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Analysis of Power Generation and Transmission from Very Large-Scale Photovoltaic Systems in Algeria

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Abstract. In addition to the well-recognised two values of vast land and sunshine of Algeria, its Sahara desert has the third value, energy production and export. Subsequently, Algeria can then become a role model to other countries in the world that has huge solar and energy feedstock. In this article, a particular attention is being given to the Algerian Sahara in terms of solar potential capability in that it could capture enough solar energy to meet the total energy needs for sustainable development of Algeria, Sahara cultivation and Repopulation and electricity Export to Europe using Very Large Scale-Photovoltaic (VLS-PV) system. Moreover, the article is also concerned with studying the energy transmission losses from the generation site, in depth Sahara of the south of the country, to the north as well to European countries.

A rough calculation of the Losses was made for a transmission overhead line of 400 kV three-phases, 1000 MVA using ALMELEC cable of 1600 mm^2. The calculated losses results were found to be 15% per 1000 km. The optimal location to start the installation of VLS-PV systems is proposed.

Keywords

Photovoltaic, Solar energy, Sustainable development, Sahara, Transmission losses

1. Introduction

At the end of oil and gas era, there will be sun, sand and free area at the Algerian Sahara, sufficient to meet the total energy needs for sustainable development of Algeria, Sahara cultivation & Repopulation and electricity Export to Europe. To prove that we calculate, at first, the area of Algeria desert suitable for the installation of VLS-PV system followed by a rough calculation of photovoltaic (PV) capacity and annual power generation for all the proposed area. A comparison with world primary energy consumption [1] allowed us to conclude that Algeria solar net annual energy potential using VLS-PV is more than the half of world energy consumption in the horizon of 2030, meaning that the solar energy potential of Algerian Sahara is sufficient for the above mentioned needs. However, the problem is not in the energy potential, as it is the case of some others countries, or in energy production, it is essential in the assessment of transmission losses of very large power of several GW and for a very long distance up to 2000 km!

Algeria population is concentrated in the north, near the Mediterranean Sea, Sahara desert of Algeria, 86% of the whole area, is mostly empty and receives about as much reliable sunlight as you could possibly hope for. Therefore, most of the electrical energy is mainly needed for the north of the country. In this case, transmission losses may be a barrier to Sahara solar energy exploitation. It is then, very important, in view of energy strategy, to analyses the gains and losses of energy generation in the depth of Sahara. May be, it is better to find the optimal position of VLS-PV system in the Sahara.

2. Algeria Desert Irradiation

Total annual irradiation for all world deserts (31 deserts of 19 million km^2), was calculated [2-4]. A summary of calculated results is depicted in Table 1. It can be seen easily that Algeria desert has an 11.4 % share of the total irradiation of world deserts. The annual Algerian desert irradiation (395600 Mtoe/y) is more than 26 times higher than the primary energy consumption of the world in 2030 (15000 Mtoe) [1].

3. Algeria desert solar net energy potential using VLS-PV

3.1. Suitable area for VLS-PV system

The deserts offer contrasting landscapes: sand dunes, oasis, wades (dry beds of rivers and streams), mountains, reg (composed of pebbles and gravel) and steppes. It is impossible to use the total area of the deserts for VLS-PV system; the suitable area for this kind of systems is the regs and the steppes only. Table 2 shows a rough calculation of the different areas of Algeria desert; it can be seen that the suitable area for VLS-PV is about 1 200000 km^2.

3.2. The range of VLS-PV system

The size of a Very Large Scale- Photovoltaic system may range from 10 MW to 1 or several GW, consisting of one plant, or an aggregation of plural units [5]. Figure 1 shows a conceptual image of a one GW system [5,6], it occupied 30 km^2 (15 km x 2 km) of land, taking into account, PV collectors, buffer plant, roods and transmission lines.

3.3. PV capacity and annual power generation

Table 3 shows a rough calculation of PV capacity and annual power generation for all the suitable area of Algeria desert using VLS-PV based on a conceptual image of a one GW system of figure 1. A comparison with world primary energy consumption [1] allowed us to conclude that Algeria solar net annual energy potential using VLS-PV without buffer plants (8100 Mtoe) is more than the half of world consumption in 2030 (15000 Mtoe).

Table 1: Algeria desert irradiation compared to world energies

WORLD REGION DESERTS	**Area (km²)**	**Annual irradiation (kWh/m²)**	**Total annual irradiation (PWh)**	**Total annual irradiation (Mtoe)**	**Share of total annual irradiation (%)**
TOTAL WORLD DESERTS (31 deserts)	**18 978 143**	**2 136**	**40 537**	**3 486 218**	**100**
North Africa (NA)	**8 600 000**	**2300**	**19 780**	**1 701 080**	**49**
Middle East (ME)	**3 052 400**	**2137**	**6 524**	**561 052**	**16**
Algerie	**2 000 000**	**2300**	**4 600**	**395 600**	**11,4**

Table 2: different areas of Algeria desert

Total area (km²)	**Sand dune area (km²) 20%**	**Oasis area (km²)**	**Mountain area (km²) 18%**	**Reg and Steppe area (km²)**
2 000 000	**400 000**	**40 000**	**360 000**	**1 200 000**

