ANALYSIS MODEL AND DEMO TESTS OF PREVENTING ISLAND FUNCTION OF PHOTOVOLTAIC GENERATION ON GRID-INTERCONNECTION CODE IN JAPAN

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ABSTRACT

In recent years, distributed generations (DG) interconnected to power distribution system increase by introduction of Feed-in Tariff in Japan. Protection function and voltage control function are provided to these DGs enough to interconnect these DGs to power distribution line. The protection function is specified to the technical standard of the electric facility, and the electric power quality is specified to the guideline in Japan. Photovoltaic generation (PV) equipment maker designs and manufactures power conditioning subsystems (PCS) according to these regulations. We have to model PV-PCS for computer simulation in order to study the influence on protection of power distribution line and electric power quality when PV equipment is interconnected to power distribution line in large quantities. Moreover, it has been not permitted that reverse power flow in part of transformer of distribution substation (DSS) occurs by voltage regulation of power distribution lines and preventing islanding in area of transformer of DSS. In this paper, we make the model of PV-PCS for computer simulation, and extract the problems when reverse power flow in part of transformer of DSS occurs. Moreover, we test preventing islanding by using actual voltage test equipment in CRIEPI.

INTRODUCTION

In recent years, distributed generations (DG) interconnected to power distribution system increase by introduction of Feed-in Tariff in Japan. Protection function and voltage control function are provided to these DGs enough to interconnect these DGs to power distribution line. The protection function is specified to the technical standard of the electric facility, and the electric power quality is specified to the guideline in Japan. Photovoltaic generation (PV) equipment maker designs and manufactures power conditioning subsystems (PCS) according to these regulations. We have to model PV-PCS for computer simulation in order to study the influence on protection of power distribution line and electric power quality when PV equipment is interconnected to power distribution line in large quantities. Moreover, it has been not permitted that reverse power flow in part of transformer of distribution substation (DSS) occurs by voltage regulation of power distribution lines and preventing islanding in area of transformer of DSS.

ANALYSIS MODELING OF POWER CONDITIONING SUBSYSTEM (PCS) FOR DOMESTIC PV

History of Function of Preventing Islanding

In Japan, conventional type method of detecting islanding of distributed generations, in order to detect an islanding accurately, it is necessary to include two methods of active and passive method. Passive method detects quickly, but possibility of unnecessary operation is high. Therefore, if passive method operates, PCS is stopped by the gate block. On the other hand, active method detects slowly, but possibility of unnecessary operation is low. The disadvantage of conventional type method of detecting islanding is that active methods together interfere with one another and function of detecting becomes lower. In Japan, there are many kinds of method of detecting islanding, using active power variations, reactive power variations, load variations, frequency variations and harmonics variations.
For conventional type method of detecting islanding of distributed generations, we reduce possibility of mutual interference of active methods. Therefore, it is called new type active method that achieves high-speed detection. We were able to coexist with high-speed detection of active method and FRT function.

Preventing Islanding of new type active method

Fig.1 shows relation frequency deviation and reactive power which is poured in by PV-PCS for preventing islanding. We made analysis model for analysis tool developed in CRIEPI (called XTAP). Fig.4 shows GUI for XTAP. XTAP is electromagnetic transient simulations tool, and has many kinds of source, load, control function and calculation block. Fig.2 shows comparing test result with simulation result of detecting islanding, and the error of detecting time was 10msec, which is a satisfactory level.

Fault Ride Through of Domestic PV-PCS

Fig.3 shows condition of fault ride through on Grid-interconnection Code in Japan. In instantaneous voltage drop showed as Fig.2(a), when drop rate is UVR-52% (including phase shift), PV-PCS has to operate continuously. PV-PCS has to operate continuously when drop rate is 52-20%. PV-PCS has to operate continuously or gate block when drop rate is 20% or less. In step change of frequency showed as Fig.2(b), PV-PCS has to operate continuously when frequency increase (+0.8Hz 20msec). In lamp change of frequency showed as Fig.2(c), PV-PCS has to operate continuously.

