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Economic Analysis of Automatic Meter Reading on Web Based in Türkiye Using Nginx Load Balancer Technology

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Automatic meter reading,
Techno economic analysis,
Load balancer

Abstract: Electricity meters, which are read manually, bring a great financial burden to companies in terms of workload, time and economy. In this study, examined the reading of electric meters automatically process, Türkiye focused on cost-benefit analysis performed. With the ever-increasing electricity consumption, the number of electricity expenses and accordingly the number of subscribers increases. Along with the increasing number of electricity consumers, the number of subscribers and consequently electricity consumption increases. Automatic Meter Reading Systems is one of the recommended solution packages for Energy Management Systems. It is for python programming language and its frameworks as software infrastructure. Nginx is used as a web server, and Web Server Gateway Interface and Gunicorn frameworks are used for the connection between the application and the web server. Thanks to automatic meter reading system, which has an extremely fast reading structure, it is predicted that tens of thousands of electricity meters can be read over the internet in seconds. Nginx Load Balancer software technology is capable of transferring tens of thousands of indexes to the database at once. This technology is able to distribute data load and respond to data traffic. In addition, the effect of reading cost on Energy Management Systems is analyzed in meters that are read manually. Türkiye's Elazig province, economic research analysis was conducted on a total of 334 thousand electricity subscribers. According to survey data, 47 million has electricity subscribers in Türkiye. In addition, cost-benefit analysis of the meters that are foreseen to be read in Nginx load balancer software technology is performed.

Nginx Yük Dengeleyicisi Kullanılarak Web Tabanlı Otomatik Sayaç Okumanın Türkiye'deki Ekonomik Analizi

Anahtar Kelimeler
Otomatik sayaç okuma,
Tekno ekonomik analiz,
Yük dengeleyici

Öz: Manuel olarak okunan elektrik sayaçları iş yükü, zaman ve ekonomik açıdan şirketlere büyük bir mali yük getirmektedir. Bu çalışmada elektrik sayaçlarının otomatik olarak okunması işlemi incelenerek Türkiye odaklı maliyet–fayda analizi yapılmaktadır. Sürekli olarak artan elektrik tüketimi ile birlikte elektrik tüketici sayısı ve buna bağlı olarak da abone sayısı artmaktadır. Otomatik Sayaç Okuma Sistemleri, Enerji Yönetim Sistemleri çözüm paketlerinden bir tanesidir. Yazılım alt yapısı olarak python programlama dili ve onun frameworkleri kullanılmaktadır. Web sunucusu olarak Nginx, uygulaması ile web sunucusu arasındaki bağlantı için de Web Server Gateway Interface ve Gunicorn framework yapıları kullanılmaktadır. Uygulama Flask framework yapısı üzerine kurulu olup veritabanı olarak gelişmiş bir yapıya sahip olan PostgreSQL framework'ü kullanmaktadır. Son derece hızlı bir okuma yapısına sahip olan otomatik sayaç okuma sistemi sayesinde on binlerce elektrik sayacının internet ağı üzerinden saniyeler içerisinde okunabilmesi öngörülmektedir. Nginx Load Balancer yazılım teknolojisi, on binlerce sayaç endeksini tek seferde veritabanına aktarabilme özelliğindedir. Bu teknoloji veri yük dağılımını yapabilmekte ve veri trafiğine cevap verebilmektedir. Ayrıca manuel olarak okunan sayaçlarda okuma maliyetinin, enerji yönetim sistemleri üzerindeki etkisi incelenmektedir. Araştırmanın ekonomik analizi ise Türkiye'nin Elazığ ilinde bulunan toplam 334 bin elektrik abonesi üzerinde yapılmıştır. Araştırma verilerinden yola çıkarak Türkiye'de bulunan 47 milyon elektrik abonesi bulunmaktadır. Nginx yük dengeleyici yazılım teknolojisiyle okunması öngörülen sayaçların maliyet-fayda analizi yapılmaktadır.

1. INTRODUCTION

Intelligent measurement technology in electricity distribution has made it necessary to meet the increasing data from demand of electricity consumers and to obtain healthy electricity networks. Therefore, web-based reading of the electricity meter in residential, commercial and industrial areas and the use of related applications are increasing [1]. In terms of energy efficiency and Energy Management Systems (EMS), it is very important for electrical measuring devices to interact with each other over the Internet without the need for people.

