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EVALUATION OF SOLAR ENERGY AND ITS APPLICATION IN LIBYA

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ABSTRACT

This study presents the solar energy used in Libya consists of solar electric (PV) and solar thermal applications. The solar energy of source can contribute in generating renewable electricity these study objectives, so that it potential in Libya and Evaluation of solar Energy application in Libya. The methodology of this study carried out in three stages as follows: The first stage involves a literature review on the status study of the assessment of the Libyan experimental with solar energy and applications in heating and cooling, and electric power generation from solar energy. The second Stage Identification Survey Based on the finding of stage 1, an identification survey will be carried out from the range of selected articles and papers. The selected articles, journals and proceedings papers are now focused on the assessment of the Libyan experimental with solar energy. The literature review covered about 42 selected journals that will be taken into consideration. The third Stage the Data Compilation and Interpretation. The data are compiled and interpreted into four subtopics; all two subtopics are discussed in details and analyzed. So the total energy received on horizontal plan reach up to 7.1 KWh/m^2 per day, the PV system has utility as a strategic source of electrical energy generation in the Southern region of Libya. It is because of the failure which occurred during its performance caused by the increase of its surface temperature during the operation. Libya has a good potential of solar energy which can be used in different applications.

Keywords: solar radiation, Libyan solar experimental, Thermal energy, PV system, Evaluation of solar energy.

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تقييم الطاقة الشمسية وتطبيقاتها في ليبيا

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الملخص:

توضح هذه الدراسة استغلال الطاقة الشمسية في ليبيا وتطبيقاتها والتي تشمل إنتاج الطاقة الكهربائية والتطبيقات الحرارية. تساهم الطاقة الشمسية في توليد الطاقة الكهربائية وبطريقة نظيفة. تهدف الدراسة إلى تقييم مشاريع الطاقة الشمسية المتوفرة في ليبيا وتطبيقاتها، وذلك تبعاً للمنهجية المقسمة إلى ثلاث مراحل كالتالي: المرحلة الأولى تتضمن مراجعة التجارب العملية في الطاقة الشمسية وتقييم تطبيقاتها المتمثلة في التدفئة والتبريد وإنتاج الكهرباء، المرحلة الثانية إجراء مسح شامل لتلك التجارب معتمدين على عدد كبير من الورقات العلمية المنشورة في هذا المجال ولكن تم دراسة 43 ورقة علمية، المرحلة الثالثة تفسير البيانات المجمعة ومن ثم تقسم إلى عناوين جانبية وتناقش كلاً على حدا. أظهرت الدراسة أن ليبيا تمتلك موقع ممتاز ومساحات شاسعة للطاقة الشمسية، بالإضافة إلى الطاقة الشمسية الساقطة على السطح الأفقي تفوق 7.1 KWh/m^2 per day ، حيث نظام إنتاج الطاقة الكهربائية باستخدام الطاقة الشمسية والمعروف (pv) في المنطقة الجنوبية لليبيا بوفرة مقارنة بالمناطق الاخرى ويمكن استخدامها في تطبيقات متعددة.

1. Introduction

Libya is located in the middle of North Africa with 88% of its area considered to be desert areas, the south is located in the Sahara desert where there is a high potential of solar energy which can be used to generate electricity by both solar energy conversions, photovoltaic, and solar thermal.

The solar radiation in Libya considered being very high the direct radiation on the horizontal plan , the total energy received on horizontal plan reach up to 7.1 KWh/m^2 per day, while Figure 1.1 shows a map for Libya indicating the radiation Level. [Mohamed Ekhlat et al 2007]

