Intelligent Systems and Synchro Phasors Protocols in Smart Grid Applications

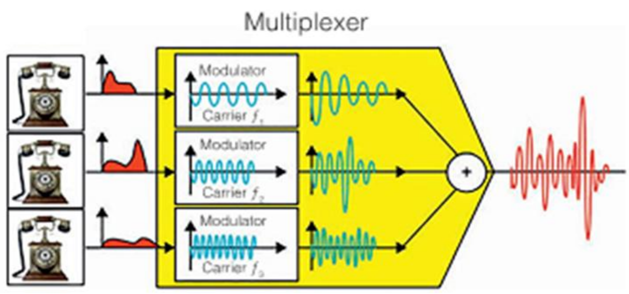
Mohammad Kamrul Hasan, Musse Mohamud Ahmed, Shayla Islam, Aisha Hassan Abdalla Hashim

Abstract*: Supervisory control and data acquisition (SCADA) is one of the existing phase measurement system provides the real-time control of power switching relays, attains information of the system status. Usually it accomplishes three-phase measurement in distributed network of smart grid through ample power quality measurement of voltage, current, and mostly the total harmonic distortion. However, the investigation of the paper suggests that SCADA delivers the updates of the grid information in times with the communication delays of 15 seconds. Of course, these timing delays can be higher, since it varies on the system complexity. Therefore, this communication delays too high in terms of synchronization, fault monitoring, and the measurement of the system variables in real-time. Therefore, this study covers the communication framework and its protocols of the smart grid application. To make the study more concise, this paper also assessed the delay of IEEE 1588 and IEEE C37.118 for the synchronization performance measurement. Moreover, this paper also includes the performance analysis of the existing the intelligent system and its protocols for smart grid application.

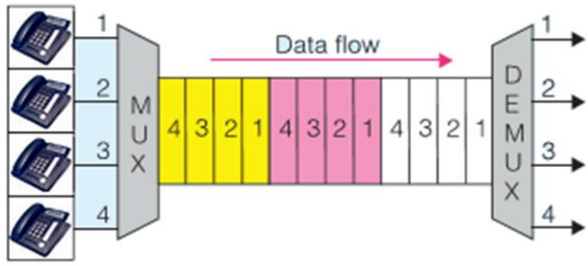
Index Terms - ISPS; IEEE 1855; IEEE 37.118; SCADA; WAMS; Smart grid.

I. INTRODUCTION

In a digital smart grid communication system, the synchronization plays a vital role in the control, measurement, and protection. The background of the communication system for telecommand smart grid is required to reveal. Alike the telecommunication system, the smart grid communication system works with two basic principles which are, switching and transmission [1]. To get detail idea and the relation of the communication framework of telecom and smart grid, it is necessary to discuss the communication. In the beginning, for the telecommunication Frequency Division Multiplexing (FDM) had implemented where the available bandwidth is allocated series of non-overlapping frequency subbands to transport separate signal. Using, the single transmission medium to be shared through multiple independent signals [2]. However, the concepts are changed for the second generation communication system (is mainly for active in GSM cellular technology) applying Time Division Multiplexing (TDM) and FDM both. The TDM technique is to transmit and receive the autonomous signals over the identical channel. Figure 1 shows the conceptual diagram of TDM and FDM [1]. However, the third generation to fourth generation advanced wireless communication such as WLAN, WiMAX for fixed line or mobile, Long-Term Evolution (LTE) and LTE-Advanced systems implemented the TDD and FDD topologies.



(a)



(b)

Fig.1: Diagram of TDM (a), FDM (b) [2]

The configuration of FDD for the duplex transmission and reception there are two preset frequencies are determined, mainly known as fc1 as well as fc2[2]. These frequencies are the uses the time slot for the transmission. While TDD systems are cheap compared to FDD systems due to the requirement of less Synthesizer, local Oscillators, as well as filters. Therefore, implementing the most sophisticated protocols still, there are many applications and systems facing challenges. For example, the Network Timing Protocol (NTP) to IEEE 1855 all has the issue for the synchronization. Still, for this type of the synchronization technique such as IEEE 1855, which was de-signed mainly for timing synchronization using external master clock server that facilitates synchronize time stamps for the devices and applications [3]. Even though implementing IEEE 1588 protocol in Wi-Fi, and the most updated LTE/LTE-

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A systems suffer a severe level of large offset and frequency error while there are asymmetric communication link exists. The functionalities of the IEEE 1588 is shown in Figure 2. Rather than this, IEEE 1855 is promising.

