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Remote reading of electricity meters using PLC

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ABSTRACT

The telecommunications platforms of the electricity industry, including optical fiber, wireless, radio and microwave, despite providing sufficient bandwidth to transmit power market data, have limitations and disadvantages that are particularly apparent in remote suburban areas. PLC technology provides such facilities relatively. So this paper aim is providing practical solutions for the transmission of electricity market meters data through this type of PLC. This paper examines how to transfer the data from the electricity market to the central server using a PLC telecommunications platform and a practical example at 132 kV. In this case, the appropriate option is PLC. In this paper, it has been shown that there is the possibility of sending market data onto the PLC platform in transient and over-voltage transmission lines, which so far seemed to be impractical. With the comprehensive implementation of this work in the country's electricity industry, especially regional electricity, a major step will be taken to create a smart grid for meter readings. Due to the successful outcome of the experiment, it is possible to easily connect the PLC, the availability of this platform in many posts, a large and new smart grid for reading electricity meter readings.

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1. INTRODUCTION

In recent years, due to the large-scale creation of high-voltage posts in several parts of the country, an increase in the number of electricity market automated meters as well as the need for constant and rapid monitoring of energy in the industry, the activity of the office of the electricity market in regional power companies has become more important than the past [1]. Installed meters in all posts should be measured and read daily and the data required by the appropriate telecommunication platform should be sent to the electricity market office in the regional electricity companies [2]. The office should also submit a daily report of its processed data to the Iranian power grid. These data are used to assess the forecast of demand for the electricity market for pricing, load estimates, production forecasting, and consumption requirements, and ultimately billing. Regarding the fines that the management of the electricity grid of Iran in the field of non-timely cooperation for regional power companies virtually all power companies determined to create suitable telecommunication platforms for the transmission of electricity market data. Among the platforms that have made it possible so far, this is leased line, Radio, Microwave and Fiber Channel Links [3-5]. In some areas where blind spots are considered telecommunications, satellite communication is a pivot, although, in the power industry, this kind of communication is rarely used. The first and easiest way

of telephony is the PSTN [6]. The availability of communication lines at the city level is one of the advantages of this platform. The data of the meters can be read using a common modem and a modem in the central server location. But in this way, the existence of a leased line is beside the required cost meter. Also, due to environmental noise, the reliability of information is reduced. Most importantly, some high-profile posts are located in remote areas of urban environments; urban cell phone bedding is not economically feasible [7]. Another communication medium is the radio communication bands which used to read meters. This bed provides a higher rate of transfer of information and, also, allows for the simultaneous reading of several meters together. The lower security of the information, as well as the maintenance and repair, is its problems. The most important barrier to using this system is that many high-voltage posts are located at locations that may not have a repeater nearby or that the antenna's power supply is not responsive [8].

Vlasa et al. (2019) investigate, develop and test experimentally a self-optimal reconfigurable PLC that constitutes the power metering infrastructure of an electrical distribution grid. A solution based on the optimization algorithm that offers the optimal configuration of the system on providing reliable field data acquisition related to the energy consumption in special requirements consumers is proposed and developed in the paper. Experimental results and discussions regarding the proposed optimization model are also presented along with conclusions and best practices recommendations that are also included [9].

Popa (2011) describes an AMI system based on PLC. Smart meters are connected through a LonWorks type industrial bus to a Gateway. The Gateway commands the maters, reads data from them and communicates, through GSM, with a Data Acquisition Center (DAC) where data is processed [10]. Elakshumi and Ponraj (2017) analyzing the performance of the proposed smart meter systems, efficient transmission and how utilities explore new developments for the benefit of consumers. The methodology followed to analyze the outcome is PLC, which is an arrangement to pass on data on an electrical conductor used for transmitting electric power from high voltage transmission lines to lower voltage lines used inside the buildings. This is achieved by using PLC modems for remote monitoring and control of energy meters. As a result, the consumption patterns at the utilities are studies and load analysis is made so that this can help in maintaining other systems associated with energy management [11].

