POWER LINE COMMUNICATION APPLICATIONS FOR SMART GRIDS

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Abstract - *Current electrical production, transmission, and distribution networks lack the capacity and structure necessary to sustain the rise in consumer demand, rising energy consumption rates, and compliance with regulatory standards. The technology advancements in communication networks should be applied to conventional electrical grid systems to overcome capacity and structural issues. In the near future, a new grid system structure will be required in place of the current grid system. This new system must allow remote control for the creation of more effective, convenient, and trustworthy systems. Electrical grid system control requirements and communication topologies are described in this article. The potential application of power line communication (PLC) to the smart grid system is investigated.*

Key Words: Power Line Communication, Smart Grids.

1. INTRODUCTION

In order to make traditional power grid systems more intelligent, it is crucial to decide the type of network communication technology. The current grid system is comprised of energy centrals linked by extensive transmission lines.

The connecting structure between these energy centrals can result in blackouts. By adopting smart grid systems, the electrical power system's dependability and power quality may be enhanced, transmission time delays can be decreased, and the system's resilience to attacks and faults can be strengthened.

There are numerous prospective technologies for application in the smart grid communication infrastructure [1-3], including fiber optics, wireless, and power line communication (PLC).

In this study, the potential structure and benefits of the smart grids system is outlined, then offer a model for its construction and simulate it using MATLAB®. It is concluded by discussing the results and drawing a conclusion.

2. GRID COMMUNICATION TECHNOLOGIES

In general, smart grid communication techniques can be separated into wired and wireless categories. Wi-Fi, WiMAX, Cellular Communication (Satellite), Bluetooth, and ZigBee are examples of wireless communication technologies now in use. Every communication technology offers distinct coverages that adhere to varying criteria. Fiber optics and power line communication are the two wired communication technologies that employ cables for transmission (PLC).

Fiber optics technology enables high-speed power transmission system communications.

It is impossible to steal data information due to the fiber cable communication's great privacy and security [4], despite its costly initial installation cost. Due to the permeability of fiber to electromagnetic fields, fiber cable communication is favoured in smart grid applications [5].

Technology	*Advantages*	*Disadvantages*
Wired-PLC	Cost-Effective Available Infrastructure Extensive Coverage High capacity Security	Signal attenuation High noise
Wired-Optical Fiber	Stable characteristics High capacity	Cost
Wireless	Rapid installation Mature technology	Limited coverage Cost Security Capacity Long delay

Fig -1: Smart Grid Communication Behaviors [5].

When examining Figure 1, it is evident that the power line communication technology has greater advantages.

Power line communication technology incorporates all of the benefits of wired fiber-optic technology and wireless technology, including quick data transmission and security. It can give a high data transmission rate on smaller networks in particular.

With PLC, the data transfer rate in a building with Local Area Networks (LANs) can reach one million bits per second. Communication include not only internet connectivity, but also any devices connected to the network through power line.

PLC can be used to manage distribution line activity and passivity. This is particularly important for substations located in locations without a communication infrastructure [1], [5].

Typically, PLC technology utilizes data transfer on medium and low voltage power lines [6].

PLC utilizes existing wire, making it suited for Home Area Networks (HANs) and Neighborhood Area Networks (NANs) [7], [8].

Different PLC technologies utilize distinct frequency bands and support various data transfer rates. Broadband Power Line Communication (BPLC) and Narrowband Power Line Communication (NPLC) are two PLC data communication systems (NBPLC).

2. DESIGNING A PLC SYSTEM FOR SMART GRIDS

PLC technology is typically employed for the transfer of low and medium voltage power supplies. Establishing transmission with variable voltage levels is quite challenging due to the large number of system characteristics, including wire sizes and electrical parameters at high frequencies, that affect system efficiency.

As noise level, signal attenuation, impedance matching, and frequency are time-dependent variables, sophisticated signal processing and channel coding can lessen the channel's disruptive effects.

In PLC applications, the communication signal must be provided with greatest efficiency. Otherwise, transmission data loss rates can be rather significant.

Despite being cost-effective options for smart grid applications, PLC environments provide significant problems to the reliability and performance of communication systems due to attenuation (transmission or route loss) [1], [5].

For these reasons, new PLC system modeling is built using Matlab Simulink and parameters of power lines, which include impedance, capacitance and inductance, were evaluated with influence on attenuation. Fig. 2 depicts the PLC system's general infrastructure diagram.

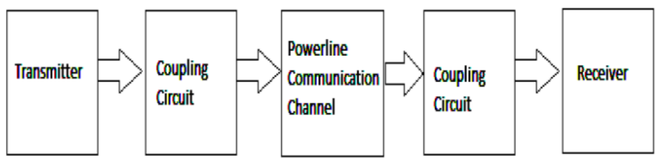

Fig -2: Power Line Communication System Blocks.

