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Technical and Economical Evaluation of a 15 kW Grid-Connected Solar PV System in Jiroft, Iran

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Abstract: *In this paper further more PV systems are introduced we is investigated Economic evaluation of a 15 kW Grid-Connected photovoltaic systems for electricity supply in rural areas and comparison with electrification through hens work electricity. The aim is to assess the potential of energy cost saving and cost effectiveness the system can achieve under the new residential feed-in tariff, referred to as residential embedded generation tariff. Simulation results show that a potential of 77.41% energy cost saving and payback period. The proposed technical and economical evaluation of a 15 kW grid-connected solar PV system in jiroft is simulated using MATLAB/ SIMULINK in power system block set.*

Keyword: *Technical, Economical, photovoltaic, electricity supply*

INTRODUCTION

The greatest source of energy is solar energy that energy emitted from the different forms is used in order to provide the required energy fossil fuels. Coal has been used for a considerable number of years as the main energy fuel in Iran because of reasons such as the abundance of coal reserves in the country, the cost effectiveness of generating electricity from coal, the reliability and efficiency of coal-fired power stations, a well-established infrastructure for electricity production from coal, etc. However, due to the outdated power stations, reduced coal reserve margins and high investment cost of new coal-fired power stations, Eskom, the main electricity supplier, is currently experiencing a big challenge to meet the continual growth of energy demand in Iran, resulting in load shedding and power blackouts [1,2]. Being part of the Kyoto protocol, Iran is also committed to reduce the carbon emission from its coal-fired power stations.

Operating the aged coal-based power generation equipment that require expensive maintenance, and also the consumption of large amounts of diesel fuel required by gas turbines, would justify the steadily increase of electricity price by Eskom. In eThekwini municipality, 1 for instance, the electricity cost has been increased by 9.80% from 2012 to 2013, by 4.95% from 2013 to 2014, by 6.80% from 2014 to 2015 and by 12.20% from 2015 to 2016 [4]. However, because of the reduced availability level of the current coal-fired power stations, due to the reasons mentioned earlier, these gas turbines are operated for longer periods than initially planned [2]. Moreover, with the forthcoming implementation of the carbon tax in Iran [5], the electricity cost is expected to ramp up owing to the fact that coal-fired power plants are one of the biggest greenhouse gas emission sources.

On the other hand, because of the steady increase in the electricity cost, Iran electricity customers are showing great interest to install distributed generation (DG) systems such as solar PV and wind. Grid-connected solar PV is seen to be the fastest growing DG resource in Iran due to the high solar resource the country has, combined with the substantial drop in the initial investment cost. The average daily solar radiation in Iran is between 4.5 and 6.5 kW h/m^2/day [7], which is higher than that of most countries in the world. The application of grid-connected PV systems has found more market in commercial and industrial sectors than in the residential sector. For urban residential buildings, however, a grid-connected solar PV system might not be cost effective owing to the fact that most electricity usage will not be offset by the investment cost of the solar PV system. The reason is that, unlike with industrial and commercial customers, the need for electricity in urban residential buildings is greater during the evening than during the day, whilst the PV panels produce power only during the day. The second solution is to store the excess power during the day and use it later in the morning and evening when the load demand is high. This option gives residential customers the freedom and flexibility to control, at any time, the bi-directional power flow between their buildings and the grid (import and export), unlike in a grid-connected PV system where the power flow is unidirectional [9]. To solve this issue, two approaches are possible. The first one is to sell the excess power to the national grid during the day when the residential load demand is insignificant. The grid-interactive solar PV system is still a new technology within PV systems. This was designed to combine both advantages of grid-connected and off-grid solar PV systems, in the sense that it supplies power to the user, feeds the excess to the grid, boosts grid stability and also provides back-up power during grid failure periods [10]. However, there are only few research studies on grid-interactive PV systems. Research papers, such as [11–13] have dealt with the optimal energy control of off-grid hybrid energy systems with the aim to minimize the diesel energy cost of load demands in remote areas.

1. Model Development

Iran is a country in terms of geographical area is hot and dry, and getting more sun light during different months of the year. In Iran Except for the Caspian Sea coast across the country Percent of Sunny days are 63 to 98% in year. The energy content of the different parts of the country show in Figure 1 [1]. Solar energy as a clean energy source that can provide most of the energy consumption is Used in the form of heat or electricity. Due to the increasing cost of energy from fossil fuels Cost of power generation using renewable energy and new developments in science and technology reduced and the economy is closely.