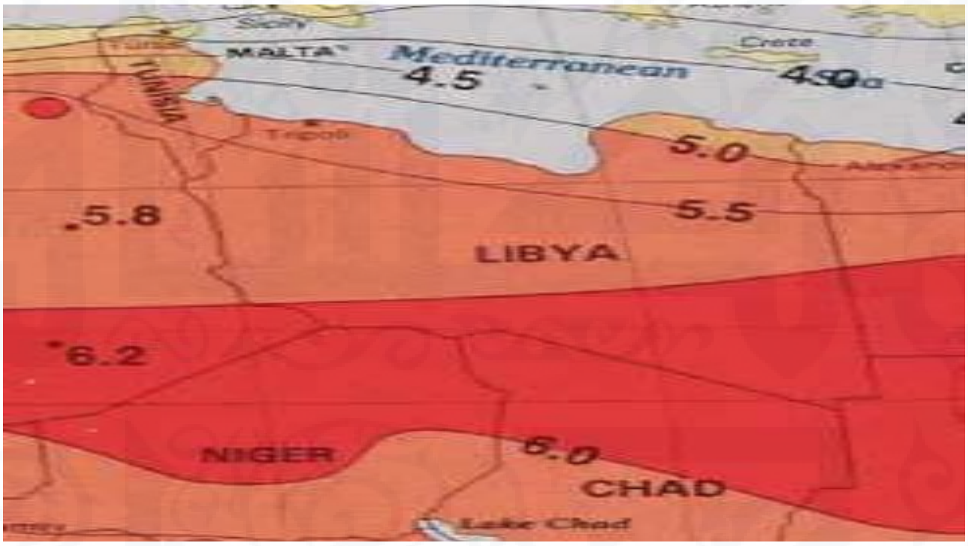

Figure1.1 The average global radiation on the horizontal plane

Source: Mohamed Ekhlat et al 2007

The use PV systems started in 1976, and since then many projects have been erected for different sizes and applications. The first project put into work was a PV system to supply a cathodic protection to protect the oil pipe line connecting Dahra oil field with Sedra Port. Projects in the field of communication was started 1980 where a PV system was used to supply energy to a microwave repeater station near Zella. Projects in the field of water pumping was started 1983 where PV pumping system was used to pump water for irrigation at El-Agailat. The use of PV systems for rural electrification and lighting was started in 2003. Water pumping projects was also erected beginning in 1984. The role of PV application was grown in size and type of application.

The use of domestic solar heater started in 1980 by installing a pilot project of 35 systems, follows by some other projects. There are all together about 6000 solar heaters in Libya. The use of evacuated tubes for solar haters has been started for some hotels and homes and expected to grow up soon. Water heating energy consumption is about 12% of the national electricity production. The use of solar heaters has not spread in all country due to

- No national or personal industry has been established for local individuals.
- Lack of Knowledge for the people.
- Low electric energy tariff.

Prospects of renewable Energy in Libya, that has although renewable energy applications in Libya were started in the middle of the seventies, they have only gained momentum in the last ten years, Highlight renewable energy applications in Libya, the gained experience, the RE resources, and the future prospects for the utilization of RE recourses. There is a good potentiality for PV systems which can be used in different applications. There is a potentiality of renewable (solar & wind) energy which can be used in different applications. A national plan has been adopted to raise the share of renewable energy to 10% by the year 2020. saleh (2006).

Energy Efficiency and Renewable Energy Libya, that has the analysis of the present energy situation in Libya clearly indicates that there are no programs toward rational use of energy. This situation related to many factors summarized as follow:

- Low electricity tariff especially for residential sector.
- Cheap oil prices for transportation.
- Lack of national policy toward the conservation of energy.
- Lack of specialized national institution which deal with the rational use of energy.
- Lack of detailed and deep studies related to the rational use of energy (RUE).

The objective of study , the main issues are focused on Evaluate solar Energy potential in Libya , and up to day, evaluation of solar Energy application and prospects for Libya.

2. Methodology

The methodology of this study is literature review. Theoretically, literature review discusses published information in particular subject area. Sometimes, it is also information in particular subject area within certain time period. A literature review can be just a simple summary of the sources, but it usually has an organizational pattern and combines both summary and synthesis. A summary is a recap of the important information of the source, but a synthesis is a re-organization of that information. It might give a new interpretation of old material or combine new with old interpretation. It also might trace the intellectual progression of the field, including major debates. Depends on the situation, the literature review may evaluate the sources and advice the reader on most relevant. This study will be carried out in three stages as follows:

2.1 Stage 1: Literature reviews

This stage involves a literature review on the status study of the assessment of the Libyan experimental with solar energy covered applications of solar energy in heating and cooling and electric power generation from solar energy. The study covered about 43 papers which are related in this field.

2.2 Stage 2: Identification Survey

Based on the finding of stage 1, an identification survey will be carried out from the range of selected articles and papers. The selected articles, journals and proceedings papers are now focused on the assessment of the Libyan experimental with solar energy. The literature review covered about 42 selected journals that will be taken into consideration.

2.3 Stage 3: Data Compilation and Interpretation

For this stage, data are compiled and interpreted into two subtopics. All two subtopics are discussed in details and will be analyzed. Graphs and Tables were provided for some subtopics in order to provide a clear understanding about the topic respectively.

3. LITERATURE REVIEW

Many projects have indicated that the country's energy demand generation could be significant reduced if improved energy utilization efficiency by the major energy sectors is achieved. Krema et al (2007).

3.1 Solar Radiation

Estimation of Global and Diffuse Radiation at Tripoli, Different correlations were used to predict monthly average global and diffuse radiation on a horizontal surface at Tripoli. It was found that the best to predict the global and the diffuse radiation respectively. Wherever, seven global models were used to estimate the monthly average global radiation on a horizontal surface. The most accurate; however the Both models arc characterize by a simple form which is linear in percent possible sunshine, and thus it is optional to use either of these two models to estimate the monthly average global radiation. Eight models were employed to estimate the monthly average diffuse radiation; all of these models use global radiation as a necessary input parameter. Some of these models use the monthly average clearness index as an input (type one), others use percent possible sunshine (type two), and only one model uses the combination of the two (type three), similarly the above statistical tests were used as a discriminating tool to differentiate between the accuracy of these models. It was found that type one models performed very well. Erbs and Klein model is the best among this group and is recommended to be used to predict the diffuse radiation for the city of Tripoli. The Lin-Jordan comes next in accuracy. R.Said et al (1998).

Monthly Average Daily Insolation on Tilted Collectors in Libya, that can be Insolation values show that the optimum value of tilt angle for space heating system is about latitude plus 150 while that for cooling system is (0^0)A combination of horizontal roof and vertical south wall gives more or less uniform Insolation throughout the whole year. The maximum annul Insolation occurs for tilt angle nearly equal to the latitude. Moustafa Mawas and Tariq Muneer (1980).

