Efficiency and power loss of solar power converter

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Abstract:

Renewable energy sources are a replacement of conventional sources to overcome the environmental pollution issues, raising prices and limited stock. Solar energy is the best alternative to provide abundant and clean source of energy. In other hand, Libya, like other countries in the world suffers from high energy consumption, high conventional energy prices and environment issues, combined with rapid demand growth. As a result, the Renewable Energy Authority of Libya (REAOL) has been founded to promote the development of renewable energy in Libya to increase the utilization of renewable energy from 6% to 10% by the year of 2020. There is huge potential for renewable energy in Libya, especially solar and wind. In this paper solar converter technique will be studied in order to integrate the solar cell with grid, this technique is called single- stage photovoltaic (PV) solar converter . This paper is focused on efficiency calculation of single- stage PV solar converter and power loss calculation in MOSFETS and diodes of Full-bridge inverter by simulink matlab environment. results show single- stage photovoltaic gives better performance in efficiency and power loss

الملخص:

تعد مصادر الطاقة المتجددة بديلاً عن المصادر التقليدية للتغلب على مشاكل التلوث البيئي ، ورفع الأسعار ومحدودية المخزون. الطاقة الشمسية هي أفضل بديل لتوفير مصدر وفير ونظيف للطاقة. من ناحية أخرى، تعاني ليبيا ، مثلها مثل بلدان العالم الأخرى ، من ارتفاع استهلاك الطاقة وارتفاع أسعار الطاقة التقليدية وقضايا البيئة ، بالإضافة إلى نمو الطلب السريع. نتيجة لذلك ، تم إنشاء هيئة الطاقة المتجددة في ليبيا (REAOL) لتعزيز تطوير الطاقة المتجددة في ليبيا لزيادة استخدام الطاقة المتجددة من 6 ٪ إلى 10 ٪ بحلول عام 2020. هناك إمكانات هائلة للطاقة المتجددة في ليبيا ، خاصة الطاقة الشمسية وطاقة الرياح. في هذه الورقة ، ستتم دراسة تقنية المحول الشمسي من أجل دمج الخلية الشمسية مع الشبكة، وتسمى هذه التقنية المحول الشمسي الكهروضوئي أحادي الطور. تركز هذه الورقة على حساب كفاءة محول الطاقة الشمسية الكهروضوئية أحادي الطور وحساب فقد الطاقة في MOSFETS وثنائيات العاكس (محول التيار المستمر الى تيار متناوب) بواسطة المحاكاة ببرنامج الماتلاب. أظهرت النتائج أن الخلايا الكهروضوئية أحادية الطور تعطي أداء أفضل في الكفاءة وفقدان الطاقة

Keywords: single- stage photovoltaic, efficiency, power loss, Full-bridge inverter

1. Introduction

Libya tends to be a significant nation in the Mediterranean basin and the richest in North Africa in terms of natural resources. Like other countries, Libya suffered from high conventional energy prices, environmental issues, rapid demand growth and high energy consumption. Libya's major source of income is oil and the country depends greatly on the oil it produces as the major source of income. Libya has a high potential of renewable energies, especially wind energy and solar energy, which can create local jobs, drive local economies and reduce carbon pollution. However, Libya attempts to use the large resources it derives from oil to invest in infrastructures that will support the quick realization of oil dependence as its major source of income. Libya wants to achieve these projects by setting up designs, development, and implementations that will support the achievement of this project. Renewable energy such as solar energy will help Libya reduce the dependence on oil as a major source of income if their components are properly and effectively designed, manufactured, and implemented. Solar energy is one of the most promising and best eco friendly energy sources among those renewable energy systems. Photovoltaic cells (PV) are employed to transform solar energy into the electrical energy. The energy obtained from PV cells can be used locally or it can be exported to the grid. However the availability of solar energy depends on weather conditions and the time of usage. Power from PV cells is also highly sensitive to the shading phenomenon. Due to this intermittent nature of source, supplies from PV cells are variable in nature and must be conditioned as per the demand of load or grid specification. This can be done in single stage PV solar converter. PV cells are acts as a DC current source that provides variable DC output voltage. This variable DC transmits to grid or local load by single stage conversion. Single stage conversion consists of inverters that invert this DC to AC as per the demand of grid (Zacharias, 2008)