These systems combined under the umbrella of Automatic Meter Reading (AMR) Systems are important applications for the automation of electrical network measurement processes [2]. Existing electricity meter reading procedures used in Türkiye is done largely manually. However, automatic reading is made in narrow areas and pilot study areas. Automatic readings are also extremely inefficient and contain a limited number of electricity meters. Using existing automatic readings can cause some other communication problems, especially the internet connection problem. With Nginx Load Balancer (NLB) software technology, web-based electricity meters can read many electricity meters instantly, and thanks to the developed smart software, they can perform operations such as billing, leakage electricity detection, on-off very quickly [3]. In Figure 1, the operation of the automatic meter reading system is schematized.

In order to meet the rapidly increasing demands for power, power systems are undergoing a transition from analogue to digital control and communication systems. While this modernisation brings numerous benefits, the introduction of new hardware and software in power systems also introduces vulnerabilities. These vulnerabilities can be exploited to alter electricity meter readings, potentially leading to significant financial losses. In order to prevent such attacks on electricity meter readings, it is necessary to develop software models for automatic reading methods [8,9]. As numerous studies have demonstrated, the implementation of smart meters around the globe is encountering a multitude of challenges [10,11]. Consequently, the slow pace of progress and mounting concerns have prompted the necessity for the development of novel applications of smart meters in domains such as the protection and monitoring of the evolving distribution system [12,13]. Additionally, the smart meter can be employed to monitor the power consumption of individual devices, thereby offering insights into customers' power usage patterns [14].

This paper proposes a software model for efficient reading of a large number of electricity meters. This software model is envisaged to perform tasks such as reading electricity meters, billing and reducing electricity leakage. In addition, in this study, the electrical data in an electricity meter is read automatically by means of the developed software. The economic analysis of the automatic meter reading system to the energy management system is also carried out in the paper. For this purpose, Elazığ province of Türkiye is taken as the research region and the necessary technical and economic analyses are carried out comparatively.

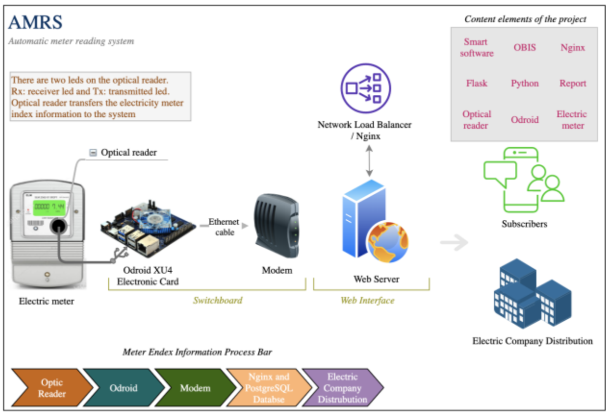

Figure 1. The path of the meter index data between the hardware units (The data is taken from the meter and reaches the electricity distribution company or the subscriber)

2. NLB TECHNOLOGY AND SMART SOFTWARE

NLB performs the task of balancing thousands of meters of index information with Load Balancer and distributing it to web servers. In this way, electricity consumption can be monitored instantly.

2.1. Material and Method NLB and Python Frameworks Configurations

NLB is a load balancing job. It is also a technology of sharing a data collection between computers, processors, web servers and their framework structures. For automatic meter reading, NLB can be defined as software technology that shares requests from users and transmits index information from the meters to the user quickly by reducing response time [3]. In the software scheme shown in Figure 2, when the meter readers or end consumers at the electricity distribution company make a request, the request data is balanced in the Nginx Load Balancer structure and sent to the Gunicorn frame structure. It is the gateway to the Web Server Gateway Interface (WSGI).

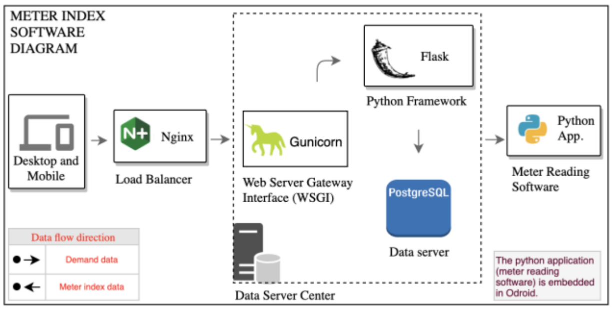

Figure 2. Load distribution of the counter index on web servers and its frameworks (Requests from computer and mobile application are balanced with the help of load balancer and transferred to the relevant framework structures. Index information from the meter is followed by the user by following the same path)

The request data is then transferred to the Flask frame server, a framework of meter reading software. Finally, a python application with meter reading software alerts the relevant counters based on this meter data and, after performing an authentication, collects the index information on the meters and saves them in the buffer section. The next process is the display of meter data in the meter reading software. Index information can be viewed by users by following the path of Flask, Gunicorn, Nginx Load Balancer.

