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LCOE Evaluation Report

No. TRHZHZPVS11003/21TC/03

Applicant: **JinKO Solar Co., Ltd.**

No.1, Lane 1466, Shenchang Road,Minhang District, Shanghai, China

File No.: HZHZPVS11003/21TC

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Applicant..... :	**JinKO Solar Co., Ltd.** No.1, Lane 1466, Shenchang Road,Minhang District, Shanghai, China
Order No..... :	HZHZPVS11003/21TC
Date of Application ..... :	11/01/2021
Evaluation data..... :	Selection of main components (PV modules and inverters) Configuration definition PVsyst simulation CAPEX estimation（EPC） OPEX and land lease estimation

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1. Introduction

At present, N-type technology has gradually become the mainstream product technology in the photovoltaic market, and such technology is leading a major change in the entire industry. The benefits brought by the N-type technology are not only reflected in the increase in the power output of the PV panels, but also in the substantial increase in the module efficiency and the considerable reduction in the cost of the system. Two utility scale ground-mounted PV power plants have been designed. For that purpose and according to the agreed mentioned offer, this report takes these two hypothetical 100MW projects as the research object. Through technical plan review and financial benefit comparison, JinKO's N-type high-efficiency modules JKM610N-78HL4-BDV (denoted by 182-78N-610W), JKM565N72HL4-BDV (denoted by 182-72N-565W) and other mainstream high-efficiency modules on the market (denoted by 210-66-665W, 210-60-605W and 210-55-555W) are compared. The two plants are located in different countries respectively. The configuration of module, tracker and inverter at a specific location is only used as examples to illustrate the LCOE difference for choosing different module technologies. Special attention has been given to the difference in product advantages and system optimization among all the cases. For this purpose, a financial model has been made, allowing us to compare each case in terms of the economic feasibility to meet the needs of investors and EPC companies. In particular:

- Compare the investment for projects, especially EPC costs
- During the full life cycle of the project, compare the internal rate of return (IRR) and the levelized cost of energy (LCOE)

2. Executive Summary

2.1 Location & Solar Resources

The two plants are located in different countries respectively. The basic information of the site is as follows:

Table 2-1-1 Site Information of Gonghe Project

Site Location	Gonghe, Qinghai, China
DC capacity (MW)	120MW
Mounting system	A single-axis tracker system with one module high in portrait orientation (1P)
GPS	100°37'59"E (100.6331) 36°5'48"N (36.0969)
Global horizontal irradiance	1647.6 kWh/m^2
Altitude	2870 m
Mean ambient temperature	3.8°C

Table 2-1-2 Site Information of Lorca Project

Site Location	Lorca, Murcia, Spain
DC capacity (MW)	120MW
Mounting system	A single-axis tracker system with two modules high in portrait orientation (2P)
GPS	-1°53'25"W (-1.8904) 37°43'44"N (37.7290)
Global horizontal irradiance	1788.8 kWh/m^2
Altitude	509 m
Mean ambient temperature	19.5°C

2.2 The Design Scheme

The PV plant land applied to this study is considered as flat and suitable for large scale power plant construction (environmental and ecological impact is neglected), and the high voltage grid electricity transmission line is available near the site. Different cases in the project sites are assumed to be constructed in an approximately equivalent land area with similar DC/AC ratio, to diminish the energy yield difference. The basic information of the design is as follows:

Table 2-2-1 System Design of Gonghe Project

Gonghe Plant			
No.	**Case 1**	**Case 2**	**Case 3**
Module type	**182-72N-565W**	**210-55-555W**	**210-60-605W**
Dimension (mm)	2278×1134×30	2384×1096×35	2172×1303×35
Temperature coefficient of Pmax	-0.30%/°C	-0.34%/°C	-0.35%/°C
Pmax at STC	565Wp	555Wp	605Wp
Vmp at STC	42.14V	31.90V	34.60V
Imp at STC	13.41A	17.40A	17.49A
Voc at STC	50.83V	38.10V	41.70V
Isc at STC	14.19A	18.39A	18.42A
Module efficiency	21.9%	21.4%	21.4%
Bifaciality coefficient	85%	70%	70%
Modules in series per tring	26	34	32
Total number of module	212394	216240	198368
Total number of string	8169	6360	6199
Strings per tracker	3	2	2
Total number of tracker	2723	3180	3100
Pitch (m)	7.50	7.85	7.14
Ground coverage rate (GCR)	30.4%	30.4%	30.4%
DC capacity (MW)	120.00	120.01	120.01

Table 2-2-1 System Design of Gonghe Project (Continued)

