Abstract—This paper presents power loss analysis of grid-connection PV systems, based on the loss factors of double line-frequency voltage ripple, fast irradiance variation, fast dc load variation, non-uniform solar cell characteristic, and limited operating voltage range. These loss factors will result in power deviation from the maximum power points (MPP). In the power loss analysis, both single-stage and two-stage grid connection PV systems are considered. The effects of these loss factors on two-stage grid-connection PV systems are insignificant due to an additional maximum power point tracker (MPPT), but it will reduce the system efficiency typically about 3%. The power loss caused by these loss factors in single-stage grid-connection PV systems is also around 3%; that is, a single-stage grid-connection PV system has the merits of saving components and reducing cost, while does not scarify overall system efficiency. Simulation results with a MATLAB software package are presented to confirm the analysis.

Index Terms—power loss analysis, loss factor, single-stage grid-connection PV system, and two-stage grid-connection PV system.

I. INTRODUCTION

Photovoltaic (PV) grid-connection systems based on either a single-stage or a two-stage configuration have been widely studied. The grid-connection PV systems can draw maximum power from PV modules and inject the power into utility grid with unity power factor. However, the loss factors, such as operational conditions, components, and grid voltage, will deviate effective PV output power.

In a grid-connection PV system (GCPVS), PV power varies with operational conditions, such as irradiance, temperature, light incident angle, reduction of sunlight transmittance on glass of module, and shading [1]-[6]. These factors have been investigated in detail and the authors present diagnosis methods to estimate the reduction of PV power. Moreover, a special condition, snow coverage, has been also discussed [7], which was compared with other coverage situations like shading and dirt. Then, another loss factor, such as components, solar cell serial resistance, and capacity loss in PV batteries, has been reported [2], [8]-[10]. The above mentioned loss factors are related to cells themselves, which do not cause deviation from the maximum power points (MPPs) during system operation. Even though a PV system is under a specific operating condition, there are still loss factors like double line-frequency voltage ripple from ac grid [11]-[16], and fast irradiance variation [17], causing deviation from the MPPs and also resulting in power loss. However, these factors have not been taken into account in power loss analysis for both single-stage and two-stage GCPVS.

This paper presents power loss analysis according to five loss factors, which might deviate the operating points from the MPPs. First, modeling of solar cells and numerical analysis including I-V characteristics of PV modules to derive the effect of double line-frequency voltage ripple on both single-stage and two-stage GCPVS are conducted. Then, power loss analysis due to fast irradiance and dc load variation is performed, which is based on the above derivation. Moreover, non-uniform solar cell characteristics, which also cause power loss, due to different MPPs in each PV module will be taken into account. Finally, since the operating voltage range of PV modules in a single-stage GCPVS might be directly applied to dc electric appliances and grid-connection inverters, their input dc voltage should be limited, such as 360 ~ 400 V. This limitation will result in power loss, since the effect of temperature and irradiance will drive the MPPs of the PV modules out of the operating voltage range.

In a two-stage GCPVS, an additional boost converter can alleviate the effect of the loss factors. However, the converter will cause power loss typically about 3% and increase component cost and count. According to a preliminary analysis of the above mentioned effects on a single-stage GCPVS, the power loss is not significant and even smaller than 3%. Therefore, a single-stage GCPVS is feasible in dc distribution and grid-connection applications, which will be analyzed in detail in this paper.

II. MODELING OF PV ARRAY

This section models a PV array, consisting of 8 in series and 2 in parallel PV modules (sun power 315) for a single-stage GCPVS or 4 in series and 4 in parallel for a two-stage GCPVS. The power loss analysis based on the loss factors will be then presented in the next section.

