American Journal of Energy Research, 2024, Vol. 12, No. 1, 21-32
Available online at http://pubs.sciepub.com/ajer/12/1/3
Published by Science and Education Publishing
DOI:10.12691/ajer-12-1-3

Cost Effective Study of Power Generation Using Photovoltaic System for Riyadh and Jubail Regions

Jehad H. Al-Sulaimani, Ahmed M. Nahhas*

Department of Electrical Engineering, Umm Al Qura University, Makkah, Saudi Ara
*Corresponding author: amnahhas@uqu.edu.sa

Received February 01, 2024; Revised March 01, 2024; Accepted March 10, 2024

Abstract Saudi Arabia intends to promote solar power generation as a discipline in most of the country's universities, as well as large solar projects and renewable energy in general. To achieve solar energy goals, the academic community of engineers and professors is now conducting a variety of facilities, research projects and analytical studies for all regions of the country to provide clean energy in the future. As a result, the country's latest solar improvements are undergoing a period of development for scientific research and analytical studies. This paper is presenting the study of the means to facilitate the work of projects in the field of solar energy in Riyadh and Jubail Regions, which is to complete the calculation of the total cost of both stations based on our previously published study. The PVsyst 7.1 simulation software is used to simulate the installation of photovoltaic cells on Saudi Arabia different regions including as the eastern western coast and the center region. Also, the tracker system may be used to track the sun and create more electricity from PV systems. The paper presents the design of three-dimensional models of two solar power plants, one in Riyadh and the other in Jubail, using Sketchup software. Design two-dimensional layouts for both stations on AutoCAD software. Also Calculating the estimated cost of each power plant.

Keywords: *PV, solar, cells, renewable, tracker system, cost effective*

Cite This Article: Jehad H. Al-Sulaimani, and Ahmed M. Nahhas, “Cost Effective Study of Power Generation Using Photovoltaic System for Riyadh and Jubail Regions.” *American Journal of Energy Research*, vol. 12, no. 1 (2024): 21-32. doi: 10.12691/ajer-12-1-3.

1. Introduction

The need for electricity in Saudi Arabia continues to increase due to the high standard of living and the growing population. The problem, however, lies in harmful emissions from traditional power plants that must be established to cover that extreme energy requirement. The current global trend has therefore become a focus on renewable energy sources to preserve the environment, increase energy production, and increase economic growth. The term "green energy" refers to such energy from clean sources. It contains no environmental damage, preserving human health and living organisms and preserving the environment from the damage it may do if we use conventional energy sources with high carbon emissions [1]. Solar power comes on top of renewable energies due to the Saudi Arabia's location and available spaces for constructing solar power plants, which was the greatest motivation to perform this study.

1.1. Solar Energy

Solar energy has become an irreplaceable source for the country that lies in the solar radiation belt because it is a suitable and renewable alternative and does not carry any environmental damage. Also, it cannot be forgotten that solar energy has two technical strengths: one has a zero operational cost, and the other is that it can be a good solution for isolated areas that the utility could not reach [2]. There are two basic types of solar energy, as shown in figure 1, which could be considered as methods of generation:

a. Photovoltaic (PV) panels.
b. Concentrated Solar Power (CSP).

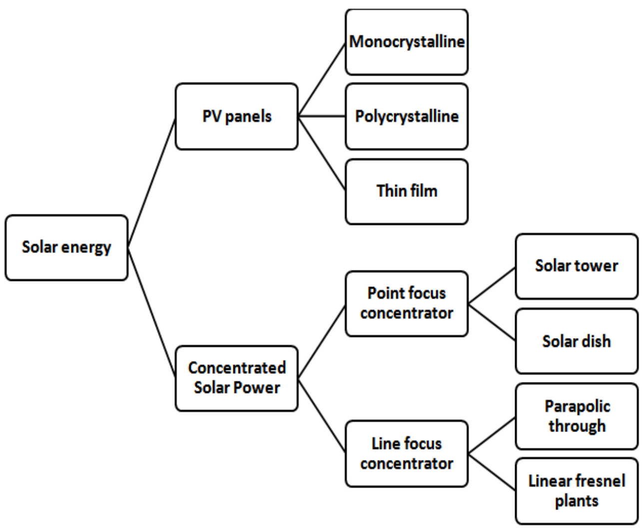


Figure 1. Types of solar energy techniques [5]

1.2. Photovoltaic Panels (PV)

The idea of solar panels is primarily to convert sunlight into electrical energy, where the energy in light (photons) is converted into electrical energy (voltage) and is therefore called the photovoltaic effect [2,3]. As illustrated in figure 2, the notion of action is very similar to that of the optical diode. When light falls on the plates, the energy in the light pushes the electrons in this layer to travel to another layer, and then the electrons flow between the two layers, which transfers the electric current to the load.

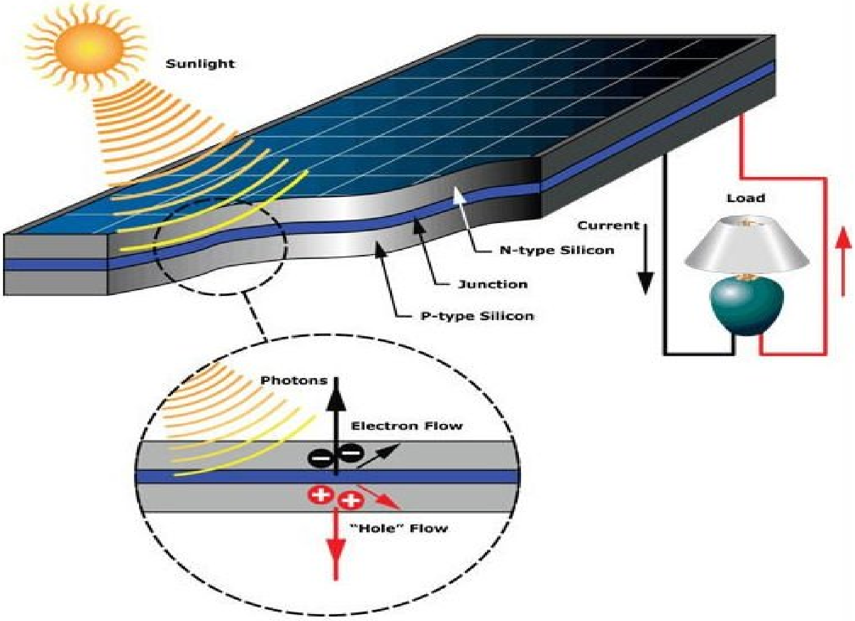


Figure 2. Solar panel diagram and the direction of electrons [6]