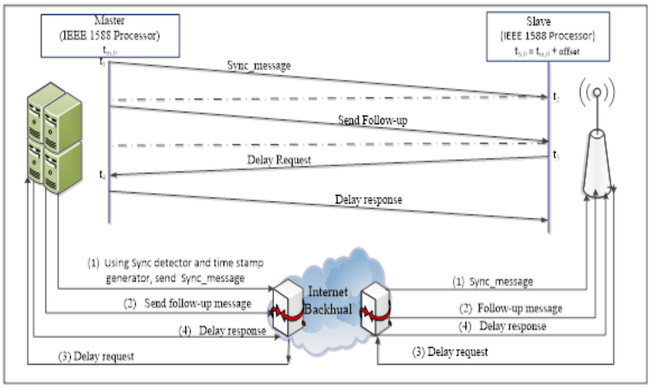


Fig.2: Functionalities of IEEE 1588[3]

This compensation of the offset and frequency error is a threat for precise synchronization [3]. The smart grid power line communication was designed using Programmable Logic Controller (PLC), and then SCADA protocol/framework at the time of the analog system. Figure 3 shows the SCADA with IECE 81650 System Architecture. The components are mainly, Remote Terminal Unit (RTU), data concentrator, transmission channel, and remote central station [4-5]. The RTU unit is mainly the microprocessor- based logic that enables the systems flexibility and enhanced performance.

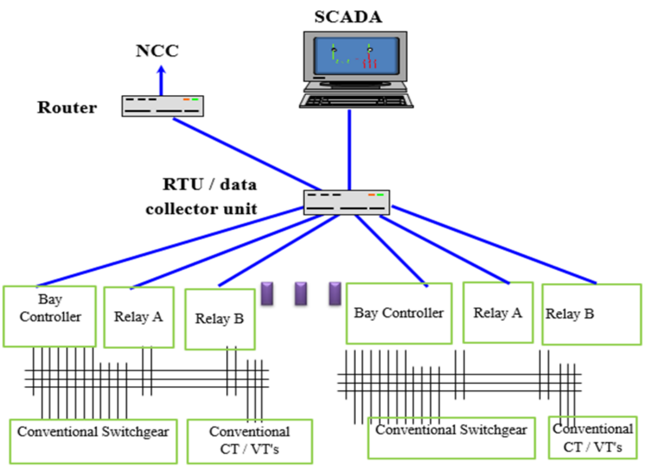


Fig.3: Existing IECE 81650 System Architecture

The existing Conventional protection and control systems are to be replaced with new protection and control systems with electronic current transformers, electronic voltage transformers and electronic control systems for monitoring as well as diagnostic operations. That is integrated to non-conventional instrument transformers, merging units and process Input/output (I/O) for bridging between analog and digital devices and complaint process I/Os from conventional IEC 61850 to the new architecture using IEC 61850-9-1/61850-9-2. IEC 61850-process bus is to be adopted at the substation bus for connecting the switchyard to the protection and control systems that could be upgraded to new IEC 61850-9-2 [6]. The advancement in communications and quicker microprocessor chips cut down the expenses and enhanced execution. SCADA is utilized for information securing, remote control, human-machine interface, sequential information examination, and in addition information profiling. The supervised information is accomplished through sensors, transducers, and status point data. The remote control includes the control of all the required factors by the administrator from the control room. At the perceptive matrix framework, the control is for the most part of switch positions; thus, advanced control yield focuses are copious, for example, electrical switch and isolator positions and hardware on and off positions. SCADA frameworks that have been the cutting edge for observing force frameworks normally give information each 2 to 4 seconds [5].