Gonghe Plant			
No.	**Case 1**	**Case 2**	**Case 3**
Module type	**182-72N-565W**	**210-55-555W**	**210-60-605W**
String Inverter	SG320HX	SG320HX	SG320HX
MPPT voltage range	500V~1500V	500V~1500V	500V~1500V
Max. PV input current	480A	480A	480A
No. of independent MPPT	14	12	12
AC output power	320kW	320kW	320kW
No. of Inverter	312	312	312
AC capacity (MW)	99.84	99.84	99.84

Table 2-2-2 System Design of Lorca Project

Lorca Plant		
No.	**Case 4**	**Case 5**
Module type	**182-78N-610W**	**210-66-665W**
Dimension (mm)	2465×1134×35	2384×1303×35
Temperature coefficient of Pmax	-0.30%/°C	-0.34%/°C
Pmax at STC	610Wp	665Wp
Vmp at STC	45.73V	38.30V
Imp at STC	13.34A	17.39A
Voc at STC	50.04V	46.10V
Isc at STC	14.11A	18.50A
Module efficiency	21.8%	21.4%
Bifaciality coefficient	85%	70%
Modules in series per tring	26	30
Total number of module	196725	180450
Total number of string	7567	6015

Table 2-2-2 System Design of Lorca Project (Continued)

Lorca Plant		
No.	**Case 4**	**Case 5**
Module type	**182-78N-610W**	**210-66-665W**
Strings per tracker	6	4
Total number of tracker	1262	1504
Pitch (m)	16.22	15.68
Ground coverage rate (GCR)	30.4%	30.4%
DC capacity (MW)	120.00	120.00
String Inverter	SG320HX	SG320HX
MPPT voltage range	500V~1500V	500V~1500V
Max. PV input current	480A	480A
No. of independent MPPT	14	12
AC output power	320kW	320kW
No. of Inverter	312	312
AC capacity (MW)	99.84	99.84

2.3 CAPEX

According to the basic equipment information in section 2.2, combined with TÜV NORD's analogy analysis of existing projects on the market, considering the same geographic location, power station type, meteorological conditions, ground coverage ratio (GCR), and power station design principles, the initial investment cost corresponding to different PV module schemes can be estimated and derived, which includes the project's early development cost, EPC cost and grid connection cost (AC cost).

For the Gonghe project, the total investment is shown in Table 2-3-1 (all prices are in RMB/W).

Table 2-3-1 Total Investment of Gonghe Project

Module type	182-72N-565W	210-55-555W	210-60-605W
Total Project Investment	¥4.2197	¥4.2576	¥4.2705
1 Development Cost	¥0.1000	¥0.1000	¥0.1000
2 Total EPC cost	¥4.1197	¥4.1576	¥4.1705
2.1 Design Fee	¥0.0200	¥0.0200	¥0.0200
2.2 Module cost	¥1.8500	¥1.8500	¥1.8500
2.3 BOS cost	¥2.2292	¥2.2585	¥2.2763
2.3.1 inverter cost	*¥0.1300*	*¥0.1300*	*¥0.1300*
2.3.2 tracker cost	*¥0.5393*	*¥0.5480*	*¥0.5647*
2.3.3 tracker installation cost	*¥0.0790*	*¥0.0782*	*¥0.0849*
*2.3.4 DC cable cost**	*¥0.0224*	*¥0.0234*	*¥0.0231*
2.3.5 DC cable installation cost	*¥0.0130*	*¥0.0094*	*¥0.0093*
2.3.6 AC cable cost	*¥0.0904*	*¥0.1051*	*¥0.0957*
2.3.7 AC cable installation cost	*¥0.0410*	*¥0.0477*	*¥0.0434*
2.3.8 transformer cost	*¥0.0667*	*¥0.0667*	*¥0.0667*
2.3.9 transformer installation cost	*¥0.0200*	*¥0.0200*	*¥0.0200*
2.3.10 labor cost for module	*¥0.0372*	*¥0.0378*	*¥0.0463*
2.3.11 land lease cost	*¥0.0902*	*¥0.0924*	*¥0.0923*
2.3.12 other cost (irrelevant with module type)	*¥1.1000*	*¥1.1000*	*¥1.1000*
2.4 Transportation cost	¥0.0205	¥0.0291	¥0.0242

For the Lorca project in Spain, the total investment is shown in Table 2-3-2 (all prices are in U.S. dollars/W).

