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Various Communication Methodologies in Modern Smart Grid - A Review

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***Abstract** - A variety of different techniques exist for communication in power systems, each of which has its own advantages and shortcomings. This paper discusses the following modes of communication- Power Line Carrier Communication(PLCC), Global System for Mobile Communications(GSM), Radio Frequency(RF) Mesh, ZIGBEE and General Packet Radio Service(GPRS).*

***Key Words:** Communication, power systems, PLCC, GSM, RF, ZIGBEE, GPRS*

1. LITERATURE REVIEW

1.1 Power Line Carrier Communication (PLCC)

<Meaning> [1] discusses the technical as well as the business aspects of Power Line Carrier Communication. The paper also describes the challenges faced by the system and proposes possible improvements. The long-existing communication challenges with local customer networks due to additional requirements needed to set up a telecommunication network are also taken into account. PLCC proves to be extremely cost-effective as it does not require existing infrastructure to be disrupted, the communication is routed through the power lines itself. PLCC is a robust methodology that remains immune to the different types of noises present in the power system network, such as harmonics. Harmonics account for a significant share of problems in power systems. Still, it rarely has any effect on PLCC because the harmonic frequencies are much lesser than those associated with the Power Line Carrier signals. PLCC systems utilize the carrier signal to synchronize the transmitter and receiver. Hence fluctuations in the frequency of the carrier wave can have effects on communication. Modulation techniques employed in PLC Communication plays another significant role in the network. If the noise signal frequency is the multiple of the system's frequency, various modulation and filtering techniques can be implemented. The paper further discusses different noise spectrums and multiple methods of eradicating them, such as error correction techniques and data transmission at select frequencies.

[2] proposes a cost-effective PLCC based receiver system based system to prevent islanding in a region's power system network. In the case of photovoltaic systems, islanding techniques still powers a small number of decentralized loads. The zone created that utilizes solar power is referred to as a Non-Detection Zone. The system proposed in [2] reduces the size of the Non-Detection Zone. In the method proposed, a Power Line Carrier(PLC) signal is transmitted through the power line. If this signal is not received by the receiver at the other end, then the Power Control Unit can be notified, or islanding can be prevented by opening a breaker. The proposed system is independent of the number of photovoltaic units or their current output. It is better than a telephone communication system as PLC Communication does not require any additional capital cost. Unlike microwave communication systems, PLC signals can be received anywhere and are incredibly reliable. In contrast, one has to be extremely selective about the sites where microwave signals can be utilized. The occurrence of a Non-Detection Zone for such a system would depend on two different scenarios, which lead to the development of subharmonics - Ferro resonance and external vibrations on motors at a particular frequency. Despite the two scenarios being highly unlikely, adequate attention has been given to eliminate them by ensuring the pre-existing decoding of information present in the receiver, to separate the PLC signal from the two sources mentioned above.

1.2 GSM

[3] uses 16F877A microcontroller to measure, compare, and control voltage and oil temperatures in a distribution transformer and display the monitored readings at the central station using ADC communication. A comparison is drawn between the present values shown by the distribution transformer and rated values. The output is then fed to a GSM Module, which transmits the data using an RF signal displaying unidirectional radiation. The distribution center can be monitored and controlled from anywhere on earth using GSM and a mobile phone. The paper further highlights the advantages of the proposed model, including worldwide accessibility, device feedback, efficiency, Real-Time analysis, and low power consumption. However, the usage is dependent on Network signal strength in both distribution transformer and central station.

[4] The proposed system uses a combination of ZigBee and GSM modules. Each node, having a meter, is connected with ZigBee, which transmits data using a 2.4GHz frequency band to the central computer equipped with GSM capabilities. The above structure was proposed keeping in mind that the nodes do not need a fast data rate

while also making sure it is low powered and low cost. The central computer is then updating data to the general server using GSM. The system is designed to add functionality to existing AMR systems in Malaysia, which is predominantly used by Large Power Consumers. Using a 64-bit permanent address, each node can be identified. Mesh routing is used to pass data from source to destination, where the path is determined by the Ad-hoc On-demand Distance Vector (AODV) routing protocol. Data was sent and received using Unicast and Multicast communications successfully.

[5] The paper proposes a prepaid and postpaid metering system using a GSM modem on each node as well as the central server. The GSM module acts as the mode of communication between the Master station and the Metering module. Integrated with a microcontroller, SMS is sent and received using the AT i.e., Attention Terminal command protocol. The modem and processing unit uses the RS-232 communication protocol. The central server uses similar settings and microcontrollers.