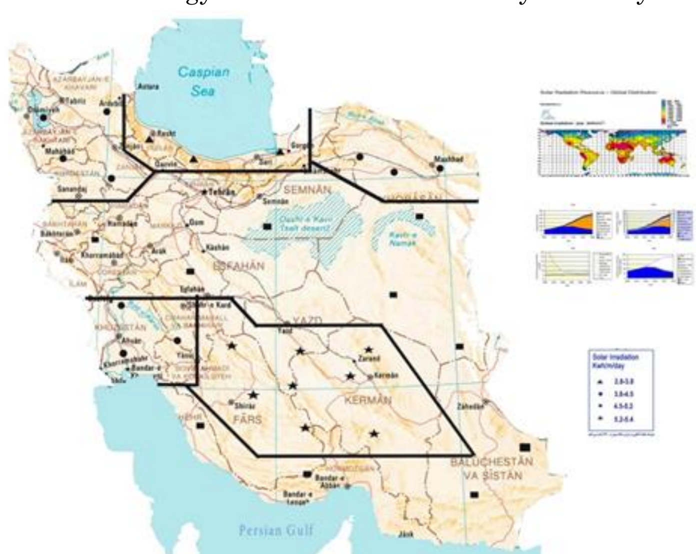

Fig 1: Map of average daily received energy in Iran

2. Objective function

The control objective to be minimized is the net electricity cost, J_C , under a given period. This is defined as the difference between the electricity cost due to the power imported from the grid, P_{IMP} , and the electricity cost due to the power exported to the grid, P_{EXP}. This is expressed mathematically as follows:

$$J_C = \sum_{j=1}^{N} \left(P_j^{P_{IMP_j} - CP_{EXP_j}} \right) t_s, \quad (1)$$

Where j is the j th sampling interval, N is the total number of sampling intervals, t s is the sampling time, p is the TOU electricity tariff and c is the FIT.

2.1. Constraints

2.2.2.1. Power balance. The power balance is one of the most important constraints in electrical circuits that need to be met. By neglecting all converter power losses, the power balance constraints to be satisfied at different nodes of the system, are expressed as follows:

$$\begin{cases} P_{MP_j} = P_{DC_j} + P_{B_j} \\ P_{DC_j} = P_{L-C_j} + P_{AC_j} \\ P_{AC_j} + P_{IMP_j} = P_{EXP_j} + P_{L-C_j} \end{cases} \quad (2)$$

During charging and discharging, the state of charge, SoC , of the battery bank has to be maintained between its minimum and maximum values, SoC_{min} and SoC^{max} , respectively. The SoC of the battery bank in Fig. 2 can be expressed in the discrete-time domain as follows:

$$soc_j = soc_{(j-1)} + \frac{\eta_B t_S}{C_n} P_{B(j-1)}, \quad (1 \le j \le N), \quad (3)$$

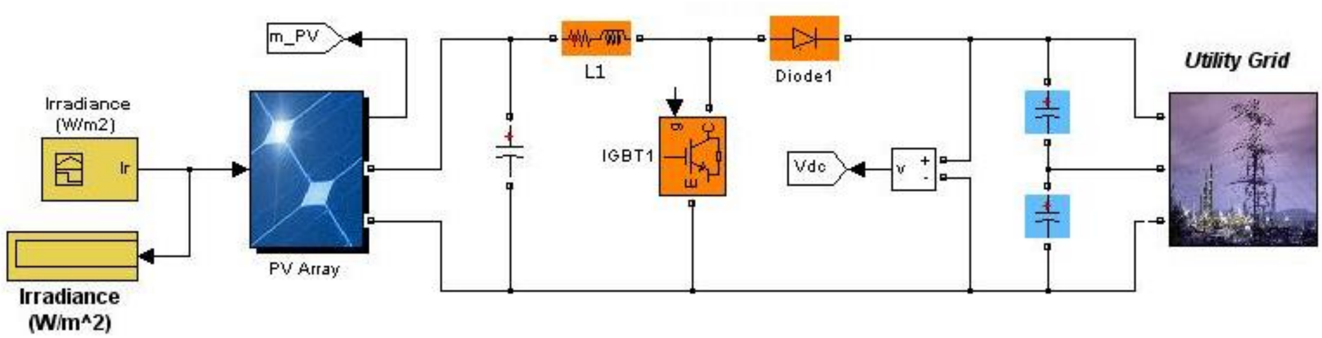

Fig. 2. Schematic diagram of a grid-interactive solar PV system.