Table 2-3-2 Total Investment of Lorca Project

Module type	182-78N-610W	210-66-665W
Total Project Investment	$0.7507	$0.7604
1 Development Cost	$0.1095	$0.1095
2 Total EPC cost	$0.6412	$0.6509
2.1 Design Fee	$0.0156	$0.0156
2.2 Module cost	$0.3000	$0.3000
2.3 BOS cost	$0.3183	$0.3271
2.3.1 inverter cost	$0.0273	$0.0273
2.3.2 tracker cost	$0.1250	$0.1319
2.3.3 tracker installation cost	$0.0200	$0.0212
*2.3.4 DC cable cost**	$0.0058	$0.0072
2.3.5 DC cable installation cost	$0.0048	$0.0046
2.3.6 AC cable cost	$0.0362	$0.0350
2.3.7 AC cable installation cost	$0.0152	$0.0146
2.3.8 transformer cost	$0.0255	$0.0255
2.3.9 transformer installation cost	$0.0015	$0.0015
2.3.10 labor cost for module	$0.0100	$0.0110
2.3.11 land lease cost	$0.0141	$0.0144
2.3.12 other cost (irrelevant with module type)	$0.0330	$0.0330
2.4 Transportation cost	$0.0072	$0.0081

*Remark：As the 210 modules have higher currents than the 182 module, a larger DC string conductor size was used for these conductors to keep the DC losses relatively similar to those of the 182 module. Specification of DC cables used by 182-72N-565W and 182-78N-610W is PV1-F 4.0 mm^2；Specification of DC cables used by 210-55-555W, 210-55-555W, 210-66-665W is PV1-F 6.0 mm^2.

2.4 Lifetime Energy Revenue

By bringing the parameters of the above-mentioned module cases into the PVsyst software, the 1st year power generation of each case can be simulated and calculated. For comparison, it is assumed that the operation and maintenance cost of each module are the same.

Table 2-4-1 Comparison of Project Power Generation

Plant	Gonghe Qinghai China			Lorca, Murcia, Spain	
Module type	182-72N-565W	210-55-555W	210-60-605W	182-78N-610W	210-66-665W
Warranty (years)	30				
Degradation in 1st year	1%	2%		1%	2%
Degradation from 2nd year	0.40%	0.45%		0.40%	0.45%
O&M in 1st year	¥60.7/kW			$9.5/kW	

3. Project financial simulation

3.1 Financial model

Table 3-1-1 Financial Model Conditions of Gonghe Project

Plant	Gonghe Qinghai China		
Module type	182-72N-565W	210-55-555W	210-60-605W
Loan/equity ratio		30/70	
Loan interest (year)		4.9	
Loan period		15	
VAT		13%	
Urban construction tax		5%	
Education surcharge tax		5%	
Corporate income tax		25%	
Discount rate		7%	
Residual value		5%	
PPA price		¥0.3160/kWh	

Table 3-1-2 Financial Model Conditions of Lorca Project

Plant	Lorca, Murcia, Spain	
Module type	182-78N-610W	210-66-665W
Loan/equity ratio	30/70	
Loan interest (year)	4.1	
Loan period	15	
VAT	21%	
Corporate income tax	25%	
Discount rate	7%	
Residual value	5%	
PPA price	$0.0550/kWh	

3.2 Levelized Cost of Energy（LCOE）

Levelized cost of electricity (LCOE) is the full lifecycle costs of a power generating technology per unit of electricity. It is an economic assessment of the average net present cost of electricity generation for a generating plant over its lifetime. It accounts for all lifecycle costs of the system including operation, maintenance, construction, taxes, insurance, and other financial obligations of the project. In the LCOE analysis, cost and benefit estimates are adjusted to account for inflation and are discounted to reflect the time value of the money.

The fundamental definition of LCOE is shown in equation below：

$$\mathrm{LCOE} = \frac{C + \sum_{t=1}^{n} \frac{(L_t + M_t + T_t)}{(1+r)^t} - \frac{R}{(1+r)^n} + \sum_{t=1}^{n} I_t}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

C：Total investment capital；

n：30 years life-cycle；

L_t：Land fee in the t year；

M_t：O&M fee in the t year；

T_t：Tax in the t year；

R：Residual value；

I_t：Interests expenditure in the t year；

E_t：Electricity generation in the t year；

r：Discount rate；

According to the project data details provided by JinKO, TÜV NORD separately calculated the LCOE of the five cases.

In the plant of Gonghe, Qinghai, China, the case that used 182-72N-565W module has the lowest LCOE, which is ¥0.2955, as shown in Figure 3-2-1.

