

An Interactive Interface of QualNet for DigSilent in Power Grid Simulation

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Abstract— Recently, power grid simulation has been widely considered for the smart grid implementation. In order to obtain the influence of communication network on power grid, the co-simulation architecture was considered, while the simulation based on QualNet and DigSilent has not been considered. In this paper, a power grid co-simulation interface (PGCI) is designed for QualNet and DigSilent to support the information exchanging, e.g., power dispatch data and control commands, for joint simulation. PGCI packets the data generated by the DigSilent into the messages that can be realized by the QualNet, by which the data can be transmitted into the network simulator, then the received messages are parsed and sent back to the DigSilent. Experiment results demonstrate that the proposed interface, PGCI, can effectively exchange the power dispatch and control commands between DigSilent and QualNet, where the influence of communication network on the power grid can be realized.

Keywords—Interactive interface; Power Grid simulation; Communication network simulation; QualNet; DigSilent

I. INTRODUCTION

With the rapid development of the smart grid, the power system has been tightly coupled with the communication system, which may involve security and stability risks to the power system. Faced with those risks, the simulation that aims to obtain the influence of communication network on power grid and improve the reliability and security of the power system through testing and researching the dynamic and static characteristics of the system has attracted more and more attention.

However, the tight interdependence between power and communication system in the present power grid increases the difficulty to analyse the interaction by a single simulator [1]. Thus, the co-simulation architecture has been taken into consideration. In [2], a joint simulation system that consists of PSLF, PSCAD/EMTDC and NS-2 was proposed to provide a methodology to extract the dynamic real time model of an electric power system. The author in [3] proposed a co-simulation framework of power system and communication network using a global event-driven mechanism to improve the practical investigation of smart grid and evaluate wide area measurement and control schemes. In addition, a WAMC

testing platform based on OPNET was proposed to facilitate the real-time simulation of dynamic power grid, the ICT infrastructure that overlays the grid and WAMS applications in [4]. However, due to the limitation of the communication network simulator, the simulation scale and accuracy in the studies above are quite limited. In addition, the QualNet network simulator is more efficient in terms of network scalability and accuracy compared to the OPNET, NS-3, and NS-2, thus, it is essential to design the interactive interface of QualNet for power grid simulation.

In this paper, an interactive interface is proposed and designed to achieve the efficient interaction between the power system, i.e., DigSilent, and communication system, i.e., QualNet. The proposed interface, PGCI, packets the data produced by DigSilent into messages that can be realized by the QualNet, so that the data can be transmitted into the network simulation system of QualNet, then the received messages are parsed and sent back to the DigSilent, by which the co-simulation of QualNet and DigSilent can be achieved.

The remainder of the paper is organized as follows. In section II, the co-simulation Architecture of QualNet and DigSilent as well as the proposed co-simulation interface of PGCI are described in detail. Then, PGCI is evaluated by intensive experiments in section III. Finally, Conclusions are drawn in section IV.

II. PROPOSED INTERACTIVE INTERFACE FOR DIGSILENT

A. Co-Simulation Architecture of QualNet and DigSilent

The co-simulation architecture is composed of DigSilent-based power simulator, UDP socket, PGCI, and QualNet-based network simulator as shown in Fig. 1.

- The DigSilent-based power grid simulator produces power application data that will be sent to QualNet and processes the feedback data from QualNet. The transformed data is utilized for power grid simulation, including power dispatch, decision-making of the control centre and so on.
- The QualNet-based network simulator is adopted to generate the communication network that includes network model and device model, while the data

produced by the DigSilent-based power grid simulator will be transmitted into this virtual network.

- PGCI can be considered as an external interface of QualNet, including PGCI receiver and PGCI sender. The receiver is responsible for parsing configuration packets into corresponding messages that can be recognized by QualNet and pre-caching them into event queues of QualNet, while the sender realizes the inverse conversion process so that the data sent back by the PGCI can be recognized by the DigSilent.
- Besides, the data exchanging between the DigSilent and PGCI is accomplished by the UDP socket.

