INVESTIGATION OF ADVANCED MEASUREMENT INFRASTRUCTURE TO MONITOR POWER QUALITY AT COMMERCIAL BUILDING IN INDONESIA

R. Ruliyanta[1], and R.A.S. Kusumoputro[1]

[1]Department of Electrical Engineering, Faculty of Engineering and Science, Universitas Nasional, Jl. Sawo Manila, Pasar Minggu, Jakarta Selatan, 12520, Jakarta, Indonesia.

Corresponding Author's Email: [1]ruliyanto@civitas.unas.ac.id

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ABSTRACT: The growth of electricity meter reading technology is growing with current telecommunications technology. It developed into Automatic Meter Reading (AMR) from conventional meter reading and continued with Advanced Measurement Infrastructure (AMI). AMI utilizes currently developing telecommunications technology. With the data mining method, state electricity companies can read electricity meters, and consumers have access to monitor the quality of their power. In this research, we investigated the use of AMI in buildings in the electronics industry in Indonesia. The result is that AMI has been proven to measure meter readings, voltage, and electric current. The quality of power that can be provided includes load and voltage unbalance and total harmonic distortion of current and voltage. This investigation shows that the I-THD value is high at 84.28%, far from the permissible threshold. Apart from that, the power factor has a low value of 0.86 under low load conditions. The power factor problem is recommended to be overcome by using capacitor banks with varying values so that the capacitor can improve the power factor at low loads. Meanwhile, to overcome high I-THD, you can install filters, both passive filters and passive filters.

KEYWORDS: *Advanced Measurement Infrastructure; Power Quality; Data Mining and Analysis; Power Factor, Total Harmonic Distortion*

1.0 INTRODUCTION

The development of electrical technology has developed rapidly in the last decade. The conventional electrical system is moving towards an intelligent electrical system. This technology is based on customer needs to obtain a power quality concept. The need for power quality is based on changes like the load. Modern electrical loads use technology that prioritizes energy savings [1]. Smart Grid offers a concept of modernization of the electricity network, which aims to improve quality, reliability, and efficiency. One of the smart grid components is Advanced metering infrastructure (AMI), which functions for continuous meter reading, monitoring power usage, fault detection on the consumer side, system management, and data control [2]. This technology has been widely used, for example, to control electrical loads in residential complexes, office buildings, green buildings, and apartments [3]–[10] .

Combining new, renewable energy with existing energy requires optimal control. This energy combination can be controlled with smart volt-var, part of the smart grid [5], [11]. Smart volt-var is also used to control transmission line voltage. PLN further applies this AMI technology to improve services to its customers following regulations issued by the government of the Republic of Indonesia regarding electricity safety [12]. Implementing Advanced Metering Infrastructure (AMI) in the context of Smart Grid development in Indonesia is a crucial step to increase the efficiency and sustainability of the electricity system. The Smart Grid is an electricity network that is enhanced by integrating information and communication technology to optimize production, distribution, consumption, and overall energy management. One of the main components of a Smart Grid is AMI, which involves the use of intelligent meters and supporting infrastructure to monitor, collect, and manage energy data in real-time.

The problem is that investment in AMI devices still needs to be considered more expensive. Apart from that, electricity customers feel they do not need AMI. For small-scale use, single-phase electrical power is considered less feasible. However, to improve customer service, operators need to provide more service with a higher level of quality. Build a reliable communications infrastructure to connect smart meters with the central system. Technologies such as 4G/5G based networks or other wireless communication technologies can transmit energy data in real time [13]. Implement advanced data management systems to collect, store, analyze, and process energy data from smart meters. This data can help manage load, predict demand, and improve operational efficiency[14], [15]. Prioritize data security and protect customer privacy by implementing strong encryption and cyber protection technology. The energy data collected must be closely guarded to prevent misuse. Develop an application or online portal that allows customers to monitor and manage their energy consumption in real time. This information can help customers take action to reduce energy consumption and costs.

In this research, an investigation was carried out on an industrial electricity customer. AMI readings were carried out at an electronic components factory in Jakarta. This factory requires good power quality to support the performance of its production equipment, which has a high level of precision to produce integrated circuits and other semiconductor devices. The observations taken are in the form of the quality of the power received. From the results that can be observed, customers can analyze improvements. Improvements can be made from the operator side or the consumer side.

