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Comparison of Stationary and Two-Axis Tracking System of 50MW Photovoltaic Power Plant in Al-Kufra, Libya: Landscape Impact and Performance

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Abstract**—**The scope of this paper is to evaluate and compare the potential of LS-PV(Large Scale Photovoltaic Power Plant) power generation systems in the southern region of Libya at Al-Kufra for both stationary and tracking systems. A Microsoft Excel-VBA program has been developed to compute slope radiation, dew-point, sky temperature, and then cell temperature, maximum power output and module efficiency of the system for stationary system and for tracking system. The results for energy production show that the total energy output is 114GWh/year for stationary system and 148GWh/year for tracking system. The average module efficiency for the stationary system is 16.6% and 16.2% for the tracking system.

The values of electricity generation capacity factor (CF) and solar capacity factor (SCF) for stationary system were found to be 26% and 62.5% respectively and 34% and 82% for tracking system. The GCR (Ground Cover Ratio) for a stationary system is 0.7, which corresponds to a tilt angle of 24°. The GCR for tracking system was found to be 0.12. The estimated ground area needed to build a 50MW PV plant amounts to approx. 0.55km^2 for a stationary PV field constituted by HIT PV arrays and approx. 91MW/ km^2. In case of a tracker PV field, the required ground area amounts approx.2.4km^2 and approx. 20.5MW/ km^2.

Keywords**—**Large PV power plant, solar energy, environmental impact, Dual-axis tracking system, stationary system.

I. Introduction

LARGE scale use of solar energy for electricity production is currently in the demonstration phase. Lessons learnt from the pilot projects will benefit the implementation of future power plants. Since the large scale PV (LS-PV) power plant concept is relatively new, so these different technologies (stationary and tracking system) are to date competing with no clear “winners”, even if most of the biggest PV plants (i.e. within the range of 40-70 MWp) have been realized as stationary systems. The scope of this paper is to examine and evaluate the potential of LS-PV power generation systems in the southern region of Libya at Al-Kufra for both stationary and tracking systems.

Aldali et al [1], [2] has been described the design of a 50MW PV power plant (stationary and tracking) which has been modelled on the conditions pertaining to Al-Kufra. The general energy situation within Libya is described, along with the solar conditions at the proposed location of the power plant. An HIT (hetero-junction with intrinsic thin layer technology which combines both mono crystalline and amorphous silicon in the one structure) type PV module has been selected and modelled.

In this paper the comparison has been carried out between stationary and tracking (two axis) PV plant with respect to landscape impact and performance.

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II. Design System for Two Axis Tracking System

The most commonly used system in sun tracking systems is controlling the motor which moves the panel by evaluating the signals received from photo sensors.

This section discusses the system which employs full two-axis tracking, ensuring that the PV modules always face directly towards the sun’s position in the sky. An HIT type PV module from Sanyo rated at 200W has been selected and modeled. The selected module specifications are summarized in Table I.

TABLE I
SPECIFICATIONS OF THE PV MODULE [3]

Electrical specification	
Model	HIT Power 200
Rated Power (Pmax)[1]	200 W
Maximum Power Voltage (Vpm)	55.8 V
Maximum Power Current (Ipm)	3.59 A
Open Circuit Voltage (Voc)	68.7 V
Short Circuit Current (Isc)	68.7 V
Temperature Coefficient (Pmax)	-0.29% / °C
Temperature Coefficient (Voc)	-0.172 V / °C
Temperature Coefficient (Isc)	0.88 mA / °C
Cell Efficiency	19.7%
Module Efficiency	17.2%
Mechanical specification	
Module Area	1.16m^2
Weight	15kg
Dimensions LxWxH	1319x880x46mm
Operating conditions	
Ambient Operating Temperature	-20°C to 46°C
NOCT	46.9°C
1	STC: Cell Temp. 25^{o}C, AM1.5, 1000W/m^2

Aldali et al. [1], [2] has been developed and presented a model to compute dew-point, slope radiation, sky and cell temperature, module efficiency and maximum power for operation of the PV modules for stationary PV system and slope radiation sky and dew-point, cell temperature, module efficiency and maximum power for operation of the PV modules for two-axis tracking system. Furthermore, the model calculates the current, voltage and fill factor for both stationary and two-axis tracking system. The model is designed to compute results for ten hours each day for a period of one year.

A detailed flow chart of the model for two-axis tracking system is shown in Fig. 1. The model of the PV module was implemented using Visual Basic for Applications (VBA), which also made use of the processing features of Microsoft Excel [2].

The DegerTraker 6000NT module has been selected as the sun-tracker system. DegerEnergy Company designed and constructed a programmable sun-tracker. Table II shows the specification of the DegerTraker 6000NT-Dual-axis [4].