Global Solar Radiation Climate of Libya, which has the general features of global solar radiation measured by 15 meteorological stations spread over Libya during the 5-yr period, 1981-1986. That can be classified into two broad divisions, coastal and desert, with two sub-divisions in each of the divisions. Station independent correlation parameters for these regions are calculated. Ahmed and Taher Abuain (1992).

3.2 Solar Thermal

A major benefit of solar thermal power is that it has little adverse environmental impact, with none of the polluting emissions or safety concerns associated with conventional generation technologies. There is hardly any pollution in the form of exhaust fumes or noise during operation. Decommissioning a system is not problematic. Each square metre of reflector surface in a solar field is enough to avoid the annual production of 150 to 250 kilograms (kg) of carbon dioxide. Solar thermal power can therefore make a substantial contribution towards international commitments to reduce the steady increase in the level of greenhouse gases and their contribution to climate change. We will divide the solar thermal to three sections.

3.2.1 Cooling

Passive Heating and Cooling Strategies for Libya that can provide indoor thermal comfort in the northern and southern regions of Libya respectively almost for the whole year, Active solar or conventional heating in the north and solar or conventional cooling the south will hardly be needed if suitable passive strategies are implemented. Ahmad et al. (1984).

An investigation into thermal comfort in the summer season of Ghadames in Libya, that has results from a field survey of thermal comfort within two types of buildings; old (traditional) and new (contemporary) in Ghadames oasis in Libya. The survey was under taken in the summer seasons 1997 and 1998 that people have an overall impression of higher standard of thermal comfort in old buildings than in new buildings. The ISO 7730 standard can be used to measure human thermal comfort in new air-conditioned buildings without modifications. Ghadames in the summer seasons that they are more satisfied and thermally neutral in old naturally ventilated buildings than in new air-conditioned buildings. Thermal comfort has been defined by ASHRAE as ``that condition of mind which expresses satisfaction with the thermal environment" and as such will be incensed by personal differences in mood, culture and other individual, organisational and social factors. Thus thermal discomfort within building environments is a prevalent and significant issue throughout the developed and developing countries. The thermal comfort standards prescribed by ISO 7730 are the first that have been used on a world-wide basis. Ealiwa et al (2001).

Solar Operated Absorption Air-Conditioner for a kufra House, that can be the cooling of prototype house in kufra city, measured the radiation and ambient data that three different types of collectors with varying efficiencies are considered. These collectors are of the evacuated tub, elective coated and black painted types. The cost difference between selective and black painted collectors is small but between evacuated tub and selective collectors is high. The thermal analysis of the absorption system showed that a cooling tower of 38 KW capacities will be needed to offset absorber and condenser loads. The feasibility of solar cooling of residences in arid regions of Jamahiriya is proved and its application is strongly recommended. Uppal and Muneer (1984).

Assessment of Ground Thermal Capacity for Space Cooling in Libya, that has identify a number of passive techniques for space cooling using the thermal capacity of the ground in traditional buildings. That the cooling potential of floor varies from o.2 MJ/m2 –day in the region near the Mediterranean coast to 0.6 MJ/m2 –day in the southern region of Libya. Ahmed et al.(1995).

Thermal comfort investigation in Libya, that has a good agreement with those found in the literature particularly the one found by Humphreys. For buildings equipped with heating and air conditioning systems, a variable indoor temperature has to be taken according to the comfort temperature calculated. This is in agreement with the common way people used to run their heating or cooling systems. Akair and Banhidi (2007).

UTES Potential for Space heating and cooling in Libya, that has A successful transfer of UTES know-how would lead to the implementation of UTES in North Africa. This would have a great economic and environmental impact on these countries. Underground Thermal Energy Storage (UTES) is a technology where local companies and labor would be engaged in design, development, and construction. Natural cooling and heating system with very low operation cost and also active seasonal storage of thermal energy would release economic resources to other important areas. Grein et al (2006).

3.2.2 Heating

Year Round Performance of Thermosyphon Solar Water Heater in Benghazi, that the change of the temperatures in year that the yearly maximum water temperatures reached was 66^0 C which occurred in the month of August. The yearly minimum temperature was 23^0 C which occurred in the month of February. The fluctuation in day-end temperature was considerable in the winter months, from a low of 23^0C to a high of 51^0 C. The corresponding fluctuations in the summer months are less intense, from 50^0 C to 60^0 C. The overall thermal efficiency of heater varies between 40 and 50 %. Hawas and Muneer (1994).

Passive Heating and Cooling Strategies for Libya, that can provide indoor thermal comfort in the northern and southern regions of Libya respectively almost for the whole year. Active solar or conventional heating in the north and solar or conventional cooling the south will hardly be needed if suitable passive strategies are implemented. Ahmad et al. (1985).

