

A PDSI-based Online Fault Configuration Approach for Communication Network in Power Grid Simulation

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Abstract— In this paper, a programmable dynamic simulation interface (PDSI)-based online fault configuration approach of network simulation is proposed to dynamically set link fault as well as route fault in the case of joint power grid simulation. The proposed approach allows the user to dynamically configure the fault situations of communication network via a graphical user interface (GUI) during the simulation process. When QualNet receives the configuration messages from GUI, it will parse the messages and push the corresponding events into the event queue to close the link port or rewriting the routing tables, which is utilized to formulate the link fault or the route fault. Experiment results demonstrate that based on the proposed approach the fault configuration of communication network can be successfully performed with an acceptable compromise at interface interaction delay.

Keywords— Online fault configuration, QualNet, Co-simulation, PDSI

I. INTRODUCTION

Since the operation efficiency of power grid system highly depends on the quality of its communication network, numerous works of co-simulation for power grid were conducted to observe the influence of fault in communication network on the power grid system [1-3].

In [1], a joint simulation system composed of PSLF, PSCAD/EMTDC, and NS-2 was introduced to analyse the topology influence of communication network on a power grid system. A hardware-in-the-loop co-simulation architecture for a SDH network based power grid system was considered to obtain the influence of the bit error rate (BER) of communication link on the function of stability controller [2]. In addition, a co-simulation framework of power system and communication network was proposed in [3] to improve the practical investigation of smart grid and evaluate wide area measurement and control schemes. However, most of the co-simulation systems mainly focus on the message or data exchanging interface design. Moreover, the fault of communication network as well as communication link fault, e.g., link fault or route fault, which may involve security and

stability problems to the power grid system, is considered as a predefined manner rather than a dynamic fault manner. In addition, an interactive real-time user interface (RTUI) has been implemented, which is a reliable human-in-the-loop framework that allows users to dynamically modify the parameters configuration of network model during the simulation process [4]. And then, based on RTUI, a programmable dynamic simulation interface (PDSI) is further proposed [5], which allows users configure the parameters with the time label to make the parameters modification more precisely. However, how to dynamically configure the link fault as well route fault of the communication network for power grid simulation is not further considered.

In this paper, based on the PDSI in [5], an online fault configuration approach of network simulation for power grid system simulation is proposed. The proposed approach allows user to configure the fault situations to the communication system via the GUI during the simulation process. When QualNet based network simulator receives the configuration messages from GUI, it will parse the messages and then push the corresponding events into the event queue of QualNet based on time order. When it is time for the event processing, the corresponding fault configuration will be performed immediately, e.g., closing the link port or rewriting the routing tables.

The rest of the paper is organized as follows. In Section II describes the proposed online fault configuration approach in detail. Section III verifies the feasibility of the approach by simulation experiments. Finally, Conclusions are drawn in Section IV.

II. PROPOSED PDSI-BASED ONLINE FAULT CONFIGURATION APPROACH

A. Co-simulation Architecture for Power Grid System

The co-simulation architecture of power grid and communication network considered in this paper is shown as in Fig.1. The co-simulation architecture is composed of QualNet simulator, data distribution service (DDS), real-time

user interface (RTUI), DigSilent, and online fault configuration module (OFCM).

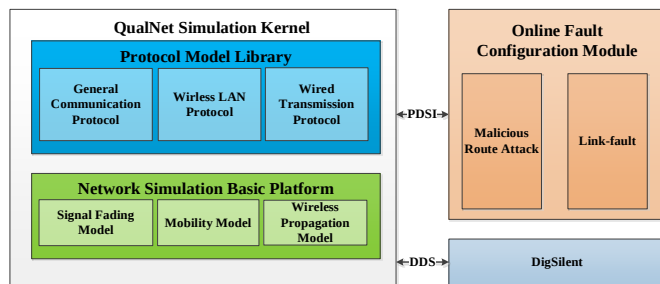


Figure 1. Joint-simulation architecture

QualNet: As the simulator of communication network for power grid system, it includes a protocol model library and a network simulation basic platform. The library not only provides protocol models for the layers of TCP/IP according RFC, but also supports dedicated network models, such as optical transmission network model based on SDH, micro-grid model, and scheduling model.