2.0 PROPOSED METHOD

AMI (Advanced Metering Infrastructure) and AMR (Automatic Meter Reading) are two systems used in energy metering management. Although both are related to energy measurements, there are fundamental differences between the two explained below:

i. Functions and Capabilities

   The AMR system is designed to read and collect automatic meter measurement data on a scheduled or periodic basis. The AMR allows service providers to obtain information about energy consumption without physically reading each meter [16]. Meanwhile, AMI collects measurement data and can carry out two-way communication. It enables data exchange between meters and energy service providers, enabling smart-grid management, rapid response to changes in demand, and integration of other innovative technologies.

ii. Communication

   AMR systems typically use one-way communication, where the meter sends measurement data to the energy service provider's server. This data is then used for bill calculations and energy consumption analysis. Meanwhile, AMI uses two-way communication, which allows sending data from the meter to the service provider and sending commands or information from the service provider back to the meter. The AMI enables more dynamic and interactive network management.

iii. Flexibility and Interoperability
The AMR system is more straightforward and less complex than AMI. Although there are various AMR vendors, their implementation is more standardized than AMI. AMI tends to be more sophisticated and complex. AMI implementations can vary more due to the different technologies used and the level of integration with existing energy infrastructure.

iv. Advanced Energy Management
The AMR system provides basic information about energy consumption necessary for bill calculation. However, it must provide more in-depth information or tools for more advanced energy management. AMI provides more detailed data, including daily, weekly, and even hourly consumption patterns. The AMI enables service providers to implement more sophisticated energy management strategies, optimize loads, and integrate renewable energy.

The fundamental difference between AMI and AMR lies in the functionality, communication capabilities, flexibility, and information that can be obtained for energy management. AMI is more sophisticated and interactive than AMR, enabling more effective energy planning and management. In its implementation, AMI applies a combination of technological breakthroughs. The flow of measurement data has different requirements from the flow of monitoring and control signals for distributed energy resources and loads, as shown in Figure 1 [17].

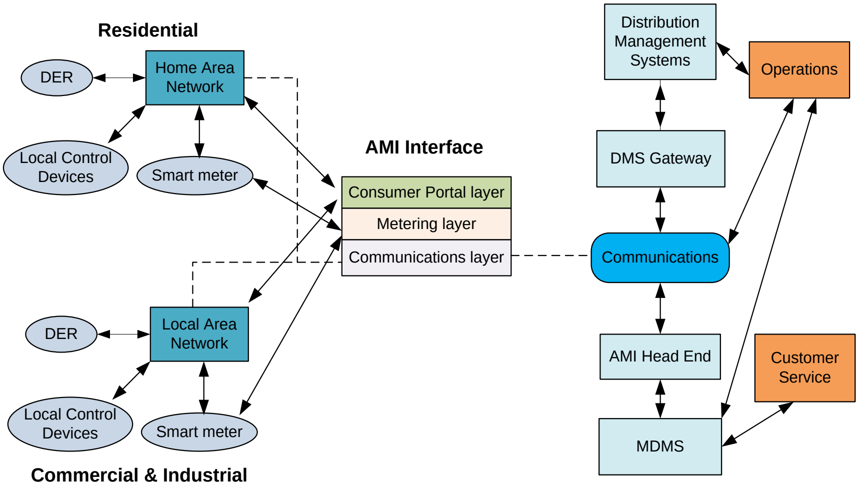

Figure 1. Overview of AMI [17]

Advanced Metering Infrastructure (AMI) can observe, measure, and manage various energy measurement, management, and control parameters. The following are some of the main parameters that AMI can observe and manage in this study. Observations were carried out 24 hours on weekdays. AMI can measure and record customers' electrical energy usage at shorter intervals, such as hourly, every 15 minutes, or even more frequently. The AMI provides more accurate data on energy consumption and usage patterns. In this study, we measured the duration per 1 minute.

AMI can measure power factor, the ratio between power and apparent power. Power factor monitoring helps ensure better energy efficiency and minimize energy loss. The ability to measure power factor is not available in AMR. The power triangle in this measurement is given in Figure 2.