The Economics of Solar Thermal Electricity for Europe, North Africa, and the Middle East, which solar thermal or concentrating solar power (CSP), a commercially available technology that uses direct sunlight and mirrors to boil water and drive conventional steam turbines. Solar thermal power production in North Africa and the Middle East could provide enough power to Europe to meet the needs of 35 million people by 2020. might have political implications that would extend project lead times considerably. Since it is costly to step down high-voltage direct current, the proposed lines need to run uninterrupted to the terminal point before distribution can begin. Overall, large-scale deployment of CSP in the MENA region is clearly attainable at levels of public subsidy that are modest, given the planetary stakes. The question is not whether CSP is feasible, but whether programs like the MENA initiative will be operational in time to prevent catastrophic climate change. For such programs to spur the clean energy revolution, efforts to arrange financing should begin right away. Wheeler and Kevin (2008).

Evaluation of the underground soil thermal storage properties in Libya, The aim of the experiment is to monitor the temperature variation of the underground soil under a depth of 4 m and around the year, in order to know the thermal capacity ability of the soil to be used as a seasonal thermal storage. The thermal properties were presented as a function of the ground depth; furthermore, that was measured temperatures of the two systems for Tripoli underground soil. Theoretically, solution of the general heat balance equation may be formulated, for unsteady state conditions tedious as a result of difficulty in setting the initial conditions. the initial temperatures of the soil layers must be supposed. Nassar et al (2006).

3.3 Solar Electric

The reliability of the photovoltaic utilization in southern cities of Libya, that can be say the Solar energy can be converted to electrical energy by means of two methods: the first one is a direct method with photovoltaic (PV) systems and the second is an indirect one by solar thermal power generation. The main disadvantage of the PV systems is the high sensitivity of the output electrical characteristics to their temperature surface. The increase of the surface temperature leads to reduce the power output according to its power temperature coefficient, the evaluate electrical behaviour of PV systems and to estimate the failure of their function. The experiment has been carried out in order to measure the following parameters: output power, surface temperature, solar radiation, ambient temperature and wind speed. Brack City is located at 27.6°N and 14.2°E, 600 km away to the south from Tripoli (Capital). Most of the Arabic countries are located in warm or hot zones; therefore, these zones are indicated by most of scientific works as the most favourable areas for thermodynamics solar power generation plants. the thermal electrical solar power can be generated in the scale of several hundreds of Megawatts the disadvantage of the PV system's utility as a strategic source of electrical energy generation, in Southern region of Libya. It is because of the failure which occurred during its performance caused by the increase of its surface temperature during the operation. The utilization of PV systems can be restricted on mini and micro PV systems (e.g. watches, calculators), small PV island systems (e.g. solar home systems), large PV island systems (e.g. village power supply), and small PV grid-connected systems. Nassar & Salem (2007).

Photovoltaic in Libya Applications and Evaluation, that can be say a good potential of PV systems which can be used in different applications. Photovoltaic systems for supplying electrical energy to remote areas are justified based on economic and technical reasons. Social changes have been noticed in the villages which have been electrified. Saleh et al (2005).

Photovoltaic Power Plant for the Southern Region of Libya, wherever the compares, a photovoltaic (PV) power plant of the same capacity (100MWe), as a clean and inexhaustible alternative. Solar irradiance in the region of 2300K Wh/m: annually, and sunshine duration is 3500 h/year. Libya has limited fossil fuel resources, used for electricity generation and for export, as a major source of national income. However, it also has an inexhaustible reservoir of solar radiation incident on the huge Sahara desert. Instead of installing gas turbine power plant in the middle of this desert near Sebha, the construction of a photovoltaic power plant in the same region, where the land is suitable and the solar irradiance is high. Technical analyses show that the construction of a PV plant will introduce new technologies, create more jobs, reduce pollution and promote even more investment in solar energy. Most of the required components can be designed and constructed by local companies. On the bases of the rival plants' lifetime of 20 years, the PV plant is more economic, due mainly to requiring no fuel and having low operating and maintenance costs. It is obvious that it is the best option available to the country when looking to the future. Eljrushi and Zubia (1995).

Regional cooperation in water-electricity co-generation Part2, Middle East and North African countries suffer from a large shortage of fresh water, that the available annual average fresh water is less than 150 L/d/capita, which less than 52 and 7% of Middle East and North African countries, and the average world resources per capita respectively. According to preliminary environmental and economic studies, advanced inherent safe nuclear power plants adapted for water-electricity cogeneration could satisfy the required demands. that an advanced inherent safe nuclear reactor of medium or large size is suitable and can satisfy the water-electricity demand up to the year 2025. The economical assessment of the proposed nuclear power plant for water-electricity cogeneration has been carried out. This assessment indicates that the proposed station is feasible and competent with the conventional desalination methods. As indicated in the Table 3.2, these demands declare that an advanced inherent safe nuclear reactor adopted for water electricity cogeneration, can cope with these demands up to the year 2025. Mohamed Shamloul (2002).

