Discussion on Reliability of Narrow-band TD-LTE Network Transmission for Distribution Automation System

CHEN Yong-tao [1], WANG Hao [1a], WANG Min [1]

[1]Guangzhou Power Supply Co.Ltd. , Guangzhou, Guangdong, 510000, China

Abstract: In Guangzhou, there is a poor communication between power control systems in equipment rooms and the 100,000 distribution terminals scattered around the city. Guangzhou Power Supply Co.Ltd. (CZPS) planned to upgrade smart power distribution grid with wireless communications technology. It built an integrated data collection platform and several small-scale test zones to collect and analyze data from a pilot. In the GZPS Communication Laboratory, to confirm the reliability and accuracy, the transmission performance indicator of DTU are compared with different RSRP by using wireless public network (GPRS) ,230MHz and 1.8 GHz wireless private network testing system.

Keywords: Power Grid Wireless Private Network; Distribution Automation; Remote Control, TD-LTE

1 Introduction

Power communication service has widely used various communication technologies. With the development of the construction of the smart grid, distribution automation system (DAS) is not just a remote control but it results into a highly reliable,efficient power system that responds rapidly to real-time events with appropriate actions.

The distribution grids have a complex network topology by feeding the power in a wide coverage area. At present, optical fiber communications are the main communication means for the access networks. However, in well-established urban areas that feature complicated terrains and tall buildings, routing of optical fibers is difficult and the costs are often very high. The power wireless private network construction attracts more and more attention. In this scenario, the LTE-based private wireless network can be used as the alternative and economic access network. It is a cost-effective solution to the last-kilometer problem.

Public networks failed to meet service requirements because of poor security, high lease costs, and insufficient service resources. The private wireless network is a solution that eased construction problems and freed wired networks from environmental restrictions. Wireless broadband private network also overcame the poor performance and limited resources of 2G/3G public networks.

1.1 Time-Division Long-Term Evolution (TD-LTE) technology

The solution uses 4G TD-LTE base stations in existing substations and office buildings. The base stations operate on a 1.8G and 230MHz industry-dedicated wireless spectrum. In addition, it deployed dedicated TD-LTE distribution terminals with Data Transformation Units (DTUs), Remote Metering Terminal, and Video Surveillance. The base stations combine data from multiple electric power terminals and send it via an existing transmission network to a host station.

1.2 Multi-level Quality of Service (QoS)

Different service applications in automatic power distribution networks work on different priorities. Private network TD-LTE system integrates radio resource management and tailored priorities for electricity services. The solution also supports multiple services while ensuring that important data, such as automatic remote service data, transmits preferentially. The QoS mechanism works with real-time online terminals and a latency minimizing solution to ensure less than 100 ms end-to-end latency. The TD-LTE solution also uses an array of end-to-end data protection methods, including 128-bit Advanced Encryption Standard (AES) and authentication encryption, to ensure high data security and reliability.

2 Performance Indicators Testing

In the Guangzhou Power Supply Co. Ltd. (GZPS) Communication Laboratory, to confirm the reliability and accuracy, the transmission performance indicator of DTU are compared with different RSRP by using wireless public network (GPRS), TD-LTE 230MHz and TD-LTE 1.8 GHz wireless private network testing system. The experiment Results is shown in Appendix I.

[a] Corresponding author: wanghao_hust@163.com

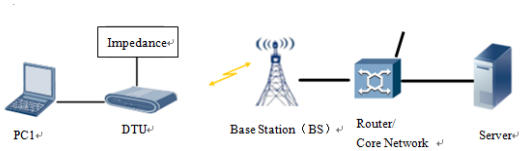

Figure 1. Testing environment.

2.1 Channel Performances

There is a positive correlation between the channel uplink /downlink speed and RSRP, its decline from large to small order is 230MHz network, 1.8GHz network, GPRS network. Besides, The packet delay and packet loss is positively related to the RSRP. The channel can remain the same under the condition of stable,

TD-LTE is the next-generation wireless broadband technology, using a variety of advanced wireless communication technologies such as Orthogonal Frequency Division Multiplexing (OFDM), Multi-Input Multi-Output (MIMO), a multi-channel smart antenna technology and so on, which effectively enhance the data throughput rate, coverage and the number of user online. GPRS is a best-effort service, implying variable throughput and latency that depend on the number of other users sharing the service concurrently.

2.2 Communication Requirements

The distribution equipment can be divided into three categories: remote measuring, remote communication, remote control(three-remote system). Currently, the transmission requirements of distribution automation system are that the largest bandwidth is not less than 64bps; packet delay is not greater than 1 second. The experiment results show that the public network GPRS and private network (TD-LTE 230MHz, TD-LTE 1.8GHz) all can satisfy the requirement of three-remote system. In addition, all the operations of switching device were controlled successfully with 1k uplink data, its purpose is to simulate the real remote signaling by loading 1k data.