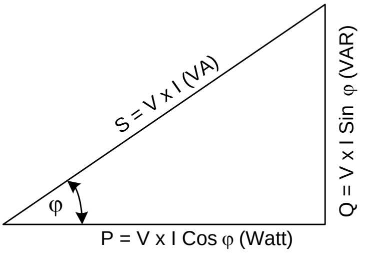

Figure 2. Power Triangle

Total Harmonic Distortion (THD) is the percentage value between the total harmonics and fundamental components. The greater the percentage of THD, the greater the risk of damage to equipment due to harmonics that occur in current and voltage. The maximum internationally permitted THD value is around 5 % of the fundamental frequency voltage or current. To find the THD value of the voltage, we use Equation 1.

$$THD_V = \frac{\sqrt{V_2^2+V_3^2+V_4^2+\cdots+V_n^2}}{V_1} \qquad (1)$$

where:

THD_V : Total Harmonic Distortion Voltage

V_n : The nth harmonic voltage

Meanwhile, to find the THD value of the current, Equation 2 can be used as follows.

$$THD_I = \frac{\sqrt{I_2^2+I_3^2+I_4^2+\cdots+I_n^2}}{I_1} \qquad (2)$$

where:

THD_I : Total Harmonic Distortion current

I_n : The nth harmonic current

The allowable voltage THD is given in percent of the rated power frequency voltage at the PCC. Table 1 provides the THD Limits standardized by the IEEE.

Table 1. Distortion Limits according to IEEE 519-2014

Bus voltage V at PCC	Individual Harmonic (%)	Total Harmonic Distortion THD (%)
V ≤ 1.0 kV	5.0	8.0
1 kV < V ≤ 69 kV	3.0	5.0
69 kV < V ≤ 161 kV	1.5	2.5
161 kV < V	1.0	1.5

The amount of THD current that can be tolerated according to the IEEE 519-2014 standard is given in Table 2 below.

Table 2. Current Harmonic Limits

Maximum harmonic current distortion in percent of I_L						
Individual harmonic order (odd harmonics)						
I_{SC}/I_L	$3 \le h < 11$	$11 \le h < 17$	$17 \le h < 3$	$23 \le h < 35$	$35 \le h \le 50$	*TDD*
< 20	4.0	2.0	1.5	0.6	0.3	5.0
20 < 50	7.0	3.5	2.5	1.0	0.5	8.0
50 < 100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
> 1000	15.0	7.0	6.0	2.5	1.4	20.0

AMI can monitor network load and energy consumption at different points in the network. This information is used to optimize load distribution and management. Load imbalance is one of the problems that often arises. Load unbalanced events can result in power losses [18].

3.0 RESULT AND ANALISYS

In this section, we provide the results of the load readings read by AMI. Figure 3 gives real power results. Meanwhile, Figure 4 shows the Apparent Power results.

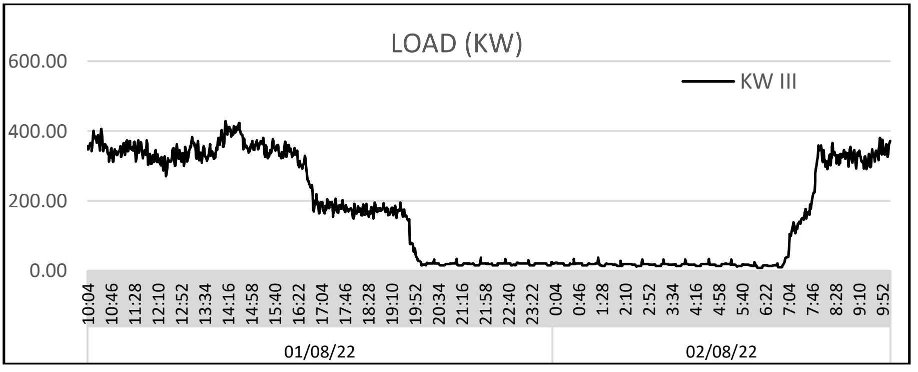

Figure 3. Results of load observations

The ideal electricity load factor from the State Electricity Company in Indonesia is 0.85. This value is far from consumer expectations. To improve this condition, consumers use capacitor banks to improve power. Based on the graphs shown in Figures 3 and 4, they are almost identical, but this occurs only under high load conditions while not under low load conditions. This condition is because the system can improve the power factor.