2.2. Smart Software

After the meter index information is shown to the electricity distribution company representative and the end user, this data billed by a smart software. With this software, which can map the electricity consumption instantly, it is thought that it will provide an important feedback contribution in the future of electrical energy investments.

3. RESEARCH METHODS AND SYSTEM DEFINITION

3.1. Research Methods

The number of electricity customers in the electricity distribution companies in Türkiye in 2020 and 2021 are shown in Table 1. [4]. The financial analysis of meter reading manually within one year is examined in this section. Türkiye's Elazig province made research on electricity meters and 334 thousand subscribers is projected to reach some conclusions. The distribution of financial expenses of companies that read meters in Türkiye is shown in Table 3 as a percentage. In Table 2 based on the results of the research indicated in Türkiye's Elazig province electricity meters are read within 30 days.

Table 1. Number of subscribers in electricity distribution regions

Region	2020	2021	Change %
Boğaziçi	5.206.237	5.309.628	1.99
Başkent	4.364.492	4.450.587	1.97
Toroslar	4.095.347	4.199.880	2.55
Gdz	3.524.199	3.642.279	3.35
Uludağ	3.380.111	3.461.642	2.41
İ. Anadolu	2.986.337	3.036.679	1.69
Akdeniz	2.261.116	2.317.587	2.5
Meram	2.227.181	2.281.186	2.42
Yeşilirmak	2.206.997	2.278.063	3.22
Adm	2.021.409	2.127.291	5.24
Dicle	1.993.050	2.055.864	3.15
Sakarya	1.963.823	2.022.256	2.98
Osmangazi	1.888.406	1.932.244	2.32
Çoruh	1.431.106	1.468.083	2.58
Trakya	1.168.941	1.207.476	3.3
Aras	1.059.704	1.095.423	3.37
Firat	1.012.087	1.059.759	4.71
Çamlibel	1.017.033	1.037.517	2.01
Kayseri	770.120	788.102	2.33
Vangölü	745.985	775.669	3.98
Akedaş	758.175	764.761	0.87
Total	**46.081.856**	**47.311.976**	**2.67**

Table 2. Research data of meters in Elazığ province

Expenses monthly	Unit	Price
Workplace rent	USD	300
Number of staff	Unit	51
Salaries of staff	USD	60000
Number of vehicles	Unit	12
Vehicle expense	USD	18000
Number of subscribers	Unit	334000
Profit share	USD	19575 %25
Meter readers/ Fixture	USD/Unit	135000 - 45
Other	USD	450

Table 3. Share of some economic factors in the cost of manuel meter reading in Türkiye

Description	Percentile
Staff expenses	59.3%
Transportation expenses	17.7%
Company profit share	19.3%
Total	**100%**

3.2. Time Loss Calculation

Manual meter reading has an economical cost and causes a decrease in work efficiency in terms of labor and time loss. 8935 personnel in Türkiye are constantly read the meter. As it is known that the number of electricity subscriber increases day by day, the time lost is constantly increasing. These decreases work efficiency by increasing the human-based workforce. We can symbolize the number of meters that a staff read in a day (8 hours) with RCD (Number of reading counters in a day). The related expression is shown in Equation 1 and Equation 2.

$$RCD = \frac{Number\ of\ subscriber}{Number\ of\ personel} \quad (1)$$

$$RCD = \frac{334.000\ SN}{45\ PN} x \frac{1}{30\ day} = 247.4\ SN/(PN \cdot day) \quad (2)$$

At the same time, we can call the waste of time reading a meter, WOT (Waste of time). Number of subscriber (SN) is shown as number of staff (PN). The related expression is shown in Equation 3 and Equation 4. The graph of the total time loss by years depending on the number of subscribers is shown in Figure 3.

$$WOT = \frac{Working\ time}{RCD} \quad (3)$$

$$WOT = \frac{\frac{8\ hours}{day}\ x\ \frac{60\ min}{hours}\ x\ \frac{1}{PN}}{247.4\ \frac{SN}{PN \cdot day}} = 1.92\ min/\ SN \quad (4)$$