The attenuation is calculated with matlab design model as 20log10 (Vtransmit/Vreceive) in decibels.

It has been measured by broadcasting a signal with a constant sine wave amplitude at a substation with MV and LV values [9], [10]. Sine wave is a signal that begins at a specific frequency and increases (or decreases) the frequency continuously until it reaches the final frequency.

Different portions of the sine wave are attenuated differentially, and the received signal provides a measure of the frequency response of the channel [10-22].

In this study, the amplitude of the transmitted signal was set to 10 V (into 50 Ohms) and the range of the sine wave was tuned to the desired frequency band. Figure 3 depicts the model for attenuation calculation.

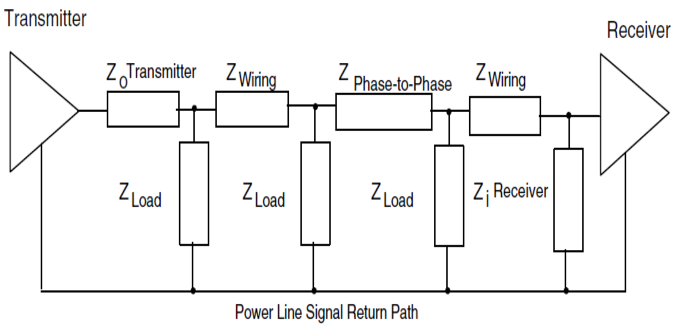

Fig -3: PLC Attenuation Model.

The methodologies described in [9], [20], and [21] were applied in the construction of the new power line communication system model (shown in Fig. 4). Our model aims for minimal loss and resemblance to the actual transmission line [1], [5].

The coupling filter, Transmission Circuit, and Receiver Circuit models make up the PLC system model. The overhead medium voltage and low voltage distribution lines are tested using a transmission line of set length.

The simulation results of the PLC system are then obtained for various line lengths in MV-to-LV and LV-to-MV communication situations.

Designing model's transmission line parameters are derived from IEEE and CENELEC standards [11], [17], and [22] This model yields superior transmission outcomes in comparison to other investigations.

After establishing the most effective model for HV-MV, MV-MV and LV-LV, the outcomes are analyzed.

Then adding HV-MV, MV-LV and LV-MV power transformers to the distribution line, the model was modified with standards, the results were analyzed after that results are compared from the authors past studies [5].

This study examines the results and also added the results of High Voltage.

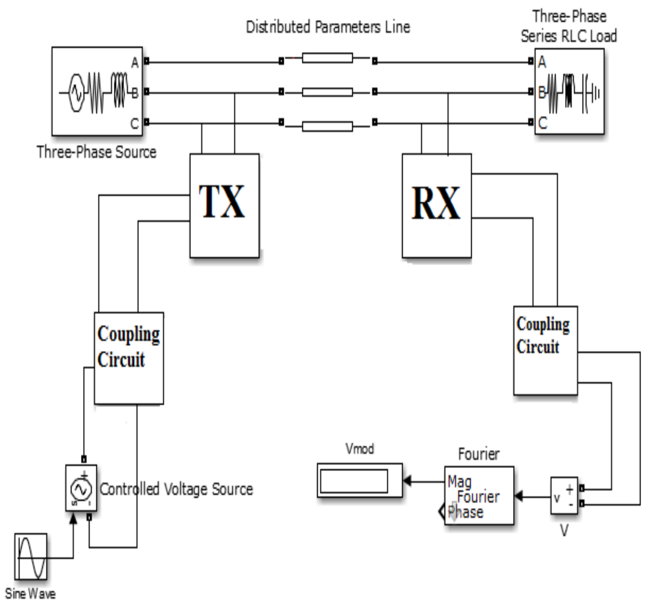

Fig -4: Power Line Communication System Model.

3. RESULTS AND DISCUSSIONS

In the first configuration, the signal was transmitted in HV and transmitted in MV. In this model, line parameters derived from IEEE and CENELEC standards [11], [17], [22], and [23] were utilized.

HV transmitted MV received PLC transmission system attenuation values results indicate a minimum attenuation value of 118.99 dB at a frequency of 327 kHz, which is less than 55 dB in the frequency range of 327 kHz 10 kHz.

In the second configuration, the signal was transmitted in MV and received in LV. In this model, line parameters derived from IEEE and CENELEC standards [11], [17], [22], and [23] were utilized.

MV transmitted LV received PLC transmission system attenuation values. The results indicate a minimum attenuation value of 18.89 dB at a frequency of 131 kHz, which is less than 28 dB in the frequency range of 131 kHz 10 kHz. These results are similar to past researches.

In the third model, the signal was transmitted and received using LV and MV, respectively. In this model, line parameters derived from IEEE and CENELEC standards [11], [17], [22], and [23] were utilized.