Where SoC_j is the SoC at the current sampling interval, j; $SoC_{(j-1)}$ is the SoC at the previous sampling interval, (j – 1); C_n is the nominal capacity of the battery bank in kW h and η_B is the round trip efficiency of the battery. However, since the SoC at the current sampling interval has to be expressed only in terms of the battery power, P_B , which is one of the control variables, $SoC_{(j-1)}$ has to be eliminated from Eq. (3). By a recurrence reasoning, the battery bank SoC at the current sampling interval can be expressed as a function of P_B and its initial value, SoC_0 , which is constant. This results in the following expression:

$$\text{SoC}_j = \text{SoC}_0 + \frac{\eta_B t_s}{C_n} \sum_{i=1}^{j} P_{B_i}, \ (1 \le j \le N), \quad (4)$$

With this, the constrains to maintain the SoC dynamics within specified values are written as follows:

$$\text{SoC}^{min} \le \text{SoC} + \frac{\eta_B t_s}{C_n} \sum_{i=1}^{j} P_{B_i} \le \text{SoC}^{max}, \ (1 \le j \le N) \quad (5)$$

2.2. PV power output

At any time, the DC power handled by the MPPT converter should be less than or equal to the available PV power output, determined by the PV module characteristics, such as the PV power output at maximum power point and PV power temperature coefficient, and weather conditions, such as temperature and incident irradiation. This is expressed as:

$$P_{MP_j} \le P_{PV_j}, (1 \le j \le N). \quad (6)$$

3. Photovoltaic systems

Photovoltaic panels are exposed to the sun are composed of photovoltaic cells. Main constituent of most commercially available solar cells are from thin layers of semiconductor materials such as silicon. The main reason for this subject is rapid development and industrial production of bulk silicon Low cost and high efficiency in comparison with other semiconductors. Common types of solar cells are described in Table (1).

Table 1- Common types of solar cells

Solar cell materials	Thickness (mm)	Efficiency(%)
Single-crystal silicon	0.3	15-18
Multi-crystalline silicon	0.3	13-15
Hybrid silicon	0.02	18

When the sun's photons to collide electrons leave these mi conductor atoms and holes that occur. If both cells are electrical conductors, Causes Creates a current that is called the current photon (I_{ph}). In the darkness, the solar cell is not active and acts like a PN junction diode that diode current is called the dark current (I_D). Equivalent circuit of a PV cell is shown in Fig 3. I_{ph} is current Photons from the sun , I_D diode current ,R_s is Connect the series resistor who Losses are shown in cells.[3][4]

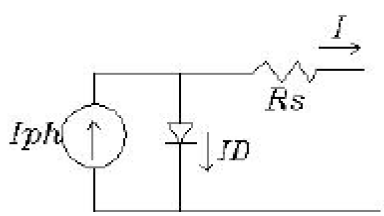

Fig 3. The equivalent circuit of a cell

The relationship between the voltage and current of cell for different loads is shown in Fig 4. As is clear from this figure, current-voltage characteristics-the solar cells is highly nonlinear. The point at which the product of voltage and current is it highest point is called maximum power cells. [5]

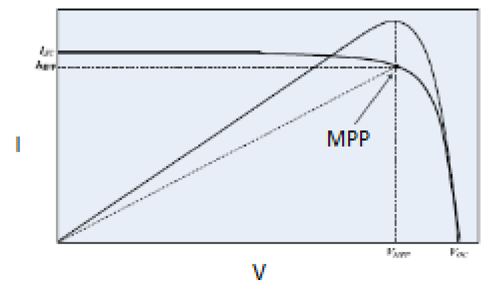

Fig 4. Current-voltage characteristics of solar cell

Current-Voltage characteristic curve–changes with two factors of solar radiation and ambient temperature. Solar cell current-voltage curves in Fig 5 and 6 show the variation of temperature and radiation. Usually produced by each cell voltage is about 5 volts. Current occurring in the cells follower are Cell area and intensity of solar radiation and temperature. To increase the voltage and current installed a group of cells connected in series and parallel to make a larger unit. That the larger units called modules. By installing some solar modules is created on the retentive plate .Fig 7 shows the electrical connection of several panels together.