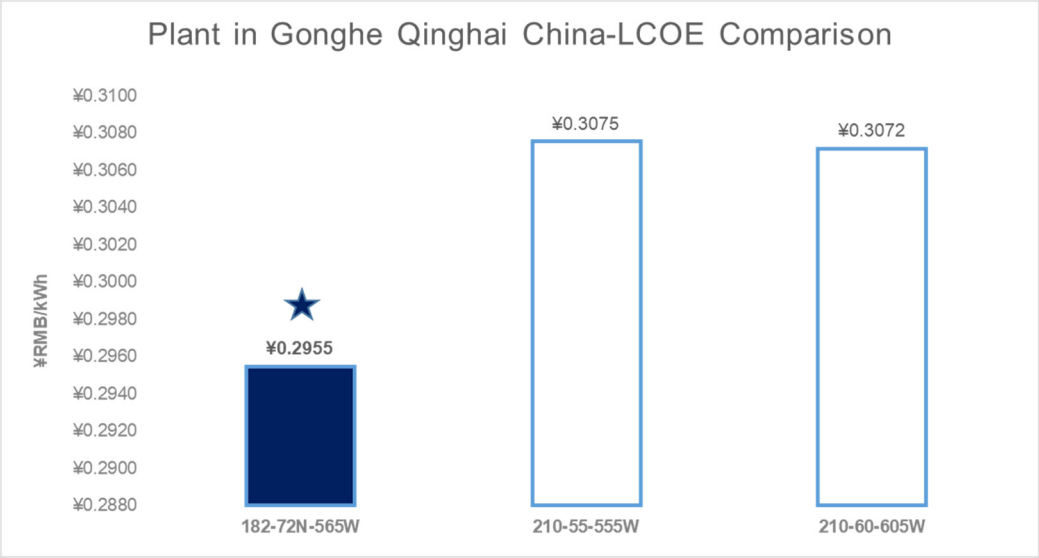


Figure 3-2-1 Comparison of LCOE of Gonghe Project

In the plant of Lorca, Murcia, Spain, the case that used 182-78N-610W module has the lowest LCOE which is $0.0480, as shown in Figure 3-2-2.

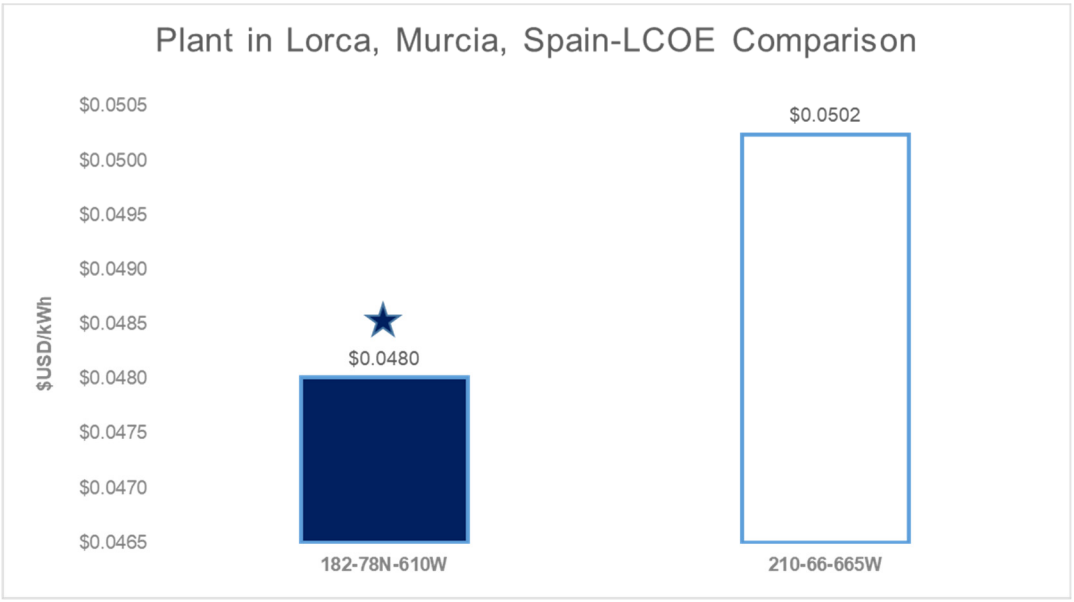


Figure 3-2-2 Comparison of LCOE of Lorca Project

3.3 Internal Rate of Return (IRR)

IRR, the full name of the internal rate of return, is generally considered to be the profitability of project investment, clearly reflecting the efficiency of investment use. Compared with net present value and net annual value, actual economic workers in all domains prefer to use the internal rate of return to evaluate projects' performance. The outstanding advantage of the internal rate of return index is that there is no need to set a benchmark discount rate in advance, which avoids a difficult and controversial issue. The internal rate of return is not given exogenously in advance, but determined endogenously, that is, calculated by the project cash flow. When the base discount rate is not easy to determine its exact value but only its approximate value range, then it is easier to judge the choice of the project by using the internal rate of return index. The superiority of IRR comparison in this case is obvious.

