Development of the "SANUPS P73J JEM1505 (A Frequency Feedback Method with Step Reactive Power Injection)"

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1. Introduction

PV inverters are equipped with active methods and passive methods in order to swiftly detect commercial power grid failures. However, active methods differ depending on the manufacturer. If a PV inverter were added to a commercial power grid already containing PV inverters made by other manufacturers, these manufacturers would be required by the local power company to perform an islanding test to confirm there is no interference between their active methods. Such tests were time-consuming and costly.

In August 2012, JEM1498 "standard active islanding detection scheme (a frequency feedback method with step reactive power injection) of single-phase PV inverters for distributed power generation" was established as the industry standard for islanding detection (active method) of single-phase PV inverters. This is incorporated in SANYO DENKI's "SANUPS P61B."

However, JEM1498 cannot be applied to three-phase PV inverters due to discrepancies in circuit type and differences in the applicable scope of grid connection regulations, therefore there was a need to establish an industry standard.

In September 2015, JEM1505 "standard active islanding detection scheme (a frequency feedback method with step reactive power injection) of three-phase PV inverters connected to low-voltage power distribution lines" was established as the industry standard for islanding detection (active method) of three-phase PV inverters.

SANYO DENKI newly developed the "SANUPS P73J" as a three-phase PV inverter that supported JEM1505 (a frequency feedback method with step reactive power injection). Figure 1 is an external view of P73J.

This paper provides an overview of the new model and presents its functional verification results.

Fig. 1: P73J external view

2. Overview of Frequency Feedback Method with Step Reactive Power Injection

Islanding detection (active method) based on frequency feedback method with step reactive power injection detects frequency change by injecting reactive power and changing AC voltage frequency.

Figure 2 shows a circuit block diagram of a frequency feedback method with step reactive power injection.

The frequency feedback portion measures the AC voltage frequency of the commercial power grid and calculates the reactive power injection amount $\theta 1$ from the frequency deviation that occurs during power failures.

If the load connected to a commercial power grid is balanced, even when a power failure occurs and islanding is occurred, the step injection portion will forcibly inject reactive power $\theta 2$ if step injection conditions are satisfied when the frequency change is small.

The inverter changes the AC voltage frequency by controlling with a current command that equals to the addition of two reactive powers $\theta 1$ and $\theta 2$.

The islanding detection portion judges that islanding is occurred if the frequency change from the measured frequency exceeds a threshold value, and stops the PV inverters.

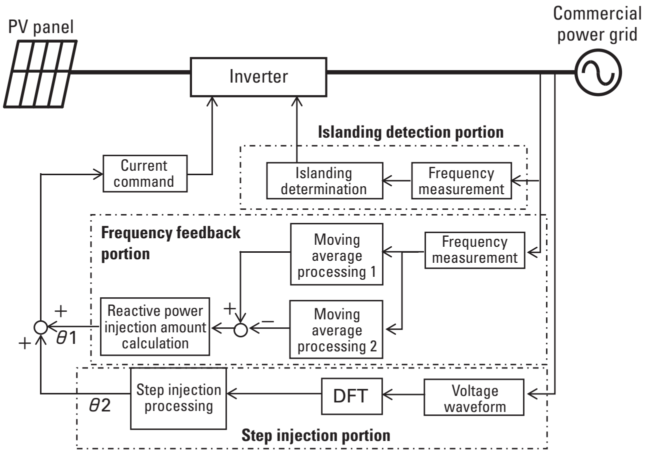

Fig. 2: Circuit diagram

2.1 Frequency feedback portion

The frequency feedback portion measures the frequency of the commercial power grid and finds the frequency deviation by subtracting the moving average frequency value of a 320 ms-duration of 200 ms prior to the moving average frequency value of the most recent 40 ms duration. That frequency deviation is multiplied by a certain value to obtain the reactive power injection amount $\theta 1$.

Figure 3 shows the relationship between the frequency deviation of a 10 kW PV inverter and the reactive power injection amount.

