A Verification Method for the Risk Management System of the Electric Power Grid (RMS-EPG) using Satellite Communication

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Abstract: In this paper, we propose a verification method for risk management system of the electric power grid (RMS-EPG) using satellite communication network. The RMS-EPG with satellite communication network should be verified with various contingencies for its design and maintenance. For the verification of RMS-PG, the proposed system composed of the satellite communication simulator and the Power flow emulator. Proposed simulator of satellite communication can evaluate not only the delay of communication with satellite but also the robustness of satellite communication according to the change of weather using simulation model for ITU-R 839. And the proposed emulator of Phase Measurement Unit for Satellite communication (sPMU) can realize its function that calculates the voltage stability by hardware implementation using FPGA. Using the proposed verification system, we verified its function of RMS-EPG for the power grid of Jeju Island in Korea

1. Introduction

Critical infrastructures include the electric power grids, telecommunications, public transportation, natural gas and oil, water supply systems, and other fundamental structures and services that are vital for the well being of our society. In particular, the electric power infrastructure is the most critical infrastructure upon which other infrastructures depend. In recent decades, the electric power system has become more and more automated, interconnected, and computerized. While interconnection and advanced technologies lead to greater efficiency and reliability, they also bring new sources of vulnerability through the increasing complexity and external threats. Due to the various threats, it is critical to develop defense plans and technologies for the electric power and related infrastructures. Defense plans for the power infrastructure should include the strategies and procedures to defend the grids against the various threats. A basic defense system for the power grid may involve load shedding in the event of a major system disturbance. More sophisticated defense systems are wide-area, real-time protection and control systems with full sensing, communication and information capabilities.

Recently, satellite communication network is widely adopted in Risk Management System (RMS) to cope with the paralyzed wired-communication. Especially, defense system of the electric power grid using satellite communication is new methodology of RMS. The satellite communication network can maintain the reliability of communication even from paralyzed wired-communication network by natural disaster or other crisis situation. The satellite communication network has the benefits not only the reliability of communication but also the ability of simultaneously transmitting data in wide area. Risk management system of the electric power grid (RMS-EPG) is defense system of the electric power infrastructure. RMS-EPG can detect the risk of electric power grid using satellite communication. And, Based on the degree of risk on power grid, RMS-EPG transmit the relevant commands to each asset of power system using satellite.

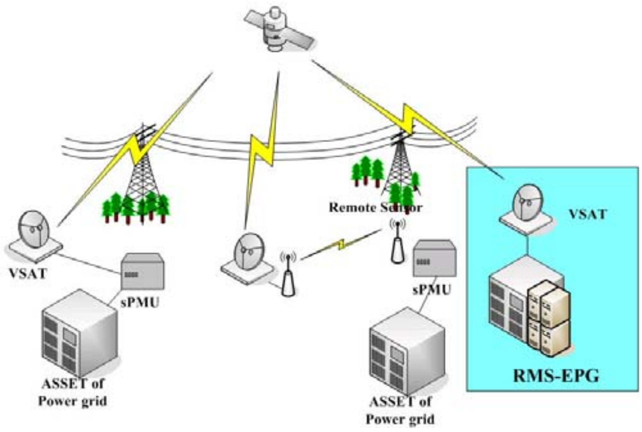

Fig. 1.RMS-EPG using SCN

RMS-EPG using satellite communication network must have the verification method for maintain of it. In Early of setup RMS-EPG, selecting the BUS and deciding the location of satellite communication modem cannot be accomplished without verification system. The purpose of this paper is to provide a verification method for RMS-PG using satellite communication network.

2. Proposed System

2. 1 A Verification Method for the Risk Management System of the Electric Power Grid (RMS-EPG) using Satellite Communication Network (SCN)

The objective of the verification system for the RMS-PG using SCN is on the simulation of all cases which can appear in operations of the combined system of real satellite communication network and defense of electric power grid. The verification system for the RMS-PG using SCN is shown in figure 1.