PLC is a telecommunications technology with a long history and tradition in electricity companies [12]. With a wide scope of applications, varieties and implementations.PLC uses high-voltage lines as a communications platform. However, this bed also has major problems, such as low carrier frequency, weakening, environmental noise, and corona phenomena. But it has a prominent feature in the electricity industry and its availability in most of the overwhelming pressures of the country. In other words, during the execution of the post design, the PLC runs simultaneously and the implementation price is also appropriate [13]. The use of PLCs in high-voltage lines as a suitable telecommunication platform for transmitting data on electricity market meters has been discussed several times [14-16]. The use of this system at the distribution voltage level and concerning the proximity of distribution companies to the location of subscribers has already been proposed and tested [17-18]. But at the transmission and redistribution level due to the long line path as well as problems such as low carrier frequency, attenuation, noise and corona phenomenon it was thought that it would not be possible to implement the system [19-24].

For this reason, in the present study, the remote meter reading system was first experimentally implemented without any change in the configuration of existing PLCs, which was not a successful test result. After the failure of meters readings through the PLC, it was decided to set up a laboratory with the same scenario and to simulate conditions similar to those of the high voltage and PLC. Therefore, the present study attempts to find a successful solution after numerous practical experiments. In this regard, different experiments will be performed by looping the STR + CD + DSR and the RTS + CTS on the two ends of the wire. This paper is organized as follows: Section 2 includes a review of the PLC systems and their evolution; section 3 is focused on the smart electricity meter reading system; section 4 describes the problematic design and objective sample and section 5 highlights the main conclusions of the paper.

2. RESEARCH METHOD

2.1. PLC technology

Telecom technology PLC is a method that has been used by the electricity industry for many years to transmit a signal to communicate between high voltage posts, sending dispatcher data including power, voltage, current, and frequency, as well as sending protection orders, independence, fast switching protection [25]. Speed, security, reliability, backup paths and easy accessibility are features that should be supported by an appropriate telecommunications platform in the electrical industry. PLC technology provides relatively such facilities. When high voltage lines are referred to as a telecommunication substrate, with

issues such as proper modulation, carrier frequency, attenuation, peripheral noise, corona phenomena, etc., each of these features can be described as a limiting factor in transmitting the data of the meters.

In the PLC system, SSB modulation is applied to the domain. Utilizing minimum bandwidth, low impact against fading effects, high gain power factor compared to AM modulation and the high signal-to-noise ratio compared to the AM modulation has been the reason for choosing this type of modulation. But in this way, the noise of the environment, such as keying in the power network, inductive and antenna effects on the quality of telecommunication communication, has a significant effect, as the amplitude of the modulated signal is affected by noise; this also affects the quality of the signal signaling. So, to transmit telemetric information, frequency modulation is used as FSK.

2.1.1. Analog PLC (APLC)

Most of the PLCs that have been installed in high-voltage posts are analog or APLC. The general principles of the performance of analog PLCs at high voltage substations now are that PLC terminals have two channels. Each of the two channels consists of a 4 kHz Tx frequency band for the transmitter and a 4-kHz Rx frequency band for the receiver. In other words, for each channel, a band of 8 kHz is assigned bandwidth, with a bandwidth of 4 kHz assigned to the channel transmitter 1 and the 4 kHz band for the channel receiver 1. Usually, two frequency bands Tx Channel 1 and `Rx Channel 1 are placed adjacent to each other. The frequency spacing of dual channels 1 and 2 is also defined by IEC 495 standard. The modulation used in this system is amplitude modulation in the form of SSB and frequency modulation as FSK.

