A Feasibility Study of the Power Infrastructure Defense System Protocol through the Network Traffic Analysis with its Simulator

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Abstract - It is necessary to maintain stabilized operation of the power system responding to a severely adverse condition in the system. There is a need to develop the intelligent Power Grid Monitoring System, in which the PMU(Phasor Measurement Unit) measures the synchrophasor and transmits it to the PIDS(Power Infrastructure Defense System). The IEEE PC37.118 protocol defines the message format to implement the communication of both the PMU and the PIDS.

In this paper, we measure and analyze the network traffic from simulation of the PMU to simulation of the PIDS according to the network routing, a time zone and latency, and thus verify the protocol in the PIDS

Key-Words: - IEEE PC37.118, Power Infrastructure Defense System, iPMS, network traffic, UDP/IP

1 Introduction

A power system requires alternative methods for dealing with conditions that are extremely bad, unpredictable weather conditions, errors in operation procedures, etc., which all exceed the level manageable.[1] To efficiently operate the power system and block any potential overall system damage which occurs in particular bus or transmission lines, it is necessary to develop an iPMS(intelligent Power grid monitoring System) that can monitor, control and protect the power infrastructure and recover autonomously. The iPMS receives phasor data transmitted from the iPIU (intelligent Power Information Unit, this is PMU), monitors the power system in real time and analyzes stability. In the process, iPIU, deployed in the power system, takes charge of the input part of the iPMS. It acquires, processes, and quickly transmits voltage and current phasor information with a synchronized clock.[2] The iPIC as a part of the iPMS receives phasor data from the iPIUs. Besides, it stores the data and supports real time monitoring and a control screen.[3]

For operating such power systems, the synchronized phasor measurement, IEEE PC37.118 protocol, was proposed and defined. Generally, synchronized phasor data is transmitted in a PC37.118 format through UDP/IP or serial connection.[4]

In this study, we configured a system consisting of an iPIU that is a form of PMU and an iPIC that collects and manages measured data from an iPIU.
Using this simulated system, we simulated the network traffic between the iPIC and iPIUs according to the network routing, and confirmed the data packet loss rate. In short, we inspected the finest network configuration between iPIUs and iPIC.

2 The Simulation System

In this paper, the Simulation System simulated communication between an iPIC and iPIU in the IPMS (intelligent Power grid Monitoring System). The iPIU transfers current and voltage measurement values as PMU, and the iPIC provides a user with the data received from the iPIU through the IEEE PC37.118.

The simulated system in this study has simulation programs for iPIUs and iPIC, a network analysis program for network traffic analysis, and the communication network. We measure the network traffic between simulated programs using the network analysis program, measure and analyze the data loss rate by means of the comparison program regarding data packet.

2.1 IEEE PC37.118 Protocol

PC37.118 standard defines data communication protocol including necessary message formats for transmission of the synchronized phasor data.[5] PC37.118 message consists of data, configuration2(CFG2), header, and command frame. Among this data, configuratin2, and header frame are transmitted from the iPIU to iPIC, and the command frame is transmitted from the iPIC to iPIC.

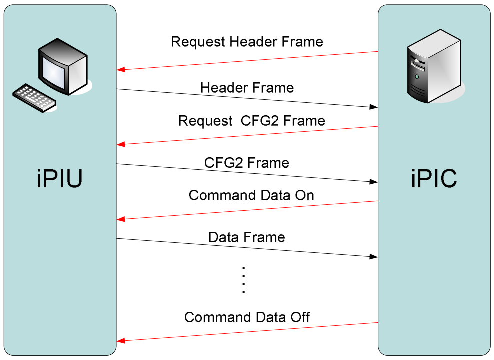

Fig.1 IEEE PC37.118 phasor data transmission flow

Fig.1 shows the Phasor data transmission flow. Request header frame and request configuration2 frame are transmitted from iPIC to iPIU. Header frame and configuration2 frame are transmitted from iPIU to iPIC. By confirming the iPIUs's configuration information, data transmission is all set. Finally, iPIC transmits the data on command to iPIU, and then iPIUs periodically transmits the phasor data to iPIC through the UDP/IP. iPIUs stops transmitting the phasor data until iPIC transmits the data off command

2.2 Composition of the Simulated System

The simulated system consists of the two computers in which programs simulated the communication of the iPIU/iPIC installed. In addition, Ethereal of the network analysis program is installed. The program that simulated iPIU's communication saved the transmitted phasor data, and the program that simulated iPIC's communication saved the received phasor data. To measure the network traffic according to the network routing, network paths used between the iPIU simulation program and the iPIC simulated program are both the public network and the private network. The public network is classified into three areas. To search the data packet loss rate, we compare the phasor data saved at the each program to simulate the communication.

