The Choice of Solar Energy in the Field of Electrical Generation - Photovoltaic or Solar Thermal - For Arabic Region

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Abstract
Many countries utilize solar energy to generate electrical power directly by means of photovoltaic cell (PV). In the same time, many of them considered the concentrating solar thermal technique as a source of heat to operate the power generation units. These are the two types of solar power generation. This paper will answer the question, which is the appropriate one for our climate condition?
The paper will give the answer during a comparison between the two technologies, providing a short description of how and where they are working, areas of operation and cost – considerations, availing from the other international experiences.

1. Introduction

All over the world, electricity remains to be a vital component of national development. Electrical energy is easy to transport and convert to other forms of energy, and available at the flick of a switch, it has kept its place as the main source of energy in commercial and residential applications and in many industrial and transportation applications. It accounts for about 40% of the total global energy consumption, and is considered to be a good indicator of economic progress.
There are increasing challenges facing people throughout the world to secure a reliable, safe and sustainable energy supply to meet their needs. In developing countries, the demand for commercial energy is growing quickly. These countries are faced with substantial financial, environmental and energy security problems. In both developed and less developed countries pressure is growing to find workable alternatives to traditional energy supplies and to improve the efficiency of energy use in an attempt to limit emissions of gases that cause environmental damage locally and globally. Developments around the world, however, may soon produce the most dramatic changes in the world energy economy in a century. The implementation of renewable energy systems, make a major contribution to finding solutions to these challenges through stimulating the early implementation of economically viable sustainable energy technologies.

2. Principles

The sun presents the main and safe source of energy on the earth. As we know the energy produced by fossil fuels causes environmental pollution and contamination, furthermore, the risk of there depletion in the near future. Electrical energy - due to there characteristics - is the most favorable, and it is easy to convey and convert it to other forms of energy. The electrical power can be extracted from solar energy directly with PV cells and indirectly by means of solar thermal generation. Solar thermal and PV electricity generation are two promising technologies for climate compatible power, witch have such an enormous potential, that theoretically they could cover much more than just the present worldwide demand for electricity consumption. Both technologies provide an important contribution to climate protection.

2.1. Photovoltaic

Semiconductor materials such as silicon are used in photovoltaic solar cells. In the cells incoming photons separate positive and negative charge carriers. This phenomenon produces an electrical voltage and the electrical current can drive a load. Since solar cells are modular, they can be assembled in units of any size. An inverter converts DC voltage to AC and feeds the solar power into the grid.

2.2. Solar Thermal Power Plants

About one percent of the surface of the Sahara desert would be sufficient to supply the entire worldwide electricity demand from solar thermal power plants. For that reason, many people hope solar thermal power will be implanted in sun-belt countries. In contrast to photovoltaic plants, solar thermal power plants are not based on the photo effect, but generate electricity from the heat produced by sunlight.

Of the various types of solar thermal power plants, parabolic trough, solar power tower plants and solar chimney, are described in more detail below.

Thermal power cycles can be classified as low, medium and high temperature cycles. Low temperature cycles working at maximum temperatures of about 100^{o}C. The working fluids normally used are organic fluids like methyl chloride and toluene, and refrigerants like R11, R113 and R114 [1]. Plants of this type of French design, having generation capacities up to 50 kW were installed in many parts of the world, particularly in Africa, in the seventies.

Among solar thermal electric power plants, those operating on medium temperature cycles and using the line focusing parabolic concentrators (trough), at a temperature of about 400^{o}C have proved to be better cost effective and successful operation behavior. The first commercial parabolic trough power plant was built in the Mojave Desert in California in the year 1984. By 1991, nine trough power plants with a total capacity of 354 MWe, which feed about 800 million kWh per year into the grid, had been erected on more than 7 km^2. Eight of them can also be driven with fossil fuel to produce electricity during bad weather or at night [2]. A large number of the plant components were produced in Europe. The levelized cost of solar electricity was reduced from 0.27 USD per kWh in the first power plant to about 0.12 to 0.14 USD per kWh in the last installed system [3]. These solar thermal power plants using the concentrated solar radiation to heat synthetic oil circulating in the absorber pipes of solar collectors. In a heat-exchanger, the circulating synthetic oil transfers the thermal energy to the feed water of a Rankin cycle.