2.2.2. Digital PLC: (DPLC)

In a simple definition, a digital PLC can be called a digital analog data transfer using an analog carrier. One of the major problems in PLC systems is the need for higher bandwidth and higher capacity. Given the ever-increasing development of telecommunication science, this is an obstacle to the development of existing systems. Therefore, in order to achieve higher bandwidths (at least twice as many) and more speeds of digital PLCs, the minimum bandwidth of Tx is 8 kHz for the transmitter and the Rx frequency band has a bandwidth of 8 kHz for the receiver. The advantages of DPLC over the APLC are in addition to improving bandwidth and speed, easier configuration, better modulation, such as OFDM encoders, and better- countering noise and interference [25]. These benefits include the ability to transfer new data, which in this article provides data on market readings. The modulation used in this system, in addition to FSK and SSB modulation, is a digital OFDM using the Trellis coding. This kind of modulation makes it possible to send more data using the same channel. Modulation in digital PLC showed in Figure 1.

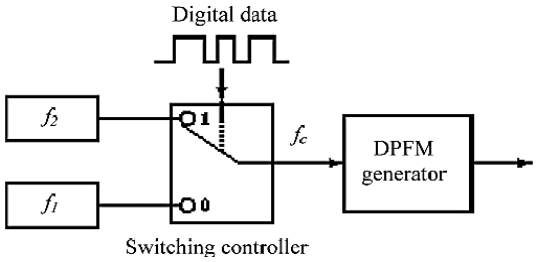

Figure 1. Modulation in digital PLC [5]

PLC systems are divided into two general categories in terms of frequency bands. The first bundle of NB-PLC is a narrow band with a working frequency of 3 to 500 kHz and includes the CENELEC/ARIB/FCC bands. The second batch BB-1.8 PLC is broadband with higher operating frequencies than MHz. Most of the PLCs installed on the NB-PLC are above the national distribution and transmission network. This type of PLC provides two different rates for data transfer. The first type is LDR which uses the single carrier method to transmit only a few kilobytes and the second type of HDR that can transmit hundreds of kilobits using the Multi-Carrier method. Due to the volume of data on current market electricity meters and current state electricity, LDR-NB-PLC should be used to measure and read meters intelligently. The purpose of this paper is to provide a practical solution for the transmission of electricity market data through this type of PLC. Due to the age of this telecommunication system, numerous university articles have been written that examine its features, including signal to noise, modulation types, error calculation, interference, and other features of this telecommunication channel.

However, due to its old standards, it is technically and industrially necessary for technicians and technical engineers to carry out the necessary experiments and to carry out feasibility studies for the transmission of the data required by the electricity market. Demodulation in digital PLC showed in Figure 2. Also the overall performance of the digital PLC communication system showed in Figure 3.

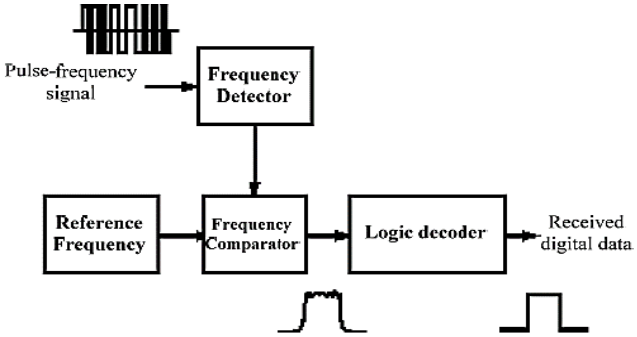

Figure 2. Demodulation in digital PLC [6]