2.2.1 Component of simulation system

The simulated system consisted of two computers, the program simulating iPIU's communication is installed in a computer, and the program simulating iPIC's communication and ethereal are installed in the other computer. Any computer in which the communication simulating program is installed performs 1:1 communication by executing one iPIU communication simulating program simultaneously.

Fig.2 Experiment location

Fig.2 shows the experiment area that measured network traffic in the public network. iPIC's location is fixed to Seoul, iPIUs's location is placed Geoje, Daejeon that is in the middle of South Korea and Seoul that have many people. Measuring of the network traffic in private network was done at Kwangwoon University.

2.2.2 Network analyzer

We measured and analyzed the network traffic by means of the Ethereal for Window, as analysis program of the network traffic. This program needs the library Wincap, which is a protocol analyzer software, and monitors the network traffic to solve the problems.[6]

The simulated iPIUs transmits the 60 of the phasor data per second. To confirm this, Ethereal satisfies the condition that requires the level of details about 0.01 second. We monitor and analyze the UDP/IP network traffic between iPIU's simulator and iPIC's simulator using the various filters.

2.2.3 Simulated program

The simulated programs in the simulation system are the iPIU simulation program and iPIC simulation program. The simulated programs of the iPIU/iPIC's communication are developed with Visual C++. Fig.3 shows the execution of the simulated programs of iPIU/iPIC. iPIUs transmitting the phasor data at normal operation and disturbance data at disturbance to iPIC by PC37.118 protocol.

The iPIU simulation program simulates the communication of the iPIU, transmits the phasor data through UDP/IP and disturbance data through the TCP/IP to iPIC simulation program. In addition, this acquires the phasor data from frame generation program instead of real phasor data. Additionally, this transmits the disturbance data frame by the request of the program of the iPIC's communication, simulates the error situation by generating error, and thus can change the transmission rate by tuning the transmission rate and accumulative transmission rate.

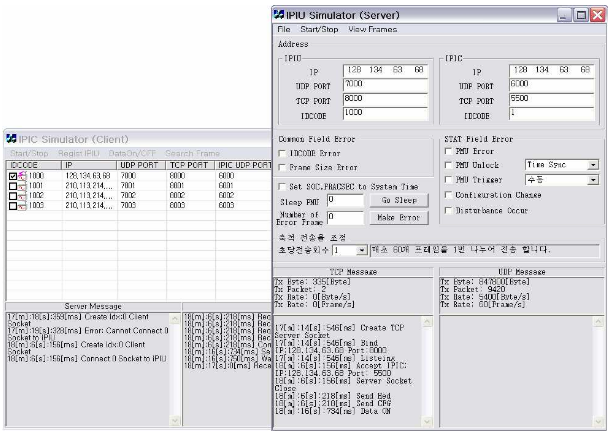

Fig.3 The iPIU/iPIC simulation program

The simulated program of the iPIC's communication simulates the communication of the iPIC , receives and saves the phasor data or disturbance data from the iPIC simulation program through UDP/IP, TCP/IP

2.2.4 The comparison program about phasor data

The iPIU simulation program sequentially saves the phasor data as text file in transmitted order and the iPIC simulation program saves the phasor data as text file in received order, too. The comparison program can search the data loss of phasor data by comparing the saved data in iPIU/iPIC simulation program.

By comparing the saved data in iPIU/iPIC simulation program as a classified frame, this program can find an omitted frame. It presents the rate of omitted frame versus total frame as percentage.

3 Network Traffic Measurement and Analysis

To implement the iPMS, it is necessary that we analyze the network traffic between numbers of iPIU and iPIC in the simulation system. By using the iPIU/iPIC simulation program, measuring and analyzing the existing public network and private network will be a good guide in choosing the right network routing.

The disturbance data is transmitted through the TCP. There is no data loss because of the reliable transmission and flow control mechanisms of TCP.[7] It means that traffic measurement of the disturbance data is wasted efforts. Otherwise, we don't believe UDP/IP because the UDP/IP traffic shows little self-similarity. Therefore, we need to measure the networks traffic of phasor data through the UDP/IP.

In the experiment, the packet transmission times per second of iPIU was set at 60, the experiment time of the public network was about 3 hours from 3 to 6pm, the time period when the internet use ratio is relatively high, and the experiment time for the private network was about an hour. As in Figure 4(b), in consideration of the time unable to be measured due to unpredictable network errors, the experiment time was set longer than other regions. By means of the tracert, the latancy of each channel was determined, and to find out the data loss rates in the experiment, the transmitted phasor data and received phasor data saved at iPIU and iPIC communication simulation program respectively were compared.