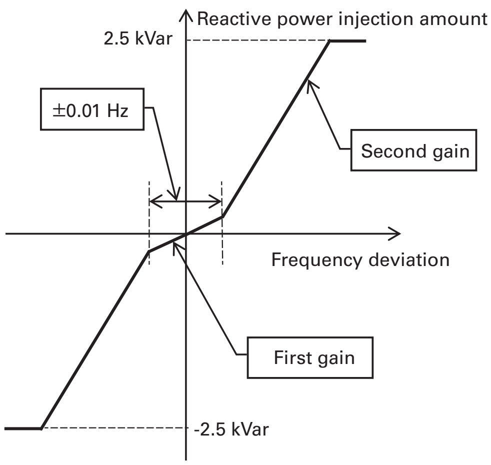

Fig. 3: Frequency deviation and reactive power injection amount

2.2 Step injection portion

By performing Discrete Fourier Transform (DFT) from the fundamental to the 7th harmonic in the voltage waveforms of a commercial power grid, the step injection portion calculates the 7th harmonic voltage from the fundamental voltage included in the voltage waveforms.

Regarding the detected fundamental voltage and harmonic voltage, if the frequency deviation is ±0.01 Hz or less, as shown in Figure 3, and the detection conditions of fundamental voltage and harmonic voltage stipulated by JEM1505 are satisfied, a 1 kVar reactive power will be injected for a set period of time in the case of a 10 kW PV inverter.

2.3 Islanding detection portion

The islanding detection portion measures the frequency of a commercial power grid, and if the measured frequency value exceeds a certain threshold value during islanding operation it will be deemed that islanding is occurred.

3. Operations of Each Portion

The results of an operational test for each portion of the frequency feedback method with step reactive power injection are summarized below.

3.1 Frequency feedback portion

Figures 4 and 5 show the waveforms when the frequency is changed from 50 Hz to 51.5 Hz and 51.5 Hz to 50 Hz at 2 Hz/s at system alternating power in a simulation. These waveforms show that the polarity of reactive power injection is consistent with Figure 3 due to the increase/decrease in frequency.

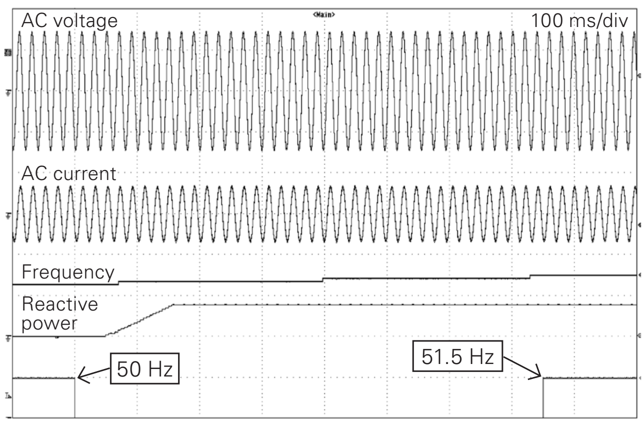

Fig. 4: Waveform for varying frequency (from 50 Hz to 51.5 Hz)

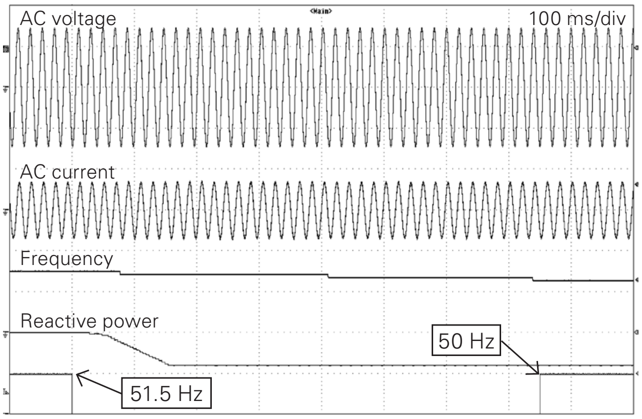

Fig. 5: Waveform for varying frequency
(from 51.5 Hz to 50 Hz)

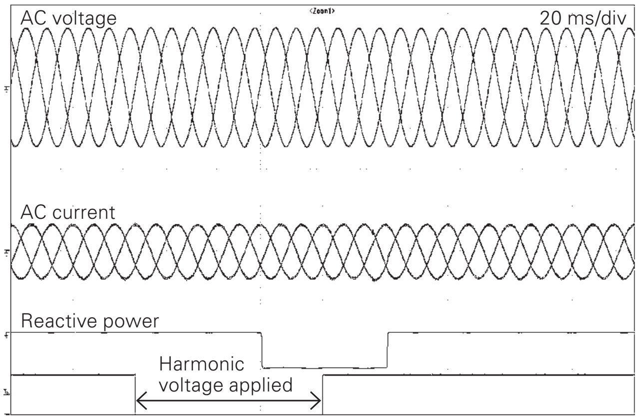

Fig. 7: Waveform for varying 7th harmonic voltage
(from 0 V to 2 V)

3.2 Step injection portion

Figure 6 shows the waveform for the reactive power injection operation when the alternating fundamental voltage is changed from 202 V to 204.5 V in a simulation with system alternating power. Figure 7 shows the waveform for the reactive power injection operation when the 7th harmonic voltage is changed from 0 V to 2 V as a typical example.

