RESULT OF REVIEW BY ELECTRIC ENERGY AMOUNT COMPARISON WITH RESONANCE LOAD TURNED TO MOTOR LOAD STANDARDIZATION

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ABSTRACT: The islanding phenomena of PV inverter are obviously influenced by the regenerative loads such as motor load and resonance circuit. In Japanese situation, the motor loads of 1KW or less are used in the certification test and evaluated in order to test the islanding detection device in a severer case from the viewpoint of safety. However, the motor load is not very clear in the specification of a standard motor to use for the examination so that there are diverse and unspecified kinds. Accordingly, it is certainly not easy to standardize the motor load for certification test around the world. On the other hand, in IEEE929-2000 and IEC62109CD2 standard, resonance circuit is used instead of motor load for the examination with consideration of regenerative load characteristic. Therefore, It is necessary to confirm whether the resonance circuit can simulate the motor load properly under the islanding condition.

Keywords: Motor load, Resonance load, Islanding, Grid-Connected, PV System,

INTRODUCTION

The islanding phenomena of PV inverter are obviously influenced by the regenerative loads such as motor load and resonance circuit. From the safety point of view, the regenerative load is generally used in the islanding prevention test to obtain more severe case for islanding detection. Less than 1kW grinder load, which has comparatively large inertia, is adopted in Japanese certification test of islanding[(1)] prevention function for PV inverter connected to low voltage(200V) distribution line. The grinder load is not so popular, but actually used by the low voltage customers such as small factory and so on. As we have to take the worst case into account for ensuring safety, we are using the grinder load in the certification test as a general worst case for islanding detection.

It is certainly not easy to standardize the motor load for certification test around the world. On the other hand, resonance circuit is standardized in some IEC standards in stead of motor load with consideration of regenerative load characteristic. Therefore, it is necessary to confirm whether the resonance circuit can simulate the motor load properly under the islanding condition.

The objectives of the study are to confirm the application of motor load on the “Testing Procedure of Islanding Prevention Measures for Utility Interactive PV Inverter” by experiment. The experiments practiced for this study are as followed.

1) The experiment concerning similarity and difference of islanding characteristic between using motor load and using resonance circuit as regenerative load.
2) The experiment concerning the possibility of standardization of motor load in the islanding prevention test.

Measuring the electric energy

Islanding phenomena tend to depend on the regenerative energy of motor load and/or resonance circuit.

From this point of view, we tried to evaluate the regenerative energy of several sampled motor loads and resonance circuit as the beginning of the study.

In the JET attestation system, the motor load is used in order to imitate the motor loads that actually exist on the electric power line and in order to imitate the situation that both a lot of PV generation systems and the motor dynamos drive parallel.

Moreover, the motor load that runs without electric power becomes a pilot of the voltage and the frequency of the electric power lines, imitates the situation in which many PV generation systems including the voltage control type are connected in parallel extremely well, and operates as an ideal motor load type dynamo that does not supply the active power.[(2)]

In addition, because it turns out that the motor load supplies and absorbs an reactive electric power in the past study results, it is used in the JET attestation examinations as the severest load condition for the inverters that try to change the frequency. However, the detail of the specification in the capacity and moment of intarsia of the motor load used for the examination have not be clarified currently; the influence to Islanding detection differs depending on the size of capacity, moment of inertia, and so on that affect the islanding detection time as a result. Therefore, it was assumed that the characteristics of electric energy of an individual motor loads were clarified by measuring the electric energy of various motor loads.

Measuring the electric energy of the motor load

Four types of commercialized inductive grinder motor load connected 200V line are used.

The rated capacity and the moment of inertia of each load are shown in Table 1.

The electric energy of the motor loads was measured by timing for the resistance load to consume about 10% (20V) of the rating voltage (200V) of the electric energy remained in the motor in the condition that a motor load and a resistance load were connected in parallel to the AC utility power simulator.