High temperature systems using either paraboloidal dish concentrators or central receivers located at the top of towers. In the paraboloidal dish concept, the concentrator tracks the sun by rotating about two axes and the sun’s rays are brought to the point focus. A fluid flowing through a receiver at the focus is heated and this heat is used to drive a prime mover. Typically, Stirling engines having efficiencies up to 30% and generating power in the range of 8 to 50kW have been developed.

In central receiver power plants, the concept is simple**:** A few thousand heliostats (mirrors that continuously tracking the sun) concentrating the sunlight onto a central receiver (a high-technology heat exchanger) that sits a top of a tower. The central receiver heats molten salt at 290°C (in some cases water or air), pumped from a “cold” storage tank, to 565°C, where it flows to a “hot” tank for storage. When the grid load dispatcher decides electricity is needed from the plant, hot salt is pumped to a steam generating system that produces superheated steam for a turbine/generator. The salt then is returned to the cold tank, where it is stored and eventually reheated in the receiver to complete the Rankin power cycle [3].

Recently the concept of a solar chimney power plant has been suggested. The solar chimney was originally proposed by Professor J. Schlaich of Stuttgart in 1968. In such plant, a tall central chimney is surrounded at its base by a circular greenhouse consists of a transparent cover supported few meters above the ground by a metal frame. Sunlight passing through the transparent cover causes the air trapped in the green house to heat up. A convection system is set up, in which, air is drawn up through the central chimney, turns a turbine located near the base of the chimney. The hot air is continuously replenished by fresh air drawn in at the periphery of the green house. A 50 kW experimental plant was built in 1981 in Manzanares – Spain, which produced electricity for eight years, thus proving the feasibility and reliability of this novel technology. The chimney tower was 194.6 m high and the collectors had a radius of 122 m. It produced an upwind velocity of 15 m/s under no load conditions. Operating costs of this chimney were found around $0.01 \div 0.02\ \$/kWh$ [4].

3. Performance and economical analyses of solar power systems

Indeed, many scientific studies referred to that, most of the Arabic countries located in area favorable for thermal applications of solar energy such as thermal power generation, as it illustrates in figure 1 [5].

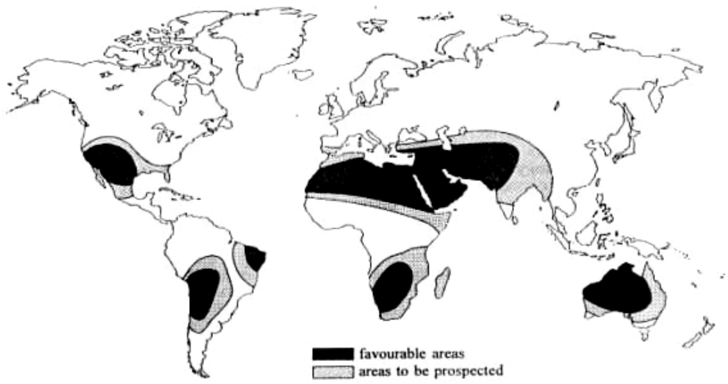
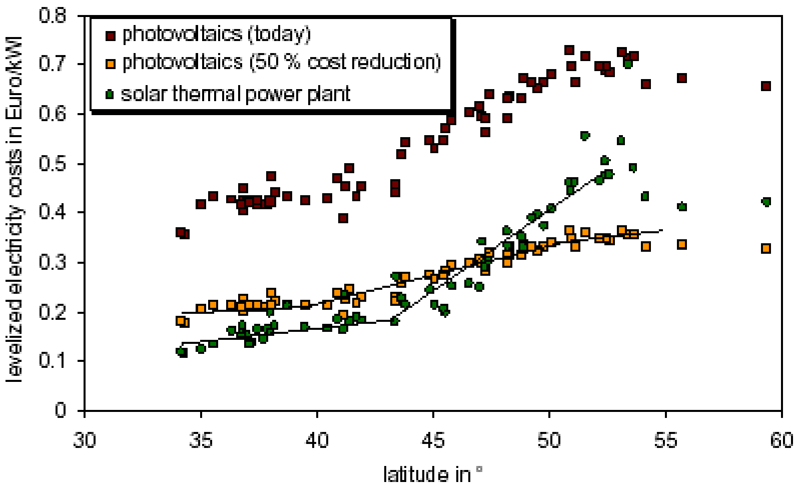