Figures 6 and 7 show that changes in fundamental voltage and 7th harmonic voltage are detected and reactive power is injected for a set period of time.

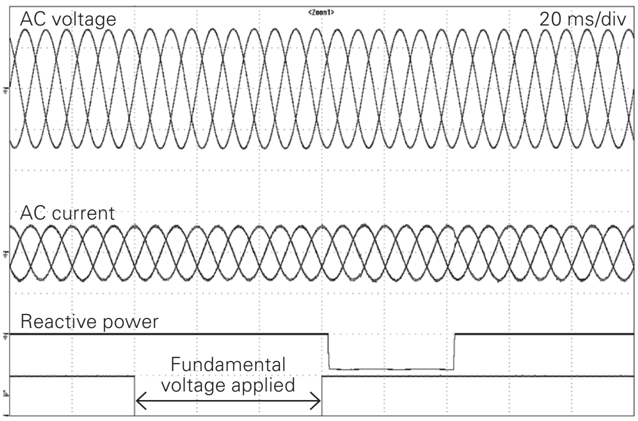

Fig. 6: Waveform for varying fundamental voltage
(from 202 V to 204.5 V)

3.3 Islanding detection portion

Figures 8, 9, and 10 respectively show the islanding detection waveforms when a power failure was simulated during operation of two, three, and four PV inverters.

