Development of Simulator System for Microgrids with Renewable Energy Sources

Jin-Hong Jeon†, Seul-Ki Kim*, Chang-Hee Cho*, Jong-Bo Ahn* and Eung-Sang Kim*

Abstract - This paper deals with the design and testing of a simulator system for microgrids with distributed generations. This system is composed of a Real Time Digital Simulator (RTDS) and a power amplifier. The RTDS parts are operated for real time simulation for the microgrid model and the distributed generation source model. The power amplifiers are operated for amplification of the RTDS's simulated output signal, which is a node voltage of the microgrid and distributed generation source. In this paper, we represent an RTDS system design, specification and test results of a power amplifier and simulation results of a PV (Photovoltaic) system and wind turbine system. The proposed system is applicable for development and performance testing of a PCS (Power Conversion System) for renewable energy sources.

Keywords: Distributed Generation, Microgrid, PCS testing, Renewable Energy Source Simulator, Real Time Digital Simulation

1. Introduction

The system state of renewable energy sources such as wind turbines, photovoltaic systems, and fuel-cell systems is decided by its environments, which are temperature, humidity, sunlight, wind speed, wind direction and etc. For an analysis of the dynamic characteristics of the system, it should be able to set any environment. In order to do that, it needs a test bed or a chamber, which must have sufficient size and energy capacity. If such a test system were to be made, it would require an enormous budget [1-4]. Such a test system would be useful for an analysis of mechanical and physical characteristics, but for the analysis of electrical characteristics, it would be best to use another method [1]. Because the electrical state of a system can be changed more rapidly than a mechanical or chemical state, an analysis of electrical characteristics can be done by using a mathematical model of renewable energy sources [2-3]. It can result in the effect that a renewable energy source operates at real environments by using a real time simulation of its mathematical model, which is an electric characteristic equation of the system and can be represented as a system status [1-2].

This paper deals with a simulator system for a microgrid with distributed generators. It presents a design scheme of the simulator and test results for a basic operation of the simulator. The simulator is designed for a simulation of the microgrid with distributed generators that have renewable energy sources. This system is made up of RTDS and power amplifiers. The RTDS performs a real time simulation for a microgrid model with distributed generators and a renewable energy source model. The power amplifier amplifies a simulated output signal of the RTDS, which is a node voltage of the microgrid with distributed generators or an output of the renewable energy source mode. This simulator can be applicable for a test system, which is used for dynamic and static performance of the PCS for renewable energy sources and other distributed generators.

2. Simulator

Some distributed generators such as wind turbines, photovoltaic systems, and fuel-cell systems consist of a renewable energy source and a PCS module, which is a device for grid connection. Because of its mentioned characteristics in the introduction, it is difficult to realize a certain environment condition for a renewable energy source. As such, a model that can be represented as a renewable energy source and its environment conditions is made for a RTDS simulator, and the model can be used to simulate and test a dynamic performance of a PCS with renewable energy source. For that, a RTDS model for a renewable energy source and a power amplifier has been studied in our project [1].

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Received October 13, 2005 ; Accepted February 28, 2006

2.1 Structure

Fig. 1 is a schematic diagram of a simulator structure for a real time simulation and a dynamic test of a distributed generator. In Fig. 1, a renewable energy source can be realized by a RTDS UDC (User Define Component) model and a power amplifier module. A RTDS UDC model plays a real time simulation for an energy source, and a power amplifier makes voltage signals with a real power level.