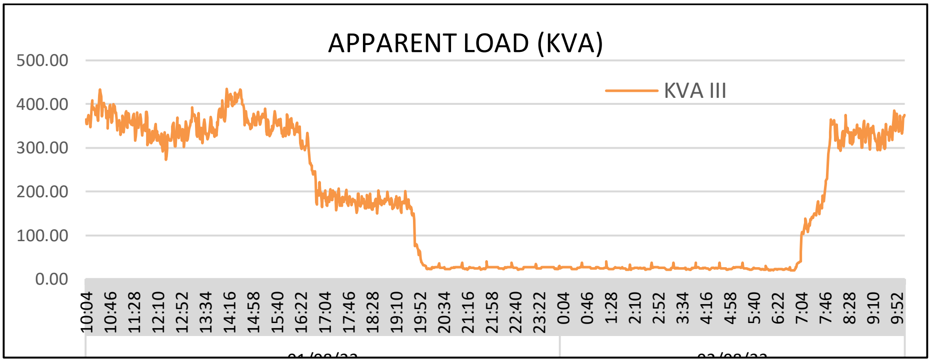

Figure 4. Observation results of apparent power

Different from low-load conditions when there is no production. The capacitor bank does not work because the load is minimal. Figure 5 shows the recording of the power factor compared to load conditions.

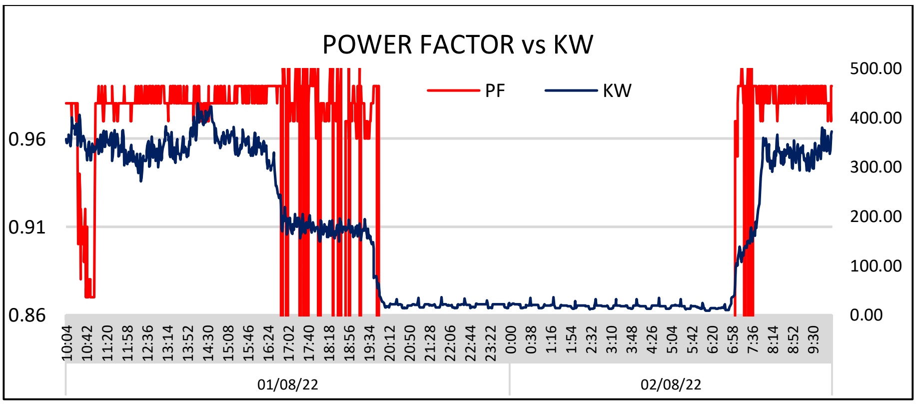

Figure 5. Graph of comparison of power factor to load

The electricity load between 20.00 and 07.00 is small, less than 50 KW. This load indicates that the power factor is low at 0.86. This condition is due to the capacitor bank not working. The system will be capacitive if the capacitor bank is forced to work. At certain hours, the power factor value is close to 1, which is very good for system performance. Figure 6 shows a graph of the results of electrical voltage observations.

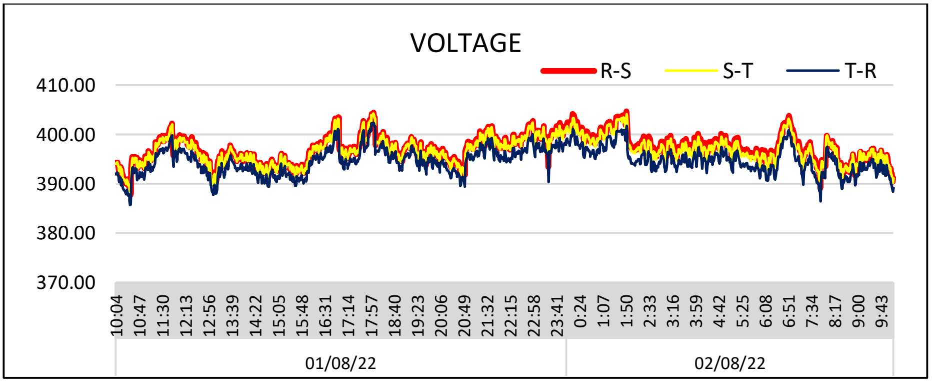

Figure 6: Results of voltage observations

Based on the IEC 60364-7-721 standard, the monitored voltage is still considered feasible [19] . It is essential to maintain the voltage value. The electricity meter will measure the current amount without ignoring the voltage. The problem is that the voltage value dramatically influences the amount of current. The smaller the voltage value, the greater the very detrimental current. Apart from the voltage value, which can decrease by 10% and increase by 5%, the level of load imbalance also has different value limits depending on the standards used, such as ANSI, EIC, or IEEE [20], [21]–[23]. This value is adjusted to the electrical device, such as an induction motor. Figure 7 is the result of observing electrical load imbalance.