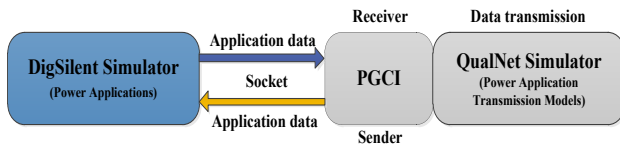


Figure 1. Co-simulation architecture of QualNet and DigSilent

B. Working Procedure of PGCI

Figure 2 depicts the working procedure of PGCI as follows.

- DigSilent produces power application data, which is sent to PGCI through a UDP socket.
- When the receiving buffer of PGCI receives packets after synchronization, the packet parser will be informed to rebuild the packets of the formats designed for PGCI, as shown in Fig. 3. In order to distinguish the packets for different functions, packets with different types of header are designed, while QualNet mainly focuses on the information in the header instead of the application data payload generated by DigSilent.
- Also, if the packets from DigSilent are incorrectly received, the corresponding error packets used for reporting error information, as shown in Fig. 3(c), will be generated and sent to the send buffer.
- Then, the rebuilt packets, e.g., the application packets and control packets respectively shown in figure 3(a) and (b), are packed into messages that can be realized by QualNet, and then the messages are pushed into the event queue based on time order. The application packets are used for the transmission of application data, such as voltage amplitude, voltage phase and so on. And the control packets are responsible for the transmission of the control policies from the control centre.
- When it is time for the transmissions of the messages, the corresponding events are assigned to the event processor by the event dispatcher [5].
- Based on the power application transmission models in QualNet, the event processor transmits the messages from the source node to the destination node, which are defined in the header of the packet.
- As soon as one node in the simulation scenario receives messages from other nodes, it transmits the messages to the send buffer of PGCI. And then the

send buffer judges that whether the packets in the messages are the data packets of power application and control or not. If they are, then the packets will be fed back to DigSilent simulator or other applications via UDP socket.

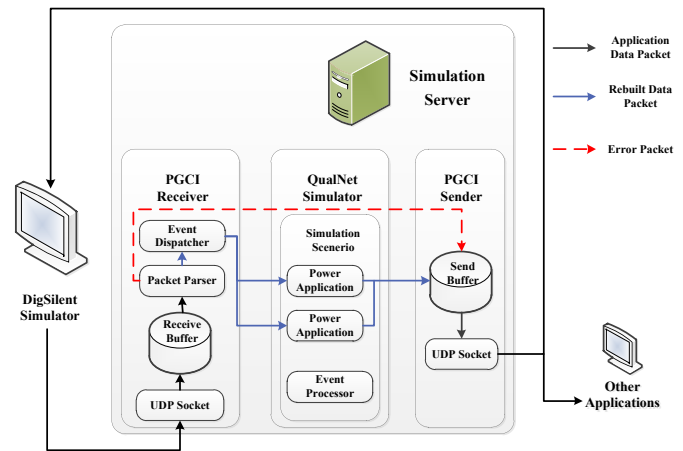
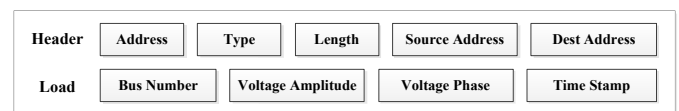
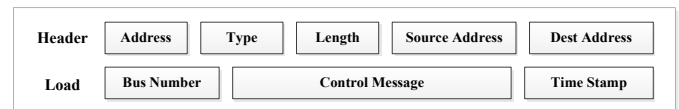