Output current \( i_{pv} \) of the solar cell can be expressed as

\[
i_{pv} = n_p I_{sc} - n_p I_{sat} \left[ \frac{q \eta_T}{k A n_s} \right] - 1,
\]

where

\[
I_{sat} = I_{sc} \left[ \frac{T}{T_r} \right] \exp \left[ \frac{qE_{gap}}{kA} \left( \frac{1}{T} - \frac{1}{T_r} \right) \right].
\]

current source \( I_{sc} \) is the light induced current, \( n_p \) is the number of solar cells in parallel, \( n_s \) is the number of solar cells in series,
q is the electric charge, k is the Boltzmann constant, T is the temperature of solar cells (in Kelvin), A is the diode ideal factor (A = 1–5), Tr is the reference temperature of the solar cell, Ir is the reverse saturation current at Tr, and Egap is the band gap of the solar cell (in electro-volts) [18]. Table 1 lists parameters of a sun power 315 PV module [19], which are used in (1). By tuning ideal diode factor A = 1.43 and energy band gap Egap = 1.11 eV, a PV module can be then simulated and compared with the commercially available results, as shown in Fig. 1. It can be observed that the simulated results are relatively close to the commercially available ones, which can insure accuracy of the following analysis.

### Table 1. Specifications of the 315 W solar module (sun power 315)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Peak Power (+/-5%) Pmpp</td>
<td>315 W</td>
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<tr>
<td>Rated Voltage Vmpp</td>
<td>54.7 V</td>
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<tr>
<td>Rated Current Impp</td>
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<td>Open Circuit Voltage Voc</td>
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<tr>
<td>Short Circuit Current Isc</td>
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<tr>
<td>Temperature Coefficient of Current</td>
<td>3.5 mA/°C</td>
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</table>

Fig. 1. PV module I-V characteristics of (a) the simulated results and (b) the commercially available results (sun power 315)

![Fig. 1. PV module I-V characteristics](image)

III. ANALYSIS OF POWER LOSS

This section presents power loss analysis of both single-stage and two-stage GCPVS, which includes the effects of double line-frequency voltage ripple, fast irradiance variation, fast dc load change, non-uniform solar cell characteristic, and limited operating voltage range, 360 ~ 400 V. The analysis is based on the simulated PV module model.

### A. Double Line-Frequency Voltage Ripple

#### (A) Single-stage GCPVS

Circuit configuration of a single-stage GCPVS is shown in Fig. 2, in which PV array output power is injected into ac grid through an inverter. We assume that the system reaches a maximum power point Pmpp under a specific irradiance. That is, its PV voltage Vpp and current Ipp are constant, and equal Vmpp and Impp, respectively. However, the effect of double line-frequency voltage ripple on deviation of PV voltage away from the MPP will cause power loss, which can be expressed as

\[
P_{\text{loss}}(kT_s) = P_{\text{mpp}}(kT_s) + \Delta P_{\text{loss}}(kT_s),
\]

where

\[
\Delta P_{\text{loss}}(kT_s) = P_{\text{mpp}} - v_{\text{mpp}}(kT_s) \cdot i_{\text{mpp}}(kT_s).
\]

First, expressions for \( v_{\text{mpp}} \) and \( i_{\text{mpp}} \) are derived, and then the power loss can be determined. Voltage \( v_{\text{mpp}} \) can be expressed as

\[
v_{\text{mpp}}(kT_s) = v_{\text{mpp}}((k-1)T_s) + \Delta v_{\text{mpp}}(kT_s),
\]

where

\[
\Delta v_{\text{mpp}}(kT_s) = \frac{T_s}{C_{\text{pv}}} \left[ v_{\text{mpp}}((k-1)T_s) - v_{\text{mpp}}((k-1)T_s) \right].
\]

From the above equations, we can determine the turn-on time interval as follows:

\[
d(kT_s) = \left[ \frac{L_{\text{ac}}}{L_{\text{ac}}} \right] \left[ v_{\text{mpp}}(kT_s) - v_{\text{mpp}}(kT_s) \right] - v_{\text{mpp}}(kT_s) \left( 1 - d(kT_s) \right).
\]

From (1) to (5), power loss \( \rho_{\text{loss}} \) deviating from the MPP during one line period (1/60Hz) can be calculated.

#### (B) Two-stage GCPVS

Circuit configuration, with a boost converter functioning as an MPPT, of a two-stage GCPVS is shown in Fig. 4. The effect of double line-frequency voltage ripple on the PV modules

![Fig. 2. Circuit configuration of a single-stage GCPVS](image)

![Fig. 3. Conceptual current waveforms of Id, Isc, and Is](image)
could become insignificant due to its filtering inductor $L_{bs}$, PV terminal capacitor $C_{pv}$ and dc-link capacitor $C_{link}$. Assuming that boost switching cycle is the same as inverter switching cycle $T_s$, the variation of PV voltage $v_{pv}$ is the same as (3) except inductor current $i_{Lb}$. Determination of boost inductor current $i_{Lb}$ is illustrated in Fig. 5. Before the next perturbation of maximum power point tracking, it is necessary to keep the average value of $i_{Lb}$ equaling MPP current $I_{mpp}$. Therefore, we can adopt an average method to determine $i_{Lb}$ where the average value of $i_{Lb}$ should equal $I_{mpp}$ during turn-on interval $d_bT_s$.