Table 3.1 Population forecast for Matrouh-Barka Site (thousands)

Site	Year					
	2000	2005	2010	2015	2020	2025
Matrouh	230	255	283	313	347	385
Barka						
Tobruk	176	210	248	286	324	356
Derna	197	235	277	319	362	398
El-Bayda	226	269	318	367	418	457
Total	599	714	843	972	1102	1211
Total Matrouh–Barka	829	969	969	1285	1449	1596

Source: Mohamed M. Shamloul 2002

Comparative study in supplying electrical energy to small remote loads in .that can be say the main sources of energy that might be available in remote low populated areas Libya are either diesel generating units or wind mills for water pumping , the economic and technical advantages of the PV generation of the required energy in such remote area. The transmission of small amount of electrical energy to such remote areas is not economically justified. The usage of diesel generators is slightly expensive than the PV generation, but adding to it the pollution effect on the surroundings will dictate the usage of PV generation. In addition, the reliability of PV generating systems is high compared with the diesel generation and it is maintenance free. Mous et al (1998).

4. Results and discussions

Libya has excellent location and has a vast wealth of Renewable energy in addition to its oil and gas. It is characterized by the highest brightness of the sun on the region. Solar energy transports from the sun to the earth in the form of electromagnetic radiation but in a different scale. On a clear day, the usual amount of solar radiation available on the surface of the Earth in the direction of the sun is 1000 watts per square meter. At any time, the solar energy potential is primarily dependent on how high the sun in the sky and the current status of clouds. There are several ways to use solar energy effectively. These ways can be classified into three main categories, namely thermal applications, the production of electricity and chemical processes. Also solar energy applications are widely used in the field of water heating. There is a growing generation of electricity using photovoltaic systems and solar thermal technologies. The potential of solar energy resources are excellent in the countries of the Middle East and North Africa, where the annual solar radiation varies.

Between 4 and 8 kW/hour per square meter, the region also enjoys a high level of direct solar radiation and a decrease in the rate of presence of clouds.

Libya with it is vast area and geographical location 20-33 N, 10-25E, has an average global radiation of 7-7.8 kW/hm2/day for the summer months and 2-7 kW/hm2/day for the rest of the year. Libya extends over 1,759,540 square kilometers (679,362m2), making it the 17th largest nation in the world by size, it is somewhat smaller than Indonesia, and roughly the size of the US state of Alaska. It is bound to the north by the Mediterranean Sea, the west by Tunisia and Algeria, the southwest by Niger, the south by Chad and Sudan and to the east by Egypt. At 1,770 kilometres (1,100 mi), Libya's coastline is the longest of any African country bordering the Mediterranean. The portion of the Mediterranean Sea north of Libya is often called the Libyan Sea. The climate is mostly dry and desert like in nature. However, the northern regions enjoy a milder Mediterranean climate.

The future is promising for the production of electricity from concentrated solar thermal power (CSP) and photovoltaic systems (PV) because the incident solar radiation throughout the region is higher than the minimum rate required. Although the use of concentrated solar thermal energy at possible lower rates is assumed to be 1800 kilowatt / hour per square meter of brightness normal direct (DNI). In an occasion to determine the technical feasibility of the overall energy, and considering the economic potential within the limits of direct brightness of 2000 kW / hour per square meter per year, this is an appropriate level to make the costs of solar power in the medium term compared with conventional sources of energy and other renewable sources of generation of electricity. Statistics show that all countries of the Middle East and North Africa are eligible for this technology, as the rates exceed 1800 kWh per square meter per year.

4.1 Solar Electric (Photovoltaic systems)

Photovoltaic is best known as a method for generating electric power by using solar cells to convert energy from the sun into electricity. The photovoltaic effect refers to photons of light knocking electrons into a higher state of energy to create electricity. The term photovoltaic denotes the unbiased operating mode of a photodiode in which current through the device is entirely due to the transduced light energy. Virtually all photovoltaic devices are some type of photodiode. Solar cells produce direct current electricity from light, which can be used to power equipment or to recharge a battery. The first practical application of photovoltaic was to power orbiting satellites and other spacecraft, but today the majority of photovoltaic modules are used for grid connected power generation. In this case an inverter is required to convert the DC to AC. There is a smaller market for off-grid power for remote dwellings, boats, recreational vehicles, electric cars, roadside emergency telephones, remote sensing, and cathodic protection of pipelines, and many electric energy generation options. The main options for electric energy production for the most sits in Libya are:

- Electric grid.
- Diesel generation.
- Photovoltaic (PV) generation plus diesel generation.
- Photovoltaic (PV) generation.
- Wind mills.

We will discuss PV generation due to its importance to the Renewable energy in Libya, Two options were considered to generate the required amount of energy using the direct conversion of solar energy, mainly the central and distributed sources. The central way of energy production was not considered at first due to the geographical nature of the site. To get a best energy supply a distribution network was used considering the problems arising with any fault in the network, the reduced storage capacity and/or other load problems. However, load of public buildings located near to each other was considered as single load. The D.C. supply system for tents and huts was considered first, and then it was decided to concentrate on the A.C supply system only to be consistent with the available appliances in the local market. Other loads were decided from the beginning to be supplied by A.C. system. PV applications may offer a promising alternative energy supply in remote areas. In many places due to remoteness and cost, it is unlikely that main grid connection will ever be established. However, the need for power still exists. In most cases, storage batteries are included in PV systems due to the fluctuating nature of the climatic conditions. The capital cost of PV generators is high and their performance depends greatly on the radiation, the temperature, and the battery voltage that change during its charge and discharge process.