Interfaces: Two types of external interface, i.e., PDSI and DDS, are considered in this architecture. PDSI realizes the interaction between OFCM and QualNet. It combines the GUI with QualNet based simulator together via a UDP socket and is responsible for parsing configuration packets into corresponding recognizable messages by QualNet and pre-caching them into event queues of QualNet depending on the execution time. Meanwhile, publish/subscribe mode based DDS is considered for the data exchanging between DigSilent and QualNet.

OFCM: Users can input the parameters of link fault or route fault via a GUI. These parameters will be capsuled into the uniform format packets and sent to QualNet through UDP socket.

DigSilent: As the simulator of power grid system, which contains almost all common analysis functions of power system, such as power flow, short circuit calculation, electromechanical transient, electromagnetic transient calculation, harmonic analysis, interference stability analysis etc.

B. Working Process for OFCM based Fault Configuration

PDSI in QualNet is to receive and parse packets sent by OFCM to configure faults and trigger the corresponding events. The function flow chart of OFCM based online fault configuration is shown in Fig. 2.

- **SocketReceive():** PDSI keeps on listening a UDP socket to receive configuration packets sent by OFCM.
- **ProcessMessage():** PDSI judges the fault type of the received packet and call the corresponding functions to deal with the corresponding message. Figure 3 illustrates the packet format for link fault, where “Node1 ID” and “Node2 ID” determines which link is broken down and execution time indicates when the event should be performed. Figure 4 shows the packet format for route fault, where “Node ID” decides which node’s routing table is rewritten due to some

fault. Destination address, next hop address, and path cost are the detailed information of the rewritten route.

- **ForwardMessage():** Function is used to send message generated by ProcessMessage() to QualNet.
- **ProcessEvent():** Function switches the two ports of the fault link to formulate link fault and modifies the static route table of the node to formulate the route fault by calling corresponding functions, e.g., ClosePortStatus, OpenPortStatus, AddStaticRoute, and RemoveStaticRoute.
- **Error():** An error report will be returned when a packet or a message with undefined type is received.

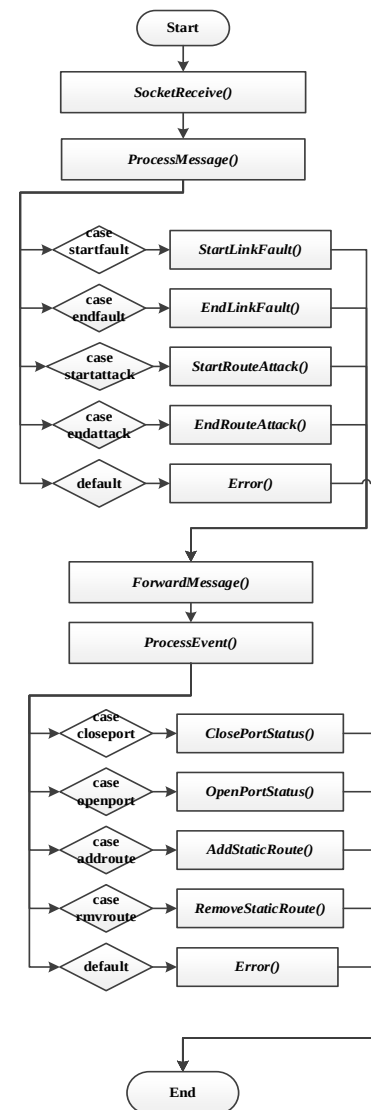


Figure 2. Flow chart of OFCM based online fault configuration

Packet Type	Packet Length	Node1 ID	Node2 ID	Execution time
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Figure 3. Packet format for link fault setting

Packet Type	Packet Length	Node ID	Destination Address	Next Hop Address	Path Cost	Execution time
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Figure 4. Packet format for route fault setting

III. EXPERIMENT AND RESULTS

The experiments are performed to evaluate the performance of OFCM based on QualNet version 5.1. Figure 5 shows the simulation scenario, in which a CBR (Constant Bit Rate) data is transmitted from node 129 to node 130 through two different paths defined by static route. The paths depicted in green and red are considered as the main route and the backup route, respectively. Before the simulation, a static routing file for QualNet is pre-configured to make sure that the CBR application data can be transmitted through the main route, i.e., the green path. In addition, the green arrows indicate the data flow during the simulation process.