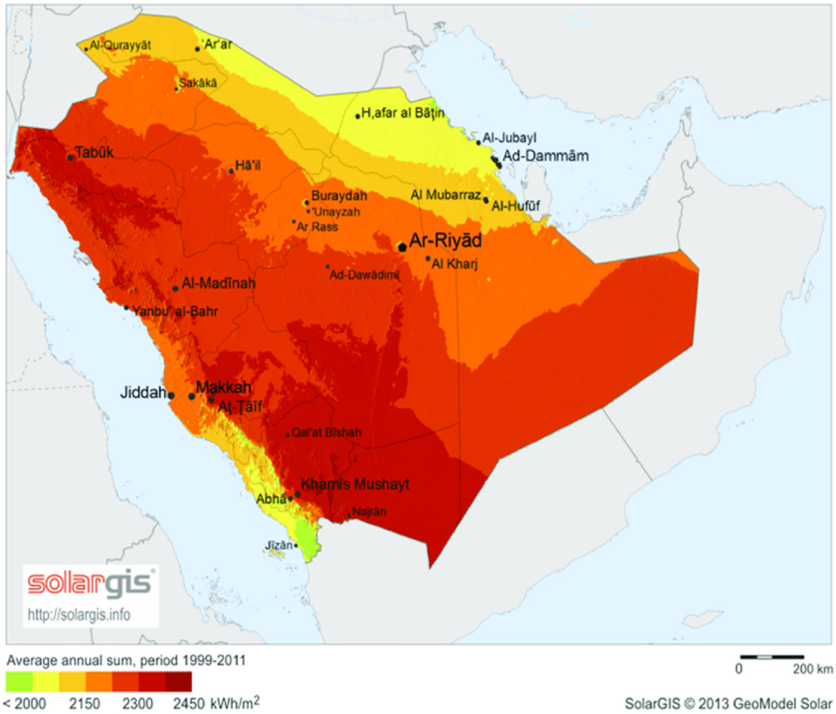


Figure 3. Global horizontal irradiation map of Saudi Arabia [1]

2. Solar Energy in KSA

Saudi Arabia's geographical location and enormous spaces have contributed to creating an environment conducive to the establishment of solar energy projects, as the Government of Saudi Arabia immediately turned to and set up some solar power plants in various places and plans to establish many plants by 2030. A review of Solar energy in KSA and the challenges, expectations, and hopes of Saudi Vision 2030 are presented in this section. Saudi Arabia's map of the amount of solar radiation shows the magnitude of the Saudi Arabia's vast wealth of sizeable solar energy available across the country, as shown in figure 3. Saudi Arabia is one of the most important Middle Eastern countries, with the highest annual solar radiation rates available. The average annual solar radiation in the Middle East countries is between 2,100 and 2,200 kWh/m^2, as shown in figure 3 [4]. The average yearly rate of solar radiation is between 100-200 W/m^2 in most high-potential solar regions, while it reaches about 250 W/m^2 in Middle Eastern countries. In Saudi Arabia, the average sunlight available is about 9 hours per day, and it has non-rainy areas with an average horizontal solar radiation of 5,591 W/m^2 [5]. Despite the Saudi Arabia's wealth of enormous solar power, it relies mainly on fossil fuel-based power plants to meet energy demand. Approximately 56% of the country's oil and 46% of natural gas are now used for domestic consumption. To avoid the environmental and economic damage caused by fossil fuels, Saudi Arabia wants to use renewable and nuclear resources to produce energy to meet a large share of the country's energy demand, which is expected to nearly triple in the next 20 years.

2.1. The Present Situation of Solar Energy in Saudi Arabia

Saudi Arabia is actively pursuing the implementation of medium and large solar energy projects on two grounds, aimed at overcoming the economic and environmental problems that result from using fossil fuels as the primary source of electricity generation. Some of these projects are still under planning and study, and the Saudi Arabia aims to implement them by 2030; others have already been implemented, which we will present in this section.

2.2. Layla Solar Power Plant

In 2019, "Taqnia" Energy announced the completion of the first phase of the Laila Solar Power Plant, which represents 10 megawatts of the plant's total capacity and is planned to become approximately 50 megawatts by 2030. The first phase of the Laila plant, as shown in figure 4, is 720 thousand square meters, the world's first solar-powered power plant directly connected to the power grid. Located in Al-Aflaj (300 meters south of Riyadh), this phase can cover approximately 10% of the region's electricity requirements. The Layla plant will contribute to increasing the overall production capacity of the Al-Aflaj zone while reducing carbon emissions from conventional energy sources, which will significantly contribute to environmental protection.

Figure 4. Layla solar power station [6]

2.3. Sakaka Solar Power Plant

According to Saudi Energy Company Aqua, the Sakaka Solar Project was completed with a total capacity of 300 MW as shown in figure 5. Initially, the terminal was connected to the network for a pilot phase of commercial operation. In addition, the knife station provided substantial employment opportunities for Al-Jawf's youth.

The Renewable Energy Projects Development Office (REPDO) commissioned the Sakaka Plant for Aqua Power establishment after it received the contract for the tenders offered by the Government. The station was set up in an area of six square kilometers in the Al-Jawf area. This project is the first of a series of projects planned by Saudi Arabia under the Saudi National Renewable Energy Program, which aims to produce 9.5 GW of renewable energy by 2023 [7].

Figure 5. Sakaka power plant [7]

3. Simulation and Results

3.1. Results for Riyadh Site

The solar energy calculations in this study were made using PV SYST software besides the Global Solar Atlas. As a result, measures were accurately made for our study case sites in Riyadh and Jubail. As shown in Table 1, there is complete information about Riyadh that could be useful for designing the solar station. Global Solar Atlas provides this information. In addition, each piece of information in this table has detailed information on Global Solar Atlas and can be easily downloaded. Both the azimuth angle of the Sun for Riyadh and its location on the map, which has coordinates of Latitude 24.413684 °N, Longitude 47.008009 °E, and Altitude is 511 m, are shown in Figure 6.

According to the design information on the PV SYST about Riyadh, the project information shown in Figure 7 is the software's output. The estimated power output of the station is 200 MW.

Figure 8 shows the azimuth and tilt angles used in the program, which are 26° and 0°, respectively. Also, the number of modules needed is 363636 units with 550 Wp each to cover the 200 MWp required from the station. In addition, the station will need 1674 inverter units with total nominal AC power equal to 167.4 MWac.

More details about the used inverter and modules are provided in Figure 9, such that each inverter is Huawei technologies type model SUN2000-100KTL-M1-400Vac [9] with nominal power of 100 kW, the number of inverters used is 1674 units. On the other hand, there are 363636 PV modules with little ability of 550 Wp each; these modules are proposed by Longi Solar, model LR5-72 HIH 550 M [10,11,12,13].