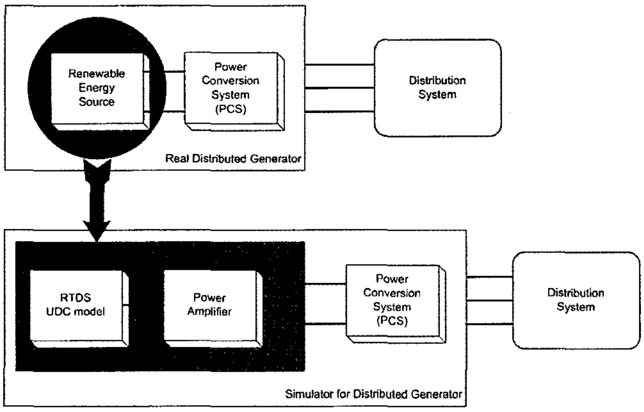

Fig. 1. The schematic structure of a simulator for a distributed generator

2.2 RTDS System

For the simulation of a distributed generator, a function of the RTDS system is a real time simulation of an energy source. In view of the RTDS system, this function can be considered as a UDC model with an analog simulator. A structure of the RTDS system for the simulation is presented in Fig. 2.

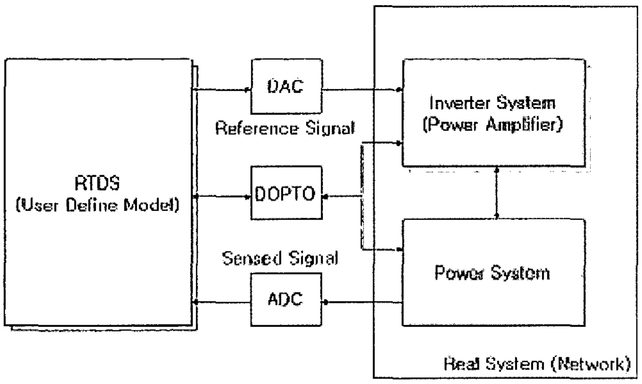

Fig. 2. A structure of the RTDS system for simulation

For the simulation, required modules of the RTDS system are a WIF card for system communication, four 3PC cards with optic ports for system interface, a dual 3PC card for a network solution, two 16 bit DA for output signal, which make a reference voltage waveform for power amplifier, and two 16 bit AD cards for signal input, which read feedback information from a grid with the distributed generator. Fig. 3 shows a case of an implemented RTDS system and its interfaces. For an interface of a real power system and power amplifier, RTDS has two sets of AD and DA interfaces with 6 channels each.

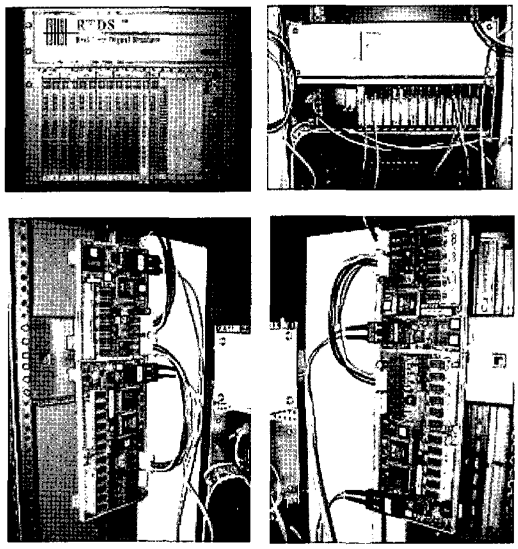

Fig. 3. Implemented RTDS system and its interfaces

2.3 Power Amplifier

The power amplifier makes a voltage signal with real level power by an output signal of the RTDS system, so its basic structure is a BTB (Back-To-Back) inverter system with a common dc link. One inverter makes a voltage waveform by RTDS output signal, and the other one supplies or absorbs the necessary power for power amplification. Fig. 4 shows an outside and inside view of a 50kVA power amplifier.