II. ANALYSIS OF IEEE C37.118

The Synchrophasors are synchronized electrical signal that has the magnitude and phase [3]. Synchro phasors are standardized with pure sine wave to measure, and monitor the accuracy of the grid by applying the 100 times faster high-speed PMUs in WAM system [6]. Figure 4 shows the PMU functional block diagram graph [6].

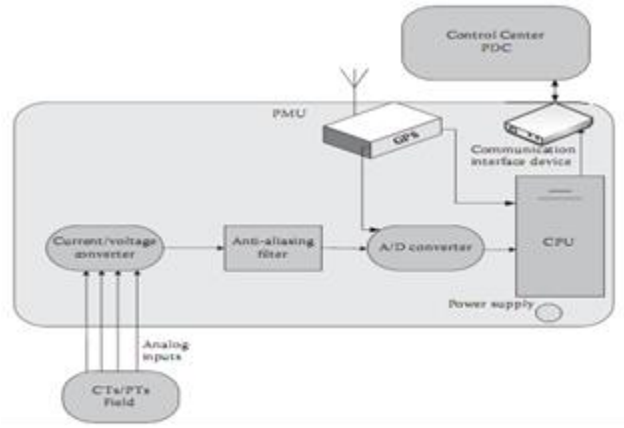


Fig. 4: Operational Block Diagram of PMU [6]

PMUs change over the deliberate parameters into phasor values regularly at least 30 esteems for every second. PMUs additionally add an exact time stamp to these phasor esteems, transforming them into synchrophasors. Time stamping permits these phasor esteems, which given by PMUs in various areas and crosswise over various power components, to be related, time-adjusted, and afterward consolidated. It is used to observe, measure, and control of the grid applications for the improvement of the execution and smooth operation of the smartgrid systems. The real-time estimation of the WAM system persistently collects the information from the substations in smart grid that is monitored at the remote monitoring station. Figure 5 shows the contextual layout of WAM Framework with PMUs that uses GPS Satellite Timestamp [6]. The existing WAM correspondence framework is composed of GPS empowered IEEE C37.118 communication convention for PMU.

Synchro phasor based monitoring and control plans truly require significant structure data than existing SCADA system. Synchro phasor's with PLLs and global positioning satellite's time stamps modify the unrefined estimations beforehand giving to the phasor data concentrator. PMU tests the synchro phasor estimations and transmits these estimations as data to the PDC through the communication network. Using IEEE C37.118.2 four categories of messages are designed that intended with communicate with PMUs. The data messages are collected through PMU to estimate the variable measurements of the grids systems. Setup messages contain the information about procedure factors and variables required to translate the data messages that are routinely in the machine be contingent framework [6]. The data word package includes distinctive layers of framework traditions basic for capable and secure the message interchange over the WAM network.