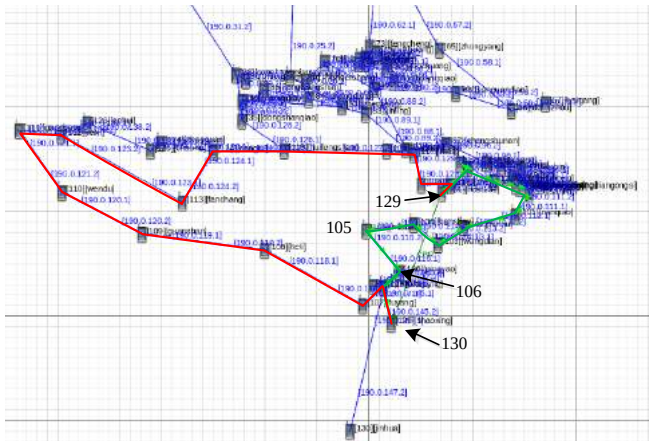


Figure 5. Network simulation scenario

A. Link Fault Test

Link fault online configuration panel

Source node ID:

Destination node ID:

Preset fault time(s):

Delay compensation(s):

Figure 6. link-fault configuration

When the simulation time arrives at 10s, a link fault between node 105 and node 106 is set via a GUI designed for the link fault configuration as shown in figure 6. As shown in Fig. 7, it's obvious to observe that the link between node 105 and 106 is broken down, which results into a route path switching, i.e., packets are transmitted through the backup route, e.g., the red path, rather than the main path. Thus, as shown in Fig. 8, the total received packets at node 113 is zero from simulation time of 0~10s. Due to the link fault between nodes 105 and 106 at simulation time of 10s, transmission path of the CBR data is switched to backup path and a linear increase trend of total received packets at node 113 can be observed. Furthermore, the link fault is recovered at

simulation time of 30s. And thus, the CBR data can be transmitted in the main path. Owing to the routing path switching, the total received packet at node 113 becomes flat and that of node 105 begins to increase linearly.

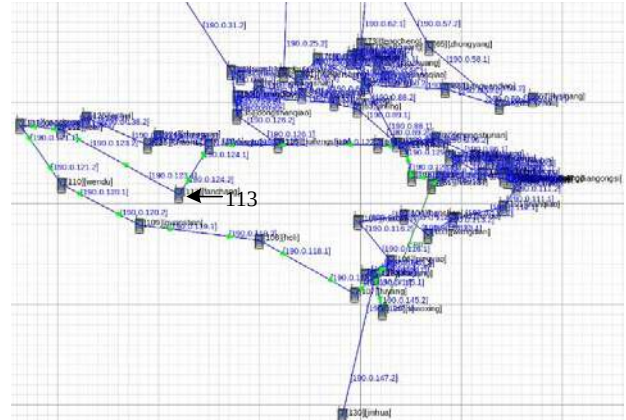


Figure 7. Route switch after link fault configuration

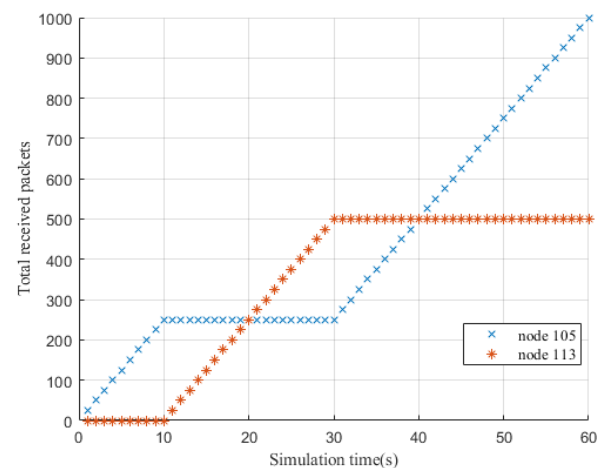


Figure 8. Total received packet at nodes 105 and 113

B. Route Fault Test

Route fault online configuration panel

Target node ID:

Preset attack time:

Insert route info: dest:

Next hop:

Interface IP:

Weight:

Figure 9. malicious route attack configuration

Similar to link fault configuration, here it is assumed that the node 94 was attacked by adding an unreachable destination address "190.0.101.1" at simulation time of 30s as shown in Fig. 9. The data transmission from 129 to 94 is successful and the total received packets of nodes 130 and 94

increase linearly. However, the total received packets at node 129 becomes flat, which means none packet is received after simulation time of 30s, since the node 94 is unable to transmit the CBR data to the next hop successfully due to the route fault.