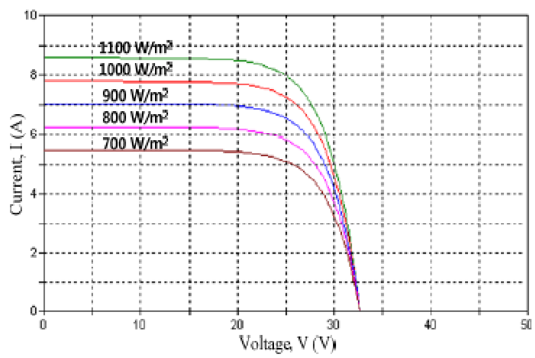

Fig 5. The effect of solar radiation on the curve of the voltage–current

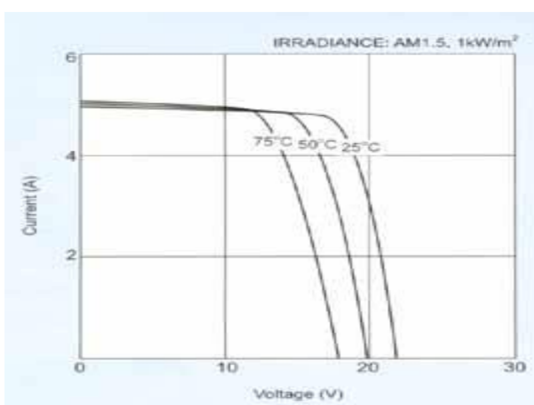

Fig 6. The effect of temperature on the voltage-curve

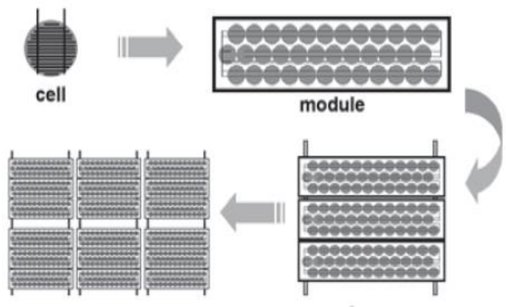

Fig 7. Cells, solar modules and arrays

3.1. Charge Control

Devices in the solar system which regulation and control the battery charge and discharge current and voltage. Prevent possible damage inflicted on the operating lifespan of a battery and maintain it. One of characters of solar panels is when changes output voltage panels with cloudy weather or change to the sun. So charge and discharge control and Stabilize the output voltage at solar power is one of the most important points it is set up with charge control. Monitor the level of charge and discharge current and voltage in the selection of this system, the benefits of existing systems in the market.

3.2. Solar battery

Battery bank number is included usually 12 to 24 volt battery that Connected in series to provide system Required voltage. Systems which are isolated from the network Energy stored in the batteries, is done when the night or orate emergency times. Support systems are used in the battery during network outages. Network-connected systems do not require batteries.

3.3. Inverter

If the output of the ac adapter is required for example, if they must Production energy of photovoltaic conversion its produced dc output voltage of converter by an electronic circuit convert to alternating voltage. Depending on the application, can be single phase or three phase. Electronic circuit used is called an inverter. Dc voltage input to the inverter in photovoltaic system Can be output from the output of solar arrays or batteries to be used in this system. Output phase voltage inverter with dc input voltage is in accordance with the following equation:

$$V_{Ph} = \frac{2\sqrt{2}}{\pi}\cos(\frac{\pi}{6}).V_d \quad (7)$$

V_d: Dc voltage input to the inverter

V_{ph}: Ac output voltage of the inverter

4. Simulation Results and Discussion

The proposed scheme technical and economical evaluation of a 15 kW grid-connected solar PV system in jiroft, iran.

شکل 8 نمونه نصب شده سیستم فتوولتائیک برای سازمان جهاد کشاورزی جیرفت می باشد

سیستم ارائه شده برای تامین برق پمپ آب 15 کیلوواتی برای ابیاری تحت فشار می باشد.

(a)

(b)

(c)

(d)

Fig 8. Case Study for 15 kW grid-connected solar PV system

The proposed control scheme is simulated using SIMULINK in power system block set. The system performance of proposed system under dynamic condition is also presented. The main purpose of performing demonstration experiment is to evaluate the effectiveness of our load shedding scheme in physical difficulties, such as the gap between sensed value of power consumption and actual power consumption, overload of power by loads, etc. Simulation of system shown in Fig 9.