1.3 Radio Frequency(RF) Mesh

[6] presents a comprehensive review and analysis of the performance of a Radio Frequency mesh for communication in smart grids. It also highlights results that indicate that the system can handle high volumes of traffic in situations where the addition of repeaters removes possible lapses in coverage. Unlike other RF communication methods such as point to point or point to multipoint, RF mesh technology does not require an uninterrupted link between two consecutive nodes and can re-route if a hindrance is in a particular path. The network architecture of the proposed system facilitated data transfer at a speed of 9.6 kbps. It utilized the ALOHA scheme for synchronization of time, with each time packet being of 700 ms. The method utilizes the latitude and longitude of the communication nodes for re-routing. The target destination is referred to as the collector. Its latitude and longitude are provided to the metering points and vice versa. During both upstream and downstream communication, the node which is transmitting is well aware of the other node's geographical configuration and chooses the one that is closest to it, thereby reducing redundancy and ensuring faster communication. Once a node sends data to its adjacent node, it waits for a specific time slot to receive confirmation that the data has been received. If no such confirmation is received within the stipulated time, the communication is determined as to have failed, and an alternative route is chosen. The system proposed is able to function even in outages and is encrypted in order to ensure maximum security. The proposed system is simulated in two different scenarios-one small scale with the number of meters being 350 and another large scale with the number of meters being 17000. In both cases, the system provided a 99.99% success rate and higher.

[7] performs an analysis of an RF mesh-based Advanced Metering Infrastructure in real scale scenarios. It allows utilities to perform an in-depth analysis of future situations without using a randomly determined simulation system on a large scale, which can be quite ineffective. The scenario taken up in this paper was a communication system with a smart meter count of 1.5 million. The topology of the network was determined by obtaining GPS coordinates from publicly available apps such as Google Maps. The least distance between two nodes was determined by using only distance as the only parameter. To relieve the system of interference, the probability of interference is calculated using a fixed point equation, which is solved by the least squared minimization model. ALOHA is once again used for the division of time slots. A MATLAB simulation of the proposed system was performed, and it was seen that the mean probability of interference stood below 10 percent. The results of the system's performance were greatly affected by delays in uplink and downlink. It was also observed that the utilization of distance as the sole metric for routing was not the most efficient. However, the model leaves scope to integrate any other means of routing.

[8]The paper evaluates Radio Frequency mesh-based smart energy management system in Neighbourhood Area Network (NAN). The Mesh system uses an architecture in which meters have meshed in the lowest layer. A second layer made of network nodes made up of routers connects the meter mesh and collection gateway that connects the Wide Area Network (WAN) where traffic is backhauled using GPRS, 3G, WiMAX, or fiber network. The meter mesh, network nodes, and Collectors are collectively called as the NAN. There were two scenarios: a small scale with 350 meters, one collector and two routers, and a large scale with 17,181 meters, multiple collectors, and routers. The simulations confirm that with traffic and one packet per 4h, the system has a success rate of 99.99% or better.

1.4 ZIGBEE

[9]The paper aims to design a newer light control system to overcome previous lighting systems issues. These issues include the Price of the system, Short circuits in PLC communication, and maintenance costs. These problems are solved using Zigbee communication techniques. The present systems in Korea use earth leakage circuit breakers and main circuit breakers to turn on or off the streetlamps. The shortcoming of these systems is solved using a Control System designed by Zigbee Communication protocol. From surveying streetlight control systems, it is identified that 10kbps data transmission rates are sufficient. The light control system's structure involves a Centralized control center that communicates with a remote concentrator, which in turn communicates with the street light control terminal. These terminals have input-output capabilities to control the light settings while also monitoring the different

parameters. The concentrator is equipped with CDMA to aid in transfer data between the central control centre and Concentrators. The paper also gives a working prototype of the same.