The RMS-PG using SCN system is composed of the satellite communication network for data communication, the defense system of EPG using satellite communication network, and the sPMU for monitoring of status of power grid. So, the proposed verification system can be structured by using sPMU emulator which can simulate the data communication and reproduce the operations of real power grid. The proposed verification system for the RMS-EPG using SCN is shown in figure 2.

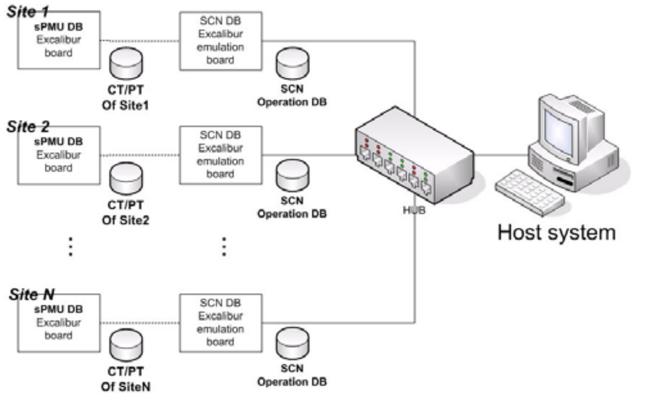

Fig. 2.Proposed verification system for RMS-EPG using SCN

2. 2 Simulator for Satellite Communication Environment.

The satellite communication system is a part which can help to recognize the status of all area simultaneously by using the properties of the satellite system such as broadband and broadcasting. The proposed simulator for the satellite communication system models communication channel and reproduces real communication environment.

The propagation delay from the terminal to the satellite which is in sky at an altitude of 30,000Km is as long as 0.5s. So, the most important point of the communication channel modeling is on the reflection of the exact propagation delay of a raw data in a terminal to a center and the element of external atmospheric phenomena related to the performance of the communication system.

A. Satellite Communication Channel Modeling

When designing of a simulation system of the satellite communication channel, one of the most important factors is a prediction of the performance degradation according to the change of the weather. There are so many prediction models of the signal strength variation according to the change of the weather, such as ITU-R[1], Glabal[2], Simple[3], DAH[4], and ETRI[5]. In these models, it is proved that the precipitation is the most effective factor among the information of the weather.

In this paper, we predict the signal strength according to the precipitation by using the model from ITU-R. Based on the prediction, we calculate the BER and the PER of local area with the real time weather information of the region from internet.

In the model from ITU-R, the performance degradation according to the precipitation is a function of the distance and the reduction constant of a unit distance as in (1).

$$A_{0.01} = \gamma_R L_E \quad dB$$

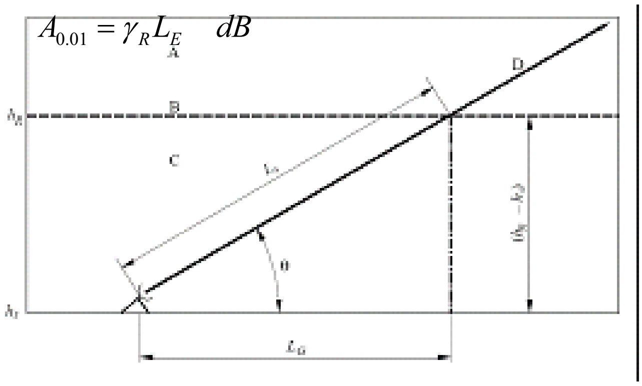

Fig. 3 A basic model from ITR-R.

