Study on Effect of Installation Location on Lifetime of PV Inverter and DC-to-AC Ratio

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ABSTRACT The reliability improvement of a PV inverter is one of the important aspects to decrease the cost of PV energy. Furthermore, oversizing the PV arrays is a commonly applied strategy to achieve the cost of PV energy reduction but it may also have a negative impact on the cost of PV energy since it accelerates the wear-out of the PV inverter. Therefore, the lifetime of the PV inverter has to be considered to find a safe limit for the oversizing of the PV arrays but there is a lack of study on this effect. This paper studies the effect of the installation location on the lifetime of the PV inverter together with DC/AC ratio. The lifetime evaluation of NPC inverter is carried out with three installation locations inclusive of the effect of the cooling capacity. Furthermore, the impact of DC/AC ratio on the lifetime of the PV inverter is investigated by taking into account the influence of the installation location to show the importance of the lifetime of the PV inverter to select the optimum DC/AC ratio to minimize the cost of PV energy.

INDEX TERMS IGBT module, lifetime, power device, PV array, PV inverter, reliability.

I. INTRODUCTION

Photovoltaic (PV) power generation has become one of the main renewable energy sources with high growth rate for the last several decades owing to the continuous decrease in cost of photovoltaic panels and Balance-of-Systems (BOS) [1]. However, it is still demanded to decrease the cost of energy generated by photovoltaic systems to increase its penetration level. The U.S. Department of Energy has recommended that the cost of PV energy for the residential PV systems has to be reduced by 0.05 USD/kWh by 2030 [2] and other countries also set the similar target cost of energy [3], [4].

Recent research makes an effort in various aspects to achieve this target. The reliability improvement of PV inverters is the important factor for reducing the cost of PV energy since it is closely connected to the annual energy production as well as the maintenance cost of PV systems [5]. It is well known that a PV inverter is one of the most reliability-critical parts in a PV system [6], [7]. Therefore, it is required to extend the lifetime of the PV inverter from the current expected lifetime of 10-15 years to 20-30 years to balance the lifetime with other parts in the PV system [2]. For example, the lifetime of the PV panels are typically warranted for 25-30 years [5]. The lifetime evaluation of the PV inverter considering a mission profile in design phase plays an important role for Design for Reliability to ensure the lifetime and to avoid unexpected failures of the PV inverter. Therefore, much research has been performed about it [8]–[10].

Another solution typically being used is to oversize the rated power of the PV arrays compared with that of the PV inverter [11]–[13]. Thereby, the PV inverter generates more energy during the period when the PV inverter is not operated under its rated power. On the other hand, the incremental cost by adding additional PV arrays to the PV system has greatly decreases owing to lower module prices. It is an important issue to find the best ratio of the rated power of the PV arrays to the rated power of the PV inverter called a DC/AC ratio ($R_{DC/AC}$) or array-to-inverter ratio to achieve the lowest Levelized Cost of Energy (LCOE) since too high $R_{DC/AC}$ results in increase of other costs in the system. The oversizing the PV arrays means that the PV inverter is operated with high power and thus it leads to higher thermal loadings in components of the PV inverter, which significantly contributes to component aging [13]. In other words, it increases the maintenance cost and decreases annual energy production and thus it may have a negative impact on the cost of PV energy. Therefore, the lifetime has to be considered to find a safe limit for the $R_{DC/AC}$ with mission profiles but there is a lack of study on this effect.
This paper studies the effect of the installation locations on the lifetime of the PV inverter together with the DC/AC ratio. The lifetime evaluation is carried out by focusing on power devices since it is one of the most reliability-critical components. A 30 kW PV system based on a three-level Neutral-Point Clamped (NPC) inverter is considered as a target system in this paper. This paper starts with brief description of a configuration of the PV system with the NPC inverter and the analysis on the power loss and junction temperature distributions of the NPC inverter is also given. After that, the mission profile based lifetime evaluation of the PV inverter is performed under different installation locations of Aalborg in Denmark, Iza in Spain and Arizona in USA inclusive of the effect of the cooling capacity on the lifetime of the PV inverter, which is described in Section III. In section IV, based on the lifetime evaluation in the previous section, the impact of the DC/AC ratio on the lifetime of the PV inverter is investigated including the influence of the installation location to show the importance of the lifetime of the PV inverter to select the optimum DC/AC ratio to minimize the cost of PV energy.