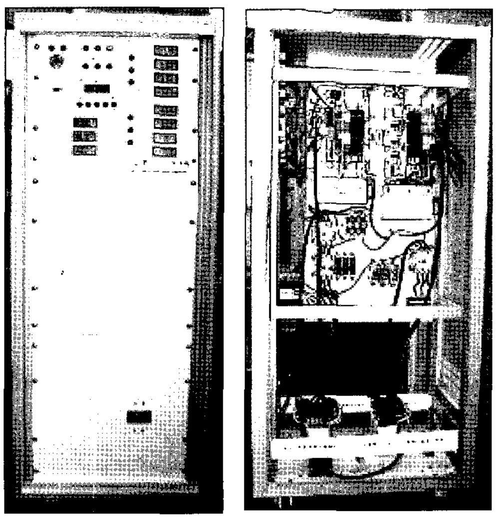

Fig. 4. Power Amplifier (3 phase, 380V, 50kVA) with BTB Inverter Structure

3. Experimental Results

3.1 Transient Response Test of Power Amplifier

Ideally, a power amplifier should make the same voltage waveform of the RTDS output signal without transients, however, due to physical limitations, this is impossible. So, it is a crucial and important aspect that monitors system performance by an analysis for a system and operates within a system capability. For safe operation some experiments were performed, and some characteristics of the system were analyzed from the experimental outputs. Some operation ranges were determined from the experimental results. One of the experiments is a transient response test for major AC voltage parameters, which are magnitude, phase and frequency. In this paper, a test result of transient response for a phase shift is presented in Fig.s 5, 6 and 7. Fig. 5 is a RTDS output signal for a phase transient response, Fig. 6 is an output voltage waveform of a power amplifier, and Fig. 7 is a zoom of the transient area in Fig. 6. In this test, the power amplifier has a 20kW resistive load.

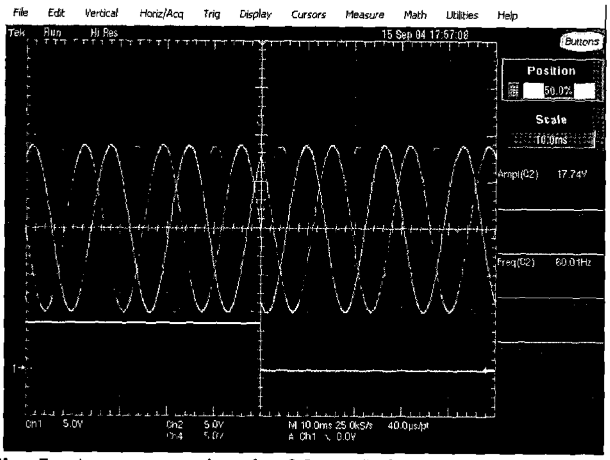

Fig. 5. An output signal of RTDS for transient response test (Phase Shift: 0° ⇒ 180°)

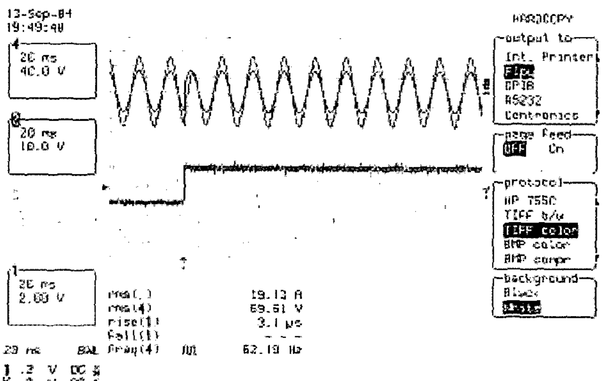

Fig. 6. An output voltage waveform of power amplifier for transient response test (Phase 0° ⇒ 180°)

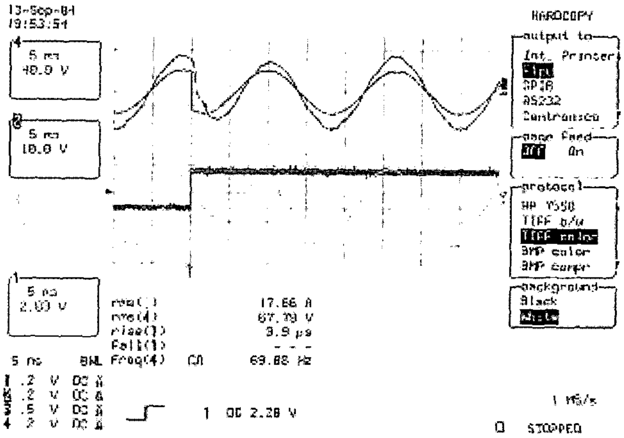

Fig. 7. A zoom of Fig. 6 in the transient area

From the above test results, the settling time of voltage waveform can be maintained in a sub-cycle in severe transient condition.