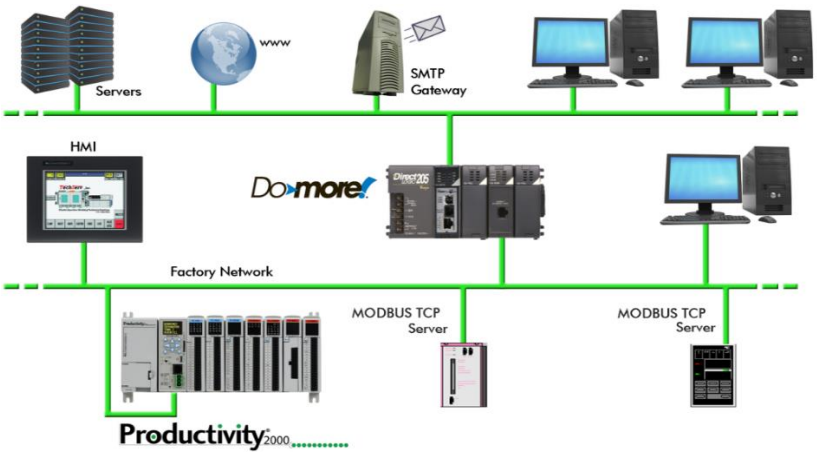

Figure 3. The overall performance of the digital PLC communication system [12]

3. SMART ELECTRICITY METER READING SYSTEM

Intelligent reading system market meters, automated data collection technology from digital meters and data transmission to the center for analyzing and billing for subscribers. AMI's integrated system includes software hardware, dual-band network and communications platform that receive information such as consumption, demand, voltage, current, and other information on the almost real-time consumer side. The system has the ability to read, configure, monitor and remotely control meters, collect, manage, process and analyze information and generate graphs and reports. All of these processes are done automatically and smartly. One of the advantages of intelligent reading system is to reduce consumption by consumers at peak times, manage and estimate load and energy and make appropriate decisions, estimate and reduce network losses, estimate the delivery power quality, finally, the implementation of the appropriate hardware and software platform for the implementation of the goals of the electricity market. A remote readout system consists of three basic parts:

- Electricity meter with proper modulator
- Channels or appropriate telecommunication substrate
- Central control center and central server with the appropriate modem

3.1. Electricity market meters with appropriate modulator

The electricity market meters are digital and intelligent, which can measure and record energy data. The meters are divided into mechanical and digital categories. Given that the purpose of this paper is the automatic meter readout system, only digital meters provide such an opportunity. These meters record power consumption at intervals of one hour or less and send the registered information at least once a day to

the central system for monitoring and billing. Advanced Smart Meter is able to communicate bilaterally between the meter and the central system. Unlike the magnetic meter, the smart meter analyzes the collected data and provides them with a report. Intelligent meters, in addition to measuring the basic parameters, should also measure other basic parameters such as network harmonics, transmit and receive power and manipulation of the meter, and ultimately, the actual cost of electricity consumption. Typically, protocols used to record and transfer information in the lower layers of PRIME and IEC61334-5-1 and in higher layers of communication protocols are SML and DLMS meters. The modulator is a modem and should be able to communicate with all of the communication protocols mentioned.

3.2. Appropriate telecommunication channel or substrate

Due to limitations in the use of optical fiber and mobile telecommunication environments in non-obstructed post offices and copper cables, it is necessary to consider provisions for back-up platforms. Radio communication is a good platform for support but has been observed. In some posts, not only urban telephones and optical fiber cannot be used, but there is no possibility of using radio communication. Therefore, the use of the dedicated power line for the telecommunications industry, that is PLC, will be on the agenda.

3.3. Control center and central server with appropriate modulator

The control center is known as the brain of intelligent reading systems and is responsible for managing all information and data related to the electricity market. The data received from the meters, including measurement registers and alarms at high-voltage posts, is collected by a data collector interface. The information is sent to the control center after sending it through the telecommunication channel and stored in the database of the electricity market servers. Then, the necessary processing is done on the stored data, and the operations can be performed on alarms and events. This operation involves reading various parameters of the meters, interrupting and other operations required remotely. Due to the importance of servers in the intelligent reading system and, on the other hand, the high number of meters in total posts, servers should have enough space to store data as well as a high-speed processor at a high speed. Main components of the remote reading system showed in Figure 4.