The mission profile based lifetime estimation of NPC inverter has been performed in the previous work in [14]. This study is extended from that approach to investigate the effect of the installation locations on the lifetime of the NPC inverter and DC/AC ratio selection.

II. NEUTRAL-POINT CLAMPED PV INVERTER
A. DESCRIPTION OF PV SYSTEM CONFIGURATION WITH NPC INVERTER
Fig. 1 shows a simplified configuration of a two-stage grid-connected PV system. A DC/DC converter and a DC/AC PV inverter are placed between PV arrays and grid as an interface.

TABLE 1. Parameters for 30 kW PV inverter system.

| Parameters                              | Value |
|-----------------------------------------|-------|
| Rated power of PV inverter              | 30 kW |
| DC-link voltage ($V_{dc}$)              | 650 V |
| Grid phase voltage ($V_g$)              | 220 Vm |
| Switching frequency ($f_{sw}$)          | 20 kHz|
| Grid frequency ($f_g$)                  | 60 Hz |
| Power factor                            | 1     |
| NPC IGBT module                         | F3L75R07W2E3_B11 |

Typically, the DC/DC boost converter is used but it can be excluded depending on applications [15].

The NPC inverter is attractive topology for PV systems because of the high efficiency and low total harmonic distortion [16]. Typically, the NPC inverter topology is widely used not only for a string inverter configuration but also for a central inverter configuration [15].

Fig. 2 shows a simplified circuit diagram of the NPC inverter. The NPC inverter is composed of 4 IGBTs ($T_{X1}(X = U, V, W)$, $T_{X2}$, $T_{X3}$ and $T_{X4}$), 4 diodes ($D_{X1}$, $D_{X2}$, $D_{X3}$ and $D_{X4}$) and 2 clamping diodes ($D_{CX1}$ and $D_{CX2}$) in each leg, where all IGBTs commonly have the same voltage and current ratings.

B. POWER LOSS AND TEMPERATURE DISTRIBUTIONS OF NPC INVERTER
In this section, the power loss distribution and the corresponding temperature distribution of the power devices of the NPC inverter are evaluated at the rated power.

The conventional control method and space vector modulation method are applied to the PV inverter. The related parameters of the PV system considered in this paper are listed in TABLE 1.

It is important to guarantee that the power module is operated in Safe Operating Area at all operating conditions. Typically, the capacity of the cooling system is chosen so that the junction temperature ($T_j$) at the rated power is about 70-80% of the maximum rated junction temperature ($T_{jmax}$) [17]. For that, in this study, the IGBT module of F3L75R07W2E3_B11 and the heat-sink to ambient thermal resistance $R_{th(a)}$ of 0.17 K/W are selected.

The total power loss ($P_{loss}$) of the power device is the summation of the switching loss ($P_{sw}$) and conduction loss ($P_{cond}$) as

$$P_{loss} = P_{sw} + P_{cond}$$  \hspace{1cm} (1)

The $P_{sw}$ of the IGBT is calculated as

$$P_{sw} = E_{sw} \cdot f_{sw}$$  \hspace{1cm} (2)

where $E_{sw}$ = switching energy and $f_{sw}$ = switching frequency of the device.

The conduction loss ($P_{cond}$) averaged in one switching cycle is represented as

$$P_{cond} = V_{CE} \cdot I_c \cdot D$$  \hspace{1cm} (3)
TABLE 2. Parameters for thermal model of IGBT module.

| Thermal Impedance          | Point (i) |
|---------------------------|-----------|
| $R_{th,a}$ (K/W)          | 1         | 0.051    | 0.117    | 0.426    | 0.506    |
| $IGBT$ ($T_{32,2,3,4}$)   | 2         | 0.097    | 0.219    | 0.576    | 0.508    |
| $Diode$ ($D_{32,2,3,4}$)  | 3         | 0.062    | 0.145    | 0.444    | 0.449    |
| $Clamping Diode$ ($D_{32,2,3,4}$) | 4       | 0.0005   | 0.005    | 0.05     | 0.2      |

FIGURE 3. The power losses distribution of the power devices of leg-U in the NPC inverter at the rated power with $f_{sw}$ of 20 kHz.

where $V_{CE}$ is the collector-emitter voltage, $I_s$ is the collector current, and $D$ is the duty cycle.