1. Increase the electric power consumed by resistance load connected to the motor load from 0 to 4000W by 100W.
2. Separate both motor load and resistance load from the AC utility power simulator by opening the switch (SW_{CB}) when the timing is t=0.
3. Observe the voltage V_2between lines of the motor load of resistance load connected in parallel and measure the time delta X (Sec) while the voltage attenuate to about 10% (20V)of rated voltage (200V).
4. In the same way above, measure the time delta X (Sec) using different motor load in table 1.

Fig.1 shows the circuit chart to measure the electric energy of the motor load.

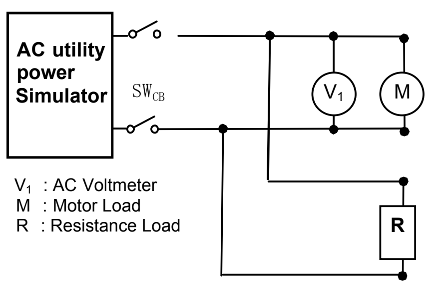

Fig.1.Measurement circuit of electric energy of motor load

Measuring the electric energy of the resonance load

In IEC standard, the inductivity load of the resonance load is defined by the formula (1) that is power conditioner ratings active effective output capacity

To execute our experiment, we had to decide the power conditioner output capacity. We examined the ratings output capacities of the certified power conditioners by JET authentication system in recent years.

As a result, since the majority of the power conditioners were 4kW of the rated output capacity, we decided the rated output capacity for the experiment was 4kW.

It is same as measuring the amount of electric energy of the motor load, amount of electric energy in resonant circuit is measured timing for the resistance load to consume about 10% (20V) of the rating voltage (200V) of the electric energy remained in the condition that a resistance load and a inductive and capacitive load were connected in parallel to the AC utility power simulator.

Moreover, the amount of inductive load was 2.6kVar, which was calculated with formula (1), and the same amount of capacitive load, 2.6kVar, was inserted.

$$P_{qL} = \mathrm{Q}_f \times \mathrm{P}_{\mathrm{EUT}} \quad \text{.....................} (1)$$

P_{EUT}: Power conditioner ratings output

Q_f: 0.65

1. The resistance load connected with the resonance load parallel increases the electric power consumed by the resistance load from 0 to 4000W by 100W.
2. Switch (SW_{CB}) is opened according to the timing of t=0, and the motor load and the resistance load are separated from AC utility power Simulator.
3. The voltage between lines of the resistance load of each resistance load connected parallel that can be put is measured, and even about 10%(20V) of 200V in the ratings voltage measures delta X(Sec) until attenuating.

Fig.2 shows the circuit chart to measure the electric energy of the resonance load.

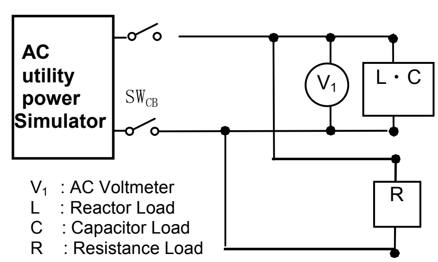

Fig.2.Measurement circuit of electric energy of resonance load

Table 1. Specifications of grinder motor loads (100V single phase)

Type	Rated capacity	Moment of inertia	Real power*)	Reactive power*)	rpm
Motor A	170 W	0.03 N-m^2	67 W	170 Var	3000 rpm
Motor B	365 W	0.03 N-m^2	80 W	270 Var	2970 rpm
Motor C	620 W	0.06 N-m^2	80 W	280 Var	2970 rpm
Motor D	645 W	0.06 N-m^2	95 W	175 Var	2960 rpm

*) in case of no load

Measurement result of electric energy

Fig.3 shows an experimental result concerning regenerative energy of motor loads and resonance circuit defined in IEC standards.