Modern electronic inverters are efficient over a wide range of outputs. If a stand-alone inverter performance reaches 87–95% at two-thirds of its rated capacity, its efficiency decreases sharply when the power supply falls below this value and can reach values under 50% at a very small load. An inverter requires some power just to run itself, so inverter efficiency will be low when running very low loads. In a typical home, there are many hours of the day when electrical load is very low. One solution consists of using as many inverters as AC loads to supply; thus, each converter has a higher performance, increasing the overall system reliability but with a significant increase of the system cost (Kjaer, at el, 2005).

The best solution in the opinion of many authors is the mixed system, in which the hybrid system is divided into two subsystems, a DC one for lighting, radio and television, for instance, and an AC one for other equipment; in this way any inverter will be turned on only when an AC load requires it.

The choice of electrical signal (square, pseudo-sinus or sinus) produced by an inverter depends on the type of connected appliances, but the inverter price increases with the quality of the signal and its performance, and so can be increased up to four times for the same nominal power.

In most publications, inverter efficiency is taken as a constant and equal to 90–95%, which is sometimes high compared with commercial data but, actually, varies with the load. When the load is fluctuating, it is desirable to use the inverter efficiency curve versus load power in any modelling (Bialasiewicz& Muljadi, 2006).

It is possible to determine the inverter efficiency if measurements of both DC input and AC output are provided. In general, the efficiency of a PV inverter is a function of the input power and input voltage, with a typical set of efficiency curves being shown in Figure. 1. At medium to high light levels and therefore input power from the array, the inverter has a high efficiency, generally well in excess of 90%. At low irradiance levels, the efficiency drops off sharply. This means that we can determine an optimum inverter capacity in comparison with the array capacity, such that the balance between energy loss at the low irradiance end due to reducing efficiency is balanced against energy loss at the high irradiance end due to limiting because of the maximum inverter capacity. assuming that the basic shape of the inverter efficiency curve does not depend on inverter capacity. Clearly, the balance between energy generation at low and high irradiance values is dependent on the climate and, therefore, so is the optimum inverter/array ratio, with the general approach of a reduction in this ratio as the latitude increases (Meinhard, et al, 2007).

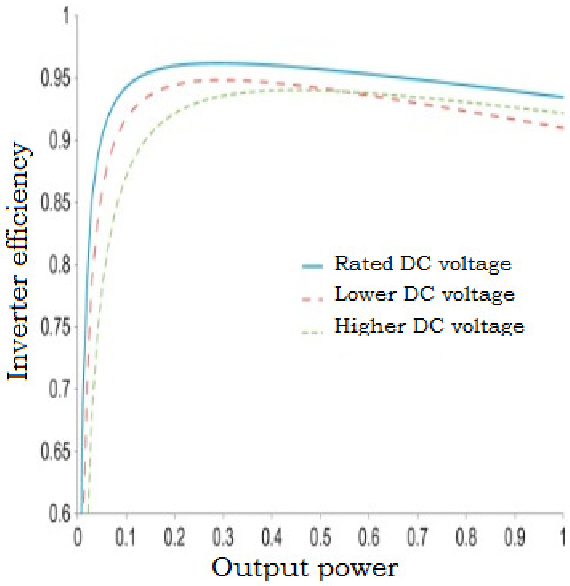

Fig. 1 Typical inverter efficiency curve as a function of DC input voltage

Because of the variation of efficiency with input power, and therefore irradiance on the array, the average operating efficiency of the inverter will vary with climate. For a stand-alone PV system, the important parameter is not the total energy generated but whether the load is met for the required time, that is, the service provided by the system. This is sometimes assessed by direct reference to the load, for example, amount of water pumped, amount of product manufactured using PV electricity. However, it is also possible to define parameters to express the system performance, such as the total amount of time for which the load is not met (to be compared with the loss of load probability defined in the system design) and the battery index, which is the percentage of days in a given period when full charge of the batteries in the system is achieved. In general, values over 30% are considered as good, although very high values may indicate an oversized array.