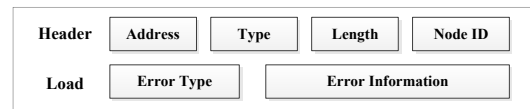
Figure 2. The working procedure of PGCI



(a) Application packet format



(b) Control packet format



(c) Error packet format

Figure 3. Designed packet formats for PGCI

III. EXPERIMENTS AND RESULTS

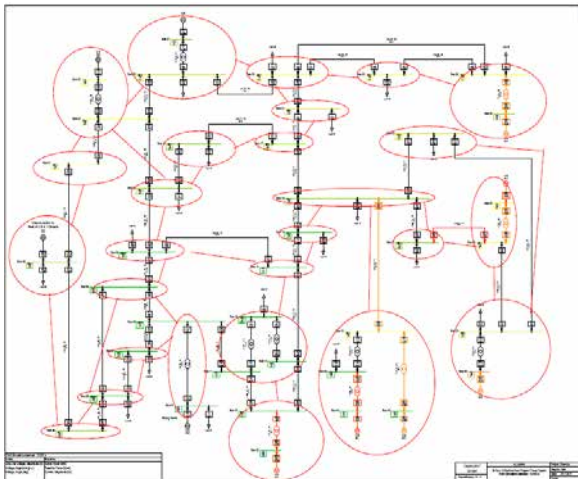
A. Experiment Scenario

The experiments are set to evaluate the connectivity and access delay of PGCI based on QualNet version 5.1 and DigSilent version 15.1.6. The parameters of simulation servers are listed in Table 1.

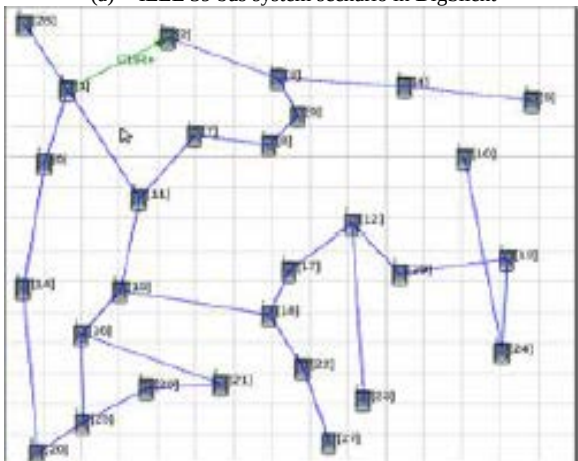
TABLE 1. PARAMETERS OF SIMULATION SERVERS

	QualNet simulator	DigSilent simulator
Operation system	Ubuntu 12.04	Ubuntu 12.04
CPU	Intel xeon(R) E5-26090	Intel xeon(R) E5-26090
RAM	23.5GiB	23.5GiB

In the experiment, the IEEE 39 Bus System, also known as New-England Power System, is chosen as the simulation scenario. The parameters are taken from [6]. And the simulation topologies in DigSilent and QualNet are respectively given by Fig. 4(a) and Fig. 4(b). Node 1, as the control centre in the power grid, makes decisions through analysing the uplink data received from the other nodes based on the control strategy. Then the control data that protects the power equipment from voltage anomaly will be fed back through the downlink. The time interval of feedback packet is 5s.



(a) IEEE 39 bus system scenario in DigSilent



(b) Corresponding network topology in QualNet

Figure 4. Simulation scenario of DigSilent and QualNet

B. Experiment Results

Figure 5 depicts the voltage of bus 09 varying with time. From the figure, we can see that there is a fluctuation of the voltage at the beginning because the power equipment doesn't know the global parameter of the grid. Then the voltage tends to be stable because of the control information received from the control centre. The result demonstrates the feasibility of the proposed interface PGCI.