As shown in Figure 10, the normalized production (per installed kWp) for each month is proposed, which clarifies the total useful power produced (Y_f), the system losses due to the components (L_s), and PV losses (L_c). Finally, in Figure 11, the Performance Ration (P_R) is proposed, representing the performance of modules inside the station. PR is the ratio between useful produced energy and the total produced energy.

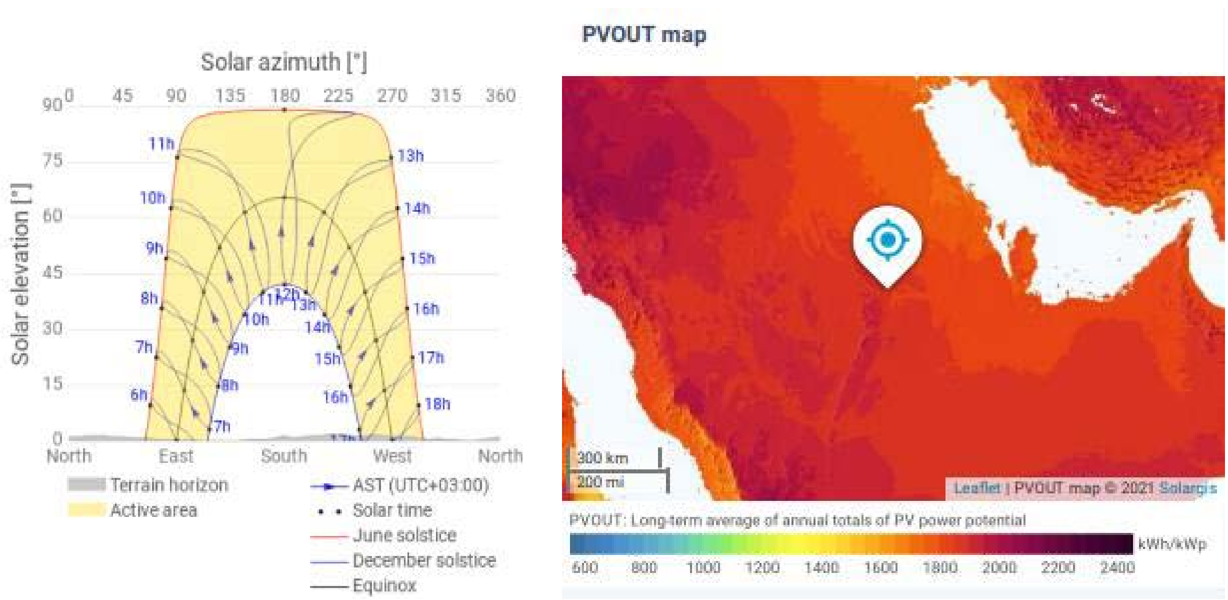
Riyadh station details are proposed in Figure 12 all over the year.

Each unit and quantity used in the Riyadh project is estimated in SR and demonstrated in the bill of quantity in table 2. The total cost of the station is also calculated in Table 2.

Finally, The CO_2 emission balance report is illustrated in Figure 13 to show how many tons of CO_2 this station could save and protect the environment from its harmful damage effect.

Table 1. Map information of Riyadh [8]

Information	Abbreviation	value	unit
Specific photovoltaic power output	PVOUT	4.98 - 5.33	kWh/kWp
Direct normal irradiation	DNI	5.45 - 6.17	kWh/m²
Global horizontal irradiation	GHI	5.93 - 6.50	kWh/m²
Diffuse horizontal irradiation	DIF	2.16 - 2.44	kWh/m²
Global tilted irradiation at the optimum angle	GTI_opta	6.52 - 6.98	kWh/m²
Air temperature	TEMP	25.3 - 28.8	°C
The optimum tilt of PV modules	OPTA	23 - 29	°
Terrain elevation	ELE	325 - 1119	m



(a) (b)

Figure 6. (a) Solar azimuth at Riyadh, (b) location of Riyadh on Map

Table 2. Total Bill of Quantity BOQ for Riyadh station

BOQ							
#	**Item**	**Manufacturer**	**Product Description**	**Quantity**	**Unit**	**Unit Price SAR**	**Total Price SAR**
1	**PV Modules**						
	PV Modules	Longi Solar	STP545-MP-BDV	363,636	Unit	887	322,580,323
	PV Modules - Spare	Longi Solar	STP545-MP-BDV	1,050	Unit	887	931,452
2	**Inverters**						
	Inverters	Huawei	SUN2000-100KTL-M1 (400 or 480V)	1,674	Unit	22,177	37,125,000
	Inverters - Spare	Huawei	SUN2000-100KTL-M1 (400 or 480V)	50	Unit	22,177	1,108,871
3	**Mounting Structure**						
	Mounting Structure		Ground Mounted Fixed Tilt	200,000	kWp	343	68,548,387
4	**Monitoring and Control**						
	Datalogger	Huawei Solis	Smart logger 3000A	30	Unit	2,419	72,581
	Weather Station	Huawei Solis	Meteocontrol Weather Station	10	Unit	50,000	500,000
5	**BOS**						
5.1	MV Components						
	Transformer Station		3200 kVA	50	Unit	498,000	24,900,000
	Switchgear		33 kv	2	Unit	6,000,400	12,000,800
5.2	DC Cables						
	DC Cables	HIS	H1Z2Z2- 1x4 mm²	2,260,500	m	4	9,042,000
	MC4		MC4	40,700	Unit	11	447,700
5.3	AC Cables						
	AC Cables - LV		(3x120)+(1x70)	103,900	m	500	51,950,000
	AC Cables - MV		(3x240)	99,200	m	820	81,344,000
5.4	Earthing System			1		3,500,000	3,500,000
5.5	LV Panels						
	LV Panels		LV Panel 800A	1	Unit	8,000,000	8,000,000
6	**Security System**						
	CCTV EQUIPMENT			80	unit	505	40,400
7	**Civil Works**						
7.1	Fence						
	Perimeter Fence			39,600	m	310	12,276,000
	Fence Gate			4	unit	25,000	100,000
7.2	Buildings						
	Control building			1	unit	190,000	190,000
	Warehouse			1	unit	190,000	190,000
7.3	Other Civil works						
	Trench - LV		1 m X 1.2 m	75,000	m	80	6,000,000
	Trench - MV		1 m X 1 m	30,000	m	10	300,000
	Waste Management System			1	Unit	50,000	50,000
	Fire alarm			1	Unit	200,000	200,000
	installation			200,000	kWp	120	24,000,000
Total Price (SAR)							665,397,513

