Solar Energy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Solar Energy

journal homepage: www.elsevier.com/locate/solener

Water consumption analysis of Moroccan concentrating solar power station

Mohamed Soufiane Ben Fares, Souad Abderafi*

Departement MIS, Ecole Mohammadia d'Ingénieurs, Mohammed V University in Rabat, Morocco

ARTICLE INFO

Keywords:
Noor 1 station
Parabolic through
Analysis
Water consumption
Energy production
Software SAM

ABSTRACT

The development of solar power plants for electrical production is made through the new strategy of the Moroccan Kingdom, to limit its energy dependency. 2016 marks the start of the electricity production of the first plant Noor 1 in Ouarzazate city. This plant use the CSP technology, with parabolic through collector. To ensure its operation and guarantee its power supply, a large amount of water is needed. In this study analyze of the water consumption per hours during the twelve months of the year indispensable for electricity production of Noor 1 plant was carried out, by using System Advisor Model (SAM). Simulation results compared to industrial data allowed us to propose optimal recommendations concerning mainly the reduction of water consumption and increase electricity production. By exceeding the required amount of water by 2%, to produce about 487 GWh instead of an anticipated quantity equal to 500 GW, the operator have to minimize its consumption to gain 32 m^3 of water which can be exploited in the new stations and at the same time increase its production by 13 GWh.

1. Introduction

Recently, for environmental, economical and social, in other words, for sustainability reasons, the world started to search for new and renewable energy sources (ENEA, 2006). In Morocco, the energy infrastructure depends essentially on hydrocarbons; nearly 70% of the total installed electrical capacity is operated by fossil fuels (Nfaoui and Sayigh, 2013). Hence, 96% of the hydrocarbons are imported for energy needs (Richts, 2012). The industrial sector in Morocco has the highest prices of electricity and the electricity consumption rate increase annually. This problem on the one hand, and the growing population and rising oil prices on the other hand push Morocco to meet its challenge for renewable energies projects (Bouaddi et al., 2015). Solar energy is the most important source of renewable energy in Morocco (El Mghouchi et al., 2016). Different sites of this country has a considerable solar field that is more than 3000 h/year of sunshine, whether an irradiation of ~5 kWh/m^2/day (Ouammi et al., 2012). Thus, the development of the solar power plant for electricity production is carried out thanks to the new strategy called "solar plant of Morocco", and aims to limit its dependence, by first installing a large solar complex of 580 MW (MEMEE, 2009). The first unit called Noor 1 is already in function with capacity production equal to160 MW making it the largest solar power plant in the world (MASEN, 2014). The site of this solar complex is about 10 km from the Ouarzazate city, on the national road, going towards the town of Er-Rachidia. Fig. 1 shows map of Moroccan solar irradiation and the Ouarzazate city (MASEN, 2012). The Ouarzazate site is characterized by a strong direct normal irradiation reaching the 2420 kWh/m^2 annually (El Mghouchi et al., 2016).

The Noor 1 power station requires a raw water supply in order to ensure its operation and guarantee its power supply 24 h/24 h. The level of satisfaction with water needs has been steadily declining in recent years. This is probably due to the growing world population and climate change (Vörösmarty et al., 2000). Water is used for human consumption, food production, and in most industrial processes such as bioethanol and electricity production (Tgarguifa et al., 2017; Colmenar-Santos et al., 2014; Spang et al., 2014). Mismanagement of water in these processes can lead to its deficiency. Noor 1 plant headed by Moroccan Agency for Solar ENergy (MASEN, 2012a,b) ignores the distribution of the water consumed, and especially the quantity reserved for the electrical production, which constitutes fundamental information for the piloting of the project. So this study consists of analyzing the water consumption for the first year of station operation. This analysis will be necessary to subsequently manage the water requirements of energy production and improve plant performance.

2. Description of the plant

Noor 1 Solar Power Station is based on the technology of Concentrating Solar Power (CSP), with parabolic through collector (PTC) (Patnode, 2006). This technology compared to Solar Power Tower, Linear Fresnel Reflector and Parabolic Dish Collector shows that the PTC with thermal oil and molten salt storage is the most mature

* Corresponding author.
E-mail address: abderafi@emi.ac.ma (S. Abderafi).

https://doi.org/10.1016/j.solener.2018.06.003
Received 13 November 2017; Received in revised form 31 May 2018; Accepted 1 June 2018

