PV Inverter Output Characteristics According to Capacitance Variation of DC Link Capacitor

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Abstract—As the usage time of the DC-link stage capacitor of the PV inverter increases, accidents occur such as electrolyte ejection and explosion due to the progress of deterioration. Therefore, in this paper, in order to proceed with the experiment on the aging of the DC-link stage capacitor, the inverter output characteristics are studied by the capacitance variation.

Keywords—Photovoltaic(PV) Inverter, DC Link Capacitor, Capacitance Variation, Reliability, Life Cycle

I. INTRODUCTION

The photovoltaic(PV) inverter, which is one of the components of the photovoltaic power generation system, has a DC/DC converter and a DC/AC inverter configuration and has a grid-linked structure[1][2]. The DC-link stage capacitor, which is the input end of such a PV inverter, serves to charge/discharge and smooth the DC voltage and smooth the ripple. Such capacitors are inexpensive and have relatively fast charge/discharge characteristics, and most aluminum electrolytic capacitors are used[3]. However, in the case of DC-link capacitors, accidents occur due to electrolyte ejection and explosion due to aging and deterioration due to increased usage time. But PV inverter manufacturers do not reflect status information of PV inverter according to usage time and related protection circuit design.

Therefore, in this paper, we proposed a circuit that can simulate the deterioration of the capacitor in order to investigate the input/output state of the PV inverter due to the change of the DC-link stage capacitor.

II. PROPOSED PV INVERTER SYSTEM CONFIGURATION

Fig. 1 shows a PV inverter that can simulate the occurrence of capacitor deterioration in order to investigate the input / output state of the PV inverter due to the DC-link stage capacitor variation. In addition, a monitoring system was implemented to diagnose the PV Inverter status by monitoring information such as output capacity (voltage, current), efficiency, THD, and MPPT efficiency according to the variable capacitor.

Fig. 1 shows the capacitor degradation simulation circuit designed in parallel structure. The value of the DC-Link stage capacitor can be gradually changed from 10% to 100% to simulate aging and deterioration. As shown in Table 1, the PV Inverter specifications used in this paper are single-phase 3.5[kW], DC-link capacitor 1300[uF], and in the deterioration occurrence simulation circuit, the capacitor is configured with 100[uF] x 13EA.

III. PV INVERTER OUTPUT CHARACTERISTIC DUE TO DC-LINK STAGE CAPACITORS VARIATION

As shown in Table 1, the input value of the PV inverter used in this experiment is V_mp=350[V], I_mp=10[A] within the MPPT control range, and the solar cell simulation DC power supply (EA-PSB 91000-40) was used. In addition, the grid-linked the PV inverter was implemented using the simulated system power supply (MX15-1Pi-LAN-SNK), and the power analyzer (WT 1800) was used to monitor the characteristics of the inverter according to the capacitance variation of the DC-link stage capacitor.

![Proposed PV Inverter](image)

**TABLE I. PV INVERTER SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Input Voltage</td>
<td>500[Vdc]</td>
</tr>
<tr>
<td>MPPT Voltage range</td>
<td>200[Vdc]–400[Vdc]</td>
</tr>
<tr>
<td>Rated Power</td>
<td>3.5[kW]</td>
</tr>
<tr>
<td>Rated Output Frequency</td>
<td>60[Hz]</td>
</tr>
<tr>
<td>Rated Output Voltage</td>
<td>220[Vac]</td>
</tr>
<tr>
<td>Rated Output Current</td>
<td>159[Aac]</td>
</tr>
</tbody>
</table>

![Capacitor deterioration generation simulation circuit](image)
A. In case of DC-Link Capacitance (100% 1,300[\mu F])

In addition, as a result of the operation characteristics according to the input/output of the solar inverter, the total distortion of the AC output current and the input/output information and efficiency of the PV inverter are shown in Table 2.

AC output current total distortion factor (THD) and efficiency show satisfactory results based on IEC 61727 Photovoltaic (PV) systems Characteristics of the utility interface technical standard.