Project summary

Geographical Site
Riyadh
Saudi Arabia

Situation

Latitude	24.41 °N
Longitude	47.01 °E
Altitude	511 m
Time zone	UTC+3

Project settings

Albedo	0.20

Meteo data
Riyadh
Meteonorm 7.3 (1998-2002), Sat=100% - Synthetic

Figure 7. Summary of Riyadh power station

System summary

Grid-Connected System	**Ground Mounted Solar PV**	
PV Field Orientation	**Near Shadings**	**User's needs**
Fixed plane	No Shadings	Unlimited load (grid)
Tilt/Azimuth 26 / 0 °		

System information

PV Array		**Inverters**	
Nb. of modules	363636 units	Nb. of units	1674 units
Pnom total	200.0 MWp	Pnom total	167.4 MWac
		Pnom ratio	1.195

Figure 8. Summary of systems' information on PV SYST

PV Array Characteristics

PV module		**Inverter**	
Manufacturer	Longi Solar	Manufacturer	Huawei Technologies
Model	LR5-72 HIH 550 M	Model	SUN2000-100KTL-M1-400Vac
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	550 Wp	Unit Nom. Power	100 kWac
Number of PV modules	363636 units	Number of inverters	1674 units
Nominal (STC)	200.0 MWp	Total power	167400 kWac
Modules	25974 Strings x 14 In series	Operating voltage	200-1000 V
At operating cond. (50°C)		Max. power (=>30°C)	110 kWac
Pmpp	182.8 MWp	Pnom ratio (DC:AC)	1.19
U mpp	527 V		
I mpp	347076 A		
Total PV power		**Total inverter power**	
Nominal (STC)	200000 kWp	Total power	167400 kWac
Total	363636 modules	Nb. of inverters	1674 units
Module area	929471 m²	Pnom ratio	1.19
Cell area	843054 m²		

Figure 9. Detailed PV and inverter characteristics of Riyadh project

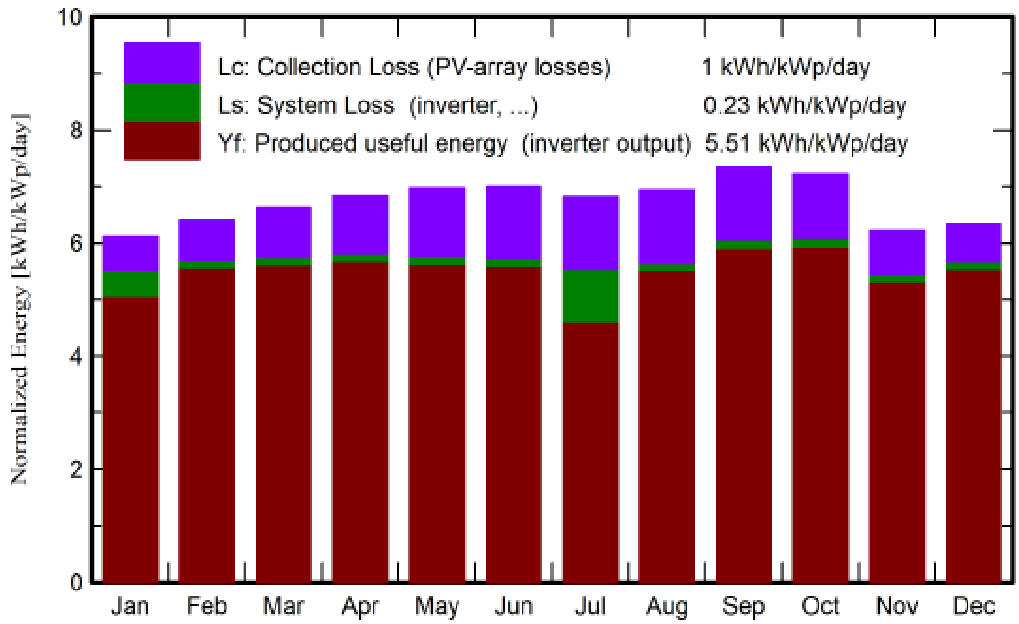


Figure 10. Normalized production for each month in Riyadh station

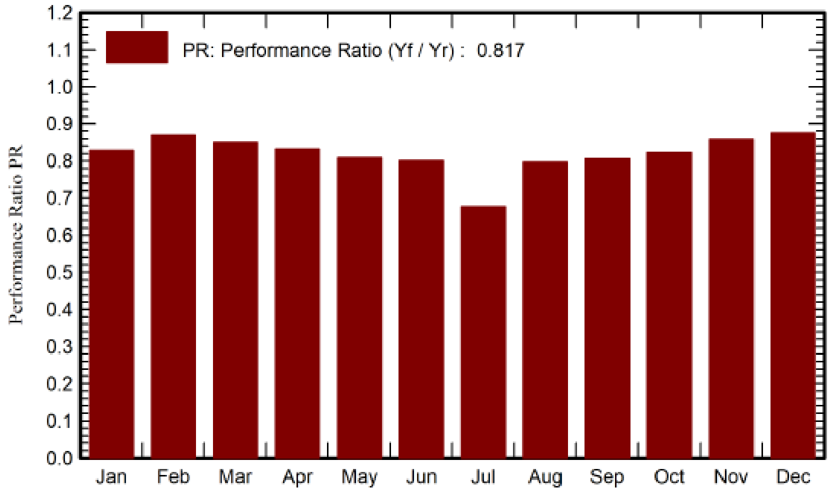


Figure 11. Performance ratio for the monthly modules at Riyadh station

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	137.1	37.9	13.89	189.6	181.7	34292	31404	0.828
February	145.0	50.5	17.18	179.5	172.1	31943	31210	0.869
March	184.4	72.7	22.32	205.3	196.5	35755	34922	0.851
April	203.2	83.5	27.47	205.1	195.6	34928	34117	0.832
May	232.3	92.4	33.85	216.3	205.9	35809	34974	0.809
June	233.0	104.4	35.77	210.0	199.6	34443	33641	0.801
July	231.6	88.0	37.51	211.3	200.9	34483	28594	0.676
August	220.6	90.0	37.49	215.2	205.1	35095	34287	0.797
September	203.8	51.7	33.49	220.0	210.3	36349	35490	0.806
October	184.7	42.9	28.64	223.8	214.3	37730	36835	0.823
November	139.2	38.4	20.88	186.2	178.6	32738	31979	0.859
December	136.9	29.3	15.83	196.8	188.8	35221	34416	0.874
Year	2251.9	781.7	27.08	2459.2	2349.6	418785	401868	0.817

Legends

GlobHor Global horizontal irradiation
DiffHor Horizontal diffuse irradiation
T_Amb Ambient Temperature
GlobInc Global incident in coll. plane
GlobEff Effective Global, corr. for IAM and shadings
EArray Effective energy at the output of the array
E_Grid Energy injected into grid
PR Performance Ratio