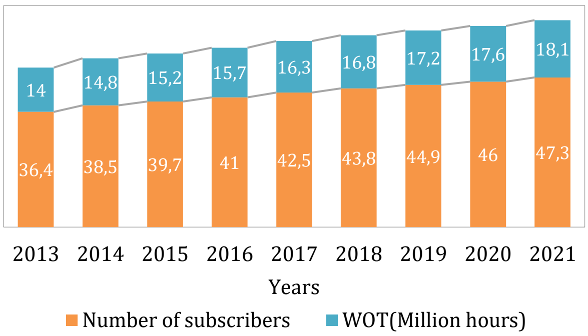

Figure 3. Total time loss graph depending on the number of subscribres (from 2013 to 2021)

3.3. Real State of the System

The real state of the system includes a digital electricity meter, optical port reader with USB output and single board computer components produced according to TSE (Turkish Standards Institute) standards. In the designed experimental setup, a 105 W incandescent bulb is connected to the meter output and it is aimed to monitor the consumption data of the measuring device instantly. An optical port reader is attached to the relevant part to enable communication with the measuring device. The data in the measuring device is read and saved in the temporary memory of the single board computer running the Linux operating system and then transferred to the web servers. The compatibility between the software blocks is very important for the data rate to be high and for the system to respond to heavy data traffic. In this study, a harmony between the software blocks has achieved in order to reduce the data rate and to read a large number of meters at once. Especially Linux operating system and other framework structures are preferred because it is python based. Because the meter reading software created is based on python. The meter reading software is embedded locally in the single board computer shown in Figure 4. The system can work with wired internet network or it can work with wireless internet network after the SIM card module is integrated into the system. This study, which realizes the remote-control event, also resolves the subscriber's electrical energy on-off event to a large extent.

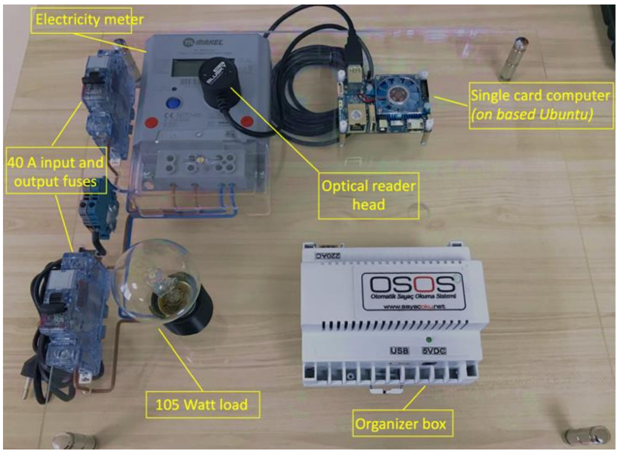

Figure 4. Prototype of automatic meter reading system

The electrical parameters inside the meter have a memory. In other words, each address belongs to an electrical data.These addresses are called Object Identification System (OBIS). Intelligent software improves its operations according to OBIS codes and generates the necessary reports. In this case, the smallest information packet is in the state of electricity stored in OBIS. Some important ones of OBIS code definitions are given in Table 4 and the necessary usage is explained [5].

Table 4. Counter object identification system (OBIS) codes

OBIS Codes	Codes Definition	Unit	Format
0.9.2	Date	-	yyyy-mm-dd
0.9.1	Time	-	hh:mm:ss
1.8.0	T Total active energy	kWh	1234.567
5.8.0	Ri, Inductive reactive energy	kVArh	1234.567
6.8.0	Rc, Capacitive reactive energy	kVArh	1234.567
1.6.0	Maximum active power demand	kW	1234.567