Because the users require the maximum available output power under any temperature and solar radiation levels, a maximum power point tracking (MPPT) device may be located between the PV array and batteries to optimize the power transfer from the PV array to the batteries. With the development of technology, MPPT devices can be more cost-effective, have a higher reliability and efficiency. This will result in a total PV system that is much more economically viable and, therefore, suitable for a wider application base for remote electrification.

The use of PV systems started in 1976, and since then many projects have been erected for different sizes and applications. The first project put into work was a PV system to supply a cathodic protection to protect the oil pipe line connecting Dahra oil field with Sedra Port. Projects in the field of communication was started 1980 where a PV system was used to supply energy to a microwave repeater station near Zella city. Projects in the field of water pumping were started in 1983 where PV pumping system was used to pump water for irrigation at El-Agailat city. The use of PV systems for rural electrification and lighting was started in 2003. The role of PV application has grown in size and type of application. The PV system is promising source of electricity generation for energy resource saving and CO_2 emission reduction, even if other technologies are applied. Furthermore the development in efficiency of solar cells, amount of material used in the solar cell and the system are designed for maximum use of recycled material that will reduce the energy requirement.

4.1.1 Photovoltaic in Communication electric Networks

The Libyan communication networks consist of more than 500 repeater station, which electricity is covering more than 99% of the population, PV systems are used to supply electricity to about 2000 inhabitants in rural areas. The share of renewable energy technologies in Libya up to now hold only a small contribution in meeting the basic energy needs, it is used to electrify rural areas for sustainable development, supply microwave repeater station, and in cathodic protection. A start-up plan was planned for implementing renewable energy sources to contribute 10% off the electric demand by the year 2020. The experience raised from PV applications indicates that there is a high potential of building a large scale of PV plants in the sought of the Mediterranean. It was the success of the PV systems technically and economically that pushes the changing of all possible diesel stations to PV stations in the Libyan communication networks. Comments that were drawn from the past experience of PV systems are as follows:

- No spare parts had been used for PV systems which are installed 26 years ago.
- No failure has been registered for the systems installed 26 years ago.
- Very low cost or no running cost for most of the PV systems.
- Batteries have been changed after about ten years from installation.
- Lack of knowledge; People in developing countries should be made aware of PV systems through increasing their understanding of this technology.
- The average production energy for systems of 1.2 KWP is 6 KWh/day.
- The AC option of electricity for rural electrification was the best convenience choice.
- The closed type battery option was the best convenience choice.

4.1.2 PV in Cathodic protection

As the price of extending utility power lines has increased significantly, photovoltaic have become the preferred source of power in many applications, including Cathodic Protection. Cathodic Protection (CP) works by impressing a current on a metallic structure that is in contact with the earth, such that the structure is maintained at a negative voltage (usually about -0.85 to -1.1 v_{dc}) with respect to a copper/copper sulphate half-cell in contact with the earth. Cathodic Protection is used to protect pipelines, steel tanks, well casings, highway bridges and even large structures in contact with the earth can be protected with a reasonably sized system. A cathodic protection professional should be contacted to evaluate the application and to specify the ground bed type and dimensions along with the current and voltage requirements. A system should normally be sized for some future growth since protective coatings deteriorate further with age.

Our experience dates back to the late 1976’s when the first systems were being designed and installed. This improves field installation by preventing "ground loops", and also minimizes lightning protection problems. The PV module frames and structures should be grounded, but the PV input cables left ungrounded. Leakage currents and static build-up are handled by the module frame grounds, and a diode drop into the positive terminal of the battery which is grounded. Lightning surge protection is provided by the PV regulators on the input side and the PV controller on the negative output side.

PV powered systems are normally designed for 5 to 10 days of autonomy (sunless days). The batteries are often protected by a low voltage cut off which shuts down the controller before damage to the batteries occurs. The total PV systems in this field are around 320 systems by the end of 2006, with total installed PV systems. PV technology is considered to be a relatively new in developing countries; we are experiencing some vandalism issues, the installation of photovoltaic systems started in the middle of 2003. The total numbers of systems installed by the General Electric Company of Libya (GECOL) are 340 with a total capacity of 220 KWp, while that which was installed by Centre of Solar Energy Studies (CSES) and Saharian Centre has 150 systems one of the systems is a hybrid system with diesel generator to supply a village of 200 inhabitancies. The total peak power is 125 KWp; others involved in using PV has installed 50 PV systems with a total capacity of 60 KWp. In these applications 440 systems have been installed with total peak power of 405 KWp. The experienced advantages of using PV solar generators can be summarized as follows:

- Low running cost.
- High reliability.
- Durability of the system.
- Fewer services visit.
- Low maintenance cost.
- Less number of thefts.
- No communication stops.
- Vandalisms.

4.1.3 PV for Water pumping

Water pumping system has a long history; so many methods have been developed to pump water with a minimum of effort. These have utilized a variety of power sources, namely human energy, animal power, hydraulic power, wind, solar and fossil fuels for small generators. Solar PV water pumping has been implemented around the globe as an alternative electric energy source for remote locations since when solar PV was invented. The solar PV systems are cost effective in many remote applications such as water pumping for households, livestock and wildlife, space heating, lighting remote vacation homes and emergency traffic applications. The PV systems involve the direct conversion of sunlight into electricity with no intervening heat engine. PV devices are solid state; therefore, they are rugged and simple in design and require very little maintenance, water pumping is one of the best PV applications in Libya as remote wells which are used to supply water for human and animals in rural places.

