OPTIMAL INTERCONNECTION DEVICE BETWEEN DNO AND SMALL SCALE DERs OF CUSTOMER

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ABSTRACT

This paper presents an interconnection device between DNO and small scale DERs of customers. It can link DERs more economically and improve the power quality for customers owing to prevent power failure by independent operation in case of power failure in DNO network and trade the electricity with DNO. In addition it can send information on the condition of the customer electricity network. So DNO can operate their distribution network efficiently. For the customer it can connect DERs efficiently and reduce installation spaces. In this device each power converter of DER connected to DC link and one bidirectional inverter wired to DC link. A static transfer switch (STS) was installed so that customers can prevent power failure by islanding operation during the DNO network failure. An intelligent electronic device (IED) was installed so that power and information can be exchanged with DNO or nearby customers and the protection control can be done to satisfy all the current standards for DERs.

INTRODUCTION

Due to the depletion of fossil fuels and environmental problem resulting from excessive use of fossil fuels, greater attention is being given to renewable energy such as photovoltaic, wind power generations, and landfill gas power generations. Although the power production costs of these systems are still higher compared to large power plants, renewable energy sources are being developed in the world thanks to government support. In Korea, these systems are interconnected to the distribution systems in the form of distributed generations. Although these links of distributed generations to distribution systems show positive effects regarding protection of the environment and energy saving, from the standpoint of the power suppliers, there are serious problems related to the protection, power quality and so on.

Therefore, to overcome these problems and actively introduce DERs, many countries are beginning to introduce 'smart grid' and 'microgrid'. Smart grid and microgrid technologies will replace existing passive systems and more actively utilize distributed generations. However, even when smart grids are activated, interconnection of DERs to DNO network involves many restrictions that must be considered such as standards for interconnection of distributed generations and economic issues.

In this paper, a smart switch panel (SSP) is proposed that can interconnect loads and DERs to one switch panel unlike existing switch panels so that the space and costs could be reduced and power can be supplied continuously to the customer in case of DNO network failure. The SSP can receive commands from distribution management systems (DMS) of DNO to increase or reduce the output of distributed generations or exchange the power with other customers.

CONFIGURATION OF SSP

Fig. 1 shows a diagram of SSP. It consists of 4 modules including STS (Static Transfer Switch), PCD (Power Carrying Device), PCS (Power Conversion System) and IED (Intelligent Electronics Device).

Table 1 Specification of the SSP

Classification	Capacity /content
Distributed generation	DE : 100kVA, PV: 50kW Battery: 1.5kW, FC : 10kW
STS	200kVA
PCS	200kVA
IED	Control the entire SSP Communication with ESP system

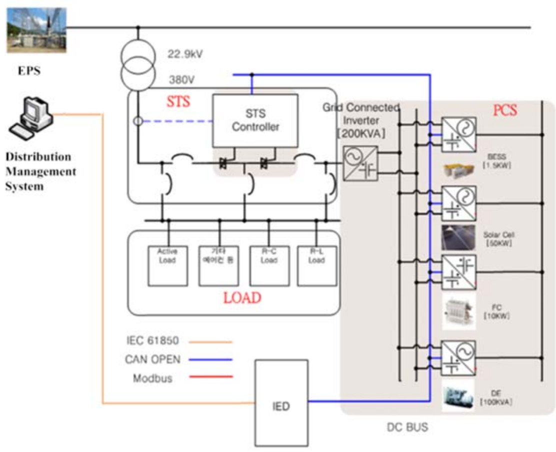


Fig. 1 Configuration of smart switch panel

The PCD physically connects the loads of existing customers with distributed generations and the PCS coverts the power produced by distributed generations into usable AC. The IED corresponds to the central control device of the SSP, which controls power exchanges and protection coordination. The major specifications of the targeted SSP are summarized in Table 1.

Static Transfer Switch(STS)

To supply stable power to loads of customers during the accidents or disturbances in EPS, electric devices in customers and upstream DNO should be quickly separated. Since existing circuit breakers cannot fulfill this purpose, in this study, switches applied with semiconductor elements will be installed in the SSP.
The operation requirements of the STS will be designed to satisfy all the operation times defined by IEEE 1547[1] and domestic standard[2]. As a switching element, SCR (Silicon Controlled Rectifier) will be used and MCCBs will be installed at both ends of the switch for the maintenance and checks of the switching element. In addition, an MCCB for bypass will be installed to handle anomalies in the switching element.

Major functions required for the STS in this paper are as follows.

- Interconnection between EPS and customer
- Judgment of anomalies in upstream EPS
- Clearing time: within 8ms
- Automatic / Manual transfer
- Automatic re-transfer
- Shorted / open SCR protection

Power Carrying Device(PCD)

The PCD is located on the secondary side (load side) of STS and this is where the STS, customers' loads, and distributed generations are physically connected. The PCD consists of a low voltage bus bar, an MCCB that protects loads and distributed generations, and PTs/CTs that can measure the amounts of loads and the amounts of generation by distributed generations.