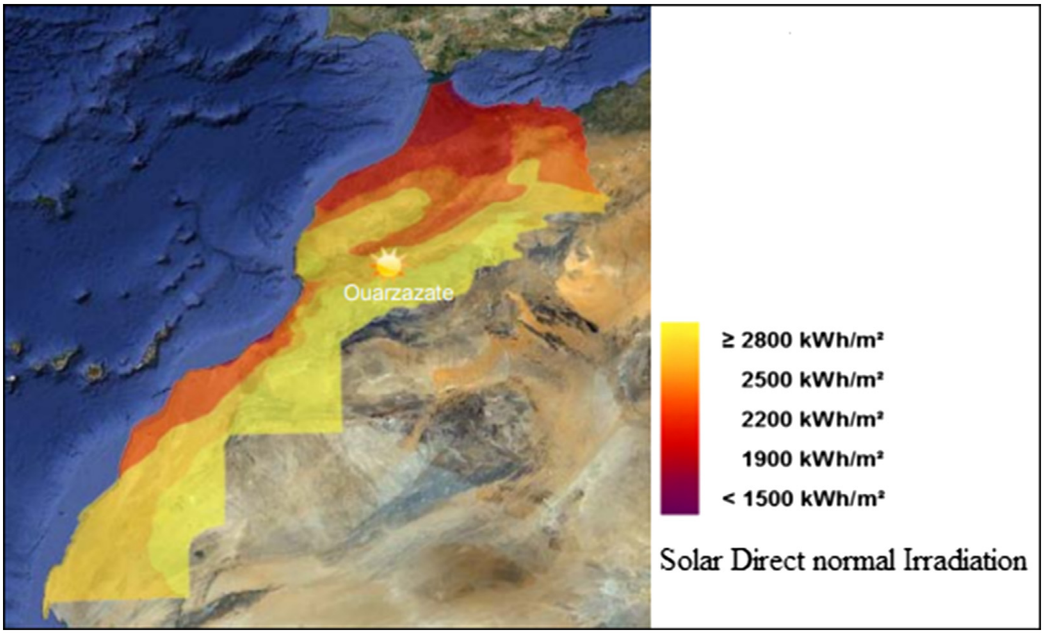

Fig. 1. Map of Moroccan solar Direct irradiation, showing Ouarzazate city (MASEN, 2012).

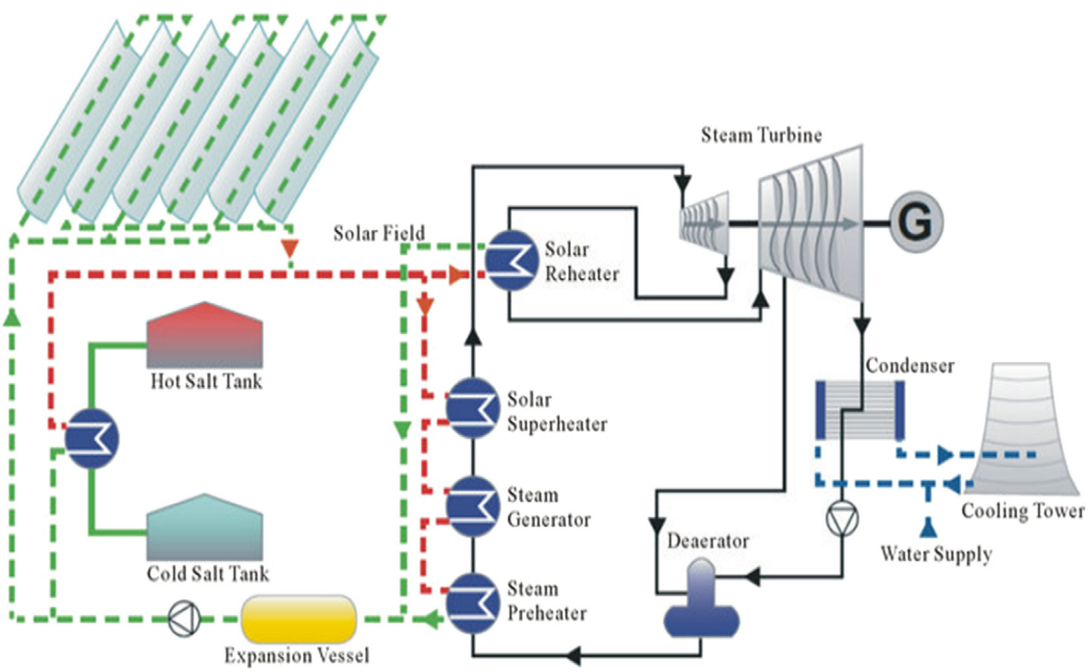

Fig. 2. Schematic of a parabolic trough solar power plant with molten salt storage.

system (Chaanaoui et al., 2016; Kuravi et al., 2013). The CSP-PTC are used in different sites of the world and showed that they are presently the most successful solar technology (Zarza et al., 2004). The Rankine cycle with molten salt storage is the operating principle of the Noor 1 station. Fig. 2 presents schematic of a parabolic trough solar power plant using Rankine steam cycle (Franchini et al., 2013). As shown in this figure, Solar plant like Noor 1 contains three blocks that are the solar field, the power block and the thermal storage system. These blocks type are described by Kuravi et al. (2013).

2.1. The solar field

The solar field of Noor 1 plant consists of 400 parabolic trough loops connected in parallel to each other. One loop contains 4 solar collector assemblies in series and each one consists of 12 solar collector elements. The later is composed of highly reflective parabolic mirrors and heat collection elements (HCE) installed at the focus of the parabola. A tracking system allows the collectors to follow the sun from sunrise to sunset (Mousazade et al., 2009). Hence, the direct solar irradiations are received on the solar field and reflected by the parabolic sensors towards the absorber, where the heat is transferred to the transfer fluid (Quoilin, 2007). The synthetic oil is used as heat thermal fluid (HTF) circulated across the heat collection elements in the solar field. At the output of the solar field, the HTF collected is then pumped to an expansion vessel that is connected to the unit of the power block in order to transfer its energy to another heat transfer fluid that is water.