

論文 / 著書情報
Article / Book Information

題目(和文)	大規模太陽光発電システムへの適用を目的とした複数の双方向チョッパを使用した三相インバータの研究
Title(English)	Study of Three-phase Inverter Using Multiple Bidirectional Choppers Intended for Utility-scale PV Systems
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

(博士課程)

Doctoral Program

論文要旨

THESIS SUMMARY

系・コース :	電気電子	系	申請学位 (専攻分野) :	博士	(工学)
Department of, Graduate major in	電気電子	コース	Academic Degree Requested	Doctor of	
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Student's Name			Chief Examiner		

要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

This dissertation presents a detailed study of a novel three-phase inverter for utility-scale PV systems where multiple cascaded bidirectional chopper cells and a three-phase line-frequency transformer with a three-limb core are used.

To reduce the consumption of fossil fuels (coal, gas, oil), which cause more pollution and will be exhausted someday, the contribution from the renewable energy sources is being increased. Among them, the PV energy is the fastest developing one. It is reported that the global PV energy production in 2021 is over 1000 TWh and it is estimated that this number should reach 6970 TWh to achieve long-term carbon neutrality, which means the developing speed will be even faster.

Meanwhile, the energy market also stimulates the development of PV energy generation. Historically, long-term contract prices from utility-scale PV generation systems have been higher than wholesale prices of fossil fuels in many large EU markets. However, significant change happened in 2021 according to the report. The prices of fossil fuels have risen at an incredible rapid speed since the last quarter of 2021, which broke historic records in many parts of the world. Consequently, even the highest price of utility-scale PV generation system contracts over the last five years is much lower than the wholesale prices of fossil fuels nowadays. As a result, more and more utility-scale PV generation systems are built and their capacity is increasing rapidly, which brings challenges to the conventional PV inverters.

To operate the PV system throughout the year, the AC output voltage has to be set based on the minimum DC input voltage at the highest temperature in summer because of the temperature characteristic of the PV array, which results in a large AC current and a large conduction loss, especially in a megawatt level PV system. In order to reduce the conduction loss, one of the methods is to increase AC output voltage. However, this method narrows the range of MPPT of the conventional PV inverters. In other words, the available MPPT range will be curtailed if the conventional three-level inverters are applied to utility-scale PV generation systems. Therefore, the authors proposed a novel three-phase inverter.

The inverter of each phase is composed of a main converter, which is equivalent to a single bidirectional chopper, and an auxiliary converter, which is composed of multiple cascaded connected bidirectional chopper cells. The number of the chopper cells could be set to any natural number. The main converter switches at a frequency of 50 Hz to match the grid frequency, whereas each chopper cell of the auxiliary converter switches at a much higher frequency, e.g., 7.2 kHz, and behave as an active-power-filter to reduce the high-frequency harmonic components. The phase-shifted PWM is applied to the auxiliary converter to reduce the harmonic voltage/current. The AC output side of the inverter is connected to the secondary side of the three-phase transformer with a three-limb core via an AC-link inductor. The primary side (i.e., grid side) of the three-phase transformer is delta connection and the secondary side (i.e., inverter side) is in Y connection.

The proposed circuit is characterized in that a DC current flows to the mid-point of the

transformer for boost operation, while it does not affect the transformer operation because it corresponds to the zero-sequence current in the three-phase circuit. Specifically, the three-limb core has an infinite magnetic impedance against the electromagnetic force produced by the DC current ideally. Therefore, the DC current has no effect on the transformer operation. In addition, the DC current will be used for the control of each DC-capacitor voltage. The AC inductor could be eliminated from the circuit if the leakage inductance is large enough. By applying the proposed inverter, a smaller RMS current and a wider available MPPT range could be satisfied simultaneously by the proposed inverter circuit. Furthermore, owing to the direct connection between the negative terminal of the PV array and the ground, no high-frequency circulating current flows via the stray capacitance, which makes the parallel operation of the inverters easier.

The operation principles and the control method are carried out and the experimental verification using a downscaled system proves the reliability of them. In addition, the detailed LVRT capability analysis of the three-phase PV inverter is carried out. The theoretical analysis based on mathematical calculation and figures, including the capacitor voltage fluctuation, the reason for overmodulation and its borderline, and the peak value of current spikes during the overmodulation, of the proposed inverter during the grid faults has been developed. Experimental verification using the same downscaled system verifies the reliability of the theoretical analysis. Furthermore, a detailed evaluation of the chopper-cell number in the auxiliary converter is carried out by conducting performance comparison between the inverter using two cells per phase (two-cell inverter) and the one using three cells per phase (three-cell inverter).

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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