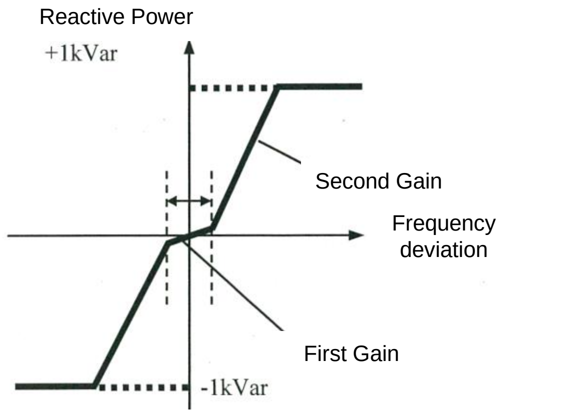


Fig.1 Active System of Preventing Islanding

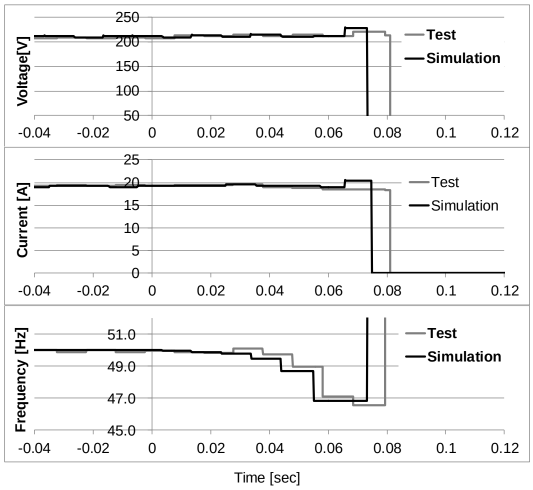
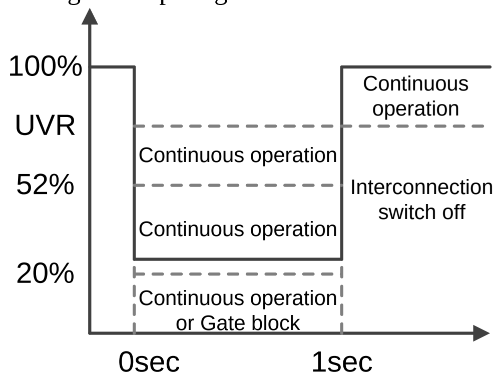


Fig.2 Comparing Test with Simulation



(a)Instantaneous Voltage Drop

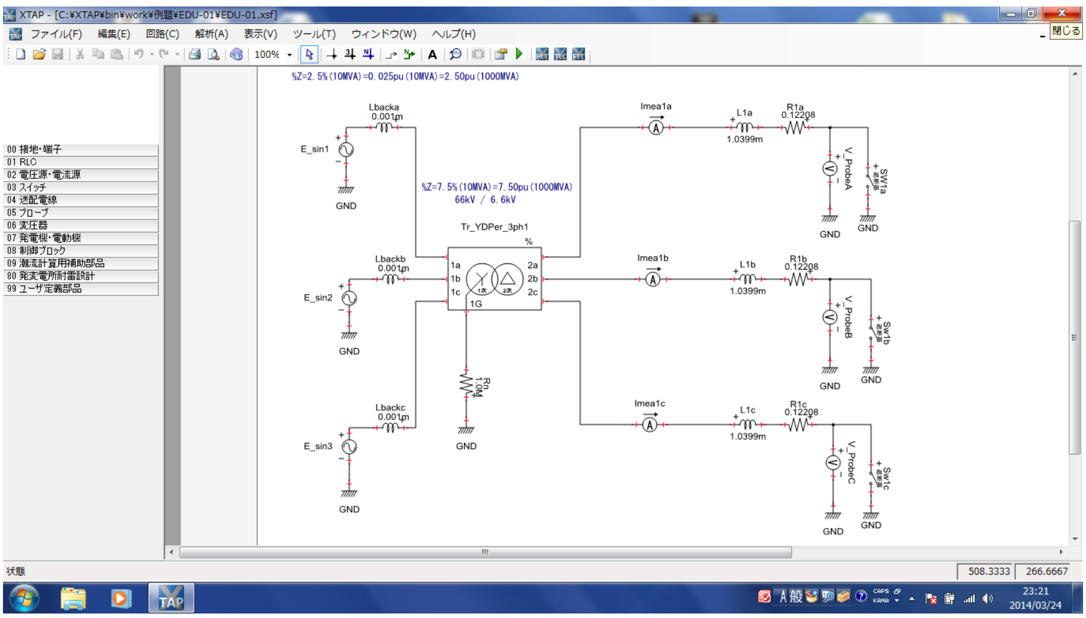
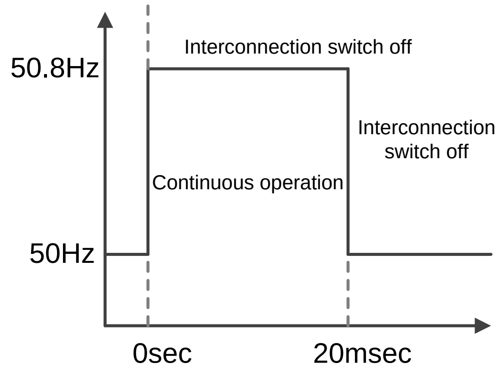
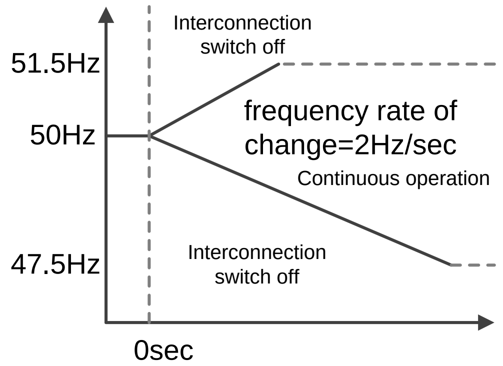