(1)

Figure 3 shows a basic model from ITU-R. Where θ is an angle of elevation, hs is an altitude, hR is the perpendicular distance of a rain, Ls is the distance of a rain considering an angle of a real signal. The Ls can be derived as in (2).

$$L_S = \frac{(h_R - h_s)}{\sin\theta}\, km \tag{2}$$

L_G is the horizontal distance of a rain, and LS is a projection to the horizontal line.

$$L_G = L_S \cos\theta \; km \tag{3}$$

The perpendicular decreasing value *r* and the horizontal applying value *v* are as in (4) and (5).

$$r_{0.01} = \frac{1}{1 + 0.78\sqrt{\frac{L_G \gamma_R}{f}} - 0.38(1 - e^{-2L_G})} \tag{4}$$

$$v_{0.01} = \frac{1}{1 + \sqrt{\sin\theta}\left(31\left(1 - e^{-(\theta/1+\chi)}\right)\right)\sqrt{\frac{L_G \gamma_R}{f}} - 0.45} \tag{5}$$

By using the above equations, we can derive the final distance which can be affected by the rainfall as in (6).

$$L_E = L_R v_{0.01} \; km \tag{6}$$

The decreasing values per Km, rR, can be derived as in (7).

$$\gamma_R = k(R_{0.01})^{\alpha} \quad dB/km \tag{7}$$

where R is the precipitation per hour, k and αare constant values according to the areas in communication.

Figure 4 shows the performance degradation of the satellite communication system according to the above equations and the models.

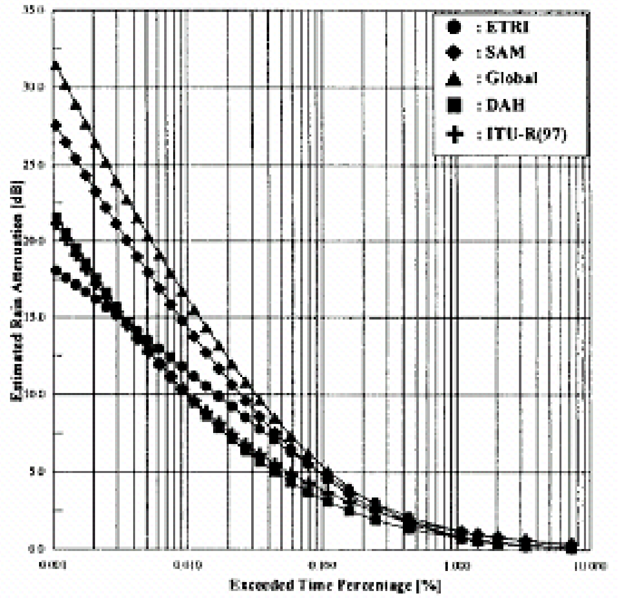

Fig. 4. the performance degradation according to the precipitation

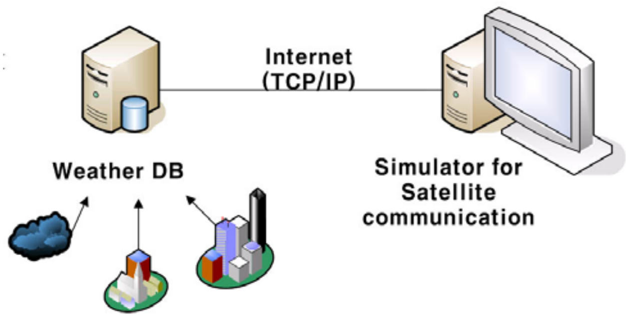

Fig. 5. A real time simulator for the satellite communication system

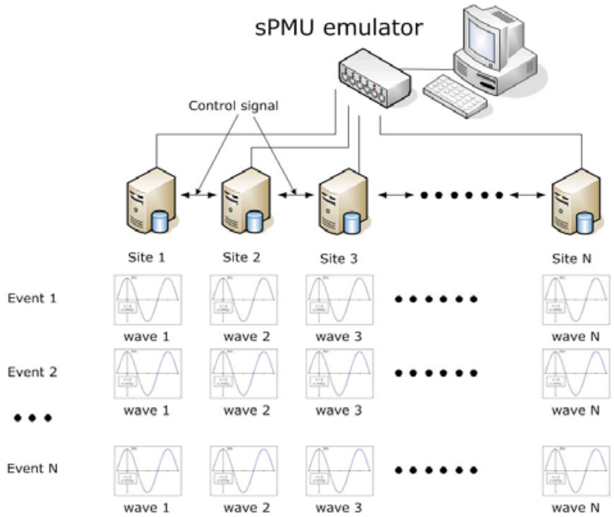

Fig. 6.Architecture of proposed sPMU emulator

2. 3 Emulator for sPMU.