Power Conversion System(PCS)

The SSP proposed in this paper is installed with a power converter to reduce costs to link DERs and minimize the space for installing electric devices for interconnections. Power converters are normally installed in each distributed generation. However, in this paper a PCS where DC links and inverters are shared is proposed to increase the conversion efficiency of the converter.

The power generated by photovoltaic systems is linked to the common DC link through DC/DC converters and the power produced by wind power generations is linked to the DC link through the AC/DC converters. Each distributed generation is installed with a control board and the state of each DERs can be directly monitored and controlled by the user through the gate drive. In addition it provides DC bus for the future DC distribution of customer.

Intelligent Electronics Device(IED)

The IED will generally control the SSP and communicate with DNO to initiate power exchanges and increase/decrease the power generation. This will cooperate with STS to control protection coordination and the amounts of loadings in an emergency.

If STS are disconnected due to accidents in the DNO network the customers are operated independently and the IED will deliver command values for voltage control and frequency control to distributed generations. The IED communicates with DNO through IEC61850.

SIMULATION

To implement the SSP, simulations were conducted on an abridged system diagram as shown in Fig. 2 using the PSCAD/EMTDC. Major input variables used in the simulations are as shown in Table 2.

Simulations were conducted on independent operation detection and maintenance, which are the most important functions of the SSP. Indoor load conditions were 10kW non-linear loads and 6.2kvar. Reactive loads, and system loads were composed of 10kW of pure resistance loads. The inverter was set to produce 20kW of constant output while compensating reactive power. Independent operation was implemented by tripping the system-side CB (circuit breaker) by force. The simulations were conducted on cases where there is little power mismatch between the inverter output and the power island.

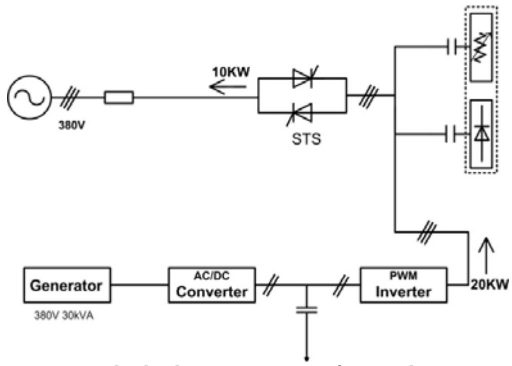
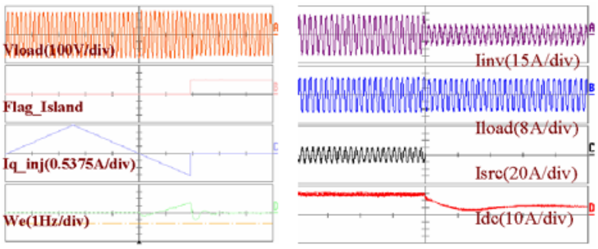


Fig. 2 Abridged System Diagram for Simulations

As shown in Fig. 3(a), even when the PCS supplied reactive power in the form of chopping waves before the independent operation occurred; the voltage of the load inside the smart switch panel was hardly affected and the system frequency maintained a constant value. When independent operation has occurred, the frequency rapidly rose and when it reached the trip point of over 61.5Hz, independent operation was detected. As soon as the independent operation was detected, STS was tripped and the control mode of the inverter was changed from current control to voltage control. The voltage and frequency soon recovered to normal values and the state of independent operation was maintained as shown in Fig. 3(b).

Table 2 Major Input Variables Used in the Simulations

Classification		Content
Power source voltage		380V, 60 Hz
Power source side impedance		0.001 Ω, 10 mH
DC capacity		3300 μF
Reference DC voltage		700 V
Inverter filter L, C		600 μH, 40 μF
Indoor load (10kVA)	Diode rectifier load R, L	20 Ω, 1 mH
	Linear load R, L	40 Ω, 50 mH
System side load (10kVA)	Diode rectifier load R, L	20 Ω, 1 mH
	Linear load R, L	40 Ω, 50 mH



(a) Voltage, Islanding, Current_PV, Frequency (b) Current (PV, Load, STS, DC link)

Fig. 3 Simulation Results

PERFORMANCE TEST

In order to verify the performance of SSP we connect all components each other like Fig. 4.

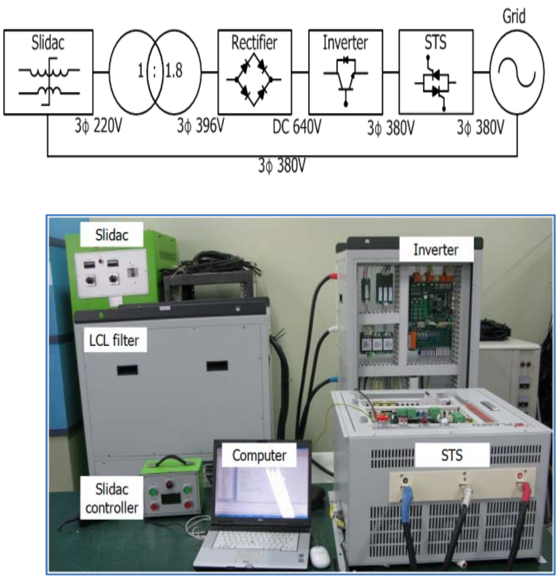


Fig. 4 Configuration of performance test

In this experiment we checked the performance of STS. Fig. 5 shows the voltage and current response of STS after disconnection. It shows the successful operation of STS.