3.4. Run of Meter Reading Software

Meter reading codes on a single board computer are run by PyCharm, a python compiler, and the results are observed [6,7]. After reading the meter reading codes, the index data from the meter is shown in Figure 5 and Figure 6. The connection between the meter and python application is provided in accordance with the IEC 62056-21 protocol. In order to get data from the meter, an authentication process must be made between the meter and the python application. In Figure 5, the python application sends an identification query code to the measuring device.

```
serialport ="/dev/ttyUSB0"
init_seq = bytes('/?!\r\n', 'ascii')
request = bytearray('\x06000\r\n', 'ascii')

serial = serial.Serial(serialport, 300, bytesize=serial.SEVENBITS,
                       parity=serial.PARITY_EVEN, timeout=5, interCharTimeout=2)
serial.flushInput()
serial.write(init_seq)
print("send init:\n> {}".format((init_seq.decode('iso-8859-9')))[:-2])
response = bytes()
newlines = 0
try:
    while newlines < 1:
        response += serial.read()
        length = len(response)
        # count newlines
        if (0x0a or 0x0d) in response:
            newlines += 1
            ehz_id = response
            print("got id:\n< {}".format((ehz_id.decode('iso-8859-9'))[:-2]))
except Exception as e:
    print("No ID")

***THIS PART OF THE CODE IS RESERVED***

    try:
        wait = 1.0
        time.sleep(wait)
        print("send ACK:\n> {}".format((request.decode('iso-8859-9'))[:-2]))
        new = 'false'
        while new == 'false':
            response2 = bytes()
            time.sleep(0.5)
            serial.baudrate = 300
            print("switch to 300 baud")
            serial.write(request)
            time.sleep(0.5)
            print("send hex:{}".format(request))
            # print (os.popen('stty -F /dev/ehz-hz').read())
            serial.baudrate = new_ascii_baudrate
            serial.timeout = 1
            print("switch to {} baud".format(new_ascii_baudrate))
            # print (os.popen('stty -F /dev/ehz-hz').read())
            response2 += serial.read()
            # print (response2.decode('iso-8859-9'))
            if len(response2) > 0:
                if 0x02 in response2:
                    print("got STX")
                end = 'false'
                while end == 'false':
                    response2 += serial.read()
                    # print ("RESPONSE:{0}".format(response2.decode('iso-8859-9')))
                    if (0x03 in response2) and (0x21 in response2):
                        print("got ETX")
                        end = 'true'
                        print("FINISH:\n{0}".format(response2.decode('iso-8859-9')))
                        new = 'true'
    except Exception as e:
        print("ERROR: {0}".format(e))
```

Figure 5. Embedded system python code written to communicate with the electricity meter and read the data in it.

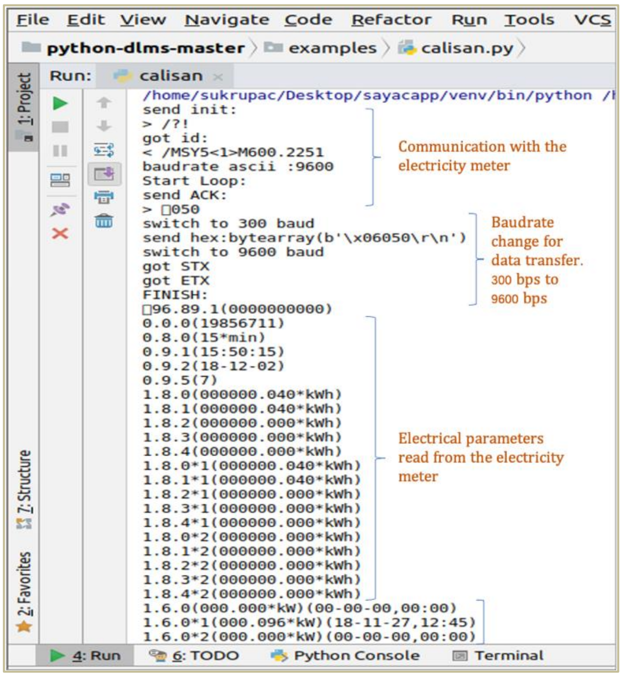

Figure 6. Monitoring the data received from the electricity meter on the PyCharm interface

The counter wakes up with this code and sends "counter identification information" to the python application, such as brand, model and year of manufacture in the memory of the meter. If the counter shows credentials, it means that it accepts communication. This initial communication with the meter takes place at 300 bps. When the index information of the meter is read, it is the second part of the communication. The second communication with the meter takes place at 9600 bps. Communication between the meter and the python application ends automatically after it is received from the meter. In addition, in Figure 6, the meter data has been successfully obtained with the OBIS codes representing the electrical index data. A python-based meter reading software has been developed that can communicate with the optical communication part of the meter. This developed software has been tested on various brands and models of electricity meters. Success rate has been achieved with high accuracy.