It can be expressed as

$$i_{Lb}(kT_s) = i_{Lb}(kT_s) + \Delta i_{Lb}((k-1)T_s) - \frac{v_{pv}((k-1)T_s) - v_{load}((k-1)T_s)}{L_b} [1 - d_b((k-1)T_s)],$$

where

$$\Delta i_{Lb}((k-1)T_s) = \frac{v_{pv}((k-1)T_s)}{L_b} \cdot d_b((k-1)T_s),$$

$$i_{Lb}(0) = I_{mpp} - \frac{\Delta i_{Lb}(0)}{2},$$

and

$$\Delta i_{Lb}(0) = \frac{V_{mpp}}{L_b} \cdot d_b(0) \cdot T_s,$$

From (6), we can have

$$d_b(kT_s) = \frac{2(I_{mpp} - i_{Lb}(kT_s))}{v_{pv}(kT_s)} \cdot L_b,$$

Power loss analysis according to the loss factor of double line-frequency voltage ripple can be attained from (1) to (8).

![Circuit configuration of a two-stage GCPVS with a boost converter functioning as an MPPT](image)

**Fig. 4.** Circuit configuration of a two-stage GCPVS with a boost converter functioning as an MPPT

$$d_b(kT_s) = \frac{p_{dc \_load}(kT_s)}{i_{Lb}(kT_s) \cdot L_b},$$

$$i_{Lb}(0) = I_{mpp},$$

**Fig. 5.** Illustration of inductor current $i_{Lb}$ varying with time

**B. Fast Irradiance Variation**

The output power of a PV array is strongly dependent on irradiance and temperature, where irradiance would change rapidly in a cloudy day. Under certain cloudy days, the variation can be dramatic and fast. A cloud passing over partial PV modules will cause operating point deviating from the MPP and resulting in power loss. Then, by setting the change of irradiance $\Delta S$ over one line period (1/60Hz) and combining (1) with the analysis of double line-frequency voltage ripple, as well as the effect of fast irradiance variation on PV voltage $v_{pv}$, power loss $P_{loss}$ for the two GCPVS can be determined as

$$P_{loss} = E_T / T_s,$$

where

$$E_T = \sum_{k=0}^{N} E_{loss}(kT_s),$$

$$N = T_s / T_l,$$

$$E_{loss}(kT_s) = \left[ \Delta P_{loss}(kT_s) + \Delta P_{loss}((k-1)T_s) \right] / 2,$$

$$\Delta P_{loss}(kT_s) = P_{mpp}(S(kT_s)) - P_{mpp}(kT_s),$$

$$P_{mpp}(S(kT_s)) = S_{k}(kT_s) = S_{k}((k-1)T_s) + \Delta S / T_s,$$

$E_T$ is the total energy loss in one line period, $T_l$ is the line period, and $E_{loss}$ is the energy loss over one switching period $T_l$. Moreover, for a boost MPPT converter in a two-stage GCPVS, sampling period and current command perturbation are 1 ms and 1 %, respectively.

**C. Fast DC Load Variation**

In both single-stage and two-stage GCPVS, when the dc load starts to absorb power, dc-link capacitor current $i_c$ will drop and PV voltage $v_{pv}$ will drop correspondingly. PV voltage $v_{pv}$ will then deviate from the MPP and result in power loss. We assume that capacitors $C_{pv}$ and $C_{link}$ can hold enough energy to supply the bi-directional inverter, and the required power $P_{dc \_load}$ for dc load and rising time $T_{rise}$ from no load to the full load are given. Thus, the expression for dc load power $p_{dc \_load}$ is shown as follows:

$$p_{dc \_load}(kT_s) = p_{dc \_load}((k-1)T_s) + \Delta p_{dc \_load},$$

where

$$\Delta p_{dc \_load} = \frac{P_{dc \_load}}{T_{rise}} \cdot T_s,$$

and

$$p_{dc \_load}(0) = 0.$$

Analysis of power loss due to fast dc load variation can be accomplished from (10), and based on the derivation of double line-frequency voltage ripple from (1) to (8).