The results indicate a minimum attenuation value of 9.53 dB at a frequency of 128 kHz, which is less than 10 dB in the frequency range of 128 kHz 10 kHz.

On this model, it is evident that the MV transmission performs gives best results than the HV or LV transmission.

4. CONCLUSION

Advanced communication technology is a crucial necessity for the development of the smart grid. Choosing the necessary communication technology for smart grid applications is now the subject of continuous debate. This article examines smart grid communication technologies and their needs, as well as the power line communication system for the smart grid system. To analyze the behavior of PLC for smart grid applications, a new PLC system model is built and researched to determine the attenuation factors, such as line length or output voltage amplitude, that influence the calculations. The simulation results of the PLC system are then obtained for various frequencies and fixed line lengths in MV transmitted- LV received and LV transmitted- MV received communication. According to simulation results, the attenuation increases with frequency when a signal is transferred from a medium voltage to a low voltage network, but decreases with frequency when a signal is transmitted from a low voltage to a medium voltage network. The attenuation values of MV transmission lines are optimal for power line communication applications.

REFERENCES

[1] S. Guzelgoz, "Characterizing Wireless and Power line Communication Channels with Applications to Smart Grid Networks " PhD Dissertation, University of South Florida, 2011

[2] A. B. M. Shawkat, "Smart Grids; Opportunities, Developments, and Trends", IEEE Transactions 2013 -978-1-4471-5209-5

[3] V.K. Sood, D. Fischer, J.M. Eklund, T. Brown, "Developing a communication infrastructure for the Smart Grid", pp. 1–7, Electrical Power & Energy Conference, EPEC, IEEE, 2009

[4] IEEE Std.802.16, "IEEE Standard for Local and Metropolitan area networks," 2009

[5] D. B. Unsal, T. Yalcinoz, "Applications of New Power line Communication Model for Smart Grids." International Journal of Computer and Electrical Engineering Volume 7, Number 3, June 2015

[6] R. Ma, H. Chen, R. Huang, W. Meng, "Smart Grid Communication: Its Challenges and Opportunities" IEEE Transactions on Smart Grid, vol. 4, issue 1, pp.36-46

[7] N. Ginot, L.IREENA, F. Nantes, M. A Mannah, C. Batard, M. Machmoum, "Application of Power Line Communication for Data Transmission Over PWM Network", IEEE Transactions Smart Grid, pp. 178 - 185, 2010

[8] G.Bumiller, L. Lampe, H. Hrasnica, "Power line communication networks for large-scale control and automation systems" Communications Magazine, IEEE, pp 106 - 113

[11] IEEE Std 1901™-2010-IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications

[12] M. Korki, N. Hosseinzadeh, H. L. Vu, T. Moazzeni and C. H. Foh, "A Channel Model for Power Line Communication in the Smart Grid," Power Systems Conference and Exposition (PSCE), 2011 IEEE/PES, pp. 1-7, 2011.

[13] NIST framework and roadmap for Smart Grid interoperability standards,Release 1.0

[14] F. Aalamifar, Viability of powerline communication for smart grid realization, Ms. Thesis, Queen's University, 2012

[15] A.Cataliotti, G. Tinè " On the Model of MV Power Line Communication System in the case of Line to Line transmission", XIX IMEKO World Congress Fundamental and Applied Metrology, , Lisbon, Portugal, September ,2009

[16] Echelon Corporation, "LonWorks PLT-30 A-Band Power Line Transceiver Module, User's Guide", Version 1.3.

[17] EN 50065-1:1991 Signalling on low-voltage electrical installations in the frequency range 3 to 148.5 kHz—Part 1: General requirements, frequency bands and electromagnetic disturbances; Amendment A1:1992 to EN 50065-1:1991; Amendment A2:1995 to EN 50065-1:1991; Amendment A3:1996 to EN 50065-1:1991.

[18] P.P. Parikh, M.G. Kanabar, T.S. Sidhu. "Opportunities and Challenges of Wireless Communication Technologies for Smart Grid Applications" IEEE Power and Energy Society General Meeting, pp.1-7, July 2010.

[19] A. Cataliotti, A. Daidone, G. Sanacore, G. Tinè "Characterization of Medium Voltage cables for power lines communications", 15th IMEKO TC4-International Symposium on Advanced of Measurement Science, Iasi, Romania, September 2007.

[20] M. Zimmermann, K. Dostert, "A multipath model for the power line channel," IEEE Transactions on Communications, vol. 50, no. 4, pp. 553-559, April 2002.

[21] A. Cataliotti, D. Di Cara, G. Tinè, "Model of Line to Shield Power Line Communication System on a Medium Voltage Network", Instrumentation and Measurement Technology Conference , 2010 IEEE

[22] IEEE Standards 643TM IEEE Guide for Power Line Carrier Applications. 8 June 2005

[23] RG7H1R Elektrotek Medium Voltage cables. www.elettrotekkabel.com