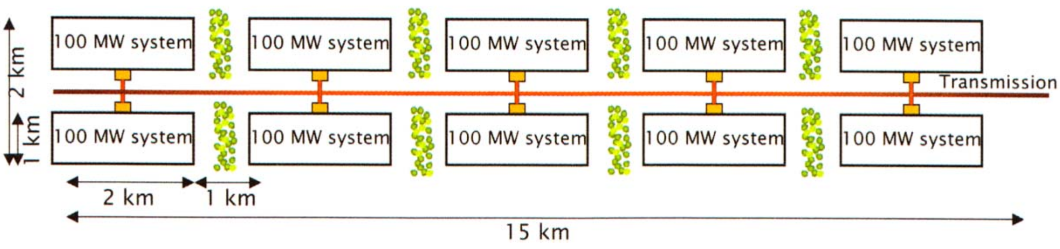

Fig 1. A conceptual image of a one GW [5,6]

Table 3: PV capacity and Annual energy generation for all the Suitable Deserts area of Algeria

PV Capacity and Energy generation using VLS-PV system	**PV capacity (TW)**	**Annual generation (PWh)**	**Annual generation (Mtoe)**	**Annual generation to gross annual irradiation %**
Without buffer plant	**60**	**95**	**8 100**	**2,1**
With buffer plant	**40**	**63**	**5 500**	**1,4**

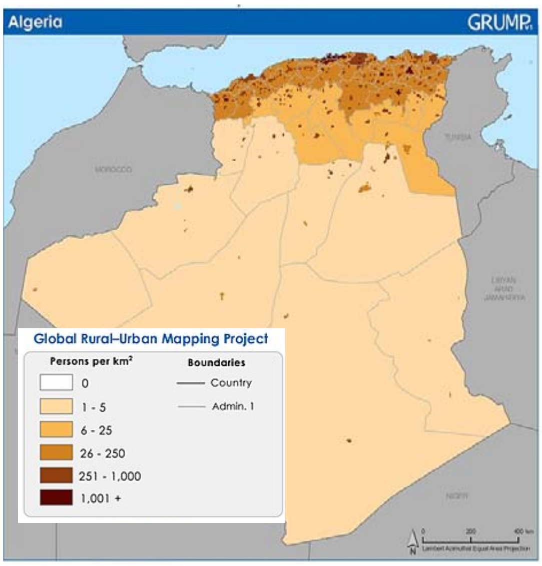

Fig 2. Population density of Algeria

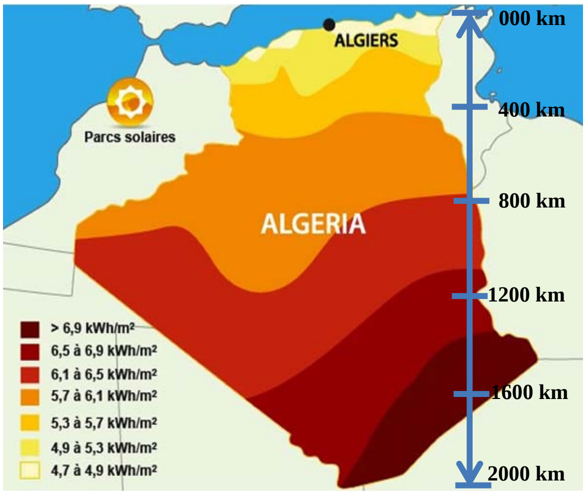

Figure 3: In the left of the figure: Annual average of global irradiation received on a horizontal surface. In the right of the figure: Distance from the sea.

4. Algeria Population and Irradiation Distribution

As show in Figure 2, the population density of Algeria [7]; is mainly concentrated in the north, near the Mediterranean sea, while in the Sahara, with 86% of Algeria's land, the density is very small and solar feedstock highest, as presented on figure 3 [8]. The importance of access to clean energy from the south, having free land and huge energy potential cannot be overstated. In this case transmission losses may be a barrier to Sahara solar energy exploitation.

A rough calculation of the losses was made for a transmission overhead line of 400 kV three-phases, 1000 MVA using ALMELEC cable of 1600 mm^2. The calculated losses rate were 15% per 1000 km. Table 4 shows the decrease in energy according to the transmission distance. The red numbers are the irradiation to the different distances from the sea, and the blacks ones are the calculated values at arrival to different distance.

For a distance from the sea equal to 1800 km the naturel irradiation is 7100 Wh/m2/day, after 400 km it become 6674 Wh/m2/day, at 1000 km from the sea it become 6248 Wh/m2/day and at 100 km from the sea it becomes 5290Wh/m2/day.

Table 4 the decrease in energy according to the transmission distance

	Annual average of global irradiation (Wh/m2/d)	Distance from the sea (km)		Losses for three-phase 400 kV, 1000 MVA, Almelec cable of 1600 mm2. Losses = 15% per 1000 km.					
1	5100	100		5290	5394	5450	5458	5335	5100
2	5500	300		5503	5595	5639	5635	5500	
3	5900	600		5822	5896	5922	5900		
4	6300	1000		6248	6298	6300			
5	6700	1400		6674	6700				
6	7100	1800		7100					

5. Discussion and conclusion

The calculation results of Table 4 show that the gain in the production of electrical energy using VLS-PV systems in the depth of Sahara, will be lost in the transmission lines from Sahara south to the north. In this case, the investment in the construction of transmission lines will be lost completely.

The optimal location to start the installation of VLS-PV systems is in the north of the Sahara, in the orange area, having an energy ranging between 5.3 and 5.7 kWh/m^2. After that we can extend toward the south gradually, waiting may be for the introduction of superconducting cables in the energy transport means! This created and proposed energy system dynamics model, in Algeria's Sahara, can be implemented in other countries, such as the ones of the Maghreb region, and the results can be compared with the current work performed in Algeria.

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