# A NEW TYPE OF SCALED - DOWN NETWORK SIMULATOR COMPOSED OF POWER ELECTRONICS

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## ABSTRACT

This paper describes a new type of scaled-down simulator for distribution grid. The most significant component in this proposal is an active interface for connecting actual size power conditioners with a scaled-down network simulator. The fundamental function of the interface is to transfer electrical properties: voltage and current at a terminal of the network side are transferred to another terminal of the power conditioner side by multiplying factors of *n* and *m* respectively. At the same time, the conditional side current and voltage have to be transferred to the network side by multiplying 1/*n* and 1/*m*, and vice versa. This principle has been demonstrated by an OP Amp circuit in this time. Other practical issues to realize this entirely new idea are also discussed.

## 1. INTRODUCTION

Recently, the number of grid-connected PV systems has been rapidly increasing in Japan. In order to connect PV systems to the grid, it is necessary to test its functions which are islanding protection, grid protection, circuit protection, THD and so on. To test their functions directly, a distribution grid of actual scale is needed. In fact, it is impossible to test PV systems in actual scale distribution system except grid companies. While in a computer simulation, it is difficult to connect actual PV systems. A scaled-down Simulator [1] has been used as a method of examination with actual PV systems, which is composed of inductance, capacitance and resistance components. Such a simulator is far smaller than actual distribution system, however it still requires large space. To expand the system scale with a lot of dispersed power sources, wide place and recourses are needed. In near future, it must be required to test such a system including many dispersed power sources about their mutual interference of islanding detection or voltage arising. The purpose of this study is to develop a new scaled-down network simulator which has advantages of size and cost.

This paper describes a new type of scaled-down simulator for distribution grid.

## 2. COMPOSITION OF THE NEW TYPE OF SIMULATOR

### 2.1 Composition of the new type of simulator

The scaled-down simulator has been large size because inductance and resistance components required actual power sources. A small scaled-down simulator which is composed of electronic circuit could be small size, and it is easy to expand it. However, the electronic circuit indicates to be broken if it is connected to actual power sources directly. Equivalent test method of function of the actual power source is presented; the conditions observed in the small scaled-down simulator are made to feed back to actual source when power energy is reduced from actual to electronic circuit scale.

A composition of the proposed simulator is shown in Fig. 1. It is consisted of power sources such as the power conditioner, the small scaled-down simulator composed of electronic circuit, and the interface. The most significant component in this proposal is an active interface to connect actual size power sources to samll scaled-down simulators.

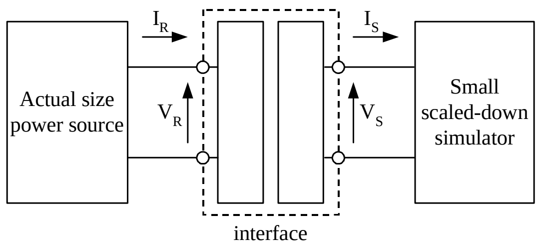


Fig. 1 Composition of the new type of simulator

### 2.2 Principle of operation of the interface

A fundamental function of the interface is to transfer electrical properties: voltage and current at a terminal of the simulator side are transferred to another terminal of the power source side by multiplying factors of *n* and *m* respectively. At the same time, the source side current and voltage have to be transferred to the simulator side by multiplying 1 / *n* and 1 / *m*, vice versa. Therefore, the interface is able to be applied to any combinations of voltage source and / or current source. That makes possible to test all of grid conditions.

### 2.3 Design of the interface

The block diagram of interface which is shown in Fig. 2 is studied based on a principle of operation of the interface. It is composed of a Voltage control unit and a Current control unit. The voltages ($V_R$ and $V_S$ shown in Fig. 2) at both terminals of the interface is controlled in the ratio of *n* to 1 by the Voltage control unit all the time. The current sensor 1 detects $I_R$ at the source side terminal, and the current sensor 2 detects $I_S$ at the simulator side terminal. In order that $I_R$ is made to correspond to $I_S$, comparative results of $I_R$ and $I_S$ are made to feed back to the Current control unit. Therefore, the currents ($I_R$ and $I_S$) at both terminals of the interface are controlled in the ratio of *m* to 1. Circuit diagram is shown Fig. 3.