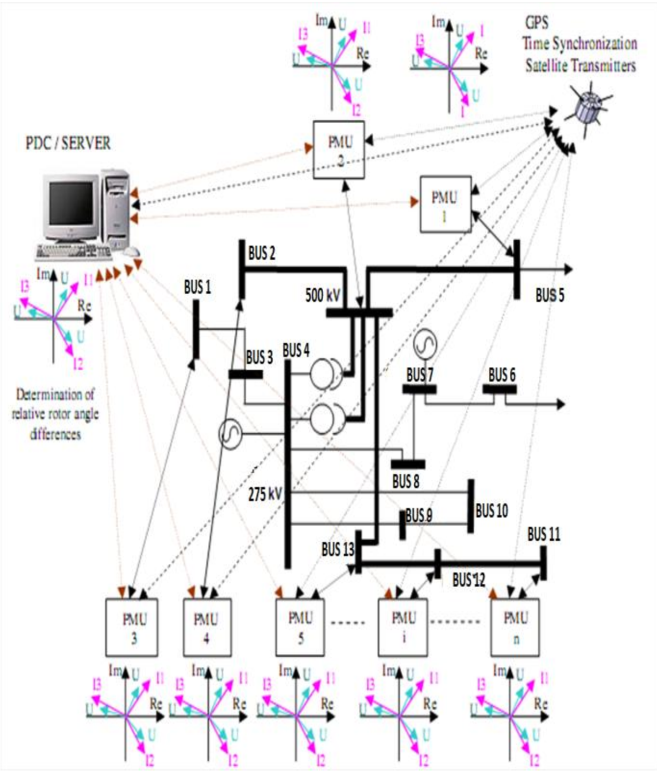
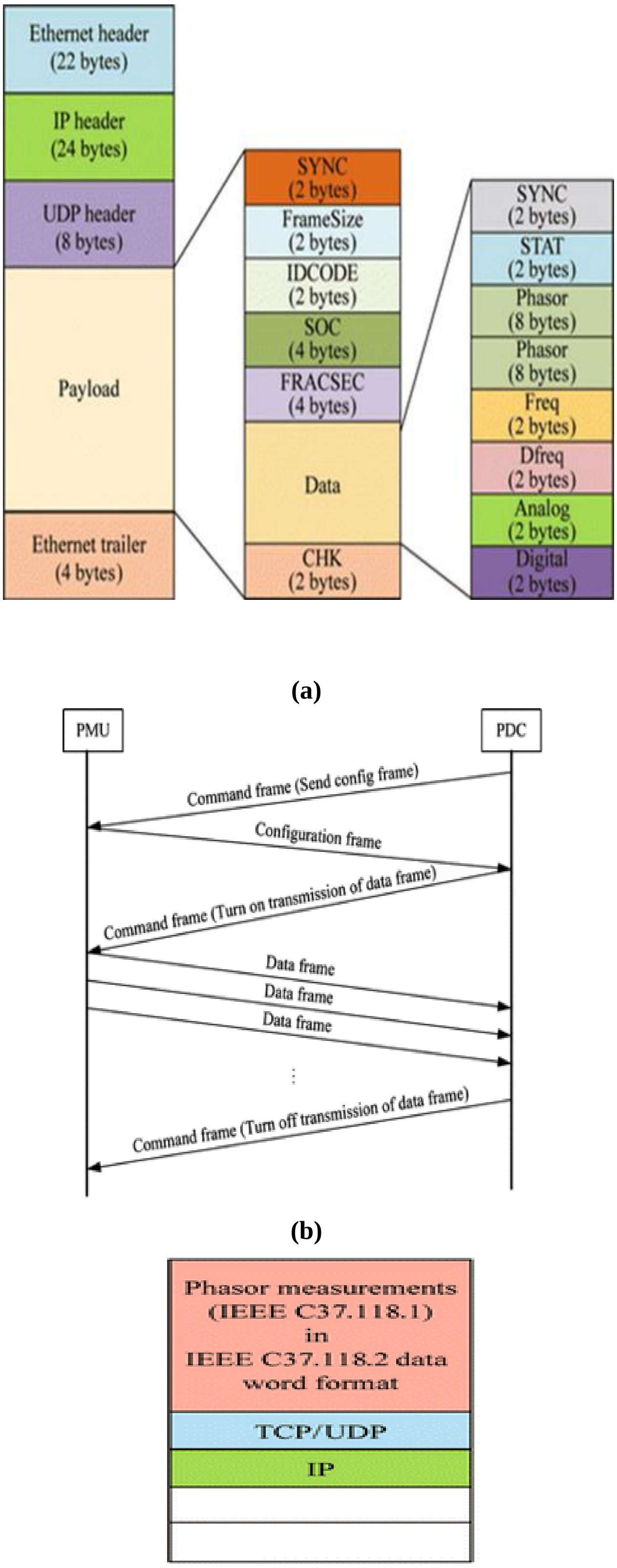


Fig. 5: GPS Satellite Timestamp based PMUs of WAM System in Sarawak Energy

Fig. 6 demonstrates the IEEE C37.118.2 data structure, protocol with detail format [7]. The "Adjust" field is of 2 bytes and is utilized to give out-line write and form number. "FRAMESIZE", "IDCODE" indicates assess the edge and 2 bytes source identifier. "SOC" means second-of-century that frames time stamp for every estimation as per UTC. To give exactness to time stamp a 4 bytes "FRACSEC" utilizes for the estimation purpose. Detail characterizes the two bytes status word that is loaded down with each and every moments information, and that allows to fetch complete status of the system. The "Information" field comprehends different estimations of phasors, recurrence for the static as well as dynamic parts. The "PHNMR" field in design 1, 2, and 3 outlines dictate the number of qualities. There is an arrangement of sending simple and computerized esteems likewise alongside different fields in the information word.