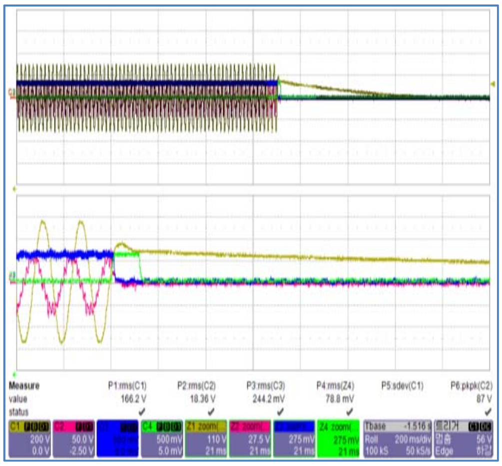


Fig. 5 Performance test

In addition we controlled dc link voltage between 650V and 750V to check the performance of inverter. It shows that the response time of voltage controller is about 50ms and current controller is about 5ms.

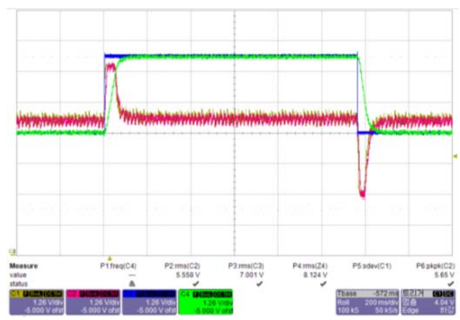


Fig. 6 Response time of inverter

Fig. 7 shows single phase voltage and current waveforms at the output terminal of inverter. Harmonics component of current waveform is due to the rectifier which acts as a high frequency load.

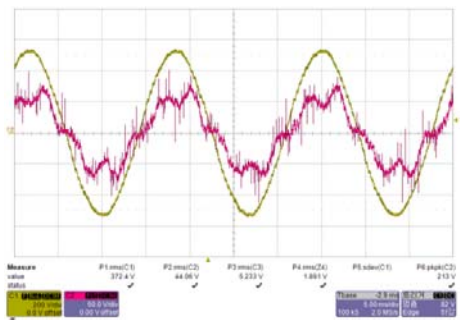


Fig. 7 Output voltage and current of inverter

After previous laboratory test SSP installed at the outdoor testing yard and connected to real 3kW PV and distribution management system.

MPPT(Maximum Power Point Tracking) operation of PCS for PV was verified in the field during the interconnection with DNO and output power control by IED was tested during the separation from DNO network. In addition performance test of bidirectional inverter was conducted. It shows good performance during the operation with PV PCS. Fig 9 and Fig 10 shows the operation profile and the output voltage of inverter respectively.

Fig. 8 Outdoor installation of SSP

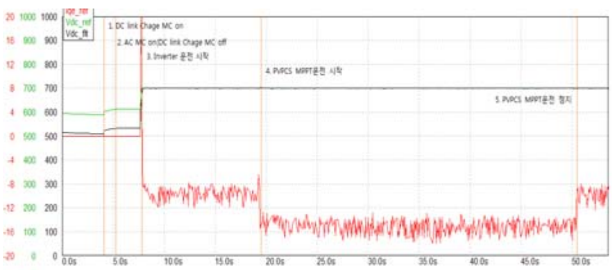


Fig. 9 Operation profile of inverter

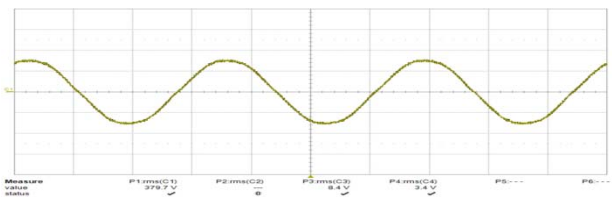


Fig. 10 Output voltage of inverter

CONCLUSION

This study proposed a smart switch panel to improve power quality and cost effective interconnection of DERs of customer. It can supply power continuously by islanding operation during the outage of DNO network. And it can exchange information with distribution management system of DNO. So DNO can handle the power from small scale DERs of customers. It will helpful for the distribution network management and power quality improvement of DNO. .

The proposed SSP was simulated through PSCAD/EMTDC abridged modeling and the results indicated that islanding was normally performed by the STS during power failure of DNO network so that independent operations could be performed smoothly. At last we conducted performance verification test of prototype SSP. During the test performance of each component was verified. In these days it installed in outdoor test yard and connected to real PV and distribution management system.

The communication between DMS and SSP is configured by IEC61850. The SSP send information on voltage, current and active/reactive power of inverter, STS and PCS to the distribution management system of DNO. Its operation mode also can be determined by the command from distribution management system. Field test will continue for 1 year in outdoor test yard.

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