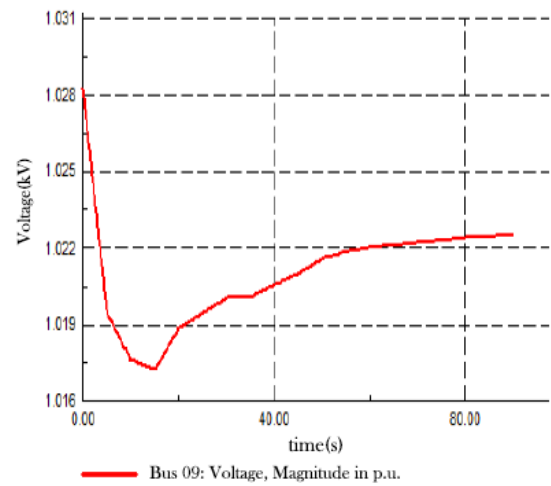


Figure 5. The voltage of bus 09 that varies with time

As shown in Figure 6, the curves of different colours describe the voltages of different buses varying with time after a breakdown in the grid at node 1. When a communication breakdown is set to the power grid at 0.1s, a fluctuation of the voltages occurs. Then, communication breakdown is set to be recovered at 4s, the curves tend to be stable, which demonstrates together with the proposed interactive interface, the influence of the communication network can be realized on the power grid.

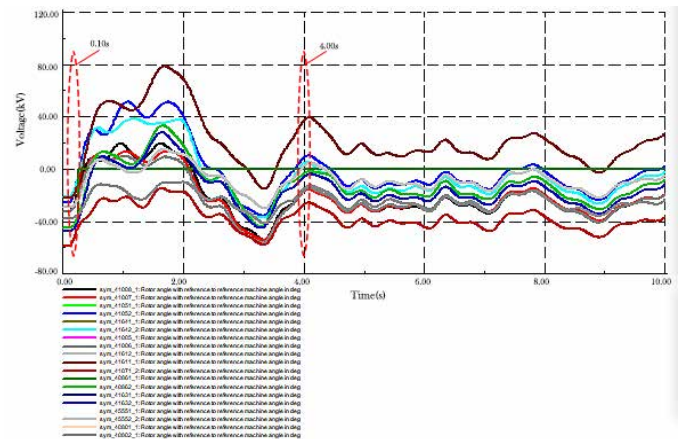


Figure 6. The voltages of buses that varies with time after a breakdown

In addition, the time delay accessed by PGCI, T , is composed of four parts as following.

- Consumption time for calling the receiving function, t_1 .
- Consumption time for packet parsing and rebuilding, t_2 .
- Consumption time for event processing in QualNet, t_3 .
- Consumption time for packet feeding back, t_4 .

Thus, the total time delay accessed by the PGCI can be given as $T = t_1 + t_2 + t_3 + t_4$. As shown in Figure 7, 100 times of experiments are performed to obtain the average time delay of PGCI. As shown in Fig. 7, an average delay time of PGCI of 0.763ms can be observed, which implies that the proposed interactive interface can efficiently support the co-simulation

of DigSilent and QualNet with an acceptable time delay of interface.

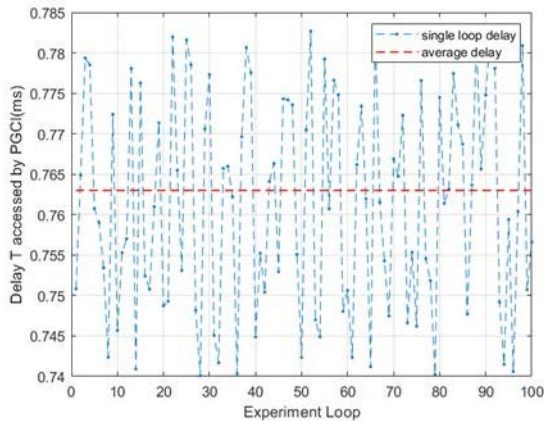


Figure 7. The delay T obtained through 100 times of experiments

IV. CONCLUSIONS

In this paper, a co-simulation interface is proposed and designed for QualNet and DigSilent to achieve the interaction of the power grid simulation system and network simulation system. The proposed interface, PGCI, packets the data produced by DigSilent into the messages that can be recognized by QualNet, so that the data can be transformed into the simulated network, then the received messages will be parsed and fed back to DigSilent. Experiment results demonstrated that the proposed PGCI can effectively exchange the power dispatch and control commands between DigSilent and QualNet, where the influence of communication network on the power grid can be efficiently realized.

ACKNOWLEDGMENT

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wireless systems, information security, and the next generation wireless systems such as 3GPP LTE, UWB, MIMO, Cognitive radio and so on.



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resource management in wireless systems and so on.



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