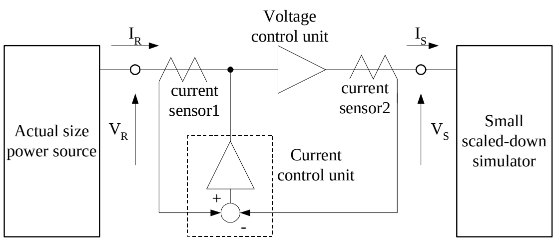


Fig. 2 Block diagram of the interface

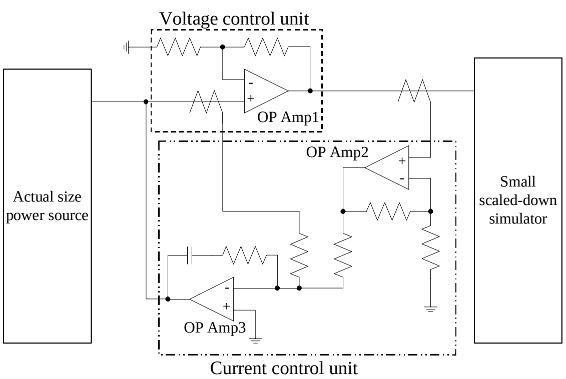


Fig. 3 Circuit diagram of the interface

In this paper, the Voltage control unit and the Current control unit is composed of OP amp circuit. The voltage proportion, *n*, at both terminals is made a choice at random if the gain of Amp1 in the Voltage control unit is controlled. The current proportion, *m*, is also been made a choice at random if the gain of amp2 in the Current control unit is controlled.

### 2.4 Simulation

In order to test functions of the interface, it was simulated by the circuit shown in Fig. 4 (a). As shown in Fig. 4 (a), the actual size power source in Fig. 2 was exchanged with DC voltage source and resistance. The small scaled-down simulator was also exchanged with capacitance and resistance. It was considered that AC wave could be controlled if transient response was controlled. In order to test the function of the interface easily, *n* and *m* were fixed to 1. In this case, Fig. 4 (b) was interchanged with Fig. 4 (a) because the voltage and the current at the terminal of the simulator side was equal to the voltage and the current at the other terminal of the power source side. By the simulation, characteristic of the V shown in Fig. 4 (b) was compared with characteristics of the $V_R$ and $V_S$ shown in Fig. 4 (a). Then DC voltage source input 5V with step in the circuit when time was zero. Characteristics of $V_{in}$, $V_R$, $V_S$, and V was shown in Fig. 5. As shown in Fig. 5, characteristics of $V_R$ and $V_S$ corresponded with characteristics of V.

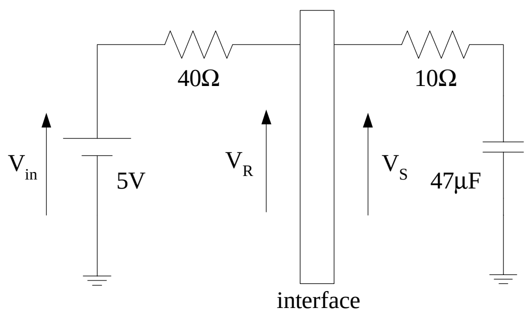


Fig. 4 (a) Circuit for tested the interface

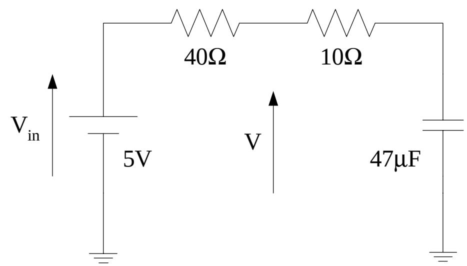


Fig. 4 (b) Equivalent circuit of Fig.4 (a) when *n* and *m* were fixed to 1

## 3. EXPERIMENT

### 3.1 DC Characteristics

The circuit shown in Fig. 4 (a) was composed of using circuit diagram shown in Fig. 3. First, in order to compare with the simulation, actual characteristic was observed in the same condition as the simulation. Characteristics of the voltage which were observed by an oscilloscope were