The EUT is disconnected from the experimental circuit in all cases. The relationships between the lapse of time from separation of SW_{CB} to the time when remaining voltage of load reaches 20V (see Fig.4 and Fig.5 as references), which is 10% of rated AC voltage(V_1) , and consumption of resistance load (AR) are indicated in Fig.3.

The lapse of time decreases according to the increase of consumption of resistance load because the consumption rate of the regenerative energy becomes faster.

The results reveal that motor C and D have almost the same regenerative energy, and the value of regenerative energy of motor A is close to the value of motor B. Besides, it is also clear that the value of the resonance circuit is almost equal to the value of motor A. Namely, it is judged that the resonance circuit and motor A is almost equivalent to the regenerative energy of the resonance circuit.

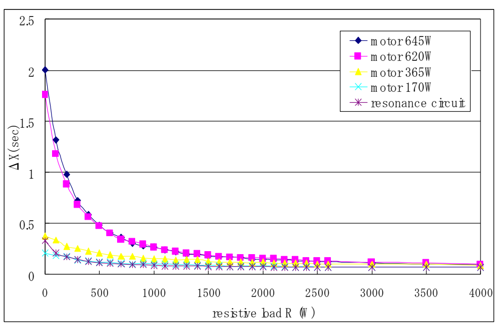

Fig.3. Measurement result of electric energy

However, because the result of above experiment is the length of time that it takes for the resistance load to consume the electric energy accumulated in each load, it is not clarified yet that whether the actual power conditioner would result in islanding by the influence of electric energy that was examined in this experiment.

Confirming the effectiveness of the motor load and resonance load by islanding experiment

The Islanding characteristics of motor A and the resonance circuit are the most similar in the regenerative energy. The 4kW PV inverter described above is used as a EUT in all islanding test below.

Fig.4 and Fig.5 show the relationship between islanding detection time, which means the time islanding continues (run on time), and imbalance condition of P and Q when both of the passive detection measure (PDM) and the active detection measure (ADM) in the inverter for islanding detection are masked.

Namely, islanding is detected only by voltage and frequency relays of the inverter in the cases.

In all figures, positive P means that load consumption is lager than real power of inverter just before SW_{CB} opened, and positive Q means that the system is in inductive condition just before SW_{CB} opened.

Table 2 and 3 also show frequency values of 0.3 sec. after S1 opened.

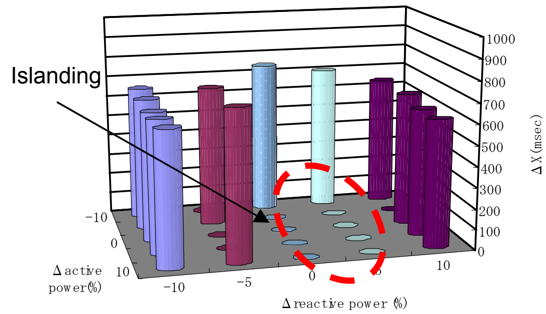

Fig.4 Islanding detection time limit by motor load

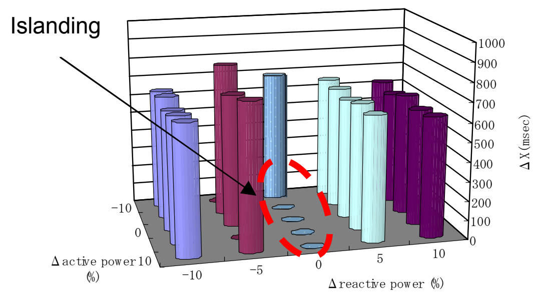

Fig.5 Islanding detection time limit by resonance load

It is shown that each characteristic of both resonance circuit case and motor load case is similar when P=0%, Q = 0% and P = 0%, Q = 5%.

Summary

By the experiment in which the electric energy of the motor loads and resonance load examined in IEC standard were measured, it was confirmed that, when the resonance coefficient was Qf=0.65, the amount of the electric energy of the resonance load had was almost equal to the amount of electric energy of the 170W motor load.