Water pumping was considered as one of the best PV applications in Libya as remote wells which are used to supply water for human and animals in rural places. The water pumping project consists of installing of 40 PV systems with a total estimated peak power for this application is 120 (kilowatt-peak) KWp. Figure 4.17 Shows PV Water Pumping Beer Tssawa.

Figure 4.17 PV Water Pumping Beer Tssawa
Source: Mohamed Ekhlat et al 2007

4.2 Thermal comfort investigation in Libya (cooling and heating)

The last twenty years have witnessed significant advances in the field of thermal comfort that build on the foundations laid by the preceding century. The PMV-model that was derived in the 1960s is still prescribed by thermal comfort standards as the most important method to evaluate thermal comfort. The greatest advantage of the deterministic PMV-model is its wide application range. The emergence of models of adaptive thermal comfort stems from research in 1990s and the first decade of the 21st century. Such models are on the threshold of widespread application. The current application range is still subject to debate, which leads to the risk of use beyond the application thresholds. The adaptive models pose advantages in terms of practical application and interpretation of results, and deal with human responses and adaptation in naturally ventilated settings. Personal control of the indoor climate and human performance has become important directions of study and practice.

Unfortunately it is very rare that people have actual control over their environment, given that the whole issue of establishing objective criteria for comfort stems right from the extreme variability that human beings display when it comes to establishing thermal comfort. If each and every one of us could freely adjust the air temperature and velocity, and/or his/her activity level or clothing there would be ‘no’ discomfort to begin with. The more control an individual has over the comfort-related parameters (both physical and behavioural); the more relaxation can be tolerated in standards. So it is not so much a matter of naturally versus artificially controlled environments but flexibility versus rigidity whether occupants are comfortable and satisfied.

The computerization of society has led to the emergence of sophisticated multi-segmental models of human physiology and computational fluid dynamics that can be used for improved thermal comfort predictions for laboratory purposes and the design of buildings. A great challenge to the use of thermo physiological models is to link the outcomes to the perception of thermal comfort. Whereas current thermal comfort standards mainly address low-resolution problems in office building, increased computational capacities will help solve high-resolution thermal comfort issues in both real-life and laboratory settings.

A thermal comfort field survey has been conducted in three towns from two climatic zones in Libya. Two hundred people were involved in this survey. They have been asked in their houses and working places under their normal living conditions once each month during 1 year. The selected sample of buildings has been chosen among free running buildings. Only few office buildings were equipped with heating systems but not with air conditioning systems.

5. CONCLUSION

This Study clearly reveals that evaluation of solar energy of Libya, in some of these local situations, however, the currently exploited solar energy resources. The use of solar energy resource should be promoted as they can contribute to.

Building standards have been based on fixed comfort temperatures found from tests held in climatic chambers. Those standards assume that the indoor temperature is fixed to a set value and controlled by heating and air conditioning systems. In Libya and all North African countries, the heating and air conditioning systems, in case they exist, are not used continuously. Thus, the indoor temperature is fluctuating. The thermal sensation of the building occupants is the only controller of the ventilation, the heating or the cooling of the building. Unlike the conventional thermal regulations, which are based on energy consumption, the special feature of the future Libyan thermal regulation is related to the fact that it must ensure a minimum level of thermal comfort when the building is free running without any heating or cooling system.

The use of a stand-alone PV power supply in the field of communications, cathodic protection, rural electrification, and water pumping was established, and a very high reliability was recorded. No or very low running cost of PV solar energy made it more and more acceptable from economic point of view, beside technical and power availability in comparison with diesel generators.

PV power supply systems for supplying electrical energy to remote and isolated areas are justified based on economic and technical reasons. It is also recommended to add more PV systems to feed all inhabitants that suffer from shortage or lack of electrical supply. Some kind of industry for the production and manufacturing of solar cells and other PV system components should start to cover the expected increase of PV systems applications. Future evaluation should take place to verify the previously estimated parameters. Finally, it can be concluded as the following:

- There is a good potential of PV systems which can be used in different applications.
- Photovoltaic systems for supplying electrical energy to remote areas are justified based on economic and technical reasons, and
- Social changes have been noticed in the villages which have been electrified.

The disadvantage of the PV system’s utility as a strategic source of electrical energy generation, in the Southern region of Libya. It is because of the failure which occurred during its performance caused by the increase of its surface temperature during the operation.

6. References

Ahmad, I., E. Khetrish, & S. M Abughres. 1985. Assessment of ground thermal capacity for space cooling in Libya *Energy* 10 (9):993-998.

Ahmad, I. , A. Mokadmy, & S. M Abughres. 1985. Passive heating and cooling strategies for Libya *Solar & Wind Technology* 2 (1):1-8.

Ahmed, S., & T. Abuain. 1992. Global solar radiation climate of Libya. *Energy conversion and management* 33 (2):117-123.

Akair, A., & L. Bánhidi. 2007. Thermal comfort investigation in Libya. *Mechanical Engineering* 51 (1):45-51.