<table>
<thead>
<tr>
<th>parameter</th>
<th>value</th>
<th>parameter</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>input voltage</td>
<td>355.04</td>
<td>output voltage</td>
<td>228.43</td>
</tr>
<tr>
<td>input current</td>
<td>9.81</td>
<td>output current</td>
<td>14.64</td>
</tr>
<tr>
<td>input power</td>
<td>330</td>
<td>output power</td>
<td>334</td>
</tr>
<tr>
<td>power factor</td>
<td>0.99</td>
<td>efficiency[%]</td>
<td>95.82</td>
</tr>
<tr>
<td>frequency[Hz]</td>
<td>60.00</td>
<td>3th THD[%]</td>
<td>2.16</td>
</tr>
</tbody>
</table>

B. In case of DC-Link Capacitance (15.38% 200[\mu F])

Fig. 4 shows the operation results of the PV inverter when the DC-link capacitance is set to 200\mu F, 15.38\% of the rated value, based on the same experimental conditions (100% 1,300[\mu F]).

Fig. 2 shows the results for the operating characteristics of the PV inverter with the DC-link stage capacitance in case of 1,300[\mu F] in the capacitor deterioration simulation circuit shown in Fig. 1.

When \( V_{MP} = 350V \), \( I_{MP} = 10A \) are input values within the MPPT control range of the PV inverter and the \( V_{MP} \), \( I_{MP} \), and input power results can be confirmed to operate normally through the solar cell model DC power device (EA-PSB 91000-40) and the simulated grid-linked device (MX15-1Pi-LAN-SK). When the DC-link stage capacitor is normal, Fig. 3 shows that the output current and grid-voltage waveform of the PV inverter are system-linked to generate power normally.
Through the deterioration simulation circuit, the DC-link capacitor deteriorates considerably to 15.38% of its rated value, and it can be regarded as a time point where maintenance is required according to the capacitor life. Compared with the result of Fig. 2, it shows that the variation range of input values through the solar cell simulation DC power supply is large in the aging state of the solar inverter.

Since the PV inverter has a function of generating maximum output through MPPT control, it operates at the set $V_{MP}$ and $I_{MP}$ values. However, it can be seen that if the DC-link capacitor deteriorates compared to the normal case, the MPPT operation range is very wide and the operation is unstable. In addition, when the DC-link capacitor is aged and changed to the limit capacity, it can be confirmed that the smooth state of the voltage and current of the DC-Link stage cannot be controlled, and the ripple of the power appears severely.

Fig. 5 shows the phenomenon that the waveform of the sine wave is distorted when the output current is compared with the result of Fig. 3 by the result of the output current and the grid-voltage when the PV inverter generates electricity through the grid linkage. Therefore, based on such a result, the operation characteristic result by the input/output can be confirmed in Table 3. As shown in Fig. 4, ripple and unstable operation of the input stage of the PV inverter are occurring due to the deterioration of the DC-link stage capacitor, and through Fig. 5 and Table 3, it is shown that the operation characteristics of the output stage are also disturbing the grid-linked.

![Fig. 5. PV Inverter output current and grid-voltage characteristics](image)

In Table 3, AC output current total distortion factor (THD) and the result values of each order do not satisfy the IEC 61727 standard values of 5% and 3%. This is a factor that threatens the deterioration of power quality through grid-linked and the safety of renewable energy facilities.

![Table III. Operating characteristics of PV inverter](image)

In Table 3, AC output current total distortion factor (THD) and the result values of each order do not satisfy the IEC 61727 standard values of 5% and 3%. This is a factor that threatens the deterioration of power quality through grid-linked and the safety of renewable energy facilities.

IV. CONCLUSION

As the usage time of the PV Inverter DC-Link stage capacitor of the photovoltaic system increases, aging proceeds due to deterioration. As a result, the life cycle of the capacitor is reduced, and accidents occur due to electrolyte ejection and explosion.

In this paper, the output voltage, output current, and power characteristics of capacitors according to capacitance variation are considered. It was confirmed that the THD, ripple, and MPPT normal operation were affected when the capacitance became smaller than the normal state.

ACKNOWLEDGMENT

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REFERENCES