The casing ends with 2 bytes "CHK" that utilized for deciding transmitted word error through the cyclic repetition check method. After this the combination of "size" of the information word expected to be 112 bytes [7].



(c)

Fig.6: Shows the data structure (a), the Communication protocol of IEEE C37.118 (b), packet format (c) [7]

The machine coherent Configuration Messages (CFG) for the procedure of action and contain information about arrangement factors, and data sorts as well. Configuration messages are of three definites: CFG1, CFG2, and CFG3. CFG1 states the data and capacity of PMU/ PDC. CFG-2 determines the estimations of synchro phasor that transferred. In any case, CFG3 is as CFG2 however contains further flexible information on PMU characteristics with assessments. PMU and PDC send the header messages that includes communicative information. Request messages are used to control the activity of device through transfer synchro phasor estimations. In this way, data, configuration and request messages reported in the machine-intelligent course of action while the header is illustrating information in the comprehensible association. The data, configuration, and header message transfers to the data sources while the request can acquire from the grid components [8]. For the grid measurement, authors have shown the different methods of absolute phase errors [9] for the two channels. The presented technique is combine with the theoretical and experimental.

III. RESULT AND DISCUSSION

The performance of IEEE 1855 and C 37.118 protocol was assessed using Matlab based simulation. The phase offset and delay were considered as the performance metric of synchronization measurement. For the delay analysis, the initial random receive delay reference was set to 15 μs, 20 μs, and 30μs. The number of samples was 10,000. The number of PMUs were 100 and 50 PDC were considered, where the link speed was symmetric. Figure 7 represents the offset and frequency errors for the IEEE 1588 proto-col. It can be seen from Figure 7 that the phase offset error is marginally acceptable while the link speed was 100Mbps and the external timing server. These offsets are mainly the delay differences between the external time stamps and the local devices. There are propagation delays, receive delays and processing delays as well. It is evident from the Matlab based analysis that the performance of the still has delays while it processed the data and communicates the PMU terminals. When it encodes the messages and transfer to the receiver then decodes the data, this procedure induce the processing delays (Shows in Fig. 8).

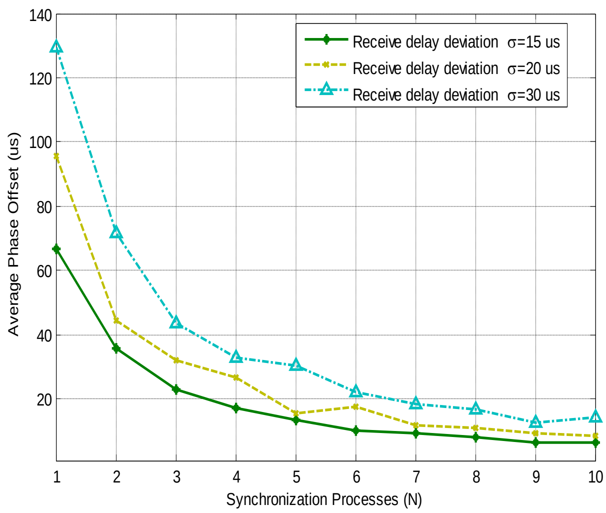


Fig.7: Analyze the Phase Offset for IEEE C37.118

Therefore, the lower the delay is better to have the real-time access to the grid. However, this protocol needs to assess for the asymmetric link speed.