Alawaji, Saleh H. 2001. Evaluation of solar energy research and its applications in Saudi Arabia - 20 years of experience. *Renewable and Sustainable Energy Reviews* 5:59–77.

Al-Jadi, Imsi, M. A. Ekhlat, & N. M. Krema. 2006. Photovoltaic in Libya applications, and evaluation. In *International conference on renewable energy for developing countries*. Washington D.C. USA, 5-7/4/2006.

Al-Karaghouli, Basel Al-Yousfi & Ali. January 28-February 01, 2007. the assessment of renewable energy sources in the Arab States confirms *International Conference on Energy and Environment*.

Cabawe, salem issa. 14-17 Nov1983. Solar energy research activities and training programs in Libya. *report*.

Ealiwa, M. A., A. H. Taki, A. T. Howarth, & M. R. Seden. 2001. An investigation into thermal comfort in the summer season of Ghadames, Libya. *Building and Environment* 36 (2):231-237.

Elhares, H., & M. Aswed. 1977. Practical behaviour of electrodialysis and reverse osmosis plants in Libya *Desalination* 22 (1-3):291-298.

Eljrushi, G. S. & J. N. Zubia. 1995. Photovoltaic power plant for the southern region of Libya. *Applied Energy* 52 (2-3):219-227.

Grein, M., B. Nordell, & A. Al Mathnani. 2007. Energy consumption and future potential of renewable energy in North Africa. *Gas* 64:249-254.

Grein, M., B. Nordell, & A. M. Almathnani. 2006. . UTES Potential for Space Heating and Cooling in Libya. In *The Tenth International Conference on Thermal Energy Storage*. May 31 – June 2, 2006.

Hawas, H. H., & T Muneer. 1984. Year round performance of thermosyphon solar water heater in Benghazi. *Energy* 24 (3):237-242.

Holm, Hani El Nokrashy &. 2003. Renwable Energy Mix for Egypt. *International Conference on Energy and Environment*.

Hunter, Peter Meisen and Lesley. 2007. Renewable Energy Potential of the Middle East, North Africa vs. the Nuclear Development Option.1-32.

I. M. Saleh Ibrahim Al-Jadi, M. A. EKhlat & N. M. Krema. 2005. Photovoltaic In Libya Applications, And Evaluation. *International Conference on Renewable Energy*.

kolb, Gregory. 1996. Several hybrid and solar-only configurations for molten-salt power towers were evaluated with a simple economic model. *Solar energy*.

Kolb, Gregory J. January 1998. Economic evaluation of solar-only and hybrid power towers using molten-salt technology. *Solar Energy* 62 (1):51-61.

Kreama, Mohamed Ekhlat & Ibrahim M. Salah & Nurredin M. September 2007. Energy Efficiency and Renewable Energy Libya.1-45.

Wheeler, Kevin Ummel & David. 2008. The Economics of Solar Thermal Electricity for Europe, North Africa, and the Middle East. *Renewable Energy*.

Mason.M. 2009. Clean Power from the Deserts; The Prospects for a Renewable Energy Transition for the Middle East and North Africa: GCREEDER 2009.

Mousa, M. A., I. M. Saleh Ibrahim, & I. M. Molokhia. 1998. Comparative study in supplying electrical energy to small remote loads in Libya. *Renewable energy* 14 (1-4):135-140.

Moustafa, M. H. & M. Tariq. 1980. Monthly average daily insolation on tilted collectors in Libya *Energy Conversion and Management* 20:213-218.

Nassar, Y., A. ElNoaman, A. Abutaima, S. Yousif, & A. Salem. 2006. Evaluation of the underground soil thermal storage properties in Libya. *Renewable energy* 31 (5):593-598.

Nassar, Y. F. & A. A. Salem. 2007. The reliability of the photovoltaic utilization in southern cities of Libya. *Desalination* 209 (1-3):86-90.

R. Chedid, N. Ghaddar, F. Chaaban, M. Fadel, T. Mezher, & F. Moukalled. 2005. A Sub-Regional Outlook of Renewable Energy Potential: The Case of Jordan, Syria and Lebanon. *Renewable Energy*.

S. A. M. Said, I. M. El-Amin & A.M. Al-Shehri. 2002. Renewable Energy Potentials in Saudi Arabia. *Renewable Energy*.

Said, R., M. Mansor, & T. Abuain. 1998. Estimation of global and diffuse radiation at Tripoli. *Renewable energy* 14 (1-4):221-227.

Saleh, I. M. 2006. Prospects of Renewable Energy in Libya. Paper read at International Symposium on Solar Physics and Solar Eclipses (SPSE)

Shamloul, M. M. 2002. Regional cooperation in water-electricity co-generation Part 2. Egypt and Socialist People's Libyan Arab Jamahiriyah. *Desalination* 153 (1-3):321-327.

Uppal, A.H. & T Muneer. 1984. Solar operated absorption air-conditioner for a Kufra house *Applied Energy* 16:259-281.

Zubia, Gibril S. Eljrushi & J. N. 1995. Photovoltaic Power Plant for the Southern Region of Libya. *Applied Energy* 52:219-227.