[10] The paper investigates the reliability of ZigBee wireless sensor networks in power system environments. It looks at the effects of interrupting RF signals caused due to different performances of RF signals. The high noise level in 13 to 16kV HV systems, impulsive transients of 10 to 34kV, according to IEEE Std. Seven hundred ninety-two turn-to-turn tests, as well as partial discharge activities in 4 to 24kV free space, are tested using real laboratory data. XBEE nodes were used as a transmitter (coordinator unit) and receiver (device unit). A group of data packets is sent and received while varying the distance between the units and applied signal strength. Data size, timeout rate, and quality of communication were assessed by monitoring the number of good and bad data and Received Signal Strength Indicator (RSSI). High voltage power line systems cause discrete Spectral Interference due to power line communication and radio communication. Furthermore, periodic pulse shaped interferences are generated from power electronic devices. Stochastic pulse-shaped interferences are generated from lightning, arching, and switching operations. An RF signal generator is used to generate noise with Carrier signal frequency 2.465 GHz and noise signal of 2.5MHz band. When the output power of the RF is adjusted to -11 dB, some packets were interrupted. The coordinator device was distanced 6m from the noise signal. Varying the distance between the two units, RSSI and good/bad packets were monitored. Using a spectrum analyzer, the power of noise signals close to the ZigBee units were measured. It was noted that there was an interruption in communication as the noise reached a measure of -70dBm. The interruption became more significant as the distance was increased. The second test simulated PD and corona discharges present near high voltage equipment. RF antenna, high-frequency current transformer, acoustic sensors, and capacitive couplers are crucial PD monitoring sensors. The PD discharges have full frequencies that reach up to a few GHz. A setup was designed to investigate the performance of ZigBee during PD in free space. In all scenarios where PD was between 18 to 1000 Pc, all data was transferred.Using a high voltage impulse waveform to a stator winding of 4kV induction machine, the effect of ZigBee in an impulse event was investigated. When the ZigBee is 2m away from the source and a 30kV impulse was applied, 1 data packet was lost. All other impulses below 30 kV did not affect. For a similar setup with the ZigBee 10cm away, Up to 3 data packets were lost. However, no direct relation was formed between the applied voltage magnitude and packet loss. IN the third scenario, the coil insulation was deteriorated under the test pulse. At 30kV, the ZigBee lost communications. The ZigBee performed reliably under PD activity but fell short when high noise levels and impulse faults were present.

[11] Uses the duPIC30F microcontroller to develop a smart metering system capable of recording outages. The proposed power meter transmits details of the power consumption data and outages for back end processing using a ZigBee system. The system records three groups of data mainly- real-time meter data, power utilization records and outage records. Simulations of the proposed model gave positive results, which indicated that the system could be integrated as part of the Automatic Metering Interface. This paper also specifies the furniture scope of including ZIGBEE in smart automation systems in power systems.

1.5 GPRS

[12]In this paper, a power monitoring system using a combination of Zigbee and GPRS is proposed, which uses CC2430 as the Zigbee module. Wireless transmission of data is done via GPRS. Various advantages of Zigbee have been mentioned, which in turn signifies why it is an excellent choice for real-time data transmission. The entire system consists of a Zigbee coordinator, various data terminal nodes, and a GPRS module. Zigbee has the main job of starting, configuring, building the network, and storing the information received from the data terminal nodes. Hardware and software design has been explained along with the software codes. It is a cost-effective method, and also complexity is reduced by the design aspect.

[13]A power system load management system using ARM and GPRS has been proposed. It consists of an electronic energy meter which transmits its information to the intelligent terminal present in the system via RS485 bus. It communicates with the management center using GPRS. The implementation of the intelligent terminal has been shown in the paper using ARM microcontroller LPC2214. This system was capable of obtaining voltage and current of the load connected, controlling the user's load, reading the electronic energy meter's reading, and communicating it to the center via GPRS.

[14]The authors propose a practical model to illustrate GPRS's application for an online power quality monitoring system. Due to this, the suppliers can immediately understand if there is a certain issue, dip, or fault related to power quality. A detailed description related to the system configuration has been shown, considering all the required factors. The power quality (PQ) meter requirements have been pointed out for the efficient working of the system. The data from PQ meters have to be stored at the central servers in proper sequence and safely taking into consideration the delay involved. From the various sites, data would be collected using the PQ meters and transmitted to the center using GPRS.

2. CONCLUSION

Table -1: Comparison between Communication Methods

Comparison Between Communication Methods			
Mode of Communication	**Range**	**Frequency of operation**	**Security Measures**
PLCC	Greater than 100km	80-500 kHz	Cryptography
GSM		933-960 MHz	A5/GEA encrypted
ZIGBEE	100 m	2.4 GHz	AES encrypted
RF Mesh	97 km	{868,915 MHz}	AES128 encryption
GPRS	Greater than 1 km	{800,900,1800,1900Mhz}	GEA encrypted

Table 1 draws a comparison between the different communication modes reviewed in this paper. A variety of feasible communication methods exist at present. The choice of communication system for the power system will depend on many factors like geographical area, distance, required speed and amount of data transfer required. While traditional methods like PLCC do not need extra infrastructure, they come short when long haul communications are required. Newer methods such as RF mesh, GPRS require much more expensive setup costs at much faster speeds.

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