3.1 Network Traffic of Each Time Zone

Figure 5 (a),(b),(c) are the graphs of network traffic at the public network of each time zone from 3pm. X-axis is time(sec) and y-axis is the average number of packets. As the tick interval is 10 sec, the ratio is 10 times of the measured value.

Regarding Seoul and Geoje, the network traffic showed constant pattern regardless of the time zone, while that of Daejeon showed heavy network traffic from 4:30 to 6:00 pm, which decreased the phasor data transmission rates drastically. (d) is the network traffic measured at the private network, which indicates the constant phasor data transmission rates.

The table.1 shows the information of network traffic according to the public network and private network. The aspects to be taken note of are the average number of packets per second, latency, and data The aspects to be taken note of are the average number of packets per second, latency, and data loss ratio. The ideal number of packets transmitted per sec is 60, but any of the three regions reached the number.

Table.1 Network traffic between simulation programs according to network routing.

Item	Public Network			Private Network
	Seoul	Daejeon	Geoje	
Capture Time(second)	10800.109	14858.079	10832.9	3611.138
Total Packet	543811	273419	532600	216720
Avg. Packet per second	50.352	25.3165	49.165	60
Total Byte (byte)	71783052	36091308	70303200	28607040
Avg. Byte per second(byte)	6646.512	3341.788	6489.783	7921.86
Latancy time (ms)	117	954	198	<1
Theoretical Data Loss Rates (%)	16.1	58.3	18.1	0
Data Loss (%)	16.9	61.4	19.1	0

Especially in the case of Daejeon, half of the phasor data was not transmitted. In addition, the data loss ratio was 3% higher than that of the ideal theoretical data loss ratio based on the average number of packets per sec, which was because the packets were broken.

3.2 The Relation between Latancy & Network Traffic

It was noted that the average number of packets per second, latancy, and data loss ratio should be focused. Among these, the relation between latancy and data loss ratio will be examined. The latancy of the communication lines in Seoul and Daejeon was about 1 second, which is outstanding compared to other sections, and thus the data loss ratio was 61%.

The latancy of Seoul and Geoje was 117ms and 198ms respectively, and the data loss ratio was less than 20%. The latancy of the private network was less than 1ms and the data loss ratio 0%, which indicates that the phasor data that was transmitted by the iPIU simulator maintained the state 100% while being transmitted by the iPIC simulator.

3.3 The New Communication Network of iPMS

The experiment result above indicates that the data transmission at the private network is reliable while the UDP/IP protocol at the public network is not.

Especially, as for Daejeon, when measures should be prepared in case unexpected communication errors and heavy network traffic take place. Besides, when there are many hosts in the private network as well, problems may take place.

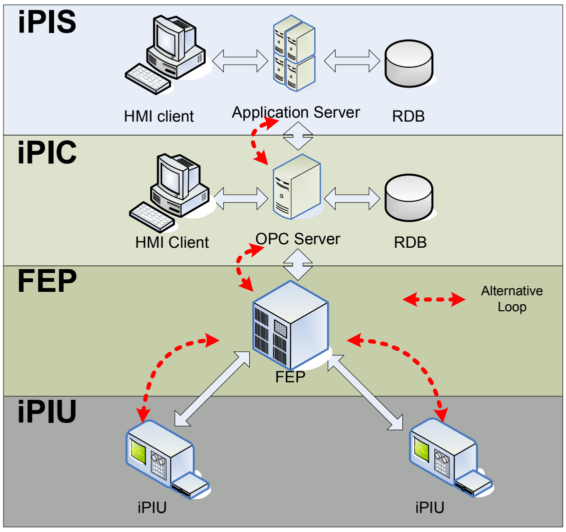

Fig 4. Concept of the Double Network Application to iPMS under Development

Figure 4 shows how the double network on iPMS under development can transmit phasor data through the detouring route when there are communication network problems.

As in Fig.5, the back up system, detouring route, and double loop network may be discussed as problem solutions. In addition, for reliability of data transmission in the public network and private networks, TCP/IP also can be considered since especially regarding iPMS Fault Tolerance, whether there is any communication network error and which system has errors in the system facility can be recognized promptly. There should be verification on this measure in the future.

4. Conclusion

This study is a part of 'the development of electric power facility agent and broad range defense system associating protocol' in 'the development of electric power infra defense system prototype and network establishment technology' being conducted by Minister of Commerce, Industry and Energy.