Figure 1: the distribution of thermal solar application around the world

In most of the Arabic countries, the power demand peaks after sunset and into the night, so the alternative must be able to efficiently store solar energy during the sunshine hours. Only solar power tower technology can operate around the clock and only solar energy alternative that cost-effectively includes storage, a prerequisite to the long-term viability of utility-scale solar electricity. Other solar technologies (like photovoltaic) do not have cost-effective energy storage and, thus, only produce electricity during daytime periods.

Figure 2 presents the resulting levelized electricity costs for both technologies. Since market introduction of photovoltaic systems is much more aggressive than that of solar thermal power plants, cost reduction can be expected to be faster for photovoltaic systems. But even if there is a 50% cost reduction in photovoltaic systems and no cost reduction at all in solar thermal power plants, electricity production with solar thermal power plants in southern Europe and North Africa remains more cost-effective than with photovoltaic systems. Therefore, there are areas in which one or the other of the two technologies should be preferred for technical and economic reasons [7].

Figure 2: levelized electricity costs comparison between solar thermal power plants and photovoltaic systems



Furthermore, the majority of the thermal solar power plant-unique hardware (heliostats, receiver, storage tanks, reflectors, etc…) can be built in the target place with regional labors. Solar photovoltaics have not this facility, because this technology suffers from high cell costs and high energy storage costs. Besides special-purpose facilities must be built to manufacture the solar cells.

4. International and Regional Experiences in the exploitation and research in the solar power systems

The power tower technology has been successfully demonstrated for the Middle-East region. During the same period, the World Bank began providing grants in several countries (such as Mexico, Morocco, Egypt, and India) to adopt new solar technologies (like power towers) to reduce CO_2 emissions and meet their power demands. The technical and economical feasibility of an Integrated Solar Combined Cycle System (ISCCS) for hybrid fossil/solar power generation in Egypt was assessed by Authorities of the Egyptian Power Sector and their Consultants. Two technical options for the solar field were analyzed: parabolic trough collectors and power tower with heliostat fields for 90 MWth and 80 MWth, respectively, as shown in figure 8. The total rated gross capacity of the ISCCS is 127 MWe. At capacity factors of about 80 % the annual solar share of the electricity generation by the ISCCS will be 8 to 9 %. Annual CO_2-avoidance will be about 25,000 tons. The predicted solar incremental cost for the project is within the limits set by World Bank for a grant from the Global Environment Facility (GEF) for such projects. The levelized electricity cost of the ISCCS is approximately 3 US cents/kWh. Thus the project is technically and economically feasible. The site selected is located about 100 km south of Cairo on the right shore of the river Nile near the village Kuraymat. The latitude is 29° North; the longitude is 32° East. The site is next to an existing of steam turbine power plant with 2x625 MW capacity [8]. The same results were obtained by the scientists from Office National de l'Electricite (ONE) of Morocco, conducting to the realization of the project of integrated solar combined cycle power plant of Ain-Beni-Mathar. The details were provided in [9]

In contrast of Solar thermal plants, the PV technology fails to supplement an existing 150 kW diesel generator -based supply in a typical secondary school located at an interior, off-grid and rural site of Sarawak state in East Malaysia [10].