The proposed of solar tracking system for the 50MW photovoltaic power plant would be divided into 50 sub-stations of 1MW each and each 1MW substation would be divided into 125 solar trackers each rated at 8kW. Each substation would feed the generated electricity to the 11kV grid through a 1000kVA transformer and each 8kW PV channel has been equipped with a grid-connected inverter to convert the DC power from the PV into three - phase AC power for the primary of the 1000kVA transformer. The output from the 50MW station connects to the national grid (220kV) through a 50MVA transformer. Each 1MW substation therefore consists of 5000 modules. The specification of the proposed inverter is shown in Table III.

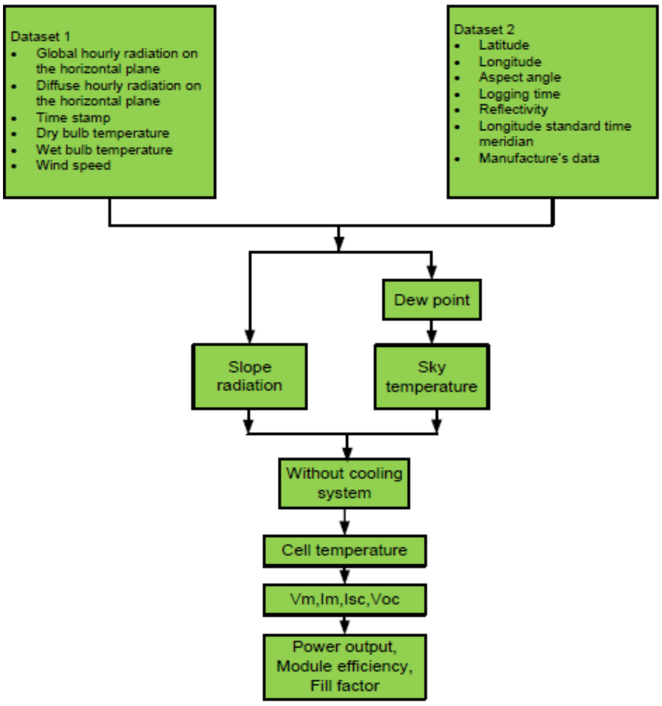

Fig. 1 Flow chart for the computer model for two-axis tracking system [2]

TABLE II
SPECIFICATIONS OF THE DEGERTRAKER 6000NT-DUAL-AXIS [4]

Module area up to	53m²
Rotation angle east – west	360° with adjustable limit switches
Elevation	15°-90°
Control unit	DEGERconecter
Operating voltage	80 … 265 VAC / 80 … 380 VDC
East –west drive	drive integrated in the rotating head
Elevation drive	1,100 mm stroke path
Internal power consumption:	
Control mode	1 Watt
With operating drives approx.	7 Watts
Power consumption per year. approx.	9 kWh
Mast height	4 m … 5,5 m
Load capacity	130 … 300 km/h
Weight (excluding mast)	1,000 kg
Art.no.	1600001

TABLE III
SPECIFICATIONS OF PROPOSED DC/AC INVERTER [5]

Rated power (kVA)	200
Maximum power (kVA)	245
Rated input DC voltage (V)	640
Maximum input DC voltage (V)	800
Rated input DC current (A)	400
AC output	Three-phase 415V±10%
Output frequency	50Hz
Efficiency	10%load:90%
	50%:load96%
	100%load:96%
Size (mm)	2000x2100x800
Weight	1400kg

The system was designed to optimize performance for the annual energy output (i.e., modules facing due south) and to maximize reliability. For example, in designing the 1MW system it was determined that 125 x 8kW arrays would increase the reliability of the system. If anyone array should fail, the system would still be operating at 90% capacity.

A. Field Requirements

It is important that the PV modules do not shade each other. On the other hand, for sun tracking systems (Two-axis), the situation is more complex because the modules also move. In order to ensure that the solar trackers do not shade each other, hexagonal structures have been used in this study [6]. Fig. 2 shows the field design for the proposed 50MW power station (Two-axis) and configuration of the PV array; each array consists of 40 PV modules.

The total area occupied by the solar tracking system power plant is 2.44km^2 and the total module area is 290,180 m^2.

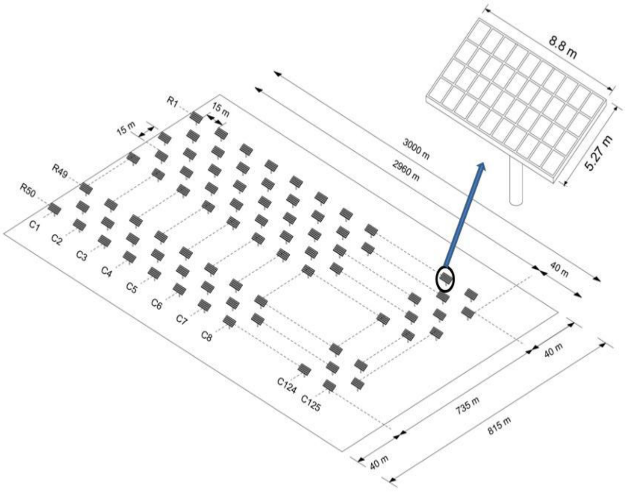

Fig. 2 Schematic of hexagonal field layout of 50MW PV power plant (for two-axis tracking system) [2]

B. Capacity Factor and Solar Capacity Factor

The capacity factor for sun tracking system (two-axis) was found to be 34% and the solar capacity factor SCF was 81%.