Figure 4. Main components of the remote reading system [14]

4. PROBLEMATIC DESIGN AND OBJECTIVE SAMPLE

The use of PLC in high-voltage lines 63, 132 and 400 kV as the appropriate telecommunication platform for the data transmission of electricity market meters has been repeatedly raised, has been proposed several times. The use of this system at the distribution voltage level and due to the proximity of the company's distribution to the location of subscribers was already discussed and tested. But at the transmission and over-distribution levels due to the long route paths and also problems such as low carrier frequency, attenuation, noise, and corona phenomena, it was thought that the possibility of implementation of this system does not exist. Because of this, the system of remote reading of the meters in the post of the clatter, initially experimentally and without the change in the configuration of the existing

PLCs was implemented, which was not a successful test result. After failure, postal code readings were made through PLC. A laboratory was launched with the same scenario and conditions similar to those of the high voltage substations and the PLCs in them are similar in the high-power post, which was the first sample tested, the data transfer through the PLC was carried out in the form of a three-wire (Tx, Rx, GND), so the same conditions were established for the PLC connection in the lab.

Electricity meters in this post are EDMI MK6E meter, which uses 9-wire 232 RS transmit data and, on the other hand, software for analyzing and reading market meters is also located in the market control center. Therefore, an EDMI meter MK6E meter along with the corresponding software was delivered to the laboratory and the studies were started to convert 9 RS232 wires to 3 between PC and meter at Khorasan Regional Electric Company. After several practical experiments, a successful solution was achieved. In this approach, various experiments were carried out by looping STR + CD + DSR and RTS + CTS to each other on the two ends of the wire, the results of which confirmed the validity of the theory. In later experiments, it turned out that the port side of the software did not need to loop and was therefore removed.

After completion of the studies, the tests on the cables and the meter were carried out on a PLC substrate. By testing the software and meter connection on the PLC and adjusting the Baud rate from 800 to 9600 bits per second, and setting the proper configuration of the PLC as software, the test was successfully carried out, and for the first time, market information was transmitted through the PLC communication platform. After successful laboratory readings of market meters, the information obtained from the test along with the necessary equipment at the KLTP post and on the telecommunication link of the 132 kV, was actually implemented and sent and the successful result was obtained. And all the information about the market was seen at the control center. Sending the data related to the open-circuit electricity meters through the PLC at 132 kV post showed in Figure 5.

Figure 5. Sending the data related to the open-circuit electricity meters through the PLC at 132 kV post [21].

5. CONCLUSION

In this paper, it has been shown that there is the possibility of sending market data onto the PLC platform in transient and high-voltage transmission lines, which so far seemed to be impractical. With the comprehensive implementation of this work in the country's electricity industry, especially regional electricity, a major step will be taken to create a smart grid for meter readings. Due to the successful outcome of the experiment, it is possible to easily connect the PLC, the availability of this platform in many posts, a large and new smart grid for reading electricity meter readings. In this method, the information of the meters is taken by a data collector, and using the PLC converter on a high voltage power line (63, 132, and 400 kV) to be sent to the data collection center. Typically, data transfer is done to a 400-volt post and then transmitted by the telecom to the center. Due to the fact that distribution companies need to have instantaneous data on the costs of electricity subscribers for network management, accurate information is needed on the causes of casualties. There are many constraints on telecommunication facilities in the electric power industry, which provide the ability to utilize smart meter readings. These limitations exist, especially in remote areas of urban environments for leased line and fiber optic platforms, which are not cost effective. In some posts, radio communication and microwave communication are not possible due to the absence of repeaters and frequency constraints. In this case, the appropriate option to solve these challenges is PLC. In this paper, it has been shown that the possibility of sending market data onto the PLC platform in transient and super-voltage transmission lines, which has so far seemed ineffective, is also present. This substrate was tested as an appropriate option in the power industry due to its specificity, availability in many posts and the need to create a separate bed beside electric lines, and implemented in practice on a 132 kV link it turned out with the comprehensive implementation of this work in the country's electricity industry, especially regional electricity, a major step will be taken to create a smart grid for meter readings.

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