2.3 Benefits of Private Wireless Network

Bandwidth of Public network GPRS is 20Kbps – 40kbps and latency is 2 second. Experimental results show that the uplink and downlink speed remain at 5KB/s,10KB/s respectively, but a gradual increase in the proportion of the retransmission packets. Compared with the TD-LTE network, the pubic GPRS is low reliability and security, its recourses shared by public and network controlled by operators.

Currently, the approved bandwidth of the 1.8GHz wireless private network is 5MHz. the testing results show that the maximum throughput of uplink and downlink are 1.95Mbps 2.27Mbps respectively. Besides, the 1.8G CPE device support multiple uplink/downlink ratio configuration, including 0(3:1),1(2:2),2(1:3) (uplink: downlink). It also offer flexible bandwidth from 5Mhz to 20Mhz. it is adapt for streaming data-intensive uplink service such as video surveillance and data collection.

TD-LTE 230 system uses Adaptation Modulation and Coding (AMC), which can offer an alternative link adaptation method that promises to raise the overall system capacity [1]. AMC provides the flexibility to match the modulation-coding scheme to the average channel conditions for each user. With AMC, the power of the transmitted signal is held constant over a frame interval, and the modulation and coding format is changed to match the current received signal quality or channel conditions. The AMC scheme of TD-LTE 230 system uses QPSK, 8-PSK and 16 and 64 QAM modulation using R=1/2 and R=3/4 Turbo code. In table 4.2, it shows that the uplink and downlink speed of LCM change with channel quality. In a system with AMC, the modulation-order or code rate will increase as the quality of channel increases (e.g. 64QAM with R=3/4 turbo codes). The maximum uplink speed can reach 45.6kbps. In order to ensure the reliability, it is typically assigned lower order modulation with lower code rates when the quality of channel decreases.

According to the State Radio Regulatory Commission frequency allocation strategy, there are 35 available frequencies for TD-LTE 230. If available frequencies are sufficiently used, the uplink and downlink speed will achieve 1.51Mbps and 289.5Kb/s respectively

2.4 The Reliability of Three Remote

As shown in the experimental results, the RSRP limit of the GPRS public network is -95dB, the RSRP limit of 1.8GHz private network is -117dB, the RSRP limit of 230 MHz private network -121dB for multi-frequency, -127dB for single frequency. The private network can tolerate lower RSRP than public network, and the channel is more stable. When RSRP = -97dB, the GPRS channel is extremely unstable, the Dial-Up networking could not complete the connection to the server. Even if successful connection, the three remote function cannot work properly. When RSRP = -120dB, the channel of private network is starting to become unstable, it will take a lot of time to connect successfully. Once the connection is established successfully, the three remote function can work well.

Compared to the GPRS public network, the TD-LTE private network is little time-delay,low packet loss rate,less retransmission rate, so the round trip time of remote control commands and shift information is expected to be much lower.

Table 1. AS the RSRP= -90dBm, a brief description of time delay are listed below

	GPRS	TD-LTE 1.8Ghz	TD-LTE 230MHz	
			LCM	CPE
Non-business state		33ms	181ms	145ms
In-business state	333.2ms	32ms	162ms	131ms

Table 2. As the channel is stable, the average time of three remote is list below.

	GPRS	TD-LTE 1.8GHz	TD-LTE 230MHz	
			LCM	CPE
Switch on	7832ms	2476ms	2808ms	2939ms
Switch off	8205ms	3141ms	2821ms	3046ms

Table 3. The measurement of GPRS network

Impedace (dB)	RSRP (dB)	Uplink speed(Kbps)	Downlink speed(Kbps)	Packet Delay (ms)	Packet Loss (%)	Packet Delay with 1k uplink	Packet Loss	Three remote test		Accuracy
								Switch-off(ms)	Switch-on(ms)	
+0dB	-65	5	10.8	335	0%	410.5	0%	7622	7575	100%
+5dB	-70	5	10.1	343.6	0%	356.9	0%	7565	8080	100%
+10dB	-75	5.2	11	367.4	0%	346.9	0%	5050	7571.5	100%
+15dB	-81	5.1	10.5	316	0%	347.7	0%	12120	7070	100%
+20dB	-85	5.1	10.1	323.4	0%	427.6	0%	7575	9090	100%
+25dB	-90	5	10.0	333.2	0%	398.2	0%	7070	8585	100%
+30dB	-95	4.9	11.3	331.4	0%	359.1	0%	8080	8585	100%
+32dB	-97	5.2	Instable	324.4	0%	387.5	0%	7576.5	9090	100%
+34dB	-98	5.2	Instable	324.4	0%	387.5	0%	Instable	Instable	Instable
+35dB	-99	5.1	Instable	1203.7	0%	514.8	0%	7095	8111.5	100%
				618.6	5%	837.2	0%			
				645.1	0%	566.3	11%			
+37dB	-101	5.2	Instable	865.4	57%/	1125.7	9%	Instable	Instable	Instable
				690.5	16%	485	2%			
				2400	40%	384.3	5%			