It should be noted that the $V_{CE, ON}$ and $E_{sw}$ of the IGBT are influenced by the junction temperature. Therefore, it should be taken into consideration when the power loss is calculated.

The junction temperature of the IGBT is obtained as

$$T_{j(IGBT)}(t) = P_{loss(IGBT)}(t) \cdot Z_{th(j-h)}(t) + P_{loss(Module)}(t) \cdot Z_{th(h-a)}(t) + T_a$$

(4)

where $P_{loss(IGBT)}$ = IGBT power loss, $Z_{th(j-h)}$ = junction to heat-sink thermal impedance, $P_{loss(Module)}$ = IGBT module power loss, $Z_{th(h-a)}$ = heat-sink to ambient thermal impedance and $T_a$ = ambient temperature.

The $Z_{th(j-h)}$ of the power devices are represented by the Foster model as

$$Z_{th(j-h)}(t) = \sum_{i=1}^{n} R_i (1 - e^{-t/\tau})$$

(5)

where $\tau = R \cdot C$ and $i$ means the different layers of the power module for the Foster model. The parameters for the thermal model can be obtained from datasheet as listed in TABLE 2.

Fig. 3 shows the power loss distributions of the leg-U at the rated power. The outer IGBTs ($T_{U1}, T_{U4}$) and the inner IGBTs ($T_{U2}, T_{U3}$) have the different power loss characteristics due to the operation principle of the NPC inverter. In the case of the outer IGBTs, both $P_{sw}$ and $P_{cond}$ are contributed to the power loss of the IGBT but only $P_{cond}$ is dominated in the power loss of the inner IGBTs ($T_{U2}, T_{U3}$). The power losses of the clamping diodes are smaller than those of the IGBTs but also take quite large proportion of the total power loss of the inverter. Consequently, the power devices in the NPC inverter have different power losses and it results in the uneven $T_j$ distributions of the power devices.

![FIGURE 4. Junction temperatures of the power devices at the rated power when $f_{sw} = 20$ kHz, $R_{th(h-a)} = 0.17$ K/W and $T_a = 30$ °C.](image)

NPC inverter have different power losses and it results in the uneven $T_j$ distributions of the power devices.

Fig. 4 shows the junction temperatures ($T_j$) of power devices in leg-U at the rated power when the $T_a$ is 30 °C. A large temperature difference between the outer IGBTs and inner IGBTs which is about is 15 °C can be seen as expected due to the uneven power loss distributions.

It means that the outer IGBTs have the highest thermal loadings and thus they are the most critical one in terms of the reliability since the temperature stress is the major cause of the wear-out failure of power modules [18]. Therefore, in this study, the lifetime evaluation is focused on them since the lifetime of the NPC inverter mainly relies on the most reliability-critical device as investigated in [19].

III. LIFETIME ASSESSMENT OF POWER MODULE IN NPC PV INVERTER

The mission profile based lifetime evaluation of the NPC inverter is carried out by focusing on the reliability-critical device under the three different installation locations. In addition, the effect of the cooling capacity on the lifetime is considered.

A. MISSION PROFILES OF PV SYSTEM IN DIFFERENT INSTALLATION LOCATIONS

The ambient temperature ($T_a$) and solar irradiation are typically regarded as the mission profile because they are the major influential factors on the power generation from the PV panels. The mission profiles recorded from three different locations, Iza in Spain, Arizona in USA and Aalborg in Denmark for almost 1 year with the sampling rate of 5 minute per data are considered as a case study.

![FIGURE 5. Mission profiles of Aalborg.](image)

Fig. 5 (a) shows the mission profiles of Aalborg. There is a relatively large variation in the $T_a$ depending on the seasons from about $-16.5$ °C to $34.5$ °C and also great temperature difference between day and night. It can also be seen that the solar irradiation is influenced a lot.
by the season. In the case of Iza, the $T_a$ ranges between about $-5 \degree C$ and $30 \degree C$ but the solar irradiation is consistently high as shown in Fig 5 (b). The mission profile of Arizona is seen in Fig. 5 (c), where the $T_a$ is relatively higher than the others. For the whole year, except for short period, the $T_a$ is above zero. Furthermore, the irradiation is high all through the year.