Inverters are designed to perform two main functions, Maximum power point (MPP) tracking and DC to AC conversion. The power generated by a PV cell (or module) is maximum at a certain voltage and current. As the *I*–*V* characteristics depend on the irradiation intensity, the MPP also varies. An MPP tracker should constantly ensure that a PV module is at its MPP; this is realized by power electronic circuits, in which pulse-width modulation techniques are employed with a feedback loop to sense PV output power upon changing the voltage over the module or system until maximum power is reached (Yu, et al, 2011). Here also DC–DC converters (buck–boost, boost–buck) are used. Low power inverters use metal-oxide-semiconductor field-effect transistor (MOSFET), thyristors are used in high-power applications, and typical efficiencies are 98% (Jain& Agarwal, 2007). DC to AC conversion can be achieved on the basis of square wave, sine or modified sine wave, or pulse-width modulated inverters. Inverter capacities may range from 500 W to 1 MW and deliver an AC output that has a waveform very close to a pure sinusoidal 50 or 60 Hz one.

Similar to PV modules, the inverter efficiency is given for its design operating power; however, the operation of inverters is usually at partial load. Therefore, it is desirable to have a high and flat efficiency curve over a wide range of partial loads.

2. INVERTER:

The power supplied by solar cell is DC. However our home appliances as well as grid works on specific AC voltage and frequency hence require inversion and conditioning of this DC power. This can be done by inverters. Inverters are circuits use to invert DC power into AC at desired output voltage and frequency. Inverters are basic circuits used single stage PV solar converter (Alaskan, 2006).

2.1 FULL BRIDGE INVERTER

It consist of four MOSFETs and four Diodes to invert the supplied DC voltage. The MOSFET are used as switch in the inverter circuit to invert the DC voltage to AC voltage. The circuit diagram of the full bridge inverter are shown in figure 2

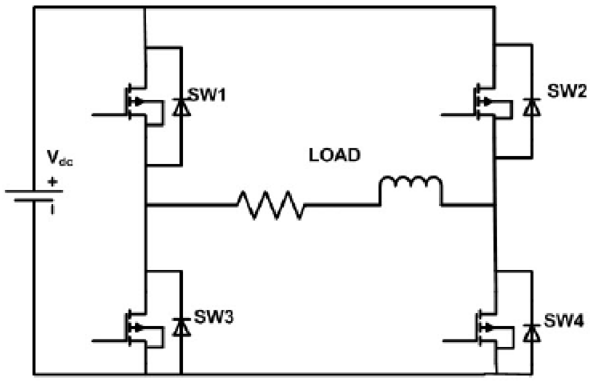

Fig. 2 FULL bridge Inverter

2.2 MOSFET Losses

There are four sources of power losses in the switching MOSFET: the conduction or on state loss, the off state loss, the turn on switching loss, and the turn off switching loss (Ashfaq, 1998, p.56; Brendel,et al, 2008; Greulich, et al, 2013; Maghami, 2016).

a. Conduction Losses or on state loss

A MOSFET has relatively high on state losses given by:

$$P_{ON} = I_D^2 R_{DSON} \frac{t_{ON}}{T} \quad (1)$$

Where T is the total period

b. off state loss

The off state loss is given by

$$P_{OFF} = V_{DSMAX} I_{DSS} \frac{t_{OFF}}{T} \quad (2)$$

C. The Turn on Switching Loss

The energy loss in the MOSFET when it switches from the off state to on state is given by

$$W_{ON} = \frac{V_{DSMAX} I_D t_r}{6} \quad (3)$$

Where t_r is the rise time of the drain current (I_D)

