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Current Status and Technology Trends of Grid-Interactive Inverter for PV Application

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1. Introduction

In recent year, with increasing concern about global environmental protection, producing natural free energy resources has been a focus of constant attention. Today the contribution from photovoltaic (PV) energy compared to the other renewable energy is so low, but the market for PV systems is one of the most stable and fastest growing in the world. To maintain the further growth of PV systems, it is important to decrease the cost and also improve the efficiency and reliability. Under the condition of stated above, efficiency and reliability improvement, and cost reduction are strongly required for grid-interactive inverter as well as PV modules. This paper aims to give an overview on recent trends in grid-interactive inverter's technology for PV systems.

2. Technology requirements for the grid connected distributed system

Grid-interactive inverter is required to equip various utility protection features such as islanding protection, utility voltage regulation, and DC components detection etc.

Fig. 1 shows the PV systems and inverter's technical feature as an example. In a grid-connected PV system, PV generator is connected to the public low-voltage grid via an inverter. As every distributed generation unit being connected to the public grid, the PV inverter has to comply with common safety standards.

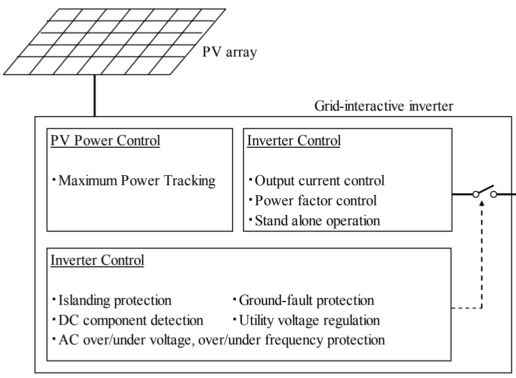

Fig. 1. PV system and technical feature

The major issue for the distributed generator, being connect to the grid, is described below.

Islanding Protection

One of the major safety issues in grid connected inverter is to avoid non-intentional operation in islanding mode when the grid is being tripped at fault conditions. To prevent this, the inverter has to equip some detection measures. The islanding protection is classified into two categories. One is the passive measure, frequency and voltage monitoring for instance. The other is the active measure, like the frequency-shift operation.

Utility Voltage Regulation

When the PV systems connect with the low-voltage distribution line, there is a possibility of line voltage rising, and exceed the allowable voltage limit due to reverse power flow and the distribution line's impedance. To prevent the line voltage rising, the inverter equips voltage regulation feature by means of the active power suppression or the reactive power regulation. This issue would become conspicuous when the PV systems are closely packed.

3. Technology trends on grid-interactive inverter for PV system in practical use.

Circuit topology of grid-interactive inverter

The inverters are categorized according to the configuration of the PV system, the configuration of the DC-DC conversion stage plus inverter stage and whether transformer is used or not. Fig. 2 indicates constitution and classification of grid-interactive inverter.

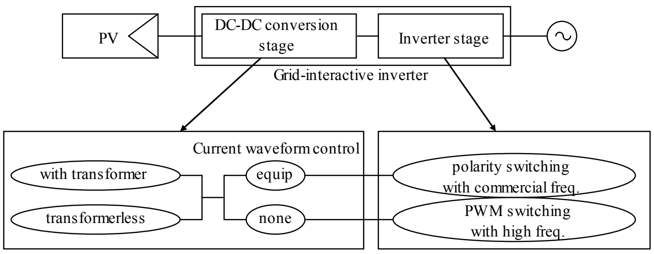

Fig. 2. Constitution and classification of grid-interactive inverter

At the present day, to improve the conversion efficiency and to realize noise reduction, soft-switching techniques and circuit topologies are investigated, and being put to practical use for the grid-interactive inverter. Not only that, the grid-interactive inverter should be applicable for PV system, especially for residential use which roof is complicated. The most of grid-interactive inverter for residential use which Sharp provides for Japanese market are made up by string inverter concept.