**B. JUNCTION TEMPERATURE PROFILES WITH DIFFERENT HEAT-SINK CAPACITIES**

The power profile generated by the PV arrays is determined based on the mission profile that is composed of the solar irradiation and ambient temperature. Based on the generated power from the PV arrays, the power loss of the IGBT is determined. Then the corresponding junction temperature ($T_j$) of the IGBT is obtained with the thermal model. After that, the $T_j$ profile of the IGBT is acquired through a look up table, which is helpful to handle long term simulations. The look up table is built in connection with input power ratings and the ambient temperatures. Consequently, the $T_j$ profile of the IGBT is generated when the generated power and the ambient temperature are given.

Fig. 6 shows the $T_j$s of the outer IGBT under the different installation locations with three different heat-sink capacities which is realized by changing the $R_{th(h-a)}$ to 0.123 K/W, 0.178 K/W and 0.225 K/W, respectively.

In the case of $T_j$ in Aalborg as shown in Fig. 6 (a), the large variation of the maximum junction temperature ($T_{jmax}$) with the seasons can be seen. It is resulted from the characteristic of the ambient temperature and irradiation in Aalborg as previously explained. It can also seen that the $T_j$ increases as the $R_{th(h-a)}$ increases but there is the same tendency of $T_j$ variation.

The seasonal $T_{jmax}$ variations in Iza and Arizona are not large compared with Aalborg as shown in Fig. 6 (b) and (c), respectively and the $T_{jmax}$ in both places are relatively high throughout the year. The highest $T_{jmax}$ are about 120 $\degree C$ and 140 $\degree C$ with the $R_{th(h-a)}$ of 0.225 K/W in Iza and Arizona, respectively. Furthermore, in all three cases with different $R_{th(h-a)}$, the $T_{jmax}$ is less than 110 $\degree C$, 120 $\degree C$ and 140 $\degree C$, separately. It means that the IGBT is operated in SOA with big margin and thus it may expect that the $R_{th(h-a)}$ can be increased. Even though, however, the $T_j$ has a big margin, the lifetime of the power module have to be taken into account since the increasing $R_{th(h-a)}$ results in higher average $T_j$ which causes the decrease in the lifetime of the power modules.

**C. LIFETIME EVALUATION BASED ON MISSION PROFILES**

From the $T_j$ profiles, the temperature stress factors considered in the lifetime model which are the junction temperature swing ($T_j$), mean junction temperature ($T_{jm}$) and on duration ($t_{on}$) are extracted by using a Rainflow counting technique [20]. The number of cycle to failure at the given temperature stresses of $T_j$, $T_{jm}$, and $t_{on}$ is calculated with the lifetime model. Typically, the lifetime model is developed based on the power cycling test results under various temperature stress conditions [21]. The lifetime model presented in [22] is used for the lifetime estimation because the lifetime model of the IGBT module considered in this study is not available. Therefore, the results should be considered only for the purpose of the comparison.

Fig. 7 shows the extracted $T_j$ and $T_{jm}$ of the IGBT with the $R_{th(h-a)}$ of 0.123 K/W under the different installation locations. It can be seen from the results that they have different $T_j$ and $T_{jm}$ depending on the installation sites.

Finally, Accumulated Damage ($AD$) of the IGBT is computed based on the Miner’s rule as

$$AD = \sum_{i=1}^{k} \frac{n_i}{N_i}$$

(6)
where $n_i$ is the number of cycles accumulated at a certain temperature stress ($S_i$) which is the combination of temperature stresses of $T_{j}$, $T_{jm}$, and $t_{on}$, and $N_i$ is the number of cycles to failure at $S_i$ determined from the lifetime model.

The $AD$ indicates how much damage is accumulated when it is operated with mission profiles and the time at which the $AD$ is reached to 1 is considered as the lifetime [23].

Fig. 8 (a) shows the $AD$ of the IGBT in the NPC inverter with the $R_{th(a-h)}$ of 0.123 K/W under the different installation locations. The $AD$ of the IGBT in Arizona is the highest value as about 2.57 % for 524500 minutes. The lowest $AD$ is about 0.62 % for 525200 minutes in Aalborg and the middle one is in Iza about 1.82 % for 504800 minutes. Even though the same PV inverter is considered, the $AD$ of the IGBT is notably different depending on the installation location of the PV inverter.