Figure 12. Main results of Riyadh station

Total: 7414021.4 tCO_2

Generated emissions

Total: 358211.74 tCO_2

Source: Detailed calculation from table below:

Replaced Emissions

Total: 8957638.4 tCO_2

System production: 401868.03 MWh/yr

Grid Lifecycle Emissions: 743 gCO_2/kWh

Source: IEA List

Country: Saudi Arabia

Lifetime: 30 years

Annual degradation: 1.0 %

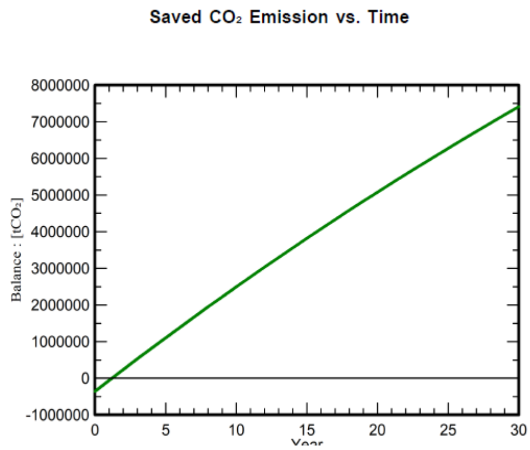


Figure 13. CO_2 emission balance of Riyadh station

3.2. Results for Al-Jubail Site

The exact Project details, PV, and inverter specs are used for the same rating station 200 MWp in Al-Jubail. The slight difference will be in the tilt angle and, for sure, the station's location, as shown in Figure 14 and figure 15.

There is a tiny difference between Al-Jubail and Riyadh in monthly energy production as shown in Figure 16, performance ratio as shown in figure 17, main results as shown in Figure 18, and the Co_2 emission balance as shown in Table 3. Also, there is a slight difference between the BOQ for Riyadh and Al-Jubail as shown in Table 4.

Project summary

Geographical Site	Situation		Project settings	
Al Jubayl Industrial City	Latitude	27.09 °N	Albedo	0.20
Saudi Arabia	Longitude	49.57 °E		
	Altitude	7 m		
	Time zone	UTC+3		

Meteo data
Al Jubayl Industrial City
Meteonorm 7.3 (1998-2002), Sat=100% - Synthetic

Figure 14. Summary of Al-Jubail station

PV Array Characteristics

PV module		Inverter	
Manufacturer	Longi Solar	Manufacturer	Huawei Technologies
Model	LR5-72 HIH 550 M	Model	SUN2000-100KTL-M1-400Vac
(Original PVsyst database)		(Original PVsyst database)	
Unit Nom. Power	550 Wp	Unit Nom. Power	100 kWac
Number of PV modules	363636 units	Number of inverters	1674 units
Nominal (STC)	200.0 MWp	Total power	167400 kWac
Modules	25974 Strings x 14 In series	Operating voltage	200-1000 V
At operating cond. (50°C)		Max. power (=>30°C)	110 kWac
Pmpp	182.8 MWp	Pnom ratio (DC:AC)	1.19
U mpp	527 V		
I mpp	347076 A		
Total PV power		**Total inverter power**	
Nominal (STC)	200000 kWp	Total power	167400 kWac
Total	363636 modules	Nb. of inverters	1674 units
Module area	929471 m²	Pnom ratio	1.19
Cell area	843054 m²		

Figure 15. Details of PV arrays and inverter characteristics for Al-Jubail station

