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전력선 통신을 위한 배전 선로 해석

김용성*, 김재철*, 권영목*, 이양진*
숭실대학교*

Analysis of distribution grid for power line communication network

Young Sung Kim, Jae-Chul Kim, Young-Mok Kwon, Yang-Jin Lee
SoongSil University

Abstract - This paper describes the model of the distribution grid for the broadband power line communication based on lumped-element circuits. In addition, this paper discusses various configurations of the MV distribution network in PLC. The distribution grid is not designed for communication so that it involves unfriendly conditions for PLC. The characterization of the MV distribution grid for PLC should be determined such as noise, attenuation, and mismatched impedance. For theses reasons, the PLC networks is described in using the scattering parameters. Finally, the n-port network is explained.

1. Introduction

PLC(Power Line Communication)technologies which become the center of attention utilize the distribution grid to deliver high speed data. For a decade, Those technologies have used in the only communication among the distribution stations in a narrow band. Recently, demands for high speed communication are increasing: for instance, home networking businesses, security systems, network switching, network monitoring, fault diagnosis, demand side management of power distribution networks, remote load control, meter reading telemetry and multimedia[1]. For these reasons, the broadband power line communication is appropriate to be applied. In addition, the higher frequencies are required to obtain wide band. There are attractive advantages using the metropolitan power distribution grid for combination of the power network within the home or office. One of the most important merits is that no new wires need to be installed and it is the largest network on earth by far. Nevertheless, the distribution grid is still tough for the power line communication because it is not designed for PLC. The power line is designed for the low frequency electric energy while the twisted pair and coaxial cable are for the high frequency signals, so the distribution grid is the extremely tough conditions for PLC. There are three critical factors called noise, impedance and attenuation. In order to analyze these factors at the high frequencies, the behavior of power line should be investigated thoroughly. Therefore, the practical method which is called the scattering parameter have to be applied unlike Y parameter, Z parameter or H parameter[2]. Moreover, There are two critical parameters to analyze the power line. Two intrinsic parameters are presented as the characteristic impedance and the propagation constants in[3].

2 MV distribution network in PLC

2.1 Various configurations of the PLC network

There are several ways to carry the PLC signals in the MV distribution grid. First of all, the signals are carried on 3ϕ overhead line in the insulated neural system as Fig.1. This method has less attenuation and it is not much influenced by loads.

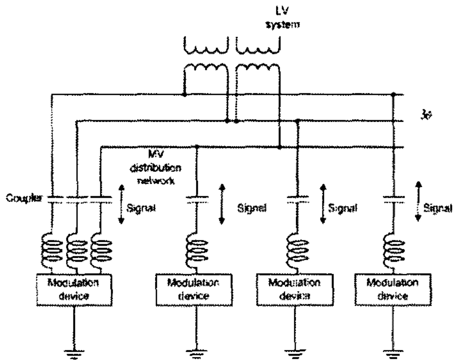

Fig.1 insulated neural system

Secondly, signals are carried on the overhead ground wire as Fig.2. This method needs additional arresters as shown Fig.2.

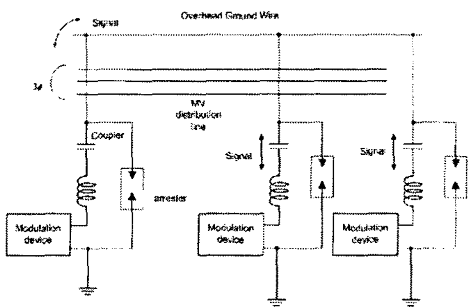

Fig.2 Method of overhead ground wire

Finally, The signals are carried on the overhead common ground wire as Fig.3. The method has an advantage of an extensive area[4].

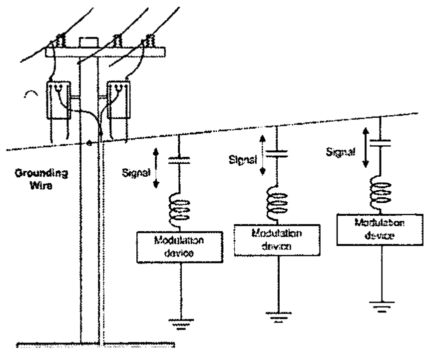

Fig.3 Method of overhead common wire

2.2 How to approach network characterization

2.2.1 The traditional methods

There are several traditional network analyses for transmission line. We have already known Y parameter sets using the two-port network theory proposed in [2]

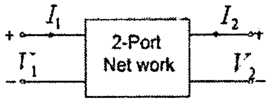

Fig.4 Model of two port network

From Fig.4 in the Y-model or the admittance model, the two voltages are assumed to be known, and the currents can be found by eq(1).

$$I_1 = y_{11}V_1 + y_{12}V_2$$
$$I_2 = y_{21}V_1 + y_{22}V_2 \qquad (1)$$

In the H-model or the hybrid model, each of the voltages and the currents is found by eq(2)

$$V_1 = h_{11}I_1 + h_{12}V_2$$
$$I_2 = h_{21}I_1 + h_{22}V_2 \qquad (2)$$

In the Z-model or the impedance model, two currents are assumed to be known, and two volt-ages can be found by eq(3)

$$V_2 = z_{11}I_1 + z_{12}I_2$$
$$V_1 = z_{21}I_1 + z_{22}I_2 \qquad (3)$$

2.2.2 The behavior of PLC network

Above all network parameters are related to total voltages and total currents at each of two ports. These network analyses are represented by the equation(1),(2),(3) which are theoretically useful at low frequencies but some problems arise when the frequencies move to higher as range from 1MHz to 30 MHz. For instance, equipment is not readily available to measure the total voltages and the total currents at the ports of the network. In addition, short and open circuits are difficult to be achieved over the broad band of frequencies. Therefore, the critical method is necessary to solve these problems. In this paper, the traveling wave is applied to approach network characterization rather than the total voltages and currents. Fig.5 shows behavior of the traveling wave at the high frequencies. In both directions along this transmission line, the voltage, the current and the power should be described as the form of waves traveling when source impedance and load impedance are mismatched.($Z_S \neq Z_L$)