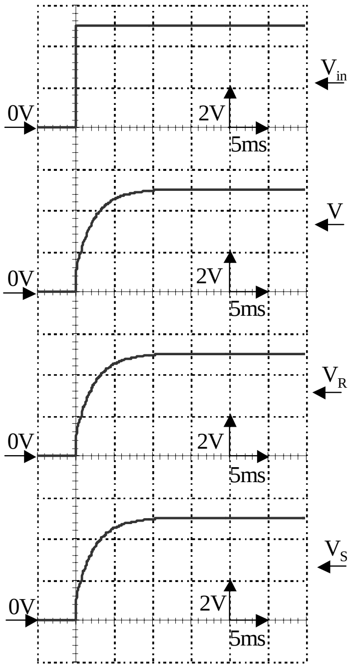


Fig. 5 Characteristics of the voltage at both terminals of the interface shown by simulation.

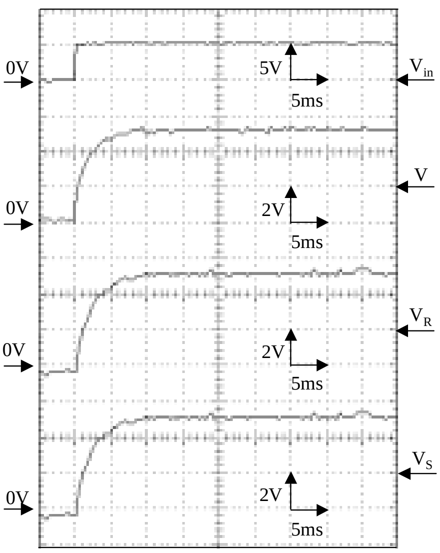


Fig. 6 Characteristics of the voltage measured at both terminals of the interface.

shown in Fig. 6. As the result of experiment and simulation, it was considered that characteristics of $V_{in}$, V, $V_R$, and $V_S$ shown in Fig. 6 almost corresponded to them shown in Fig. 5. As these results, the interface would be able to fulfill the proposed functions because transient response by resistance and capacitance was correctly controlled.

Second, it was tested with different power level whether voltage and current at both terminals of interface were controlled. Power level at both terminals were controlled in the ratio of 4 to 1. Therefore, *n* and *m* was fixed to 2. Characteristics of $V_R$, $V_S$, $I_R$, and $I_S$ were observed. Characteristics of $V_R$ and $V_S$ were shown in Fig. 7(a). As shown in Fig. 7(a), it was considered that $V_R$ and $V_S$ were always controlled; the ratio, $V_R$: $V_S$, was 2: 1, and turn on time of $V_R$ was equal to it of $V_S$. Characteristics of $I_R$ and $I_S$ were shown in Fig. 7(b). As shown in Fig. 7(b), it was considered that $I_R$ and $I_S$ were always controlled; the ratio, $I_R$: $I_S$, was 2: 1, and turn on time of $I_R$ was equal to it of $I_S$. From these results, it was considered that the interface was controlled if power level at both terminals was different.

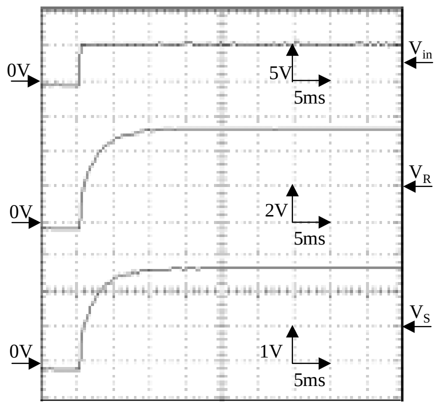


Fig. 7 (a) Characteristics of the voltage measured at both terminals of the interface when *n* and *m* were fixed to 2.