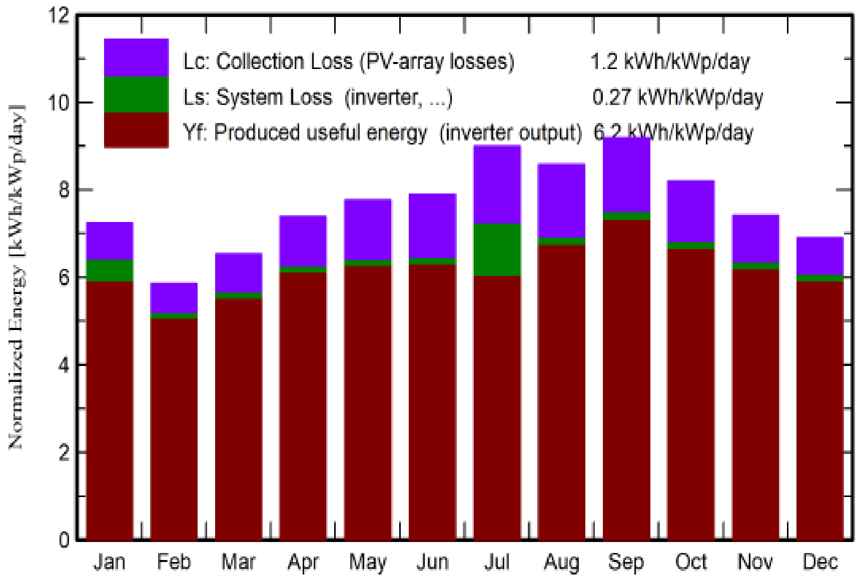


Figure 16. Normalized production per installed kWp for Al-Jubail station monthly

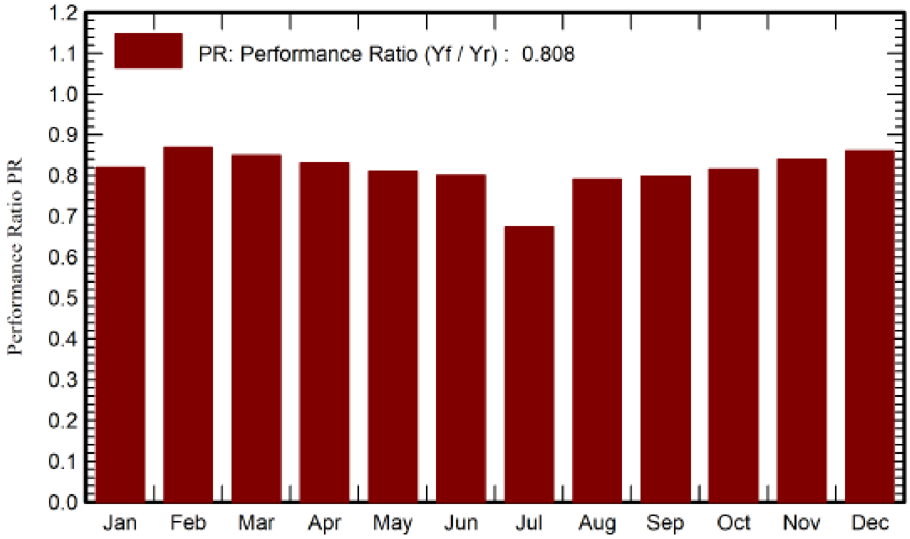


Figure 17. Performance Ratio of Al-Jubail station for each month

Table 3. Main results for Al-Jubail station

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	123.6	39.9	14.54	224.6	217.1	39941	36829	0.820
February	116.2	62.2	16.77	163.9	157.9	29134	28489	0.869
March	156.2	84.2	21.40	202.3	194.9	35208	34409	0.850
April	180.3	92.9	26.47	221.8	213.7	37709	36841	0.831
May	199.6	103.8	32.77	240.7	232.0	39905	38996	0.810
June	200.4	107.3	35.42	237.0	228.4	38861	37980	0.801
July	227.3	103.2	37.23	278.8	269.1	44996	37620	0.675
August	213.9	99.5	36.56	265.7	256.3	43028	42031	0.791
September	195.3	57.2	32.59	275.7	266.5	45091	44009	0.798
October	165.1	56.3	28.92	254.1	245.5	42447	41443	0.816
November	129.6	40.3	22.07	222.3	214.8	38207	37287	0.839
December	116.5	38.2	16.85	214.1	206.9	37732	36843	0.860
Year	2023.9	885.1	26.86	2801.0	2703.1	472261	452776	0.808

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

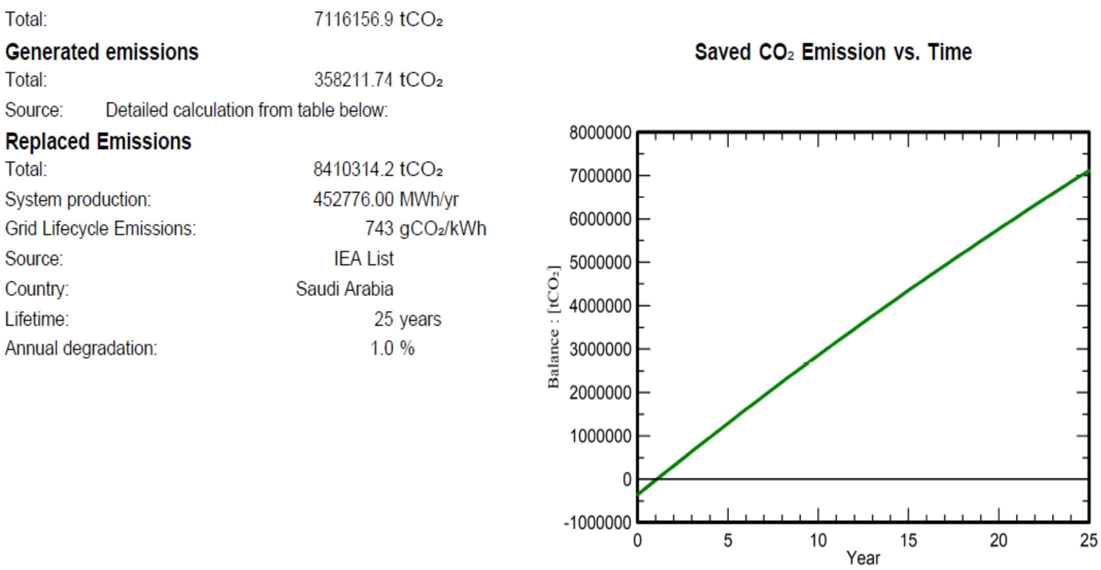


Figure 18. CO_2 emission balance caused by the Al-Jubail station

Table 4. Bill of Quantity for Al-Jubail station

BOQ							
#	Item	Manufacturer	Product Description	Quantity	Unit	Unit Price SAR	Total Price SAR
1	PV Modules						
	PV Modules	Longi Solar	STP545-MP-BDV	363,636	Unit	887	322,580,323
	PV Modules - Spare	Longi Solar	STP545-MP-BDV	1,050	Unit	887	931,452
2	Inverters						
	Inverters	Huawei	SUN2000-100KTL-M1 (400 or 480V)	1,674	Unit	22,177	37,125,000
	Inverters - Spare	Huawei	SUN2000-100KTL-M1 (400 or 480V)	50	Unit	22,177	1,108,871
3	Mounting Structure						
	Duel Axis Tracker Structure		(120/-120) EW , (0/80) tilt angle	36,364	kWp	898	32,654,872
4	Monitoring and Control						
	Datalogger	Huawei Solis	Smart logger 3000A	30	Unit	2,419	72,581
	Weather Station	Huawei Solis	Meteocontrol Weather Station	10	Unit	50,000	500,000
5	BOS						
5.1	MV Components						
	Transformer Station		3200 kVA	50	Unit	498,000	24,900,000
	Switchgear		33 kv	2	Unit	6,000,400	12,000,800
5.2	DC Cables						
	DC Cables	HIS	H1Z2Z2- 1x4 mm²	2,760,500	m	4	11,042,000
	MC4		MC4	40,700	Unit	11	447,700
5.3	AC Cables						
	AC Cables - LV		(3x120)+(1x70)	103,900	m	500	51,950,000
	AC Cables - MV		(3x240)	99,200	m	820	81,344,000
5.4	Earthing System			1		3,500,000	3,500,000
5.5	LV Panels						
	LV Panels		LV Panel 800A	1	Unit	8,000,000	8,000,000
6	Security System						
	CCTV EQUIPMENT			80	unit	505	40,400
7	Civil Works						
7.1	Fence						
	Perimeter Fence			39,600	m	310	12,276,000
	Fence Gate			4	unit	25,000	100,000
7.2	Buildings						
	Control building			1	unit	190,000	190,000
	Warehouse			1	unit	190,000	190,000
7.3	Other Civil works						
	Trench - LV		1 m X 1.2 m	75,000	m	80	6,000,000
	Trench - MV		1 m X 1 m	30,000	m	10	300,000
	Waste Management System			1	Unit	50,000	50,000
	Fire alarm			1	Unit	200,000	200,000
	installation			200,000	kWp	120	24,000,000
Total Price (SAR)							626,103,999

4. 2D and 3D Layouts of Both Stations

It was vital to design the solar power station on any three-dimensional software like 3D-MAX or SketchUp to imagine the total layout of the station and search for the availability of applying this design in real life. This chapter will show the 3D design of both stations, Riyadh and Al-Jubail. Because of the large number of PV panels for each station, the 3D simulation was hard to execute as many details will be fuzzy and hard to detect. So, in the 3D model, we will represent only 10MW, and a total of 200MW will be represented by a 2D model using AutoCAD software.