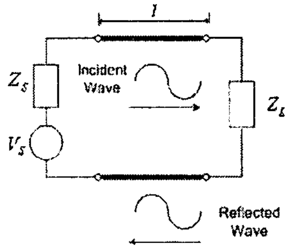

Fig.5 Reflected wave of power line

Two intrinsic line parameters for the transmis-sion line such as the propagation constant γ and the characteristic impedance Z_0 can be written as eq(4),(5).

$$\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)} \qquad (4)$$

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \qquad (5)$$

Fig.6 shows the model of the power line in the distribution system.[5]

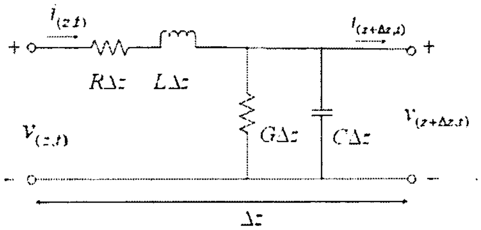

Fig.6 Two-wire transmission line model

Γ is the reflect coefficient. At each point of the transmission line voltage and current can be written as

$$V_{(Z)} = V_0^+ e^{-j\beta Z} + V_0^- e^{+j\beta Z}$$
$$= V_0^+ (e^{-j\beta Z} + \Gamma e^{+j\beta Z}) \qquad (6)$$

$$\Gamma = \frac{V_0^-}{V_0^+} \qquad (7)$$

$$I_{(Z)} = \frac{V_0^+}{Z}(e^{-j\beta Z} - \Gamma e^{+j\beta Z}) \qquad (8)$$

2.2.3 Scattering network in PLC

The additional traveling waves are recognized in Fig.7. There is interrelation between the incident waves and reflected waves. When a output port is terminated in a matched load, S_{11} is a input reflection coefficient and S_{11} is also express-ed as Γ_{IN} When the output port is terminated in the matched load. S_{21} is a forward transmission coefficient. When the input is terminated in a matched source. S_{12} is a reverse transmission co-efficient. When the input port is terminated in the matched source, S_{22} is a output reflection co-efficient and S_{22} is also expressed as Γ_{IN} All of the S parameters are defined as eg(11)

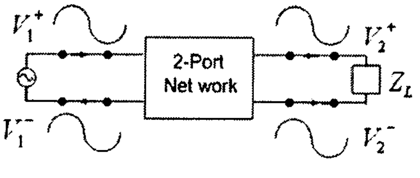

Fig.7 Traveling waves of two-port network

Relation between the incident waves and the reflected waves could be written as[7].

$$V_1^- = S_{11} V_1 + S_{12} V_2$$
$$V_2^- = S_{21} V_1^+ + S_{22} V_2^+ \qquad (9)$$

The appropriate representation is called the scattering matrix and scattering parameters[5].

$$\begin{bmatrix} V_1^- \\ V_2^- \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix} \qquad (10)$$

$$S_{11} = \left.\frac{V_1^-}{V_1^+}\right|_{V_2^+ = 0} \qquad S_{22} = \left.\frac{V_2^-}{V_2^+}\right|_{V_1^+ = 0}$$

$$S_{12} = \left.\frac{V_1^-}{V_2^+}\right|_{V_1^+ = 0} \qquad S_{21} = \left.\frac{V_2^-}{V_1^+}\right|_{V_2^+ = 0} \qquad (11)$$

2.3 Analysis of multiple-port network

Two port networks have been discussed so far, but the ports of the distribution network are at least more then two. The number of measurements needed for determining the more complex networks increases as the square of the number of ports.[6]

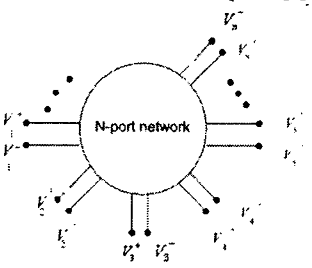

Fig.8 n-port network

The concept and the method of the parameter analysis are equal to two port network. Using the scattering matrix, the n-port network is represented as

$$\begin{bmatrix} V_1^+ \\ V_2^+ \\ \vdots \\ V_n^+ \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & \cdots S_{1n} \\ S_{21} & S_{22} & \cdots S_{2n} \\ \vdots & \vdots & \vdots \\ S_{n1} & S_{n2} & S_{nn} \end{bmatrix} \begin{bmatrix} V_1^- \\ V_2^- \\ \vdots \\ V_n^- \end{bmatrix} \qquad (12)$$

3. Conclusions

The distribution grid is unfriendly environment unlike other communication lines. The critical parameters called noise, mismatched impedance and attenuation should be determined for the high frequency communication signals. Therefore, this paper discusses that the scattering parameters could be the appropriate method at the n-port network in order to overcome the difficulties of implementation over broadband. Consequentially, the n-branch network is used. Moreover, there are still many disturbances in the distribution grid for PLC such as distribution transformers, breakers, surge arresters, switches, and so on. The behavior of the power elements should be identified and studied at the frequency range from 1 MHz to 30 MHz in the future. In addition, the distribution components that have different parameters of various capacities should be practically measured by appropriate equipment accurately. Furthermore, the analysis of the distribution grid in this paper could be used in design-ing matching circuits.

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