The discount rate when the cash outflow and the inflow of the investment project are equal, is the IRR value, and the formula is as follows:

$$\sum_{t=1}^{n} \frac{CF_t}{(1+IRR)^t} - I_0 = 0$$

CF_t：Cash flow in the t year；

n：30 years life-cycle；

I_0：Initial self investment；

According to the project data details provided by JinKO and considering the bank's capital leverage, TÜV NORD separately calculated the Equity IRR of five cases.

In the plant of Gonghe, Qinghai, China, the case that used 182-72N-565W module has the highest IRR, which is 13.79%.

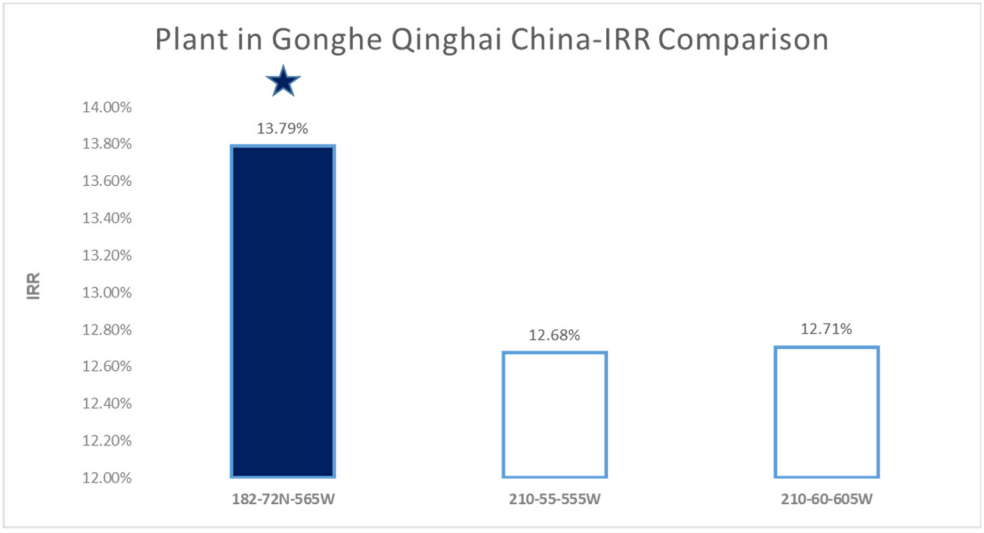


Figure 3-3-1 Comparison of IRR of Gonghe Project

In the plant of Lorca, Murcia, Spain, the case used 182-78N-610W module has the highest IRR which is 15.80%：

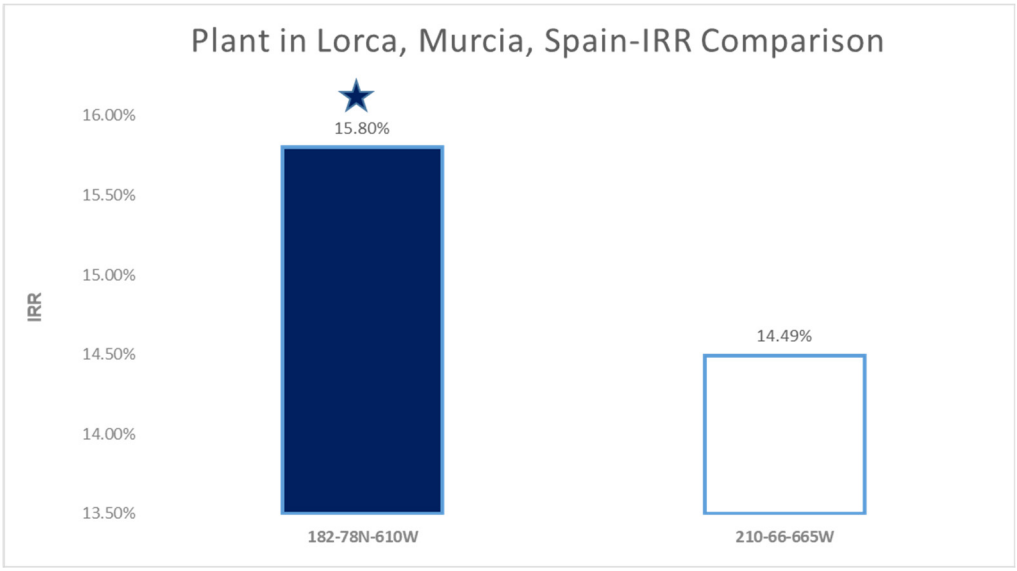


Figure 3-3-2 Comparison of LCOE of Lorca Projects

4. Analysis Conclusions

From the results of this analysis, when the unified DC side capacity, land availability, system design principles and module prices are determined, Jinko's N-type products have great advantages in terms of the cost per kilowatt-hour and profitability investment in large-scale ground power station projects in China and Spain. The advantages of Jinko's N-type modules are mainly reflected in:

1. High-efficiency modules can greatly reduce the initial investment cost of the project (modules, BOS equipment procurement costs, EPC construction costs, etc.);

2. It can save the use area of the plant, thereby reducing the annual land lease cost;

3. JinKO's N-type modules have a lower power degradation (1% in the 1st year, 0.4%/yr from the 2nd year), higher bifaciality coefficient (85%). **In the TÜV NORD outdoor performance project, compared with the P-type module with the same dimension, the kW power generation capacity of the N-type module is 5.26%* higher**. Therefore, the electricity generated during the whole life cycle of the N-type modules project increased, which greatly reduces the LCOE.

The following is a comparative summary of the three cases in Gonghe Qinghai China project:

Table 4-1-1 Comparison Summary of Gonghe Project

Case	Case 1	Case 2	Case 3
Module type	182-72N-565W	210-55-555W	210-60-605W
Pmax at STC	565Wp	555Wp	605Wp
Module efficiency	21.9%	21.4%	21.4%
Enery Production in the 1st year	251,335 MWh	244,681 MWh	245,556 MWh
DC/AC ratio	1.2	1.2	1.2
Total number of module	212,394	216,240	198,368
Total number of string	8,169	6,360	6,199
EPC cost per watt	¥4.1197	¥4.1576	¥4.1705
Total Project Investment	¥506,378,030	¥510,956,865	¥512,506,604
Total Equity investment	¥151,913,409	¥153,287,059	¥153,751,981
LCOE	¥0.2955	¥0.3075	¥0.3072
Equity IRR	Baseline	91.96% (ratio)	92.17% (ratio)

The following is a summary of the comparison of the two cases of the Lorca projects in Spain.

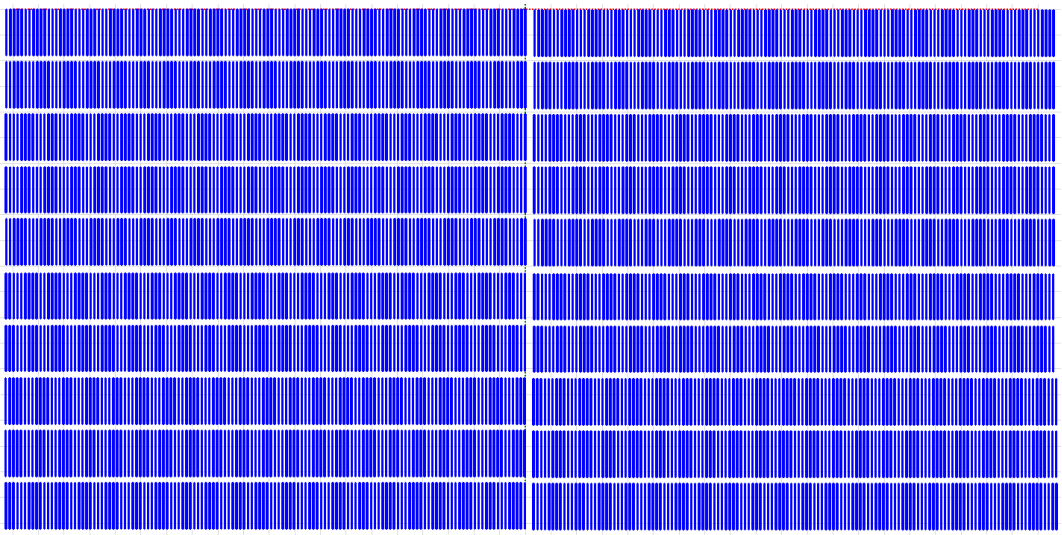
Table 4-1-2 Comparison Summary of Lorca Project

Case	Case 4	Case 5
Module type	182-78N-610W	210-66-665W
Pmax at STC	610	665
Module efficiency	21.8%	21.4%
Enery Production in the 1st year	260,084 MWh	252,619 MWh
DC/AC ratio	1.2	1.2
Total number of module	196,742	180,450
Total number of string	7,567	6,015
EPC cost per watt	$0.6412	$0.6509
Total Project Investment	$90,088,807	$91,244,009
Total Equity investment	$27,026,642	$27,373,203
LCOE	$0.0480	$0.0502
Equity IRR	Baseline	91.71% (ratio)