4.1. Riyadh Station

As shown in Figure 19, the panels have a fixed-tilt mounting structure, and the array pitch N-S is 12 meters. In addition, the total number of modules is 363636, with 550 Wp for each module. Each module weighs 27 kg, and its dimensions are 2256×1133×35 mm. The number of transformers used in this station is 50 units with a capacity of 3200 KVA and an energy yield of 401868 MWh, as shown in figure 20. The solar panel manufacturer is Longi Solar, and the model's name is LR5-72550M with an efficiency of 21.5%. It should be highlighted that the inverter model name is SUN200-100KTL-M1, and its type is Smart String Inverter supplied by Huawei Technologies, shown in Figure 21. The other dimensions are 1035×700×365 mm, it weighs 90 kg, and the nominal power of each inverter is 100 KW shown in Figure 22.

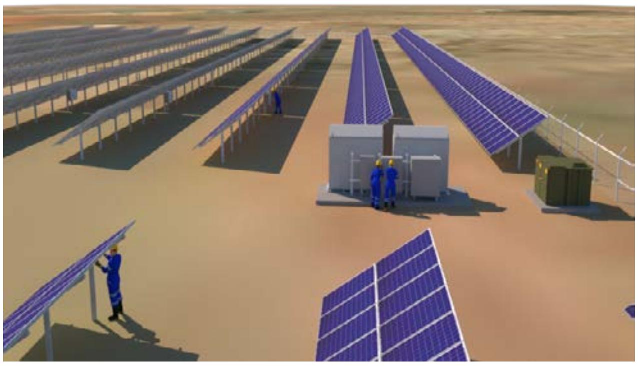


Figure 19. Riyadh PV station view 1

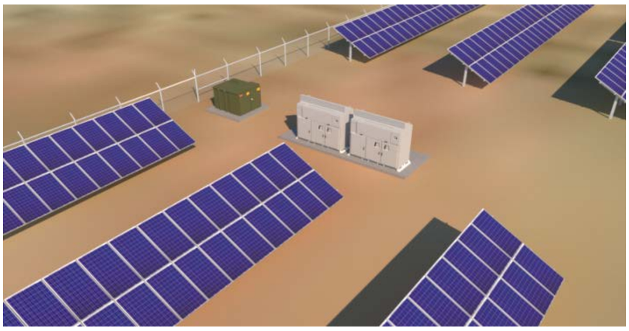


Figure 20. Riyadh PV station view 2 - Transformer

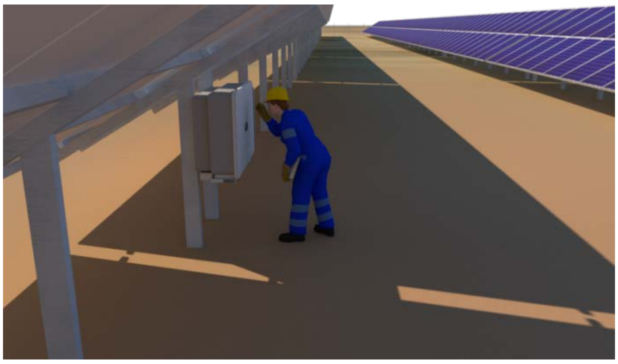


Figure 21. Riyadh PV station view 3 - Inverter

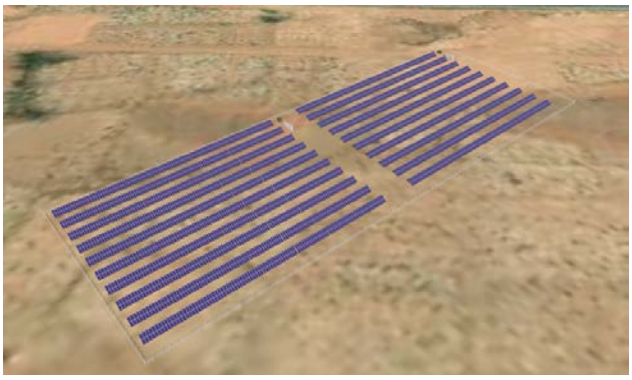


Figure 22. Riyadh PV station view 4

For a complete design, a 2D layout design of the whole station 200 MWp is done on AutoCAD as shown in Figure 23.

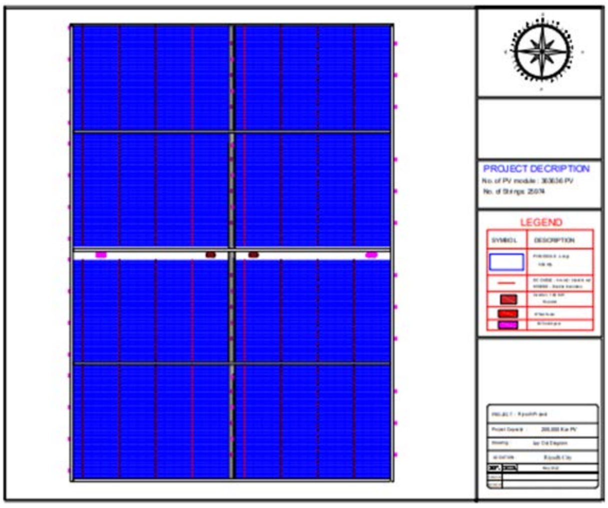


Figure 23. 2D layout of Riyadh PV station

4.2. Al-Jubail Station

Al-Jubail station maybe is like Riyadh station in many specs, but the main difference between them in 3D simulation is that Al-Jubail station has a dual-axis tracker structure, as shown in Figure 24. The number of tracker units is 25974, the number of PV modules is 363636 with 25974 strings, and the distance between trackers is 30 × 30 m. Inverter with same specs of Riyadh station is used here as shown in Figure 25. Solar panels with the same specs of Riyadh station are used here as in Figure 26.