Fig.4 GUI for XTAP



(b) Step Change of Frequency

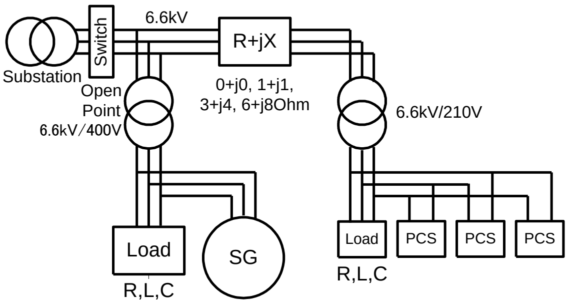


(c) Lamp Change of Frequency
Fig.3 FRT Condition

INFLUENCE OF REVERSE POWER FLOW OF TRANSFORMER IN DISTRIBUTION SUBSTATION

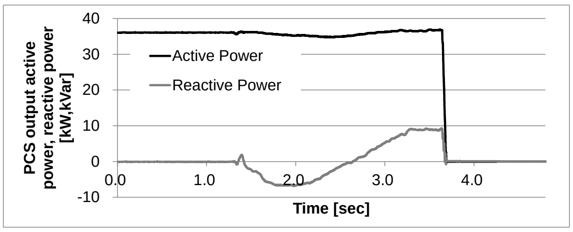
Demonstration tests of preventing islanding using test system of actual voltage

Fig.5 shows demonstration test system for preventing islanding when reverse power flow of transformer in DSS occurs. The test system has 2MW transformer (66kV/6.6kV), 6.6kV power distribution system, 1.6MW load system, rotational distributed generators and power conditioning subsystems. The condition of this test is balancing DGs output and load in active power and reactive power, 3-9 sets of PV-PCS and 150kW synchronous generator.

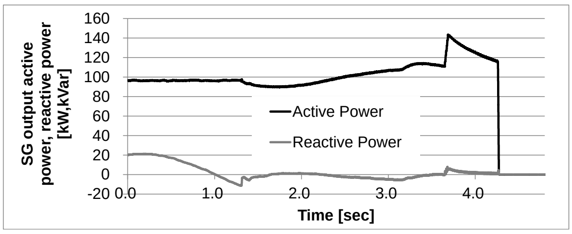


(a)Test Circuit for Preventing Islanding

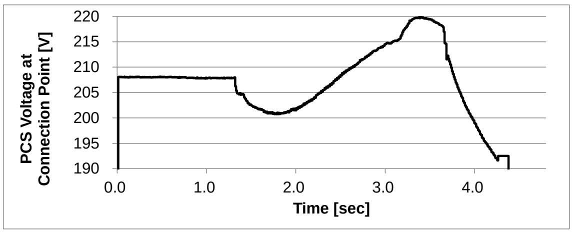
(b)PCS (c) Synchronous Generator
Fig.5 System for Preventing Islanding