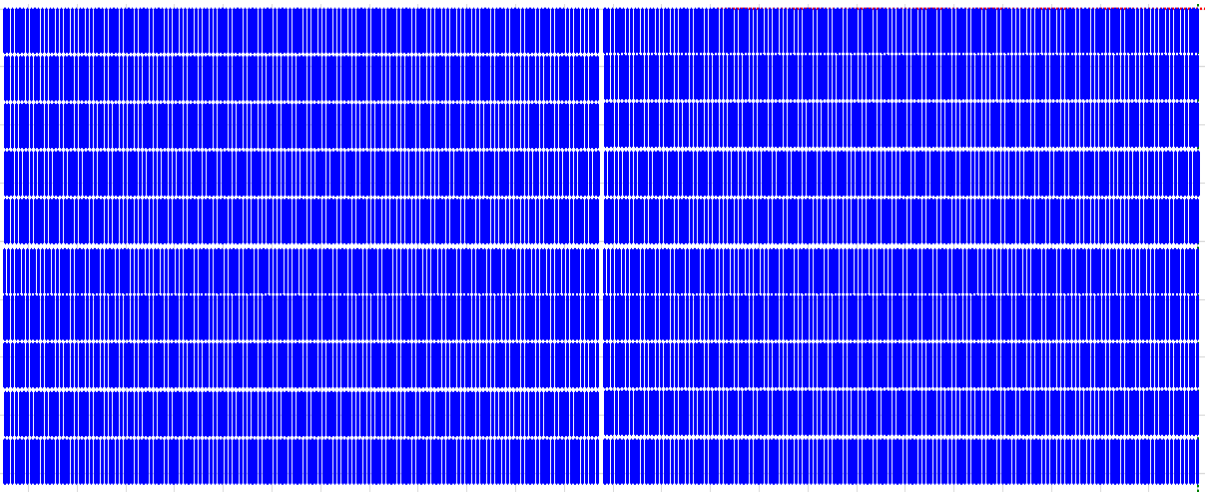
*Remark: The data source is the TÜV NORD China Yinchuan Outdoor Demonstration Base. During 04/22/2017-07/08/2017, the N-type modules and P-type modules with the same dimension are installed on the same fixed mounting system.