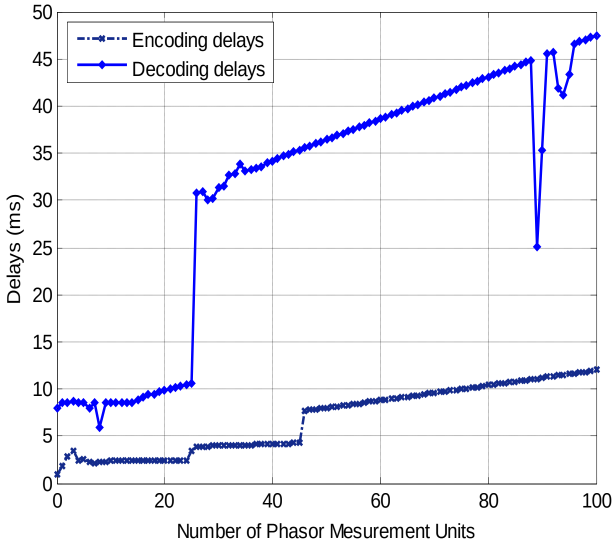


Fig. 8: Analyze the delays of IEEE C37.118

The receive delay and propagation were found very minimum for the C 37.118. However, the delays of IEEE C 37.118 was reviled at the time of coding and encoding process. These delays are huge while the number of PMU devices and systems reached to the maximum. Moreover, from the analyses of the existing IEEE C37.118 protocol, the limitations i.e. Requirements of GPS satellite's external timestamp. The absence of GPS can imbalance the precision of the grid monitoring system. Therefore, the asynchronous communication and phase error can affect the measurement of the real-time data in the smart grid. The enormous data names are used that prevents the auto-discovery as well as self-description. Moreover, the interoperability and the integration is not operator friendly. This is mainly because when the grid requires extra features to include the customization is strictly not allowed that is more on vendor specific features.

IV. CONCLUSION

This paper discusses the smart grid industry standard basic communication frameworks, systems, and its protocols. The modern smart grid deployed C37.118 with PMUs in WAM applications. Synchrophasors have turned into a basic part of the advanced smart grid communication framework and their applications. In the investigation, the IEC 61850-9-1/61850-9-2. IEC 61850, SCADA systems are also discussed. From the analysis, it is evident that the C37.118 framework uses the GPS based timestamps in order to synchronize grid applications. In compare with SCADA with PLC, the WAM with PMU is the newest communication application framework in smart grid though it has some challenges in terms of lower the delays.

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REFERENCES

1. Kurth C (1971), SSB/FDM utilizing TDM digital filters. IEEE Transactions on Communication Technology 19, no. 1 (1971): 63-71.
2. Baroncini, F., & Salicone, S. (2017). How synchronization evolved from analog to digital in the TLC world. *IEEE Instrumentation & Measurement Magazine*, *20*(5), 30-34.
3. Hasan MK, Ismail AF, Abdalla AH, Ramli HAM, Hashim W, Razzaque A & Khairolanuar MH (2016), A self-organizing approach: time synchronization for the HeNodeBs in heterogeneous network. In: Sulaiman H, Othman M, Othman M, Rahim Y, Pee N (eds) Advanced Computer and Communication Engineering Technology. Lecture Notes in Electrical Engineering, Vol. 362: 365-374. Springer, Cham.
4. Thomas MS & McDonald JD. Power System SCADA and smart grids, CRC press, 2015.
5. Alexandru M et al. (2011), From SCADA to smart grid in power transmission and distribution systems. Bulletinul, General Association of Engineers in Romania (AGIR): 191-198. Available online: http://www.agir.ro/buletine/1070.pdf
6. Ikbal ALI, Aftab MA & Hussain SS (2016), Performance comparison of IEC 61850-90-5 and IEEE C37. 118.2 based wide area PMU communication networks. Journal of Modern Power Systems and Clean Energy 4(3): 487-495.
7. De La Ree J, Centeno V, Thorp JS & Phadke AG (2010), Synchronized phasor measurement applications in power systems. IEEE Transactions on Smart Grid 1(1): 20-27.
8. Khan R, McLaughlin K, Laverty D & Sezer S (2016), IEEE C37.118-2 Synchrophasor Communication Framework: Overview, Cyber Vulnerabilities Analysis and Performance Evaluation. In Proceedings of the 2nd International Conference on Information Systems Security and Privacy, pp. 159-170. SciTePress. DOI: 10.5220/0005745001670178.
9. Crotti, G., Delle Femine, A., Gallo, D., Giordano, D., Landi, C., & Luiso, M. (2019). Measurement of the absolute phase error of digitizers. *IEEE Transactions on Instrumentation and Measurement*, *68*(6), 1724-1731.