3.2 Steady State Response of Power Amplifier

In the transient state of an energy source and power system, there are some abnormal voltage components such as dc offset, unbalance, and harmonics. Therefore, a power amplifier should be able to make these abnormal voltage components. For checking these abilities of a power amplifier several experiments were performed, and this paper presents results for the case of the dc offset. For the dc offset test, a certain simulation condition is assumed. An instantaneous sinusoidal voltage of A, B, or C phase is applied at a certain dc offset voltage with 83.33ms time constant. This voltage waveform is simulated at RTDS in real time, and this RTDS output signal is applied to the power amplifier input with 20kW resistive load. Fig. 8 is an output signal of RTDS, and Fig. 9 is an output voltage waveform of a power amplifier.

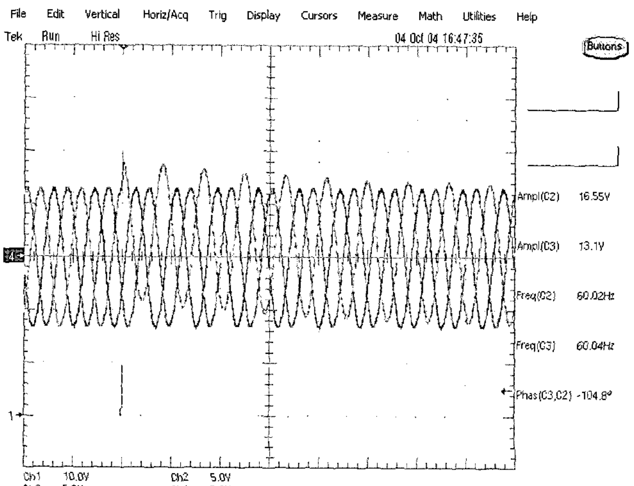

Fig. 8. An output signal of RTDS for DC offset test

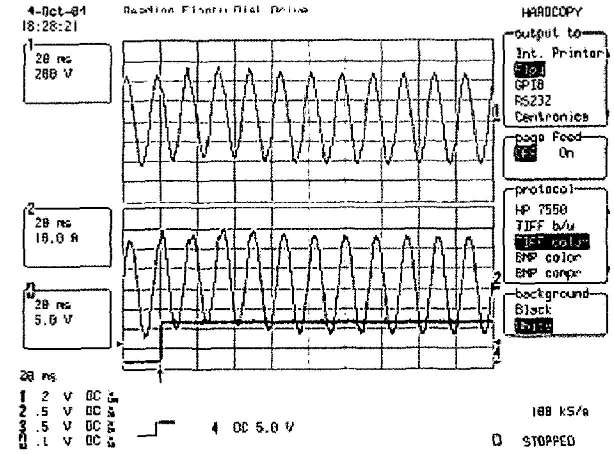

Fig. 9. An output voltage waveform of power amplifier for DC offset test

From Fig. 8 and Fig. 9, an output voltage waveform of a power amplifier allows dc offset effectively.

3.3 Simulator Operation Test

For a test of an entire simulator system, which is mentioned in Fig. 1 and Fig. 2, we make two simulation cases, which are the PV system and the wind turbine system.

In the PV system simulation case, we make a simulation model of photovoltaic array for RTDS and power amplifier, and connect the simulator output to a grid connected PCS for PV. As operating points of the PV array model in the simulator are changed, the simulator system and gird connected PCS outputs are changed. Its results are recorded in Fig. 10.