d. The Turn off Switching Loss

The energy loss in the MOSFET when it switches from the on state to the off state is given by:

$$W_{OFF} = \frac{V_{DSMAX} I_D t_f}{6} \qquad (4)$$

Where t_f is the fall time of the drain current (I_D)

e. Switching Power Loss

The switching power loss is

$$P_{SW} = (W_{ON} + W_{OFF}) * f \qquad (5)$$

Where f is the switching frequency

f. Total Power Loss in the MOSFET

$$P_T = P_{ON} + P_{OFF} + P_{SW} \qquad (6)$$

2.3 Diode losses

The total power loss that occurs in a diode is the sum of the on-state, off- state and switching losses:

$$P_T = P_{ON} + P_{OFF} + P_{SW} \qquad (7)$$

Where

$$P_{ON}=V_F*I_F*t_{ON}/T \qquad (8)$$

$$P_{OFF}=V_R*I_R*t_{off}/T \qquad (9)$$

$$P_{SW}=P_{SWON}+P_{SWOFF} \qquad (10)$$

$$P_{SWON}=V_{FMAX}*I_{FMAX}*t_F*f/6 \qquad (11)$$

$$P_{SWOFF}=V_{FMAX}*I_{FMAX}*t_R*f/6 \qquad (12)$$

In these equations,

V_F =forward voltage, I_F= forward current, V_R= reverse voltage, I_R= reverse leakage current, t_{ON}=time of diode conduction, t_{OFF}=time during which diode is reverse biased, t_F=switching time in forward direction, and t_R= switching time in reverse direction

2.4 The Efficiency Calculation

The efficiency of solar power converter can be calculated from the following equation:

$$efficiency = \frac{100*(P_{DC}-P_{LOSS})}{P_{DC}} \quad (13)$$

3. Implementation solar power converter

Figure 3 shows the implementation of solar power converter by simulink matlab, the solar panel parameters are : the total photovoltaic cells are 700 cells, the diode saturation current is $3.15*10^{-7}$ A, solar generated current 3.8 A, the irradiance used for measurement is $1000w/m^2$, and the quality factor is 1.4.

The MOSFET parameters are: R_{DSON} = 0.1 ohm, I_D for R_{DSON} = 15 A, V_{GS} for R_{DSON} = 10v, and gate source threshold voltage is 1.7v

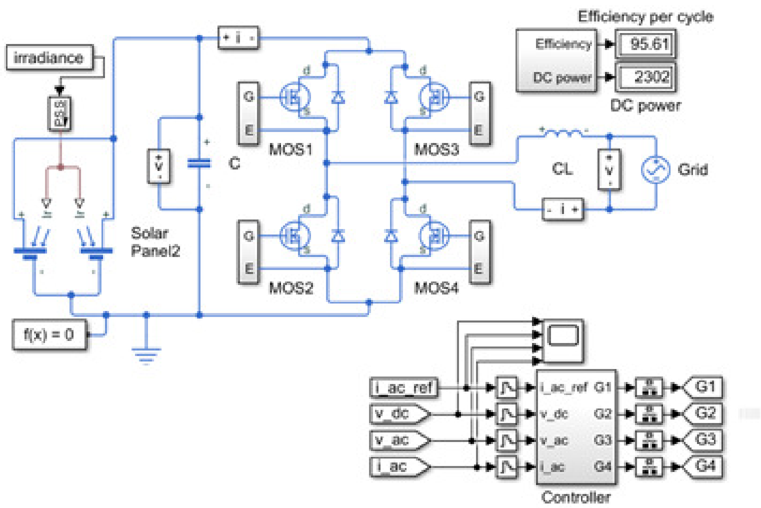

Fig. 3 implementation solar power converter by simulink matlab

The efficiency and DC power can be calculated from the circuit as shown in figure 4