**D. Non-uniform Solar Cell Characteristic**

In a PV array, the characteristics of solar cells might vary from cells to cells, which will result in different maximum power point voltage $V_{mpp}$ and thus power loss. By tuning the diode ideal factor $A$ in (1) slightly, we can simulate a voltage difference of about $\pm 5$ V in a PV array. The power loss caused by the characteristic mismatch can be expressed by

$$P_{loss}(CM) = P_{mpp}(A_s) - P_{mpp}(A_t),$$

where $A_s$ is the original diode ideal factor, and $A_t$ is the tuned diode ideal factor. With equations (1) and (11), comparison of the power loss due to this loss factor in a single-stage and a two-stage GCPVS can be then simulated.

**E. Limited operating voltage range**

In a single-stage GCPVS, operating voltage range of PV arrays must be limited due to finite ac grid voltage. For instance, the peak value of 220 V ac grid voltage is close to 311 V.
so that the MPP voltage of PV arrays should be higher than 311V for possible grid connection. Therefore, we set the MPP voltage range, from 360 to 400 V for a single-stage GCPVS. In general, MPP voltage changes with irradiance and temperature. Therefore, from $I-V$ characteristic equations of the cells, the power loss caused by the limited operating voltage range can be determined as

$$P_{\text{Loss}} = P_{\text{mp}}(S_i,T) - P_{\text{pp,L}},$$

where $P_{\text{mp}}(S_i,T)$ is the MPP under certain irradiance and temperature, and $P_{\text{pp,L}}$ is the PV output power under a limited operating voltage range.

**IV. SIMULATION RESULTS AND DISCUSSION**

This section shows simulation results of the power loss analysis due to the loss factors, and the plots of power loss versus different operating conditions such as irradiance, dc-link capacitance, and PV-side capacitance. In addition, effects of the loss factors on both single-stage and two-stage GCPVS are discussed.

(A). Double Line-Frequency Voltage Ripple

For the PV module model shown in section II, the operating conditions, irradiance $S_i = 1000 \text{ W/m}^2$ and temperature $60 \degree \text{C}$, are selected. In both a single-stage and a two-stage GCPVS, maximum power $P_{\text{mp}}$ of PV arrays is about 4.5 kW. The range of PV capacitor $C_{pv}$ has six levels from 470 $\mu$F to 4700 $\mu$F in a single-stage GCPVS. According to the above power loss analysis of double line-frequency voltage ripple with MATLAB, the waveforms of $v_{pp}$ and $p_{pp}$ can be simulated, as shown in Fig. 6, in which the system is operated with $C_{pv} = 2000 \mu$F. Then, by calculating the voltage ripple of $v_{pp}$ and the power loss, plots of $C_{pv}$ versus voltage ripple and power loss are illustrated in Fig. 7. When PV capacitor $C_{pv}$ is larger than 1000 $\mu$F, voltage ripple is lower than 9 % and power loss is below 0.6 %; that is, for a 4.5 kW PV system, capacitance above 1000 $\mu$F is high enough to alleviate the effect of double line-frequency voltage ripple.

For a two-stage GCPVS, dc-link capacitor $C_{\text{link}}$ is fixed at 2000 $\mu$F, and the range of $C_{pv}$ varies from 47 to 470 $\mu$F. Fig. 8 shows the ripple waveform of dc-link voltage $v_{\text{link}}$, PV voltage $v_{pv}$, and PV output power $p_{pv}$ with $C_{pv} = 470 \mu$F. The voltage ripple of $v_{pv}$ and the power ripple are approximated to be zero, hence the ripple effect can be even ignored. Finally, the plots of $C_{pv}$ versus the percentage of PV voltage ripple and power loss are shown in Fig. 9. The component of the power ripple is almost due to switching-frequency. Therefore, we can select PV capacitor $C_{pv} = 100 \mu$F, which is sufficient enough to filter out the effect of double line-frequency voltage ripple.