At current market price of PV panels, which is US$3.50/W, the hybrid system may not be a viable option for the selected school. An extensive study has shown that at a PV purchase price of US$2.90/Wp, a 35 kW sized PV system without battery back-up can be the optimum choice to supplement the diesel system of the selected school. The saving from this supplement for the whole life span is US$2,780. This means it is only marginally viable. Use of higher than 35 kW PV systems at the price of US$2.90/Wp are not viable options to supplement the diesel supply of the selected site [10].

The exploitation of the PV systems in Libya is very limited and restricted to rural and off-grid communication stations [11]. The performance of the PV system providing a solar house located in Sebha City (south Libya) is not efficient, the efficiency reaches 5%. The experimental researches achieved by the solar laboratory – Sebha University – indicated that, the failure in the power production by the PV systems was found as high as 70% from the nominal began for Sebha outdoor conditions, due to the high temperature of the PV surface, which effect substantially on PV system efficiency [12].

5. Conclusions

This paper addresses the technical viability and economy of using various types of solar power conversion systems to replace the existing conventional fossil-fuel power plants supply in mainly Arabic countries and the same climatic regions, even for off-grid and rural site. The findings of the present study, would therefore, help the electrical authorities to have a realistic picture of the techno-economic aspects in implementing its vision regard solar power generation technologies.

References

1. Badran, O. O., Study in Industrial Applications of Solar Energy and the Range of its Utilization in Jordan, Sharjah solar energy conference, Sharjah-UAE, 19-22 February, 2001, 252-RTO.
2. Eck, M., Zarza, E., Eickhoff, M., Rheinlander, J. and Valenzuela, L., Applied research concerning the direct steam generation in parabolic troughs, Solar Energy 74, 2003, pp. 341-351.
3. Sukhatme, S. Solar Energy, McGraw-Hill, New Delhi, 1997.
4. Bernardes, M. A., VoB, A. and Weinrebe, G., Thermal and Technical analyses of solar chimneys, Solar Eneergy 75, 2003, pp. 511-524.
5. Francois Pharabod, Economic and strategic aspects of solar electricity for large applications, Solar power systems, the ECE energy series, United Nations, New York, 1993, pp. 278-290.
6. Hugh E. Reilly, Solar Power Tower, Sandia National Laboratories, department of snergy national laboratory, 1999.
7. Quaschning Volker and Muriel Manual Blanco, Splar Power – Photovoltaics or Solar thermal power plants, Plataforma Solar de Almeria, Spain.
8. Jürgen Rheinländer, Mechthild Horn and Heiner Führing, Integrated solar combined cycle system for Egypt technical and economic feasibility of an isccs power plant at Kuraymat in Egypt, Sharjah solar energy conference, Sharjah-UAE, 19-22 February, 2001, 402-STOF04.
9. Filali, K. and Squalli, B., Project of integrated solar combined cycle power plant of Ain-Beni-Mathar, Forum international sur les energies renouvelabels, 8-10 mai, 2002, Tetouan-Maroc, pp 88-93.
10. Christopher, W. A., Shahnawaz, A. S., Hussien, B. A., Faridah Taha and Mohd Zin V. B., On the policy of photovoltaic and diesel generation mix for an off-grid site: East Malaysian perspectives, Solar Energy 74, 2003, pp. 453-467.
11. Salem, A. A. and Nassar, Y. F., Potential and exploitation of renewable energy resources in Libya, The 3rd International Conference on Fuel Conservation in Building, Tehran-Iran, February 17-18, 2004, V3, pp. 50-66.
12. Nassar, Y. F., Yousif S. A. and Salem, A. A., The reliability of the photovoltaic utilization in Southern Cities of Libya, The 8th Arab International Solar Energy Conference & Regional World Renewable Energy Congress, Kingdom of Bahrain, 8-10 March, 2004.