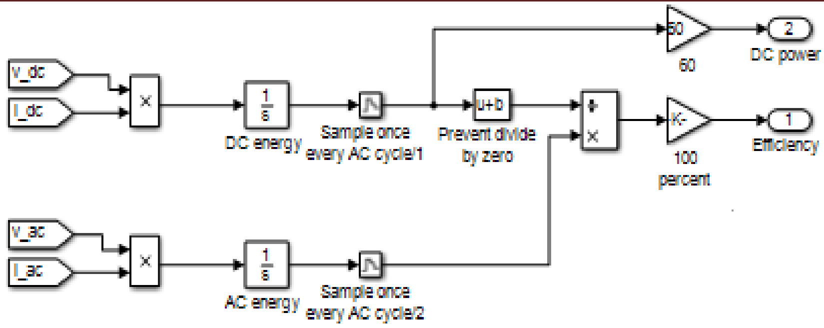

Fig.4 Calculation efficiency end DC power of solar power converter

4. Simulation results:

When we run The simulation program we got the following results:

the efficiency = 95.61 %

DC power = 2.3 KW

The losses from MOSFETs and diodes are shown from table 1

Table 1 shows power loss of MOSFETs and diodes

component	power loss
MOS1	14.6 W
MOS2	17.09 W
MOS3	15.01 W
MOS4	17.57 W
DIODE1	2 W
DIODE2	3.09 W
DIODE3	1.87 W
DIODE4	2.94 W

The total power losses = 74.17 W

The wave forms of solar power converter are depicted in figure 5

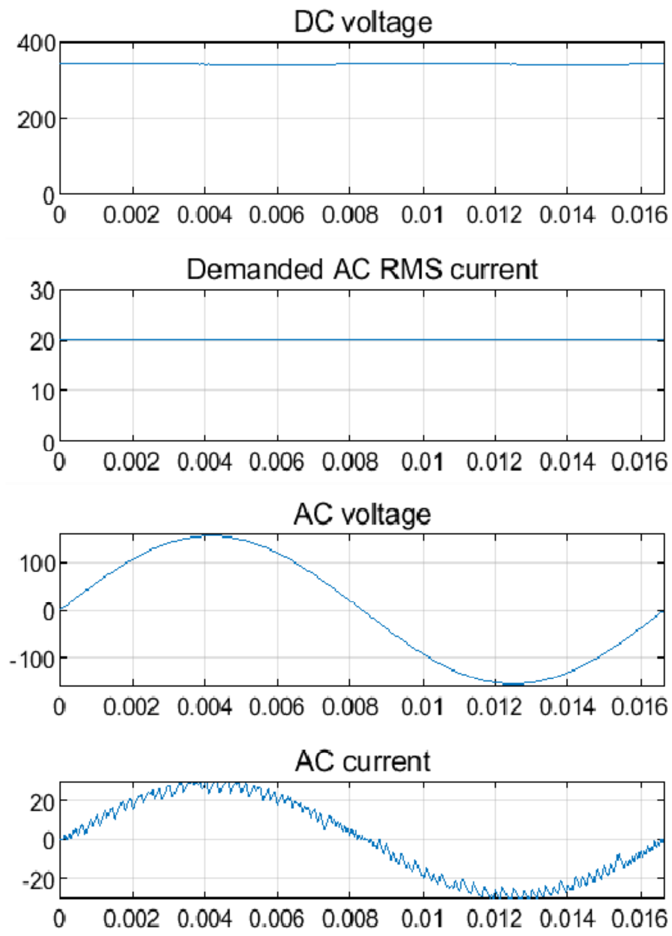

fig.5 The wave forms of solar power transform

From figure 5 the optimal values have been determined as 342V DC and 20.05A AC for an irradiance of 1000W/m^2 and panel temperature of 20 degrees Celsius.

5. The conclusion

This paper concentrated on how to calculate the efficiency and power loss of single stage solar power converter, we got the total efficiency by simulation was 95.61% , compared with calculated efficiency from equation (13) is 96.6% that is acceptable. when we compared the power losses from MOSFETs and diodes of single stage inverter with output power, we found about 74.14 W dissipated from the inverter while 2302 W delivered to the load, that is acceptable.

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