4. DISCUSSION AND CONCLUSIONS

Manual reading / control of electricity meters brings a huge workload and financial burden to companies. In this study, it is aimed to reduce the loss of labor and save time by reading the electricity meters automatically. Overall, the study focuses on local Elazig province in the Türkiye. In this context, the necessity of working with cost-benefit analysis was examined. With the increasing electricity consumption, the number of electricity consumers and subscribers increases accordingly. Thus, some studies have been made and many solutions have been proposed to use the energy produced efficiently. One of the important solutions proposed by Energy Management Systems (EMS) for the solution of existing problems is the addition of Automatic Meter Reading Systems (AMRS). In the study, Python programming language and frameworks are used as software infrastructure. Nginx web server and Web Server Gateway Interface (WSGI) and Gunicorn frameworks are used for connection. The application is based on the Flask framework structure and PostgreSQL framework, which has an advanced structure as a database, has been tried. Based on the data obtained from the studies, it is thought that many (tens of thousands) of electricity meters can be read over the Internet network in a short time (seconds). In addition, Nginx Load Balancer (NLB) software technology has the ability to transfer many electricity meters indexes to the database at once. This technology can make data-load distribution and respond to two-way intensive data traffic. An important dimension of the study is in the context of researching and examining the effect of reading cost on energy management systems in meters that are read manually. The economic analysis of the research was carried out on 334 thousand electricity subscribers in Elazig province. Based on the survey data towards Elazığ, 47 million in Türkiye of electricity subscribers through this methodology, the impact could be detailed techno-economic efficiency.

REFERENCES

[1] Amer W, Attique Y, Ghafoor A. “Comprehensive e-Monitoring, e-Management and e-Billing (eM2B) system with Zoom_ın and Zoom-Out capabilities to reduce electricity distribution loses for developing countries”. *IEEE 2010 International Systems Conference*, San Diego, USA, 05-08 April 2010.

[2] Wibisino G, Saktiaji GP, Ibrahim I. “Techno economiz analysis of smart meter reading implementation in PLN Bali using LoRa technology”. *2017 International Conference on*

Broadband Communication, Wireless Sensors and Powering (BCWSP), Jakarta, Indonesia, 21-23 November 2017.

[3] Chi X, Liu B, Niu Q, Wu Q. "Web Load Balance and Cache Optimization Design Based Nginx under High-Concurrency Enviroment". *2012 Third International Conference on Digital Manufacturing & Automation*, Guilin, China, 31 July – 02 August 2012.

[4] Republic of Türkiye, Energy Market Regulatory Authority. "Electricity Market Sector Report 2013-2021". Republic of Türkiye, Energy Market Regulatory Authority, Ankara, Türkiye, 2021.

[5] International Standard, IEC 62056-21. "Electricity metering, data exchange from meter reading, tariff and load control". International standard 2018.

[6] Fernandes SL, Bala GJ. "Odroid XU4 based implementation of decision level fusion approach for matching computer generated sketches", *2016 Journal of Computational Science,* Tamil Nadu, India, September 2016.

[7] Qusay IS, Szatmari A, Toth R, Beszedes A. "CharmFL: A Fault Localization Tool for Python". *2021 IEEE 12st International Working Conference on Source Code Analysis and Manipulation (SCAM)*, Luxembourg, 27-28 September 2021.

[8] Xia, X., Xiao, Y., Liang, W., & Cui, J. (2022). Detection methods in smart meters for electricity thefts: A survey. *Proceedings of the IEEE*, *110*(2), 273-319.

[9] Chakraborty, S., Das, S., Sidhu, T., & Siva, A. K. (2021). Smart meters for enhancing protection and monitoring functions in emerging distribution systems. *International Journal of Electrical Power & Energy Systems*, *127*, 106626.

[10] Gaggero, G. B., Marchese, M., Moheddine, A., & Patrone, F. (2021). A possible smart metering system evolution for rural and remote areas employing unmanned aerial vehicles and internet of things in smart grids. *Sensors*, *21*(5), 1627.

[11] Sharma, R., Gandhi, R., Sungheetha, A., Chinnaiyan, R., & Deepaletchumi, N. (2024, February). Smart Measuring Device for Power with Digital Debiting System Using Mobile Application Tool. In *2024 4th International Conference on Innovative Practices in Technology and Management (ICIPTM)* (pp. 1-6). IEEE.

[12] Vlasa, I., Gligor, A., Dumitru, C. D., & Iantovics, L. B. (2020). Smart metering systems optimization for non-technical losses reduction and consumption recording operation improvement in electricity sector. *Sensors*, *20*(10), 2947.

[13] Dimkpa, V. C., Agba, J. C., & Ogu, V. U. Design and Construction of a GSM Based Energy Meter Reader and Load Control System.

[14] Shunmugalatha, A., Balamurugan, K., Aravind, D. S., & ShanmugaSundarapandi, B. (2023, August). Design and Development of Autonomous Smart Energy Meter with Remote Management Control. In *2023 Second International Conference on Augmented Intelligence and Sustainable Systems (ICAISS)*(pp. 1782-1785). IEEE.