III. Comparison of Stationary and Tracking Systems

In the current section, the comparison between the stationary and tracking systems has been performed on the basis of the following main design principles:

- 50MW size, reasonably assumed as reference size for both technologies.
- HIT PV module technology for both stationary without water cooling and tracking systems.
- Location: southern Libya in Al-Kufra.

The main factors used for comparison have been:

- Landscape impact
- Performance

A. Landscape Impact

The key factor in designing the PV plant is to gain, for any specific site, the optimal ground cover ratio (GCR) without valuable reduction of expected performance ratio. The GCR is defined as the ratio of the PV array area to the total ground area [7].The GCR for a stationary system installation localized in Libya, Al-Kufra, is 0.7, which corresponds to a tilt angle of 24°. The GCR for tracking system was found to be 0.12.

The estimated ground area needed to build a 50MW PV plant amounts to approx. 0.55km^2 for a stationary PV field constituted by HIT PV arrays and approx. 91MW/ km^2. In case of a tracker PV field, the required ground area amounts approx.2.4km^2 and approx. 20.5MW/ km^2.

It can be observed, in terms of land impact, that a stationary PV field requires about quarter of the area necessary for a tracker PV system and the selection of PV modules may play an important role in determining the area required by the plant. Therefore it can be concluded that for LS-PV plant, the stationary PV field arrangement should be preferable when compared in terms of land impact.

B. Performance

The expected performance of a 50MW PV plant, located in Al-Kufra, Southern-East Libya, is shown in the Table IV; the tracker PV system produces approximately 30% more energy per annum than a stationary PV system, with the same nominal installed power. Furthermore, the cost of a PV tracking system is greater than the cost of stationary PV system.

TABLE IV
PV Power Plants Performance Table

	Stationary PV System	**Tracker PV system**
Total slope radiation GWh/m^2/year	592	767
Solar field total surface m^2	290,500	290,500
Total Plant area km2	0.55	2.4
Installed PV peak power MW	50	50
Total energy output GWh/year	114	148
Capacity factor %	26	34
Solar capacity factor %	62.5	82
Reducing CO_2 emissions, kT	76	96

Fig. 3 shows the monthly production of energy of the stationary and tracking plant. The result was a 30% higher production of energy in the tracking plant. This increase in energy production, although significant, is not enough to compensate the other disadvantages of plants with trackers:

- Increase in cost due to trackers. Trackers are expensive, and their price is not expected to be reduced.
- Increased Operation and Maintenance cost due to trackers. While static device plants are very easy to maintain, the trackers need more maintenance work since they are a moving system.
- Risk of durability of the tracker system. It is very difficult to be sure that the tracking system will work during the whole life of the plant.
- High risk of incident related to strong winds. High speed winds can cause serious problems to the trackers that mean losses of production and cost in reparations.

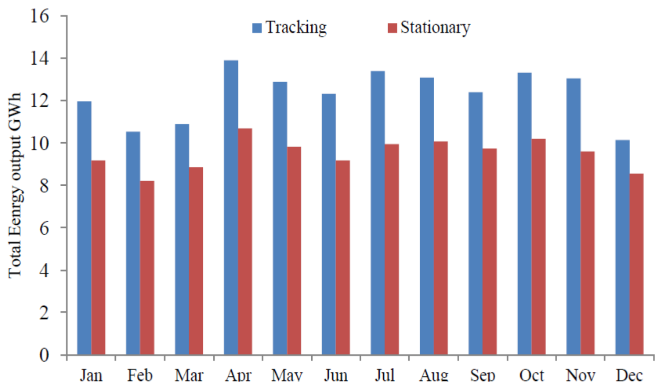

Fig. 3 Monthly total energy output for both stationary and tracking systems

IV. Conclusion

This paper presented an extended analysis for comparison a

50MW PV-grid connected (stationary and tracking) power plant in Al-Kufra, Libya. The HIT solar PV module from Sanyo, rated at 200W, has been used in this study due to its high efficiency.

Long-term meteorological parameters for Al-Kufra region have been collected from Renewable Energy Authority of Libya (REAOL) and the results confirm that Al-Kufra has high levels of annual solar radiation. The collected meteorological parameters were: long-term average daily global radiation, average daily sunshine hours, long-term hourly ambient temperature and average daily wind speed.

The results for energy production show that the total energy output is 114GWh/year for stationary system and 148GWh/year for tracking system. The average module efficiency for the stationary system is 16.6% and 16.2% for the tracking system.

The values of electricity generation capacity factor (CF) and solar capacity factor (SCF) for stationary system were found to be 26% and 62.5% respectively and 34% and 82% for tracking system.

Therefore it can be concluded that for LS-PV plant, the stationary PV field arrangement is preferable when compared in terms of land impact and the disadvantages of plants with trackers.

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