The corresponding lifetimes to the $AD$s are 39, 161 and 53 years in Arizona, Aalborg and Iza, separately. The longest lifetime is 161 years in Aalborg, which is more than 4 times longer than the shortest lifetime of 39 years in Arizona and also longer than that of Iza more than 3 times. However, it is worthwhile mentioning that the lifetime of the IGBT in Aalborg is not practical value in general from the wear-out failure point of view. It may be expected that the failure of the IGBT due to temperature stress is not observed during its service life and other failure mechanisms in the IGBT or failures in other components could be the main factor that limits the lifetime of the PV inverter.

It can be clearly seen from above results that the lifetime of the PV inverter is closely dependent on the installation location because they have different solar irradiations and ambient temperatures. It also shows the importance of the mission profile based analysis in the reliability of the PV inverter. Therefore, it should be taken into account for the Design for Reliability to guarantee the lifetime and to avoid unexpected failures of the PV inverter.
The ADs of the IGBT under the mission profile in Iza with the different heat-sink capacities represented by the $R_{th(h−a)}$ are shown in Fig. 8 (b). The ADs are obtained as 1.8 %, 3.3 % and 5.1 % and the estimated lifetimes are 53 years, 29 years and 19 years when the $R_{th(h−a)}$ are 0.12 K/W, 0.178 K/W and 0.225 K/W, respectively.

Typically, the capacity of the cooling system is selected from the over-stress failure point of view so that the $T_{j,max}$ is in Safe Operating Area (SOA) at the rated power. However, this result also shows the importance of the cooling system capacity for the reliability of the power module in PV inverters not only from the over-stress failure point of view but also from the wear-out failure point of view. Even though the $T_j$ of the IGBT is in SOA with all three $R_{th(h−a)}$, the different $R_{th(h−a)}$ are required depending on the target lifetime. For example, if the target lifetime is about 20 years, the $R_{th(h−a)}$ which is less than and close to 0.219 K/W should be selected. In the case of the target lifetime of 30 years, the $R_{th(h−a)}$ of about 0.178 K/W is recommended according to above analysis. Further, the different heat-sink capacities are required to satisfy the target lifetime depending on the installation sites. In this case study, for the 20 years of the target lifetime, the $R_{th(h−a)}$ of about 0.35 K/W, 0.219 K/W and 0.187 K/W are necessary in Aalborg, Iza and Arizona, respectively. The lifetime evaluation results under the different installation sites with different $R_{th(h−a)}$ are summarized in TABLE 3.

IV. DC/AC RATIO CONSIDERING LIFETIME

As the cost of PV array has decreased, oversizing the rated power of the PV arrays compared with that of the PV inverter is typical strategy for the reduction of the cost of energy.

In this section, the effect of the DC/AC ratio ($R_{DC/AC}$) on the lifetime of the PV inverter is discussed under the different installation locations.

The target lifetime of 30 years of the PV inverter is assumed based on [8]. Furthermore, the $R_{th(h−a)}$ of 0.12 K/W is chosen for the case study based on the previously analyzed lifetime results because the lifetime with the other $R_{th(h−a)}$ is already close to 30 years in some locations.

A. EFFECT OF DC/AC RATIO ON THERMAL LOADING

The $T_j$ profiles with two DC/AC ratios in the three installation locations are shown in Fig. 9. It can be seen from Fig. 9 (a) that there is a significant increase in the $T_j$ in Aalborg throughout the whole year when the $R_{DC/AC}$ increases from 1.0 to 1.5. This is due to that the generated power from the
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FIGURE 10. Amplitudes of $\Delta T_j$ and $T_{jm}$ extracted by Rainflow counting method from the junction temperature profiles with different array-to-inverter ratios (a) Aalborg (b) Iza and (c) Arizona.

PV array is smaller than the rated power of the PV inverter all through the year due to the low average irradiation level and ambient temperature. It results in the large increase in the thermal loading represented by the $T_j$ and $T_{jm}$ when the $R_{DC/AC}$ is 1.5 compared with that of the $R_{DC/AC}$ of 1.0 as illustrated in Fig. 10 (a). In the cases of Iza and Arizona, there are less increases in the $T_j$ when the $R_{DC/AC}$ increases from 1.0 to 1.5 as shown in Fig. 9 (b) and Fig. 9 (c), respectively. Furthermore, it is observed that there are smaller increases in thermal loadings due to higher $R_{DC/AC}$ when the PV inverters are installed in Iza and Arizona compared with that of in Aalborg as shown in Fig. 10 (b) and Fig. 10 (c), separately. This is because of the fact that the generated power is clamped to the rated power of the PV inverter in many occasions due to the high irradiation during the whole year.