(B). Fast Irradiance Variation

Assuming that fast variation of irradiance $\Delta S_i$ during one line cycle (1/60 Hz) is 100 W/m$^2$ and the PV array temperature does not change. Moreover, the operation conditions, $C_{pv} = 2000 \mu$F for a single-stage GCPVS, and $C_{\text{link}} = 2000 \mu$F and $C_{pv} = 330 \mu$F for a two-stage GCPVS, are selected. According to the above power loss analysis of fast irradiance variation, the ripple waveforms of PV output power $p_{pv}$ can be simulated as shown in Fig. 10. The power loss in a single-stage and a two-stage GCPVS are 0.16 % and 0.11 %, respectively. It can be seen that the operating power do not deviate from the MPP significantly; that is, this effect is not significant.

(C). Fast DC Load Variation

For common dc home appliances, some like air-conditioners consume high power above 500 W per set and others such as lamps and computers just consume low power below 300 W. Assuming that a set of dc equipment includes two air-conditioners (maximum power is 2000 W), ten lamps (about 400 W), two computers (about 500 W) and the rising times of their power are 3 min, 1 ms, and 0.5 ms, respectively. That is, the fastest variation is 500 W/0.5ms. Moreover, the
operating conditions, $C_{pv} = 2000 \mu F$ for a single-stage GCPVS, and $C_{slak} = 2000 \mu F$ and $C_{pv} = 330 \mu F$ for a two-stage GCPVS, are selected. The simulated results can be obtained from (10) with parameters $P_{dc} = 500 \text{ W}$ and $T_{rise} = 0.5 \text{ ms}$, as shown in Fig. 11 and Fig. 12. The power loss caused by a deviation from the MPP under fast dc load variation is 0.34 % in a single-stage GCPVS and 0.005 % in a two-stage GCPVS.

(D). Non-uniform Solar Cell Characteristic

With the parameters shown in (1) and setting an ideal diode factor $A = 1.43$, one can simulate a PV module to fit a real one. Additionally, we assume that the voltage difference of about $\pm 5 \text{ V}$ at $S_i = 1000 \text{ W/m}^2$ and $60 \text{ °C}$ for three PV arrays, A, B, and C, where array B is the reference model which is kept with the original PV modules, while the operating voltage of arrays A and C are $V_{mpv,a} \pm 5 \text{ V}$. By tuning the factors, $A_d = 1.56$ for array A and $A_C = 1.31$ for array C, which can achieve the voltage difference of about $\pm 5 \text{ V}$, the simulation results for both single-stage and two-stage GCPVS can be obtained and are shown in Table 2 and Table 3, respectively. The power deviation in arrays A and C from array B is around $\pm 2.5 \%$, and the difference between single-stage and two-stage GCPVS is insignificant.

(E). Limited Operating Voltage Range

As mentioned above, operating voltage $V_{mpv}$ deviating out of the limited range, $360 \sim 400 \text{ V}$, will cause power loss. In the following, the power loss versus irradiance and temperature under the limited voltage range is investigated and plotted. Notice that seldom are occurring operating conditions removed from the plots, since some temperature levels could not happen under certain irradiance, such as $25 \sim 30 \text{ °C}$ under $S_i = 700 \sim 1000 \text{ W/m}^2$, $50 \text{ °C}$ under $S_i = 100 \sim 200 \text{ W/m}^2$, and $60 \text{ °C} \sim 70 \text{ °C}$ under $S_i = 100 \sim 300 \text{ W/m}^2$. With simulation, plots of irradiance versus MPP voltage and plots of irradiance versus power loss are illustrated in Fig. 13. The power loss due to the limited operating voltage range is about $0 \sim 2 \%$, and the maximum one under 600 $\text{ W/m}^2$ and 25 $\text{ °C}$ is 2.05 %.

B. Efficiency Comparison

In a two-stage GCPVS, the loss factor, limited operating voltage range, does not result in power loss, since a PV array is not directly connected to a grid-connection inverter. As a result, the power loss due to the factor is set to 0 %. Table 4 shows the operating conditions for the two systems. A boost converter loss typically about 3 % is considered. Then, according to the above simulation, the power loss due to the loss factors under the discussed operating conditions are shown in Table 5. It can be seen that the total loss in a single-stage GCPVS is smaller than that in a two-stage GCPVS.