Table 4. The measurement of TD-LTE 1.8GHz Network

Impedace (dB)	RSRP (dB)	Uplink speed(Kbps)	Downlink speed(Kbp)	Packet Delay (ms)	BER	Packet Delay with 1k uplink	BER	Three remote test		Three remote test
								Switch-off(ms)	Switch-off(ms)	
+0dB	-92	1.95	2.27	33	0	32	0	3030	2530	100%
+5dB	-97	1.12	2.38	31	0	32	0	3015	4040	100%
+10dB	-103	0.684	2.24	34	0	34	0	2020	3030	100%
+15dB	-108	0.303	2.2	45	0	42	0	2020	3080	100%
+20dB	-112	0.143	2.49	49	0	49	0	2525	3030	100%
+25dB	-117	0.095	1.73	83	0	197	0	2525	3030	100%
+30dB	-120	0.011	1.67	228	0	Instable	Instable	2525.5	3570	100%
+32dB	-122	0.008	1.1	291	0	Instable	Instable	2559	3030	100%
+34dB	-124	0.005	0.463	594	6%	Instable	Instable	2525	3540	100%
+36dB	-126	Instable	Instable	2079	83	Instable	Instable	2020	2530	100%

Table 5. The measurement of TD-LTE 230MHz network for CPE

	Rsrp	Downlink snr	Uplinksnr	Uplink speed (Mbps)	Downlink (kbps)	Packet Delay (ms)	Packet Loss (%)	Packet Delay with 1k uplink	Packet Loss (%)	Switch-off (ms)	Switch-on(ms)
CPE (Multi-frequency)	-80	28	24.6	1.51	289.5	147	0	130	0	2631	2020
	-90	28	24.6	1.51	290.6	145	0	131	0	2525	2525
	-100	27	18.4	1.14	290.2	143	0	146	0	2525	5555
	-105	26	13.6	0.714	290.2	148	0	143	0	2610	2640
	-110	25	10.6	0.6796	288.8	141	0	139	0	3030	2518
	-115	21	4.2	0.2837	208.3	157	0	142	0	5050	4033
	-120	18	2.2	0.1098	128.4	178	3%	162	0	2525	3030
	-121	15	-1	0.0545	127.6	178	2%	167	3%	3030	3030
	-122	14	-2.2	0	126.7	287	8%	268	10%	2525	2065

Table 6. The measurement of TD-LTE 230MHz network for LCM

	Rsrp	Downlink snr	Uplinksnr	Uplink speed(Mbps)	Downlink (kbps)	Packet Delay (ms)	Packet Loss (%)	Packet Delay with 1k uplink	Packet Loss (%)	Switch-off (ms)	Switch-on(ms)
LCM (Single frequency)	-80	25	21.6	45.6	15.5	187	0	154	0	3032	3030
	-90	25	21.2	45.5	15.4	181	0	162	0	2519	2525
	-100	24	20.6	45.2	15.1	193	0	164	0	3030	3030
	-105	23	20.4	45.2	14.3	185	0	181	0	2560	2670
	-110	20	19.4	44	10.8	227	0	253	0	3535	3030
	-115	18	16.2	33.04	6.7	239	0	316	0	2525	2525
	-120	13	12.2	18	3.3	403	0	410	0	3029	3030
	-123	10	10.2	16.6	2.1	462	0	431	0	2020	2525
	-127	9	9.2	16.6	2	517	0	501	0	3030	3032

3. The Security of Network

The GPRS was originally designed to offer circuit-switched service (voice and circuit-switched data) primarily, with limited capability to offer low-bit-rate packet data service. When the amount of data is very large, there is no guarantee for the priority of key customers. Besides, the GPRS public network cannot support massive real-time online terminal, so most of the users in the standby state. The TD-LTE solution uses an array of end-to-end data protection methods, including 128-bit Advanced Encryption Standard (AES) and authentication encryption, to ensure high data security and reliability.

References

1. TSGR1#17(00)1395, Adaptive Modulation and Coding (AMC), Adhoc#24, HSDPA, 20th-24th Oct 2000
2. ZHONG Yu-Qing, WANG Hao, CHEN Bao-ren. Research on Application Principles of Communication Technologies in Smart Distribution Network, Electric Power Information Technology. 2013, 11(5):43–47.