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Viability study of the use of grid connected photovoltaic system in agriculture: Case of Algerian dairy farms

M. Bey [a], A. Hamidat [b], B. Benyoucef [a], T. Nacer [c]

[a] Université de Tlemcen, URMER, B.P 119, Route de Abi Ayad Abdelkrim, 13000 Tlemcen, Algeria
[b] Centre de Développent des Energies Renouvelables, CDER, BP.62 Route de l'Observatoire Bouzaréah, 16340 Algiers, Algeria
[c] Université de Blida 1, Faculté de Technologie, Département d'Electronique, LabSET, Route de Soumaa, 09000 Blida, Algeria

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ABSTRACT

To meet the rising electricity demand and decreasing produced gas, the Algerian government plans for the installation of 22 GW of renewable energy by 2030 and it ensures the purchase of the produced electricity. The photovoltaic energy will be the first energy with 13.5 GW. In this paper, the performances of the photovoltaic systems destined to supplying the dairy farm and the grid in a rural environment have been studied. The methodology is based on the irrigation and lighting optimization. Whereby, the quality of lighting (150–250 lx) in cow building and irrigation has a direct impact on the production of milk and the growth of crop plants, respectively. The system is optimized by computational program, using global solar radiation and the electricity consumption profile of the dairy farm. A computational program is developed to define the appropriate motor-pump, number of lamps, photovoltaic surface and investment cost. After optimization, the farm becomes a complementary source of photovoltaic electricity 34 MW h/year. The consumed energy of farm from the grid decreases with 67%, and the injected energy is estimated at 30.9 MW h/year, the produced milk increases with 8% and the CO_2 emission decreases with 68%. Hence, the dairy farm becomes an electricity producer instead of electricity consumer with less environmental damage.

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1. Introduction

The Algerian economy is a heavily rent one, dependent on oil and natural gas. According to the National Agency for the Promotion and Rationalisation of the Use of Energy (APRUE), oil and natural gas represent over than 98% of export income in 2008 [1]. Unfortunately, this reserve of fossil fuels is gradually diminishing, that will inevitably lead to the increase in energy prices. This situation causes serious concerns at the economic competitiveness and supply security.

The natural gas represents more than 96% in the electricity energy production [2]. The residential sector is the biggest consumer of electricity, representing 38% of the nationally consumed energy (Fig. 1) [1]. Other important sectors are the tertiary sector 21% and the manufacturing industry 18%. The agricultural sector represents only 2% of the total electricity consumption. Despite the low electricity consumption of this sector, its available area enables the sector to be a good producer of solar energy electricity.

Various academic studies have analyzed the use of renewable energy at the agricultural sector [3–5]. According to Gil and Hiremath, the decentralized production by renewable energy sources at the agricultural farms may be a good energy policy [6,7]. The consumers installing their own Dispersed Energy Generators (DEG), either connected to the conventional grid or not connected, will increase the reliability of their provisioning and decrease their energy bills in consuming the renewable energy. The DEG which is not connected to the conventional grid (off-grid) is appropriate for the geographically remote and sparsely populated rural areas [8–10]. According to Bhattacharyya, the hybrid combination of DEG at an off-grid location can be a cost-effective alternative to grid extension and it is also techno-economically viable [11]. The grid-connected DEG is the best solution in remote regions, where the conventional grid is available [12–14]. According to Mouheb, using photovoltaic solar energy injected into the LV grid can rectify the voltage during periods of high demand and reduce the purchase of electricity from the grid [15,16].

The original idea for writing this paper blew in after a number of review papers which were published in the literature on using the grid connected photovoltaic system in the agriculture sector, where the purpose is to estimate the generated PV electricity [17–20], in order to predict the agricultural farm participation in the electricity power grid. This study paper is based on two aspects to install a grid connected PV system in dairy farms. The first aspect, the artificial lighting and pumping are optimized, whereas the second aspect is to forecast the produced photovoltaic energy by the dairy farm.

2. Solar energy situation in Algeria

Algeria's geographical location has several advantages for a large use of solar energy. Algeria is situated at the center of North Africa in 38–35° North and 8–12° East with the surface 2,381,741 km^2. According to the Development Center of Renewable Energies (CDER), the solar radiation is between 1530–1970 kW h/m^2/year for the north, and 1970–2410 kW h/m^2/year for the Sahara, shown in Fig. 2 [21]. Hence, the solar resources and geographical location of Algeria provide a strategic position to play an important role in the electricity energy generation. A report of the International Energy Agency's (IEA) says that a country such as Algeria could be an exporting solar energy to Europe [22].

2.1. Oil and gas production

At the African level in 2005, Algeria is the leading natural gas producer at 79.4 Million toe and among the top three oil producers at 86.4 Million toe [23]. Besides, it is the second-largest natural gas supplier to Europe. However, natural gas and oil production have gradually declined in recent years after 2005, as shown in Fig. 3.

The life-cycle of a natural gas field has been divided into three separate phases, the build-up phase, the plateau phase and the decline phase [24]. Following the prediction work of Guseo et al. the gas production is in the penultimate phase (plateau phase), shown in Fig. 3 [25].

2.2. Electricity generation

According to Hamich, electricity generation (EG) in Algeria, which was 62.2 TW h in 2014 [23], would rise in 2030, taking into account the impacts of energy efficiency actions, to 110 TW h for a low scenario, to 125 TW h for an average reference scenario, or to 147 TW h for a scenario of high economic efficiency [26].

This electricity generation (EG) increases in two phases, as shown in Fig. 4 [23]. A first phase from 1985 to 2000 and second phase from 2000 to 2012. After the data analysis of EG, it has a linear growth at the first phase (1985–2000). This phase is described with the following equation:

$$EG = -1659.05294 + 0.84191\text{year} \quad (1)$$

At the second phase (2000–2012) and according to the Investment Development National Agency [27], Algeria has succeeded to increase the volume of productive investments. The need of electricity energy in this phase, render the linear model to the Boltzmann model:

$$EG = 135 + (13.5 - 135)/\left(1 + \text{EXP}\left(\frac{\text{year} - 2015}{6.4}\right)\right) \quad (2)$$

The growth in electricity generation is clearly seen in Fig. 3. According to Eq. (2), EG is predicted to be 83, 97 and 124 TW h by

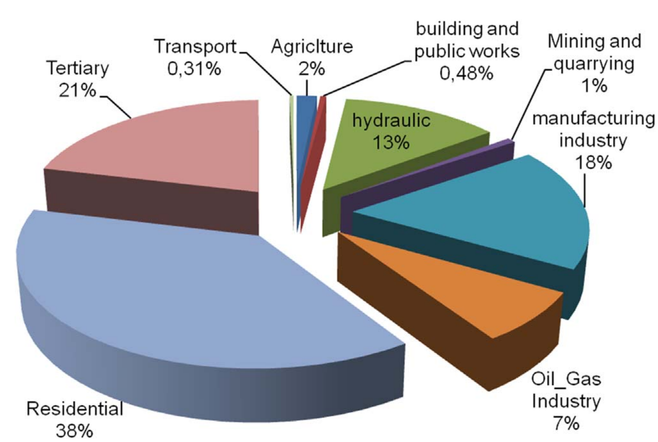

Fig. 1. Electricity consumption by sector in 2012 [1].