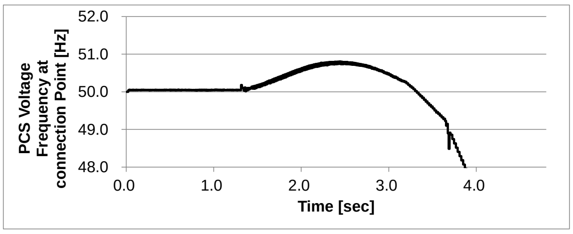
(a) Test Results of PV-PCS



(b) Test Results of Synchronous Generator (Co-gene)



(c)System Voltage at PCS connection point



(d)Frequency at PCS connection point
Fig.6 Demonstration Tests of Preventing Islanding

Fig.6(a) shows active power and reactive power of PV-PCS output. Islanding started when switch was opened at 1.3sec, PV-PCS stopped at about 3.7sec. The reactive power decreased once and increased then because of active signal of preventing islanding system according to Fig.1.

Fig.6(b) shows active power and reactive power of synchronous generator (SG) output. SG stopped at about 4.3sec. The reactive power varied sinusoidally before

islanding because of signal of preventing islanding system, and was almost constant while islanding. In grid-interconnection code, after opening switch, DGs have to stop within 3sec. These DGs stopped within required time, because they have active preventing islanding function.
Fig6(c) shows system voltage at connection point of PV-PCS. The system voltage dropped once and rose then because of active signal of preventing islanding system.
Fig6(d) shows system frequency. The system frequency rose once and dropped then because of signal of preventing islanding system.

Demonstration tests of FRT Function

We tested FRT function of some new type PCS. In FRT tests, we use Back to Back system and control system. The control system can generate instantaneous voltage drop, step change of frequency and lamp change of frequency. The results means almost OK.

Simulation of preventing islanding using XTAP

Table 1 shows calculation results using XTAP in the case that SG capacity is 2MW and without active signal. The vertical axis means PCS capacity / SG Capacity (Ck). The horizontal axis means electrical distance (Ed). OK means that islanding stops within 3.0 sec. In the case of Ck=0.3, if Ed=3+j4[Ohm] or 6+j8[Ohm], islanding can stop within 3.0 sec. But if Ed=0+j0[Ohm] or 1+j1[Ohm], islanding cannot stop within 3.0 sec. In the case of Ck=0.4, islanding can stop within 3.0 sec. These results means that if distance between PCS and SG is short, SG maintain voltage and frequency constant and PCS cannot break islanding condition. On the other hand, If distance between PCS and SG is long, SG cannot influence PCS and PCS can break islanding condition.

Table 1 Calculation Results

electrical distance [Ohm] PCS Capacity / SG Capacity	0+j0	1+j1	3+j4	6+j8
0	-	-	-	-
0.3	-	-	OK	OK
0.4	OK	OK	OK	OK
0.6	OK	OK	OK	OK
0.8	OK	OK	OK	OK
1	OK	OK	OK	OK
1.1	OK	OK	OK	OK
1.2	OK	OK	OK	OK

CONCLUSION

We made the model of PV-PCS for computer simulation, and extracted the problems when reverse power flow in part of transformer of DSS occurred. Moreover, we tested preventing islanding when revers power flow by using actual voltage test equipment in CRIEPI.

REFERENCES

(1) S.Uemura, M.Takagi and K.Kawahara : "A Study on Preventing Islanding by Distributed Power Generation at Transmission System Fault - Evaluation of Characteristic of Detecting Islanding by Power Conditioning Subsystem for Interconnecting Many Distributed Power Generations in Area with Rotated Type Distributed Power Generation -", CRIEPI Report, R12020(2013.7) [in Japanese]
(2) Grid-interconnection Code JEAC 9701 -2012