Annex: Project layout

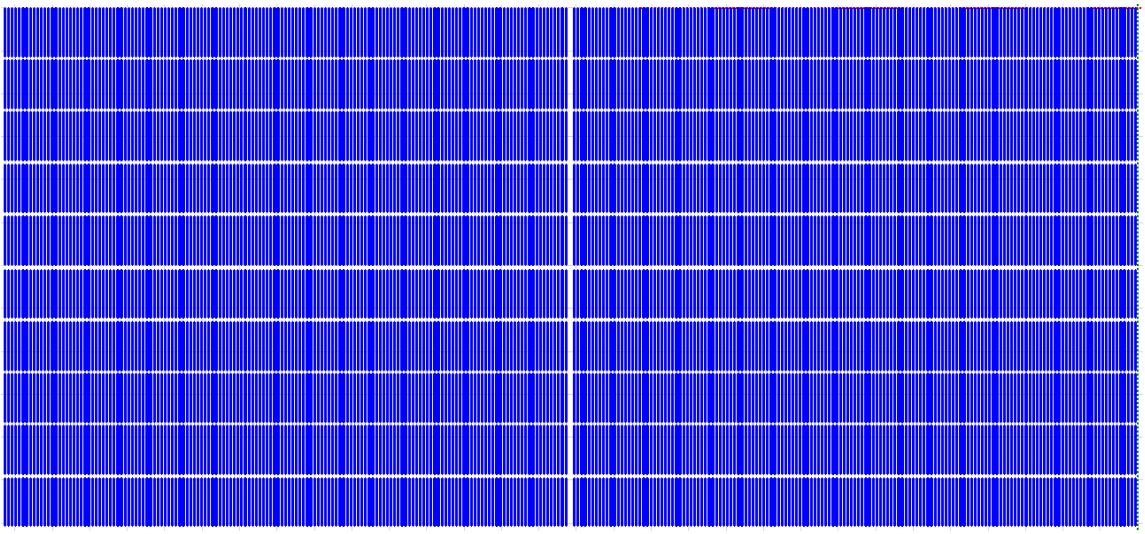
Case 1： 182-72N-565W 1P Tracker



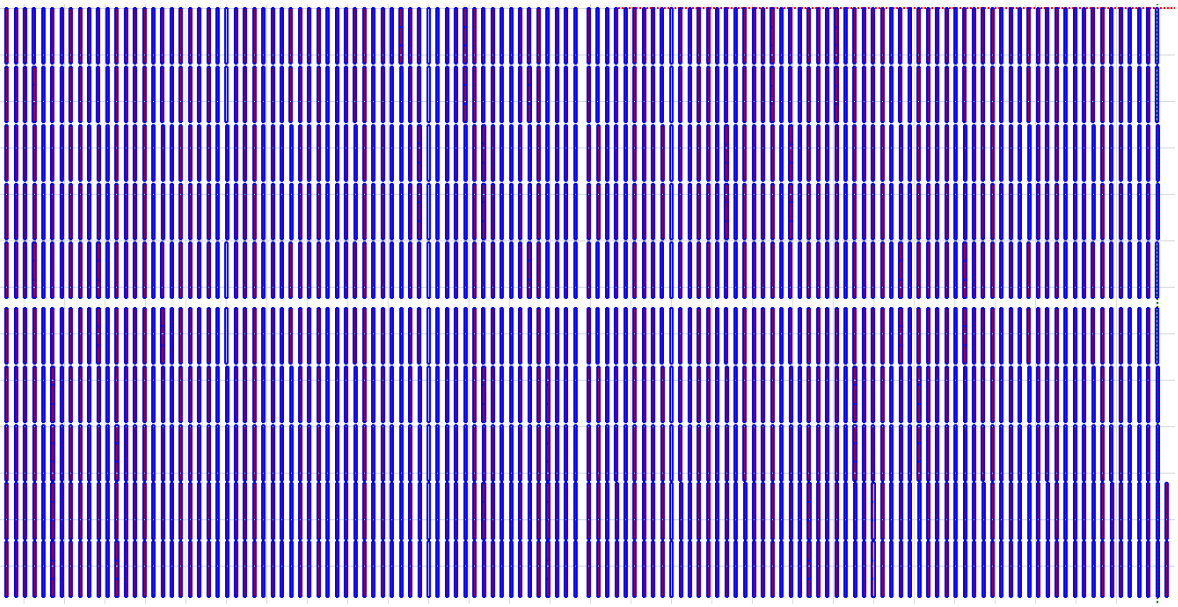
Case 2： 210-55-555W 1P Tracker



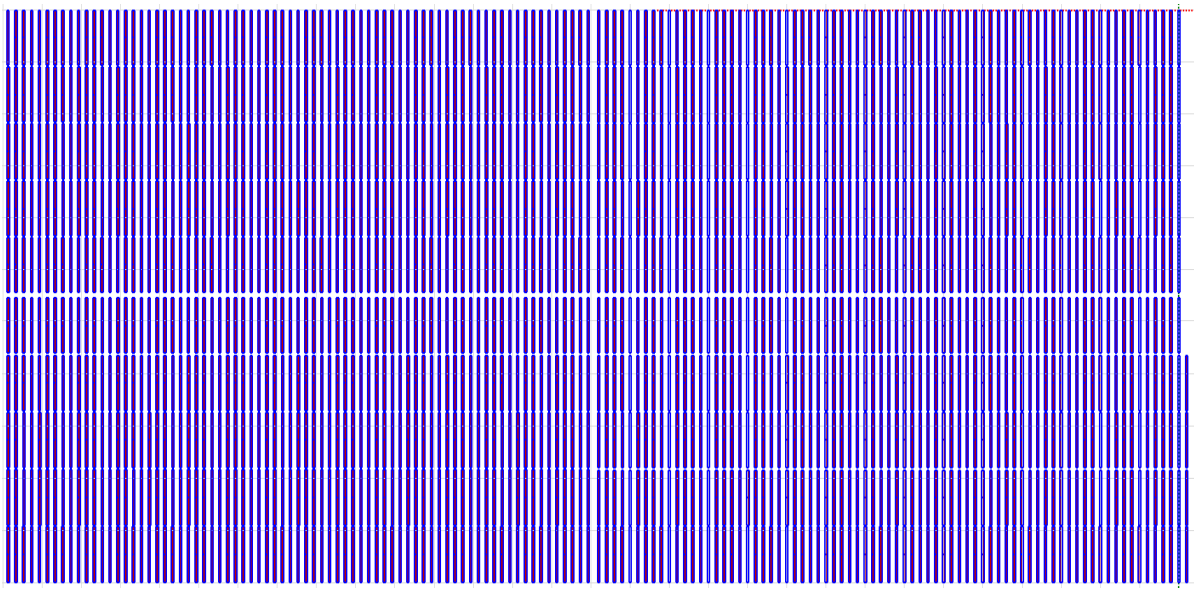
Case 3： 210-60-605W 1P Tracker



Case 4： 182-78N-610W 2P Tracker



Case 5： 210-66-665W 2P Tracker



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