Abstract—The solar PV has become an alternative solution in Malaysia to generate electricity. Unfortunately the solar PV installed in Malaysia is attracted to the lightning strike. There were two points that have high possibilities of being strike by the lightning; on the DC side between the solar PV and inverter and on the AC side, between the inverter and the substation. Therefore, this study was performed to analyse the effects of lightning strike at these two different points at the solar PV farm without any lightning protection system (LPS).

Keywords—solar PV, lightning current, striking point, transient voltage, inverter, DC, AC

I. INTRODUCTION

The solar PV farm in Malaysia was attracted to the lightning strike since the installation is in wide open area. Malaysia located near the equator give high radiation and also high lightning densities. According to the United States National Lightning Safety Institution, Malaysia has an average thunder level of 180-260 days per year [1]. A lightning strike can cause an interruption and damage to the electronic equipments of the solar PV system like solar PV modules, string inverters, transformers, and cables. [2]. This interruption or damage can contribute to losses and affect the solar PV performance [3]. The extent of the electronics component damage depends on few characteristics like lightning peak current, lightning current waveshapes and the location of striking points. This study will analysed the impact of striking points on the DC and AC side at the solar PV farm without any LPS install. In addition, this study will give the impact if the designer ignored or underestimate the importance of installing the LPS in the solar PV farm.

II. SOLAR PV FARM

A solar PV farm (1 MW) was developed in the PSCAD/EMTDC simulation. This solar PV farm consists of 4032 solar PV modules of 250 W each with 42 string inverters to convert the DC output of solar PV to AC output. The illustration of the solar PV farm was shown in Fig.1.
III. LIGHTNING CURRENT OF 10/350 µS

The lightning current waveshape was modeled using the Heidler function as defined in Equations 1 and 2 [4] since the Heidler function provides more realistic results and recommended by IEC 62350-1 [5].

\[
I(t) = \frac{l_{m}}{\eta} \left(\frac{t}{\tau_1}\right)^n \exp\left(-\frac{t}{\tau_2}\right)
\]

(1)

\[
\eta = \exp\left[\frac{-r_1}{r_2\left(r_2/r_1\right)^{1/(n+1)}}\right]
\]

(2)

where \(l_{m}\) = peak current
\(\eta\) = correction factor of peak current
\(\tau_1\) = rise time constant
\(\tau_2\) = fall time constant
\(n\) = steepness factor

Fig.2 illustrate the 10/350 µs lightning current waveshape using the Heidler function.

IV. IMPULSE WITHSTAND VOLTAGE (\(U_{\text{sw}}\)) FOR ELECTRONIC COMPONENTS IN SOLAR PV SYSTEM

The components of solar PV system have its specific withstand voltage. Table 12 in Section 7.3.7.1.4 in the MS IEC 60664-1 tabulated the withstand voltage of the electronic components on the DC and AC side of the solar PV system as shown in Fig.3.

For this solar PV farm, the impulse withstand voltage for the solar PV array and inverter for the DC side is 6 kV. While on the AC side, the impulse withstand voltage for the inverter is 2.5 kV and 4 kV for the transformer.

V. RESULT AND DISCUSSION

The lightning strike was apply at two separate point; SP1 and SP2 that have high possibilities strike by the lightning in the solar PV farm. SP1 is on the DC side between the solar PV array and inverter and SP2 is on the AC side between inverter and substation as shown in Fig.4.
The lightning current waveshape of 10/350µs representing a direct lightning strike since the solar PV farm was installed in open area. A 50kA lightning peak current was used for this analysis.

<table>
<thead>
<tr>
<th>Lightning Amplitude (kA)</th>
<th>SP1 (Vpv) (kV)</th>
<th>SP2 (Vinv DC (kV))</th>
<th>SP2 (Vinv AC (kV))</th>
<th>SP2 (Vtrans (kV))</th>
<th>SP2 (Vinv sub (kV))</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1 (PV Array)</td>
<td>328.60</td>
<td>113.39</td>
<td>4.44</td>
<td>0.27</td>
<td>0.27</td>
</tr>
<tr>
<td>P2 (before Inverter)</td>
<td>2.00</td>
<td>2.00</td>
<td>399.83</td>
<td>354.79</td>
<td>354.79</td>
</tr>
<tr>
<td>P3 (after Inverter)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>P4 (before Transformer)</td>
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<tr>
<td>P5 (before Inverter 2)</td>
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</tbody>
</table>

When the lightning strike hit the conductor, the voltage and current were generated and travel along the conductor line at the solar PV farm. All the results were analyse by plotting in a graph based on the lightning strike at 50 kA peak current with 10/350 µs lightning current waveshape at each measured point as below.

Fig.5 illustrates 328.60 kV of transient voltage appearing at the solar PV Array 1 which exceeds the impulse withstand voltage when the lightning strike was at the SP1. A 2 kV transient voltage measured when the strike was at SP2 which does not cause a damage to the solar PV module but this voltage can cause degradation to the solar PV module, as studied in [7]. Therefore, the solar PV modules sustained damage when the lightning strike at SP1 and faced degradation if the lightning strike were to be at SP2.

Fig.6 shows the transient voltage and current detected prior to entering the inverter at DC output. The transient voltage is 113.39 kV for lightning strike at SP1 and at SP2 is similar to transient at solar PV array.

Fig.7 presents the transient voltage after leaving the inverter (AC output) at P3. The AC output shows at least one phase was impacted by the lightning strike. The inverter faced a total damage from when the lightning strike at SP2 and SP1. The difference between these two points of strike were a high transient (399.83 kV) was detected at AC side when the lightning strike was at SP2 compared to that a high transient (113.39 kV) was detected at DC side when the lightning strike was at SP1. In other words, high transience occurs at the nearest point of the lightning strike.
Whilst Fig. 8 shows a high transient voltage; 354.79 kV were measured at the transformer (at P4) when the lightning strike was at SP2, which again will damage the transformer and cause degradation when lightning strike was at SP1 [8, 9].

Although the lightning strikes were at SP1 and SP2 in the series line of the solar PV array 1, the transient voltage also could cause damage to the other parts of the string inverter due to generated travelling waves throughout the system. Obviously, high transient voltage of 354.79 kV that damage the subsequence string inverter appears when the lightning strike is at SP2, as shown in Fig. 9.

VI. CONCLUSION

In conclusion, the electronic components near the striking points have highest possibilities of being damaged compared to the far one. The electronic parts in the long connection also will be damaged if the LPS are neglected. This is because the transient voltage and current can travel along the connected cable from the lightning striking point although the damage may not be as severe as the electronic parts near the striking point. In addition, the transient voltage also causes a degradation of the electronic parts that are not damaged directly by high voltage and current cause by the lightning strike [10]. Therefore, the installation of LPS was important to protect all the electronics components in the solar PV farm.

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REFERENCES