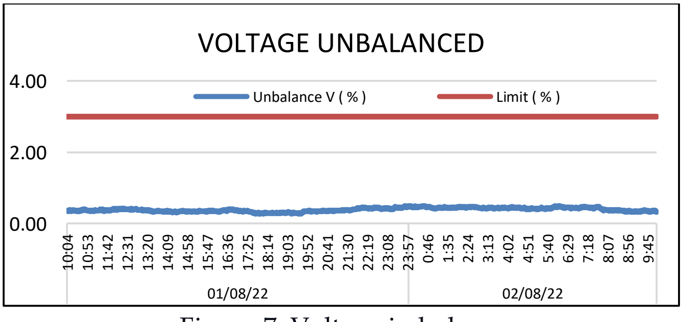

Figure 7: Voltage imbalance

Based on the monitoring results, the voltage balance results show good values. The voltage unbalanced value is less than 0.5%. The standard we use at 3% uses the ANSII standard [15], [24], [25]. This value provides good working performance of electrical equipment. The advantage of AMI is that it can measure the level of electrical power quality. These power qualities are shown in Figure 8 and Figure 9. Figure 8 is the chart of Voltage Total Harmonic Distortion, and Figure 9 is chart of Current Total Harmonic Distortion.

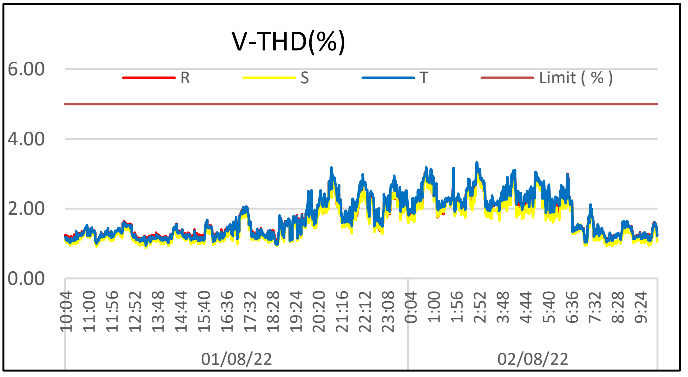

Figure 8. Voltage Total Harmonic Distortion

This image shows the V-THD value with a limit of 5%. From the graphic results in Figure 8, V-THD does not exceed the value of 3.3%. The use of nonlinear electrical loads greatly influences the power quality.

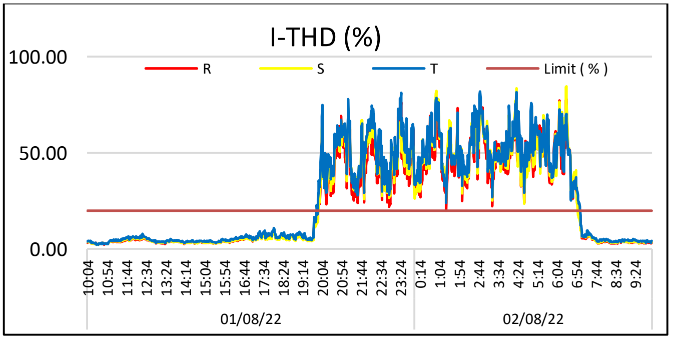

Figure 9. Current Total Harmonic Distortion

In contrast to V-THD, I-THD has inferior power quality characteristics. In low electrical power conditions, I-THD has a value reaching a maximum of 84.28%. I-THD must be addressed because it will impact the performance of other equipment. The transformer will become hot if conditions exceed the tolerance limits, which will damage the transformer in the long term.

Following the primary purpose of power reading to read power usage, AMI is developing rapidly to meet customer satisfaction to obtain power quality. This development follows development growth, where customer satisfaction is the main factor. With the results of observations made on the user (Customer) side, the user can improve the quality of electrical power on the customer side. For example, in this investigation, customers can improve large I-THD by installing an active or passive filter[18], [26], [27]. Meanwhile, to overcome significant power factors in low load conditions, install capacitor banks with varying values, for example, 25 KVAR, 50 KVAR, or 100 KVAR, according to the power used.

4.0 CONCLUSION

AMI is very effectively implemented to provide power-quality service levels to the customer. Customers can easily monitor their power quality parameters and energy usage. From the investigation results, AMI can provide electrical conditions such as voltage, load balance current, voltage balance, and power factor apart from measuring the amount of power consumption. Ami can also observe the power quality conditions of both V-THD and I-THD. In this measurement case study, it was significantly identified that the I-THD reached 84.28%. It is recommended to use capacitor banks with varying values so that the capacitor can improve the power factor at low loads. Meanwhile, to overcome high I-THD, it can install filters, passive filters, or passive filters.

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