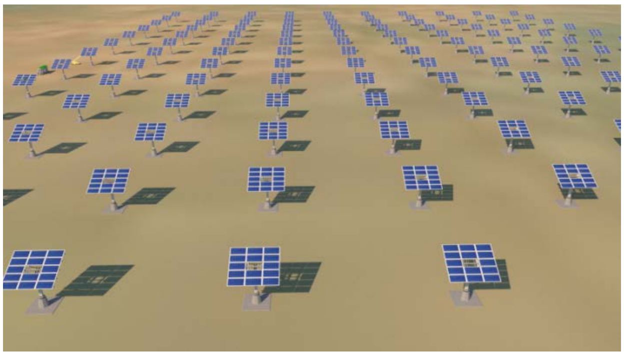


Figure 24. Al-Jubail PV station view 1

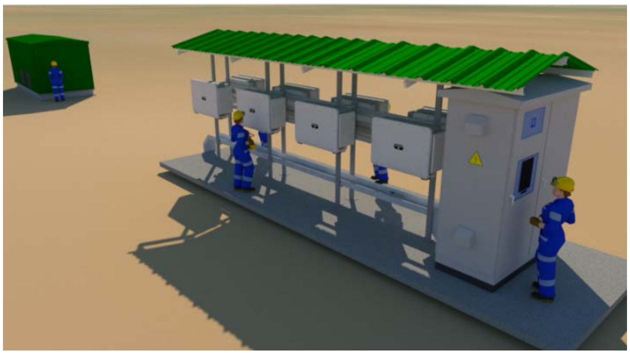


Figure 25. Al-Jubail PV station view 2 - Inverter

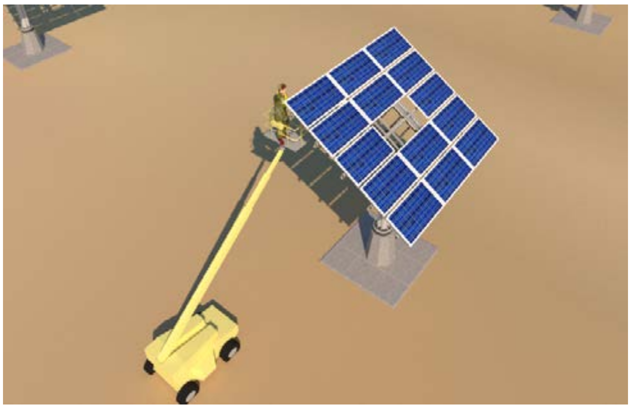


Figure 26. Al-Jubail PV station view 3 - Panels

A comparison between the fixed-tilt option and dual tracker is shown in Figure 27. It could be demonstrated from this comparison that using a dual-axis tracker is more expensive by 32% than the single tracker for only a 15% increase in energy output. Although the area of the dual axis is 14 times larger than the single tracker area, the dual tracker's maintenance cost is very high.

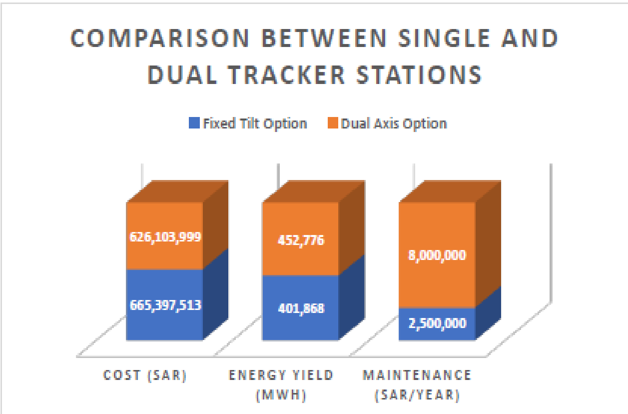


Figure 27. Comparison between single and dual tracker stations

5. Conclusion

There are enormous non-rainy spaces in Saudi Arabia, which with intense solar radiation inside Saudi Arabia that exists all the time, represent a national wealth. In addition, this wealth represents the Saudi Arabia's economic safety in the challenging future. Therefore, Saudi Vision 2030 is a crucial step on the road to renewable energy within Saudi Arabia. The search for the most suitable places to construct solar power plants is a burden for scientific research teams within Saudi Arabia, which must continue to work tirelessly to help the Government implement its plan in 2030. Riyadh and Jubail are vital areas where solar power plants can quickly be built to cover these areas' electricity needs and provide clean energy, reducing environmental and economic damage that can be done with traditional power plants. The establishment of stations elsewhere could contribute to more research enrichment that could result in implementing one of those projects on the ground. In addition, it is possible to study the establishment of medium or small stations and research the feasibility of linking them to the grid or their isolated presence to cover a remote part and provide it with the necessary electrical power. The subject of solar energy is a new topic in Saudi Arabia. However, it can be studied on a broader scale as it contributes to the country's energy supply and job creation for young people.

References

[1] A. Bajawi, Ahmed M. Nahhas, Analytical Study of Power Generation Using PV System for Al-Shuaiba and Al-Shuqiq Regions in Saudi Arabia, American Journal of Energy Research, Vol. 9, No. 1, 21-29, 2021.

[2] Q. Alabdali, A. Bajawi, Ahmed M. Nahhas, Review of Recent Advances of Shading Effect on PV Solar Cells Generation, Sustainable Energy, Vol. 8, No. 1, 1-5, 2020.

[3] G. Alzahrani, F. Alzahrani, Ahmed M. Nahhas, Study of the Specific Factors Effecting the PV Solar Cell's Efficiency in Saudi Arabia, Sustainable Energy, Vol. 8, No. 1, 6-11, 2020.

[4] Q. Alabdali, A. Bajawi, A. Fatani, Ahmed M. Nahhas, Review of Recent Advances of Wind Energy Sustainable Energy, Vol. 8, No. 1, 12-19, 2020.

[5] K. Althobiti, Ahmed M. Nahhas, Recent Advances of Hydropower Energy in Saudi Arabia, American Journal of Energy Research, Vol. 8, No. 1, 1-6, 2020.

[6] Q. Alabdali, Ahmed M. Nahhas, Simulation Study of Grid Connected Photovoltaic System Using PVsyst Software: Analytical Study for Yanbu and Rabigh Regions in Saudi Arabia, American Journal of Energy Research, Vol. 9, No. 1, 30-44, 2021.

[7] G. Alzahrani, Ahmed M. Nahhas, Analytical Study of Power Generation by Photovoltaic System for Al-Riyadh and Al-Jubail Regions in Saudi Arabia, American Journal of Energy Research, Vol. 9, No. 1, 45-55, 2021.

[8] A. Jee, J. Alsluimani, A. Alqurashi, A. Akkur, Ahmed M. Nahhas, Review of Recent Advances of Supercapacitors Energy Storage Systems, Sustainable Energy, Vol. 10, No. 1, 29-42, 2022.

[9] A. Albarrak, A. Alshareef, A. Alshareef, Ahmed M. Nahhas, Review of Hydrogen Based Fuel Cells Energy Storage Systems, Sustainable Energy, Vol. 10, No. 1, 1-20, 2022.

[10] A. Shendi, Ahmad M. Nahha*s*, Power generation by using Photovoltaic systems for Yanbu and Rabigh regions in Saudi Arabia: a cost-effective study, The Islamic University Journal of Applied Sciences (JESC) Vol. 5, No. 1, 2023.

[11] M. Mohandes, S. Rehman, Estimation of global solar radiation using artificial neural networks. Renewable energy, Vol. 14, No.1, 179-184, 1998.

[12] A. Salam, A. Khan, Transition towards sustainable energy production– A review of the progress for solar energy in Saudi Arabia. Energy Exploration & Exploitation, Vol. 36, No. 1, 3-27, 2018.

[13] W. Alnaser, N. Alnaser, The status of renewable energy in the GCC countries. Renew Sustain Energy Rev, Vol. 15, No. 6, 3074-98, 2011.