To simulate and analyze the communication between iPIU and iPIC, the simulation system was structured, and measured were the network traffic and data loss rates of each time zone according to the connection channels between iPIU simulator and iPIC simulator. The latancy of each channel also was analyzed. Based on the result, it turned out that UDP/IP, the protocol between iPIU and iPIC was unreliable, and thus presented is the fundamental measure to problems that can possible take place in the development process of ‘intelligent broad range monitoring system’ that will be conducted in the future.

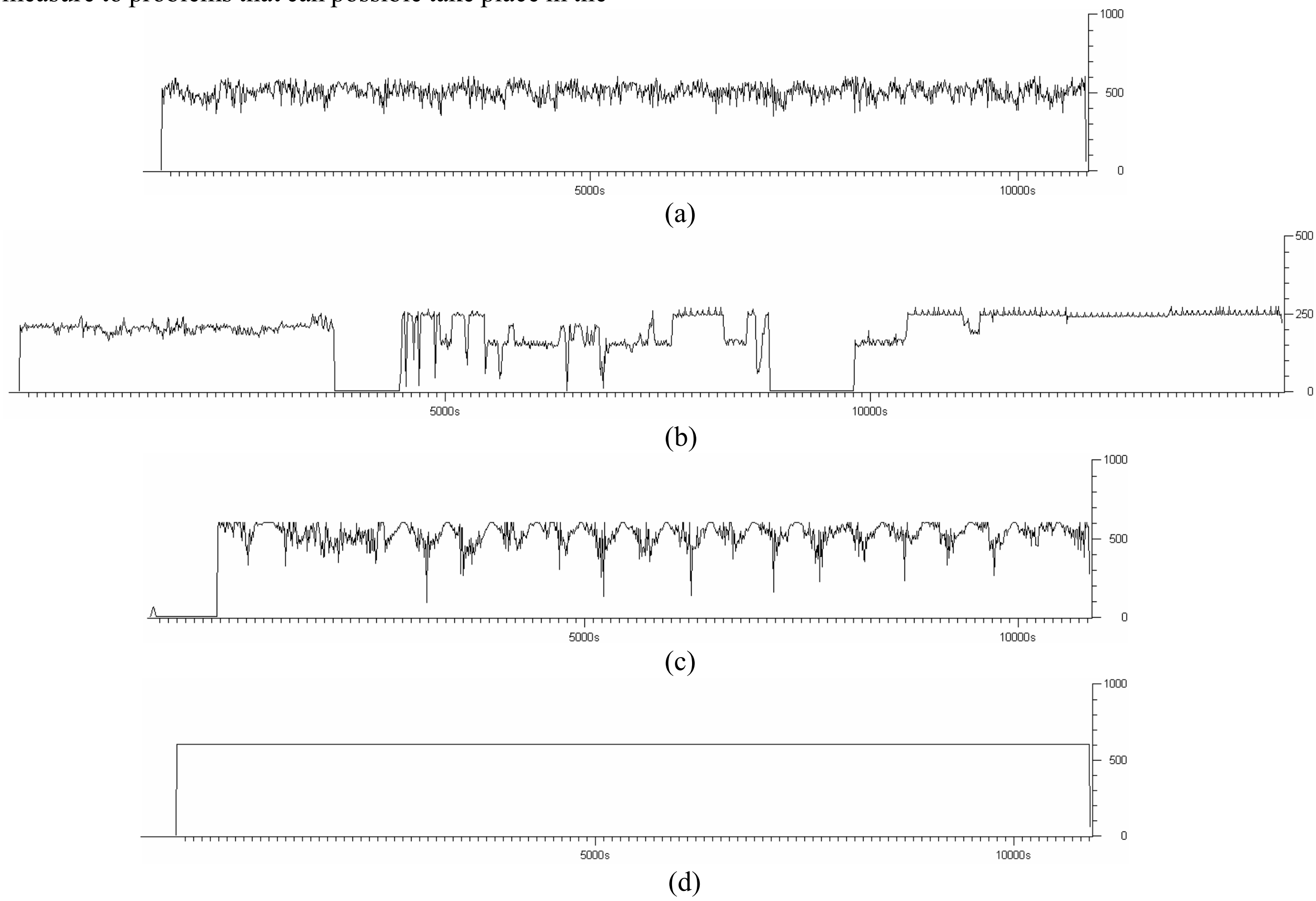

Fig. 5 Regional UDP/IP traffic of each time zone; (a) Seoul, (b) Daejeon, (c) Geoje, (d) private network, x-axis indicates time (sec), y-axis indicates average number of packets per sec; Since the Tick interval is 10 sec, the ratio is 10 times.

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