As an example, Fig. 3 illustrates the circuit configuration of grid-interactive inverter in practical use. Plural of a high frequency PFM controlled current resonant type DC-DC converters are parallely-connected at the output

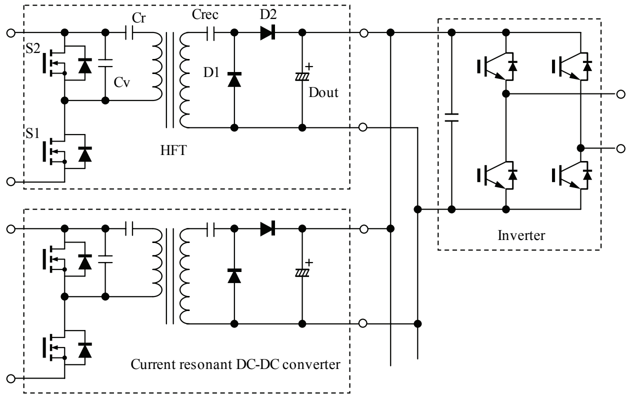

Fig. 3. Circuit configuration of grid-interactive inverter

terminal. At the latter part, the sinewave modulated inverter operated by high frequency PWM control is used in order to feed the grid. Each DC-DC converter performs MPPT control so as to output its individual maximum power supplied by each PV string even their output voltage are different. Thus, the string inverter contributes improvement of the system's generating efficiency.

MPPT Control using Genetic Algorithm

The maximum power point changes with solar radiation and temperature, so the inverter controls the output voltage of PV modules to maximizing the output power. However, when some PV modules are in the shade, power versus voltage characteristic may have two or more peaks and it is considered to be one of the causes of system efficiency's decrement by risk of operating at local maximum point. To prevent this, genetic algorithm (GA) is applied to MPPT control. GA is the general-purpose search method which obtained the idea from the biological evolution.

GA is applied to MPPT control for the PV characteristic that has plural peaks. First, genes of each individual are determined randomly, and the population of 1st generation is formed. The output voltage set to the voltage corre-

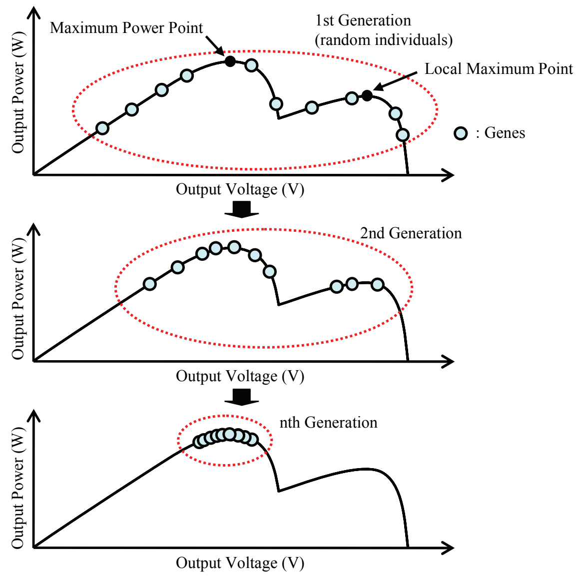

Fig. 4. Control schematic of MPPT using GA

sponding to the gene of each individual by operating the inverter, the output power is measured in this state to be memorized as "fitness value" of individuals. After the fitness value of all individuals is memorized, "selection", "crossover", and "mutation" are performed to the genes, and the population of next generation is formed. By repeating such a series of procedures indicated in Fig. 4, genes are converged on a point where "fitness value" becomes maximum power point.

Qty Control by Power Generation Prediction

Power generated by PV cells varies due to the solar irradiance. The efficiency characteristic of inverter depends on its input power, and especially conversion efficiency will decrease in lower input power range.

To prevent the decrease in lower input power range, Qty control is adopted so as to improve total system's conversion efficiency. Fig. 5 indicates the total conversion efficiency of ten units of 120kW inverters to show the effectiveness by Qty control for industrial use.

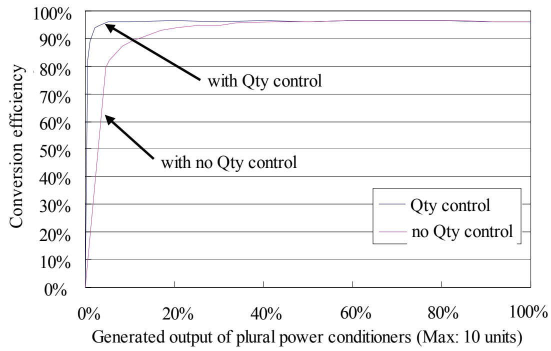

Fig. 5. Conversion efficiency of plural inverters

4. Conclusions

This review has focused on grid-interactive inverter for PV application. Their topologies, safety, electromagnetic compatibility, etc. are still being intensively investigated. Also, progresses in power semiconductor technology and magnetic materials has had significant impact on PV inverter topologies, efficiencies, and cost reduction.

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