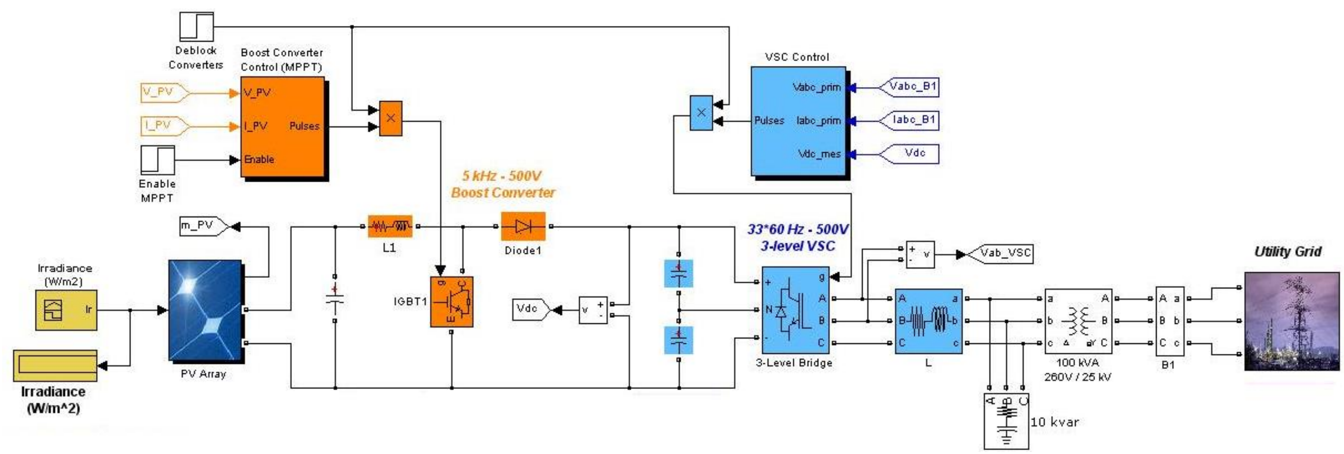

Fig 9. Simulation of 15 kW grid-connected solar PV system

This paper is analyzed a system, using the simulation software Matlab. Results are shown in Fig 10 and Fig 11.

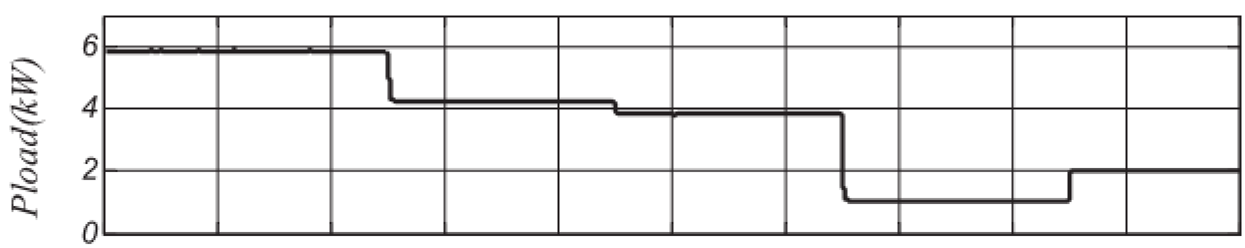

Fig 10. 15 kW grid-connected solar PV system; Total load (kW)

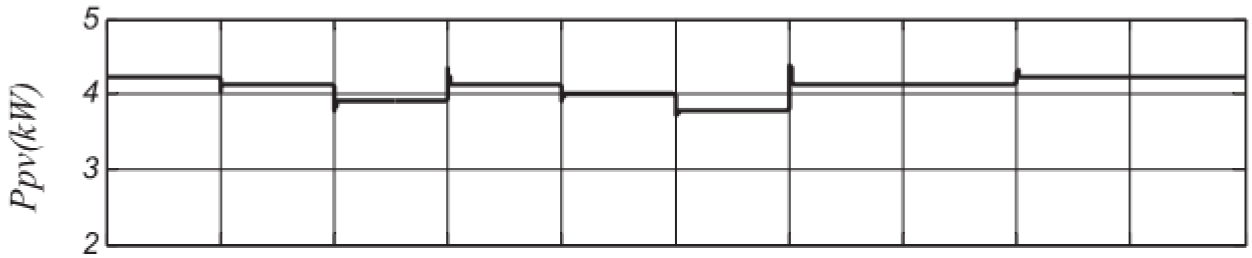

Fig 11. 15 kW grid-connected solar PV system; PV power generation (kW)

5. Conclusions

In this paper further more PV systems are introduced we is investigated Economic evaluation of a 15 kW Grid-Connected photovoltaic systems for electricity supply in rural areas and comparison with electrification through hens work electricity. Simulation results show that a potential of 77.41% energy cost saving is possible when the energy cost management is applied to the residential grid-interactive PV system, under the current FIT, that is USD 0:046/kW h. Simulation results also show that the higher the grid electricity price, the higher the profitability of the system.

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