power quality," 19th Conference on Electrical Distribution Networks, Tehran, 1393.
[4] Approval of the Ministry of Energy "electricity tariffs and general conditions," 18 4 2014. [Online]. Available: http://tariff.moe.gov.ir [Accessed 4 1 2015].
[5] Y. SOLAR, "PANDA 60 Cell Series," 9 2014. [Online]. Available: WWW.YINGLISOLAR.COM. [Accessed 4 1 2015].
[6] N. R. E. L. &. H. Energy, "Getting Started Guide for HOMER Legacy (Version 2.68)," HOMER Energy, Colorado , 2011.
[7] SMA, "SUNNY BOY 1300TL / 1600TL / 2100TL," 2 3 2014. [Online]. Available: http://www.sma.de. [Accessed 4 1 2015].
[8] P. Gevorkian, Large-Scale Solar Power System Design: An Engineering Guide for Grid-Connected Solar Power Generation, New York: The McGraw-Hill Companies, Inc., 2011 .
[9] W. W. Online, "Tehran Monthly Climate Average, Iran," World Weather Online, 4 1 2015. [Online]. Available: http://www.worldweatheronline.com. [Accessed 4 1 2015].
[10] K. B.-S. a. P. K. G. Ádám, "Energy production estimating of photovoltaic systems," in International Conference on Renewable Energies and Power Quality (ICREPQ’12), Santiago de Compostela (Spain), 2012.
[11] R. Ross, "Flat-Plate Photovoltaic Array Design Optimization," in 14th IEEE Photovoltaic Specialists Conference, San Diego, CA, 1980.
[12] B. a. W. Sullivan, Engineering Economy, 11th Ed., New York: Prentice-Hall, 2000.
[13] U. S. E. P. Agency, "eGRID 9th edition Version 1.0 Year 2010 GHG Annual Output Emission Rates," 2 2014. [Online]. Available: http://www.epa.gov/egrid. [Accessed 5 1 2015].