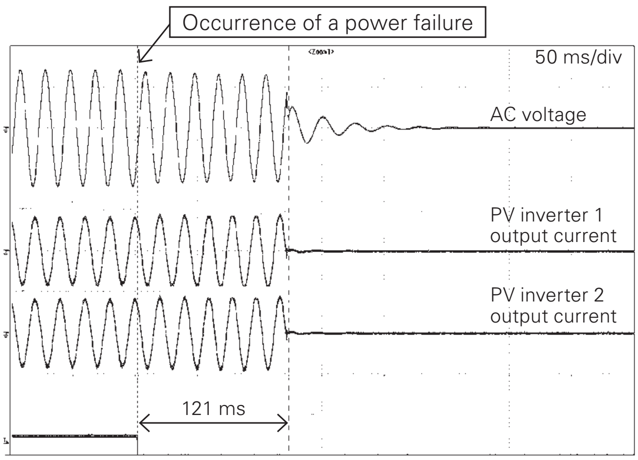

Fig. 8: Waveform for islanding detection
when operating 2 units

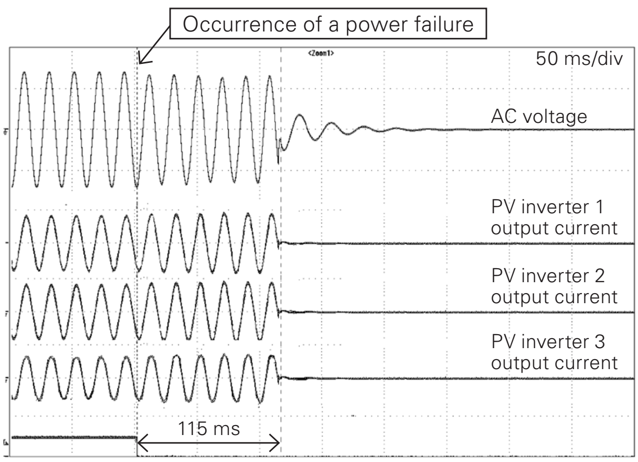

Fig. 9: Waveform for islanding detection
when operating 3 units

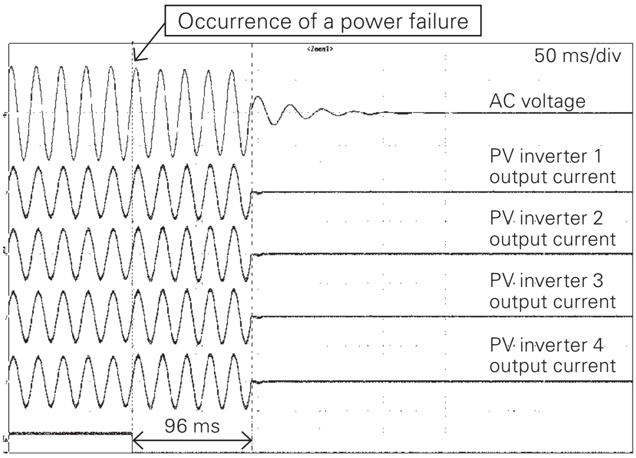

Fig. 10: Waveform for islanding detection when operating 4 units

From Figures 8 to 10, the results showed that even when the number of PV inverters operating were increased, there was no interference with the islanding detection of the PV inverters, which stopped within 200 ms of a power failure occurring.

4. Specifications

Table 1 shows the electrical specifications of the "SANUPS P73J" frequency feedback method with step reactive power injection.

Table 1: Specifications of the "SANUPS P73J" frequency feedback method with step reactive power injection

Item		**Grid-connected type**		**Remarks**
Output capacity		9.9 kW	10 kW	
Main circuit type		Self-commutated voltage type		
Switching method		High frequency PWM		
Isolation method		High frequency isolation		
Cooling method		Forced air cooling		
DC input	**Rated voltage**	400 VDC		
	Maximum allowable input voltage	570 VDC		
	Input operating voltage range	150 to 570 VDC		Rated output range 250 to 540 VDC
	Maximum power point tracking range	190 to 540 VDC		
	No. of input circuits	7 circuits (Max. of 11 A per circuit) 1 circuit (in the case of batch input)		In the case of batch input, an external junction box is required
AC output	**No. of phases and wires**	3-phase 3-wire		
	Rated voltage	202 VAC		
	Rated frequency	50 Hz / 60 Hz		
	Rated output current	28.3 AAC	28.6 AAC	
	AC output total harmonic distortion	Total current: 5% or less, Single harmonic: 3% or less		Rated output current ratio
	Output power factor	0.95 Min.		At rated output, when the power factor is 1.0 Power factor setting range: 0.8 to 1.0 (0.01 increment)
Efficiency		93% (except for junction box function)		Procedure for measuring efficiency based on JIS C 8961
Grid protection		Overvoltage (OVR), undervoltage (UVR), overfrequency (OFR), underfrequency (UFR)		OVGR shall be externally connected and normally-closed dry contact input shall be the standard
Islanding detection	**Passive method**	Voltage phase jump detection		
	Active method	**Frequency feedback method with step reactive power injection**		
Communication		RS-485		
Noise		50 dB Max.		A-weighted, 1 m from front of PV inverter
Operating environment	**Ambient temperature**	-25 to +60°C		Operates with derated output above 40°C
	Relative humidity	90% Max. (non-condensing)		
	Altitude	2000 m Max.		
Paint color		Munsell 5Y7/1 (semi-gloss)		
Heat generation		688 W	695 W	
Transducer function		Yes		For pyranometer, thermometer
Mass		64 kg		

5. Advantage for Customers

Below is a summary of the advantages customers can enjoy due to the adoption of industry standard JEM1505 (a frequency feedback method with step reactive power injection).

(1) Advantageous for grid connection of multiple PV inverters for distributed power due to no interference in the islanding detection (active method) of each manufacturers' PV inverters.

(2) Synchronization signal cable not required for multi-unit grid connection.

(3) When connecting to the same grid system as other manufacturers' PV inverters, no need for islanding tests with the said other PV inverters which require discussion with the power company, therefore alleviating the related burden (cost/time) (however, limited to JET-certified models supporting a frequency feedback method with step reactive power injection).

6. Conclusion

This paper has provided an overview of the industry standard, JEM1505 (a frequency feedback method with step reactive power injection). Moreover, a favorable result was obtained from multi-inverter islanding tests performed with the "SANUPS P73J," a three-phase PV inverter incorporating the above method.

SANYO DENKI wishes to express its appreciation to the many people who cooperated and offered advice in the development and production of this product.

References

(1) Japan Electrical Manufacturers' Association (JEMA) standards: JEM1498 "standard active islanding detection scheme (a frequency feedback method with step reactive power injection) of single-phase PV inverters for distributed power generation"

(2) Japan Electrical Manufacturers' Association (JEMA) standards: JEM1505 "standard active islanding detection scheme (a frequency feedback method with step reactive power injection) of three-phase PV inverters connected to low-voltage power distribution lines"

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