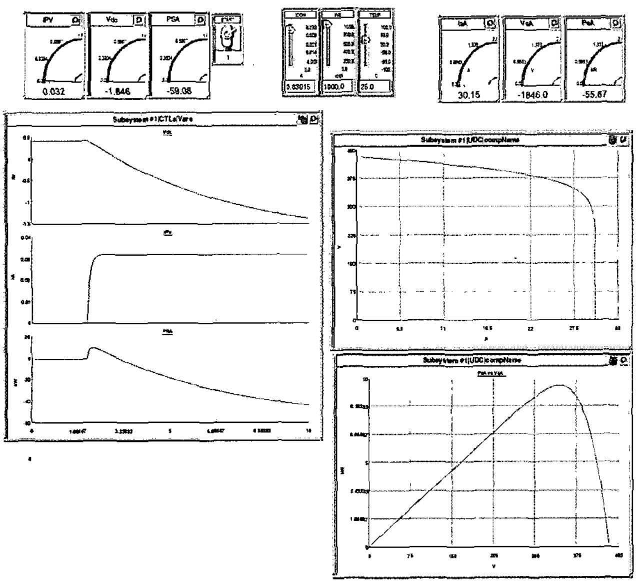

Fig. 10. Test results of PV array model characteristics by power amplifier and RTDS system

In the wind turbine system simulation case, we make a simulation model of wind and wind turbine for RTDS and power amplifier and connect the simulator output to a grid connected PCS for the wind turbine. As a pattern of wind speed, operating points of the wind turbine model in the simulator are changed and then gird connected PCS makes its output. Its results are recorded in Fig. 11.

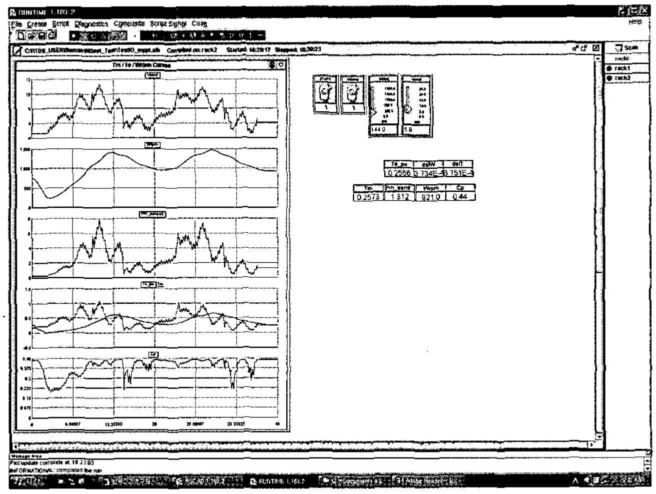

Fig. 11. Test results of wind turbine model characteristics by power amplifier and RTDS system

According to the results in Fig. 10 and Fig. 11, the proposed simulator system shows typical PV array output characteristics and wind turbine output characteristics. From the mentioned test results, the simulator system can be applicable for the performance test of PCS for renewable energy sources.

4. Conclusion

In this paper a simulator system for microgrids with distributed generators was presented. It contained a design scheme of the simulator, a test result for a steady-state and transient-state operation of the power amplifiers and two simulation case results of a PV system and wind turbine system. The simulator was designed for a simulation of a microgrid with distributed generators including a renewable energy source. This system consisted of a RTDS and a power amplifier. The RTDS performed a real time simulation for a microgrid model with distributed generators and a renewable energy source model. The power amplifier was used for a simulated output signal of the RTDS, which was a node voltage of the microgrid with distributed generators or an output of the renewable energy source mode. This simulator can be applicable for a test system, which is used for a dynamic and static performance of PCS for distributed generators. In a future study, the performance improvement of the system and model development for the distributed generator will be performed.

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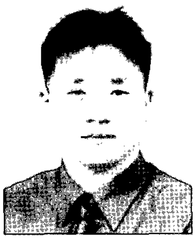

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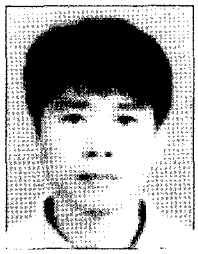

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