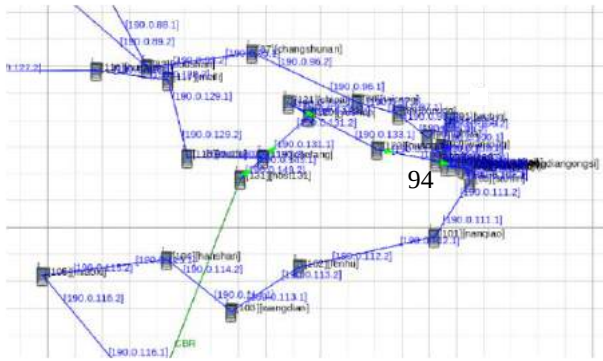


Figure 10. Router fault at node 94

The received packet of node 94 and 105 was also recorded when the attack occurred at 300s in Figure 11.

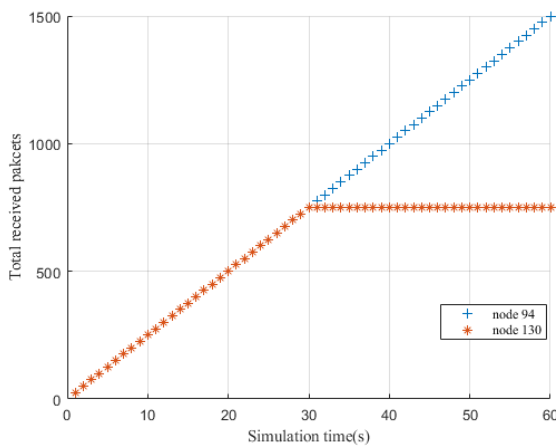


Figure 11. Total received packet at nodes 94 and 130

C. Interface Interaction Delay Test

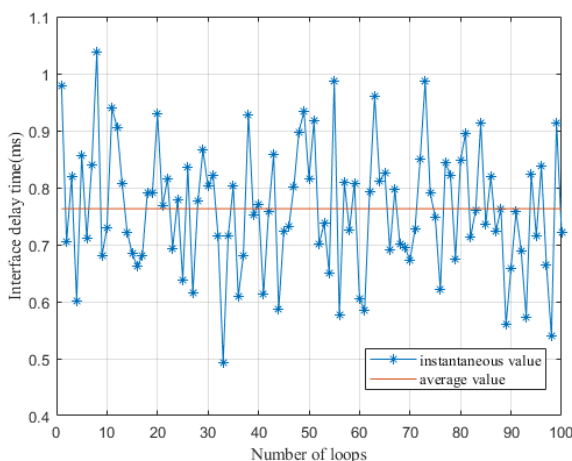


Figure 12. interface delay of OFCM

In addition, the time delay of OFCM is composed of four parts: consumption time for calling the receiving function, consumption time for packet parsing and rebuilding, consumption time for event processing in QualNet and consumption time for packet feeding back. 100 times of experiments are performed to obtain the average time delay of OFCM. As shown in Fig.12, an average delay time of OFCM of 0.76ms can be observed, which implies that the proposed interactive interface can efficiently support the online fault configuration of communication network with an acceptable time delay of interface.

IV. CONCLUSIONS

In this paper, a PDSI-based online fault configuration approach for network simulation of power grid is proposed to dynamically set link fault as well as route fault in the case of joint power grid simulation. Together with the proposed approach, users can dynamically configure the fault situations of communication network via a graphical user interface (GUI) during the simulation process as an online manner. When QualNet receives the configuration messages from GUI, it will parse the messages and push the corresponding events into the event queue to close the link port or rewriting the routing tables. Experiment results demonstrate the efficiency of the proposed online fault configuration approach.

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