sPMU contains the function of monitoring , recording and transmitting the events on the BUS of the power grid in real time. It sends event signals that have been calculated from the equation of voltage stability. It takes real time data, so it should consider timing synchronization by GPS.
We need a high speed process when we emulate the data directly. At this point, produced data generates voltage & current of the system by function and applies the phaser operator with the generated voltage & current data.
Proposed system was designed and emulates the processed data after the phaser operation. That operated data is converted to the type of transmission data and transmission data rate for use in satellite communication, and then it sent to the verification system by TCP/IP interface.
The data of voltage & current is produced independent of the sPMU's location. The emulation of system data should represent the installation's voltage & current data accurately, because they have not the same voltage & current data during the event.

3. Results of Proposed Verification System

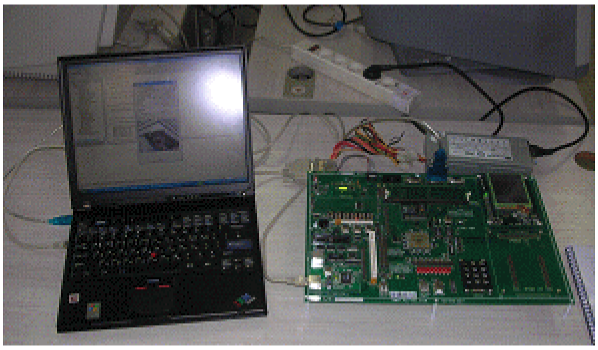

Fig. 7. simulator for Satellite communication using Excalibur board

Proposed verification system for RMS-EPG is realized

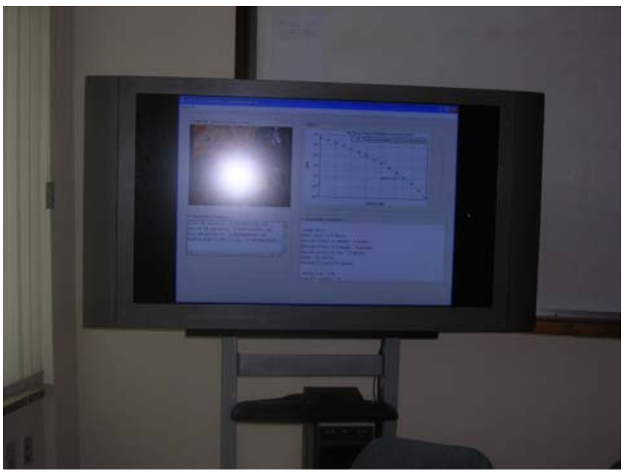

Fig.8. Proposed testbed system

by Excalibur board and testbed server system. In figure 7 and 8, the pictures of proposed system are presented. In specially, proposed SCN simulator takes real time weather information from external DB, measure reliability of satellite communication in different weather condition. And the proposed emulator of sPMU can realize its function that calculates the voltage stability by hardware implementation using FPGA.

3. Conclusion

In this paper, we present a verification method for RMS-EPG using satellite communication network. In the proposed system, the satellite communication simulator and the Power flow emulator are presented. The verification system for the RMS-PG using SCN can simulate all cases which can appear in operations of the combined system of real satellite communication network and defense of electric power grid. Using the proposed verification system, we verified its function of RMS-EPG for the power grid of Jeju Island in Korea

Acknowledgement

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