### Table 2. Power deviation due to non-uniform PV array in a single-stage GCPVS at 60 °C

<table>
<thead>
<tr>
<th>Irradiance (W/m²)</th>
<th>$V_{mpv,A}$ (V)</th>
<th>$V_{mpv,B}$ (V)</th>
<th>$V_{mpv,C}$ (V)</th>
<th>$P_{mpv,A}$ (W)</th>
<th>$P_{mpv,B}$ (W)</th>
<th>$P_{mpv,C}$ (W)</th>
<th>Power Deviation (Array A)</th>
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### Table 3. Power deviation due to non-uniform PV array in a two-stage GCPVS at 60 °C

<table>
<thead>
<tr>
<th>Irradiance (W/m²)</th>
<th>$V_{mpv,A}$ (V)</th>
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</table>

V. CONCLUSIONS

This paper has presented numerical analysis with MATLAB to simulate the power loss caused by deviation from the MPPs for both a single-stage and a two-stage GCPVS. The deviation is primarily due to the loss factors of double line-frequency voltage ripple, fast irradiance variation, fast dc load variation, non-uniform solar cell characteristic, and limited operating voltage range. These loss factors are almost independent so that the overall power loss can be summarized from each individual one. Analysis and simulation procedure of the power loss has been described, which provides engineers a guide for building a PV array model and performing the power loss analysis. According to the loss analysis, the total power loss in a single-stage GCPVS is close to a two-stage GCPVS, while the single-stage one can save a stage of maximum power point tracker. That is, from the viewpoint of efficiency, cost and system size, a single-stage GCPVS is feasible in dc distribution and grid-connection applications.
<table>
<thead>
<tr>
<th>Irradiance (W/m²)</th>
<th>Vmpp,A (V)</th>
<th>Vmpp,C (V)</th>
<th>Pmpp,A (W)</th>
<th>Pmpp,B (W)</th>
<th>Power Deviation (Array A)</th>
<th>Power Deviation (Array C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>191</td>
<td>193.5</td>
<td>196</td>
<td>1094</td>
<td>1117</td>
<td>1140</td>
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<tr>
<td>900</td>
<td>189</td>
<td>192</td>
<td>194.5</td>
<td>975</td>
<td>997</td>
<td>1018</td>
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<tr>
<td>800</td>
<td>187.5</td>
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<td>878</td>
<td>897</td>
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<tr>
<td>700</td>
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<td>188</td>
<td>191</td>
<td>741</td>
<td>759</td>
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<td>642</td>
<td>658</td>
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<tr>
<td>500</td>
<td>180</td>
<td>183.5</td>
<td>186.5</td>
<td>513</td>
<td>527</td>
<td>541</td>
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<tr>
<td>400</td>
<td>176.5</td>
<td>180</td>
<td>183.5</td>
<td>401</td>
<td>414</td>
<td>425</td>
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</tbody>
</table>

Table 3. Power deviation due to non-uniform PV array in two-stage GCPVS at 60 °C

<table>
<thead>
<tr>
<th>Loss factors</th>
<th>System type</th>
<th>Single-Stage GCPVS</th>
<th>Two-Stage GCPVS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double Line-Frequency Voltage Ripple</td>
<td>0.14 %</td>
<td>0.006 %</td>
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</tr>
<tr>
<td>Fast Irradiance Variation</td>
<td>0.16 %</td>
<td>0.11 %</td>
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</tr>
<tr>
<td>Fast DC Load Variation</td>
<td>0.34 %</td>
<td>0.005 %</td>
<td></td>
</tr>
<tr>
<td>Non-uniform Solar Cell Characteristic</td>
<td>2.5 %</td>
<td>2.5 %</td>
<td></td>
</tr>
<tr>
<td>Limited Operating Voltage Range</td>
<td>2.05 %</td>
<td>0 %</td>
<td></td>
</tr>
<tr>
<td>Boost Converter Loss</td>
<td>0 %</td>
<td>Typically 3 %</td>
<td></td>
</tr>
<tr>
<td>Total Loss</td>
<td>5.19 %</td>
<td>5.621 %</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Operating conditions of the two PV systems

Table 5. Power loss of the two PV systems

REFERENCE