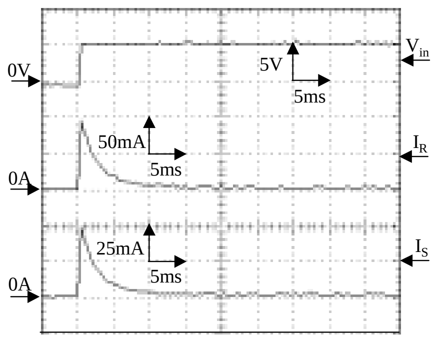


Fig. 7 (b) Characteristics of the current measured at both terminals of the interface when *n* and *m* were fixed to 2.

### 3.2 AC Characteristics

The interface also was tested under the condition of AC voltage input The DC voltage source in Fig. 4 (a) was exchanged with AC voltage source. Then AC voltage source input sine wave of 5V and 50Hz. In the same condition as section 3.1, *n* and *m* were fixed to 2. Voltage and current at both terminalswere shown in Fig. 8 (a) and (b). As shown in Fig. 8 (a) and (b), voltage and current at both terminals were controlled in the ratio of 2 to 1 all the time. Therefore, it was considered that the interface was controlled under condition of AC Voltage input.

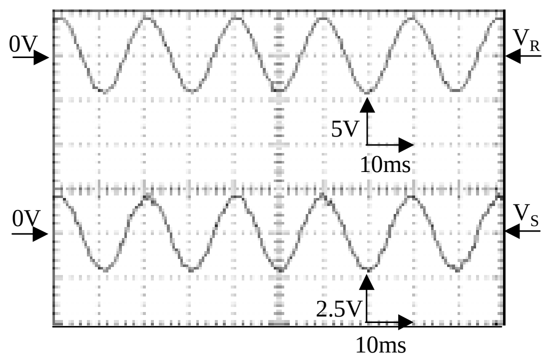


Fig. 8 (a) Characteristics of the voltage measured at both terminals of the interface when AC voltage was input in Fig. 4 (a), and *n* and *m* were fixed to 2 under the condition of AC voltage input.

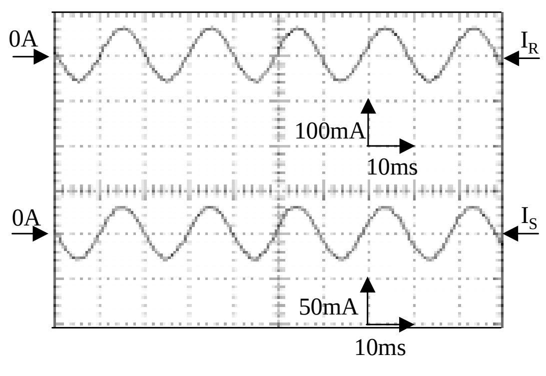


Fig.8 (b) Characteristics of the current measured at both terminals of the interface when AC voltage was input in Fig. 4 (a), and *n* and *m* were fixed to 2 under the condition of AC voltage input.

## 4. CONCLUSION

This paper described a new type of scaled-down simulator for distribution grid. This simulator was a small scaled-down simulator composed of electrical circuit and interface. Function of the interface was to connect actual size power source to the small scaled-down simulator. As a result of simulations, the interface was shown basic characteristics and the result of experiments were shown DC and AC characteristics. Therefore, The new concept of the interface was very valuable. Moreover, the actual power source such as PV system would be examined by a small scaled-down simulator although power level at actual power source side of interface was low in this paper.

It is considered that this study would be fulfilled a major role for not only the study of PV system but also all study of power electronics.

## *REFERENCE*

[1] Y. Noda, T. Mizuno, H. Koizumi, K. Nagasaka, K. Kurokawa: “The deployment of a scaled-down simulator for distribution grid and its application for verifying interference behavior among a number of module integrated converters (MIC)”, 29th IEEEPVSC, pp.1545-1548, May 2002.