Proceedings of Symposium on Electrical, Mechatronics and Applied Science 2018 (SEMA'18), pp. 109-110, 8 November 2018

Inverter selection impact to large scale solar photovoltaic power plant layout in Malaysia

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Keywords: Inverter; Solar; Power Plant

ABSTRACT – This paper presents method of optimisation design of the large scale solar photovoltaic (PV) power plant. The techno-economic of the large scale solar power plant (LSSPV) was direct impact from on the plant layout design, PV module and inverter technology selection, and cable selection and strategy of inverter and combiner boxes locations respectively. The key findings suggest the right methodology of the large scale solar power plant design to achieve competitive system price and optimum solar PV plant performance. The methodology of optimisation of the solar power plant can be consider by Malaysian Project Developers and Contractors as reference.

1. INTRODUCTION

Since June 2011, Malaysia Renewable Energy (RE) Act 2011 was gazette with introduce Feed-in Tariff (FIT) scheme [1]. 1.6% collection scheme from public electricity bill as RE projects development supporting scheme. Solar PV system is one the RE program which encouraged by Sustainable Energy Development Authority (SEDA) [2]. However, the install capacity of the Solar PV is reached to maximum target capacity under the FIT scheme in 2017 [2]. To sustain the solar industrial, the Malaysia Energy Commission (EC) and SEDA to launch several solar PV programs to industrial. The large scale solar photovoltaic plant (PSSPV) is one of popular programs implemented to public since April 2016 with installation target 1GW [3].

Project Developers and Engineering, Procurement, Construction and Commissioning (EPCC) contractor would like to know the lowest solar PV power plant system price with high quality construction to achieve fastest project financing return in global investment condition. Researches on solar PV system design mainly focus on PV module and inverter technology selection, cable selection and strategy of inverter and combiner boxes locations and solar PV system evaluation. Furthermore, the plant layout design method is one of the key factor to determine the cable length and cable energy loss along transportation energy which may cause to investment return.

From solar PV market, more investor to solar system cause by degradation of the system price. The right methodology of design and construction to be firm respectively. There would direct reflected to components and implementation price to be increased or reduced. Various solar PV system price would impact to project financial modelling, energy tariff, and return year. This paper aims to techno-economic impact from various design method and components selection.

2. METHODOLOGY

The standard equations to calculate the PV module Open circuit voltage, number of PV modules in string connection, and copper weight of cable were used in this case study [4,5].

The number of PV modules in string connection equation can be written as:

$$N_{string} = 1500 / (V_{oc}(1 + \gamma_{coef}(T_{cell} - T_{stc}))) \quad (1)$$

where:
N_{string} is the number of PV modules in string connection
V_{oc} is the Open circuit voltage
γ_{coef} is the temperature coefficient, %/ °C
T_{module} is the PV module cell temperature, °C, and
T_{stc} is the temperature at standard test condition, 25 °C

The cable copper weight equation as below

$$Q_{DC} = 2*[(\rho*L_{DC}{}^{2}*P^{2}*\delta) / (P_{loss}*V_{DC}{}^{2})] \quad (2)$$

where:
Q_{DC} is the total weight of the solar cable conductor (kg),
P is the power output of PV modules at STC (W),
δ is the conductor density (kg/dm^3), and
V_{DC} (V) is the line voltage.

The technical characteristics of the solar inverters are show in Table 1 with string inverter and central inverter but difference brands. The plant layout design based on IEC TS 62738 Ground-mounted Photovoltaic Power Plants – Guidelines and Recommendations.

Table 1 solar inverter characteristic.

Characteristic	Central Inverter	String Inverter	Unit
Maximum power	1498	60	kW
Maximum voltage	1500	1100	V
MPPT voltage	850-1320	200-1000	V
Maximum input current	2,000	22	A
Maximum out current	1,575	86.7	A
AC output voltage	550	400	V
Frequency	50/60	50/60	Hz
Efficiency	98.9	98.7	%
MPPT	1	6	W
Power factor (capacitive and inductive)	0-1	0.8 -1	
Weight	1600	74	kg

3. SYSTEM DESCRIPTION

Typical solar PV plant characteristic per block for central inverter and string inverter are 7.84MW and 7.68MW respectively with both 6MW output capacity from both types of solar inverter to transformer.

4. RESULT AND DISCUSSION

This section discussed the total cable length, copper weight, cable loss and cost impact total cable length and losses both plant layout. Cable is one of the cost can be controlled by proper plant layout design the strategy location of combiner box for central inverter and string inverter of the plant layout. To optimise the plant layout design, the combiner boxes are located at vertical of the central inverter plant layout, while string inverters are located vertical of each sub-block. From strategy of combiner boxed and string inverters for each combination plant layouts. The result showing that the cable cost and copper weight used by central inverter plant layout is lower than the string inverter Plant layout. Differences of the price and copper weight are MYR 562,037.86 without installation cost and 13,185.46 kg respectively for each 6.0MW_{ac} block. The cable loss from central inverter and string inverter PV plant are 1.11% and 1.22% respectively. Although the cable loss between central inverter and string inverter is very close with 0.11% differences. The energy loss does not much impact to energy generation. In addition, 3 short lines of cable trenching from central inverter, while string inverter require 5 short lines of cable trenching. With extra works on cable trenching will cost impact to EPCC propose solar PV system price. Moreover, the labour and installation cost will be more impact to PV system price based on the plant layout design.

Table 2 comparison of cable between central inverter and string inverter typical plant layout per block.

Characteristic	Central inverter	String inverter
4mm^2 Cable length (m)	95,650	298,912.16
Total copper weight for 4mm^2 cable (kg)	6,886.80	21,521.68
Total 4mm^2 cable cost (MYR)	286,950	896,736.48
50mm2 cable length (m)	2,598	-
Total copper weight for 50mm^2 cable (kg)	1,532.82	-
Total 50mm^2 cable cost (MYR)	70,353.70	
Total AC low voltage cable length (m)	-	200
Total AC low voltage cable copper weight (kg)	-	83.4
Total AC low voltage cable cost (MYR)		22,140.48
Total copper weight (kg)	8,419.62	21,605.08
Total DC and AC cable cost (MYR)	357,303.70	919,341.56
Cable loss (DC cable and cable loss before transformer	1.11%	1.22%

5. CONCLUSION

The paper presented a comparative study of typical solar PV plant layouts by used central inverter and string inverter in inverter station components, cable length copper weight, cost impact to system price shows that central inverter will be more beneficial to Project Developer and EPCC Contractor in large scale solar PV power plant design. Total difference price for components cost and cable cost for each 6.0MW per block is MYR 1,045,873.06 without installation cost. From all reasons show that the central inverter is more suitable applied to large scale solar PV power plant compare to string inverter which are suitable install to small scale solar PV system.

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