From the above results, it may expect that the lifetime of the PV inverter is affected by the $R_{DC/AC}$ but its impact is different depending on where it is placed. The lifetime of the PV inverter located in Aalborg is greatly influenced by the $R_{DC/AC}$. On the other hands, there is a less impact of the $R_{DC/AC}$ on the lifetimes of the PV inverters installed in Iza and Arizona.

B. LIFETIME EVALUATION

The accumulated damage ($AD$) from the thermal loadings with different DC/AC ratios from 1.0 to 2.0 is evaluated in different installation locations.

Fig. 11 (a) shows the $AD$ of the power device for one year with different $R_{DC/AC}$ under one-year mission profiles of Aalborg, Iza and Arizona compared with that of in Aalborg as shown in Fig. 10 (b) and Fig. 10 (c), separately. This is because of the fact that the generated power is clamped to the rated power of the PV inverter in many occasions due to the high irradiation during the whole year.

In Aalborg, the lifetime is longer than those of the other locations because the $AD$ itself is small but the variation of the lifetime depending on the $R_{DC/AC}$ is substantial as it is expected from the normalized $AD$. The lifetime is more than...
100 years with $R_{DC/AC}$ of 1. It is continuously decreases as the $R_{DC/AC}$ increases and about 30 years with $R_{DC/AC}$ of 2.0. The lifetime in Iza is about 30 years when the $R_{DC/AC}$ is about 1.2 and is kept regardless of the $R_{DC/AC}$. Therefore, the lifetime of the power device is not the limiting factor to increase the $R_{DC/AC}$ for the PV inverter in Aalborg and Iza. However, it is worthwhile mentioning that the $R_{DC/AC}$ is typically chosen between 1.0 and 1.6 since there is no benefit of the oversizing PV array on the Levelized Cost of Energy (LCOE) [14].

On the other hand, it is clearly seen that the lifetime can be the critical factor to select the $R_{DC/AC}$ for the PV system installed in Arizona. The lifetime is 30 years when the $R_{DC/AC}$ is about 1.06 and saturated as about 15.5 years at the $R_{DC/AC}$ of 1.4. It cannot be selected above 1.06 to meet the target lifetime in this case study.

In order to increase the $R_{DC/AC}$ to have its benefit, some strategies for the PV inverter are required to increase its lifetime such as the improvement of the cooling capacity, the reduction of the switching frequency and the modification of the modulation method, which may cause the increase in the capital cost of the PV system. From above results, it can be expected that the lifetime should be taken into account for selecting the optimal $R_{DC/AC}$ for the PV system since its effect is different depending on the installation sites.

V. CONCLUSION

In this paper, the effect of the installation location on the lifetime of the PV inverter is investigated with the DC/AC ratio. The three mission profiles from Aalborg, Iza and Arizona are considered for the lifetime evaluation, where the lifetime of the power device is taken into consideration representatively since the power device is one of the most reliability-critical components in the PV inverter.

It is found from the lifetime evaluation that the lifetime of the PV inverter is significantly affected by its installation site due to the different solar irradiances and ambient temperatures which lead to different thermal loading on the PV inverter. Therefore, it is essential to carry out the mission profile based lifetime evaluation to guarantee the specific lifetime of the PV inverter. Furthermore, the impact of the cooling capacity on the lifetime is discussed. It is clearly seen from the results that the cooling capacity has a significant impact on the lifetime of the power device. Therefore, the cooling capacity should be chosen by considering the safety margins in terms of both the maximum junction temperature limit from the over-stress failure point of view and the lifetime of the power device from the wear-out failure point of view.

Finally, the impact of the PV array size represented as the DC/AC ratio ($R_{DC/AC}$) on the lifetime has been studied including the influence of the installation location. The result shows that the lifetime is not the limiting factor to select the $R_{DC/AC}$ for the PV inverter in Aalborg and Iza but it is the limiting factor to select the $R_{DC/AC}$ for the PV inverter in Arizona in this case study. Therefore, the lifetime should be taken into account for selecting the optimum $R_{DC/AC}$ for the PV system to minimize the cost of PV energy since the oversizing the PV array decreases the lifetime of the PV inverter below the target lifetime and thus it leads to a negative effect on lowering the cost of PV energy.

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