However, we cannot tell whether the influence by both loads on the islanding detection device of an actual power conditioner would be the same only by the evaluation of the electric energy that each load had.

Therefore, the islanding experiment was performed respectively of the resonance load and the 170W motor load with a real power conditioner.

It was confirmed that using either the resonance load or the 170W motor load, it resulted in islanding when the active power and the reactive electric power were in the state of equilibrium

In the same time, it was confirmed that, when the reactive electric power of both of the loads were in the state of equilibrium, it takes about 600ms for

Table 2. Frequency analysis result after 0.3 seconds after it blacks out (motor load 170W)

		Reactive power (Var)				
		-10%	-5%	0%	+5%	+10%
Active power (W)	-10%	45.45Hz	49.99Hz	50.51Hz	52.09Hz	55.24Hz
	-5%	45.84Hz	47.14Hz	50.05Hz	49.99Hz	50.00Hz
	0%	45.62Hz	50.05Hz	50.02Hz	50.04Hz	53.27Hz
	+5%	43.37Hz	49.96Hz	49.96Hz	49.99Hz	53.31Hz
	+10%	45.61Hz	48.51Hz	49.96Hz	49.97Hz	54.92Hz

Table 3. Frequency analysis result after 0.3 seconds after it blacks out (resonance load).

		Reactive power (Var)				
		-10%	-5%	0%	+5%	+10%
Active power (W)	-10%	46.75Hz	48.43 Hz	52.37 Hz	53.53 Hz	54.14 Hz
	-5%	46.47 Hz	48.25 Hz	50.21 Hz	53.12 Hz	54.46 Hz
	0%	46.88 Hz	48.05 Hz	50.59 Hz	52.09 Hz	54.03 Hz
	+5%	46.82 Hz	48.47 Hz	48.51 Hz	52.74 Hz	54.08 Hz
	+10%	46.78 Hz	48.35 Hz	48.81 Hz	52.12 Hz	54.39 Hz

the power conditioner to detect islanding and stop its operation even when the active power is increased and decreased.

From these results, it was shown that the resonance load and the 170W motor load have a similar characteristic in the influence given to the islanding detection device.

However, it also turns out from the result that the motor load cause islanding in wider range of load condition than the resonance load.

Therefore, we focused on the result of the frequency analysis after the black out considering the frequency would be the reason that the motor load caused islanding in wider range of load condition.

As a result, it was confirmed that in the load condition to cause the islanding phenomenon the frequency change after a black out is significant with the resonance load where the frequency barely changed with the motor load.

It is assumed that with the motor load the islanding phenomenon was caused in a wider-ranged load condition because the motor load maintained the frequency before blackout by absorbing and supplying the reactive electric power after the black out.

In the meanwhile, it is confirmed that the motor loads radically increases and decreases the frequency far more than the resonance loads in the other load conditions than that what causes islanding.

It is assumed that there is a possibility that the motor load increased the degree of the frequency change affected by the other inductive loads or capacitive loads.

The result of the experiment shows that there is similarity between both loads since the power conditioner resulted in islanding in the same load condition with either resonance load or the 170W motor load.

For the future study, the load condition to cause the islanding phenomenon will be confirmed by using other motor loads, the similarity between the 170W motor load and other loads will be verified, it will be confirmed whether a motor load absorb or supply reactive electric power after black out, and other influences by inductive loads and capacitive loads conditions will be clarified.

(1) October,2002 Electrical Safety & Environment Technology Laboratories”Test Procedure for Grid-connected Protective “Equipment, etc. for Photovoltaic Power Generation Systems

(2) 'New Sunshine project New Energy and Industrial Technology Development Organization (NEDO) consignment business result report' (PV) systems practical use technology development "Research and development of photovoltaic use system evaluation technology" and (research and development of technological in surrounding evaluation system) in 1994 fiscal year'