PMU-BASED METHOD FOR POWER LINE PARAMETERS ESTIMATION

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Abstract: **The paper presents a method for estimating parameters of a power line, developed and tested by the Author. The parameters are being estimated by means of an interpretation of indications of synchrophasors installed on both ends of a power line. The real-time estimation of a power line's parameters can be used to determine a condition of the line. Correlated with weather information and a log of events occurring in a power system and statistically analysed, they can improve knowledge and awareness of the state of the power system.**

Keywords: **PMU, phasor, synchrophasor, power line, power line parameters, power line model, parameter estimation .**

I. INTRODUCTION

Since when the team lead by Prof. A. G. Phadke developed the first phasor measurement unit (PMU) in 1992, there is a growing interest in the device and its capabilities. Initially, the interest was limited to scientific circles, eager to invent new applications of synchrophasors and perform base studies. Eventually the industry began to catch on with research. Especially interested are power systems operators, whose primary task is to provide consumers with electrical power of adequate quality.

The benefits coming from using the phasor measurement units encourage the industry to invest in the new technology. However, a large number of PMU installation nodes and a high price of a unit slow down an implementation of PMUs.

II. POWER LINE MODEL

A power line may be modelled in different ways, depending on the aim of a model. For instance, for power flow calculation one may use the π model, which imposes full symmetry of all phases. Such an approach reduces the complexity of calculations, as a three-phase system may be examined as a single-phase one. The full symmetry assumption is dictated with practical reasons, but it ignores the real-world asymmetry of a power line caused by the line capacitance which depends on the lines mutual position and their distance from the ground.

In practice, the asymmetry issue should be solved by interleaving wires. However, even a power line with interleaved wires cannot achieve full symmetry.

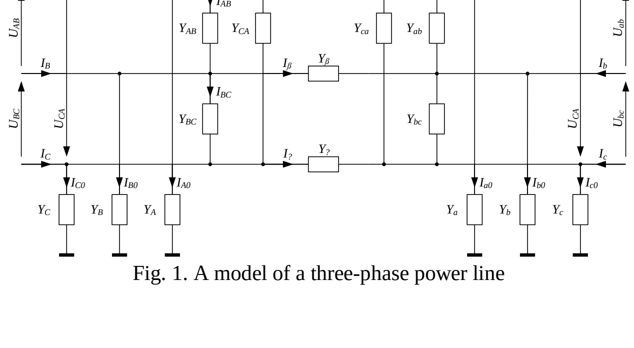

Fig. 1. A model of a three-phase power line

Using the data obtained with a synchrophasor, the Author has proposed a new model, taking shunt and series admittance into account. Physically, the shunt admittance may be interpreted as an element responsible for a power loss resulting from connecting the line to a voltage source. This power loss in independent from a load of the line and depend only on the configuration of the line and the weather conditions (the corona discharge effect). The series admittance represents the power loss resulting from the current (power) flow. Additionally, the flow of current causes the power line to heat up, reducing the power transfer capabilities of the line and increasing its inclination.

III. SYNCHROPHASOR MEASUREMENT UNIT

A phasor – the information about the RMS and angle shift of an electrical value – has been long used in the electrical engineering. The developments in electronics and GPS positioning and time-synchronization led to the creation of synchrophasor measurement units, which perform the sampling of the value being measured and calculate a phasor of the value. Such measurements have been long possible; however, only the recent developments in the area of time synchronization opened an opportunity to draw conclusions from multiple sets of samples taken at distant places. With time-stamped phasors, one gains an opportunity to analyze wide area power systems. Information retrieved by synchrophasors may be collected at one node and subjected to further analysis and storage.

If the data is transmitted with a separate, dedicated telecommunication network, the information will be delivered quickly and without unnecessary delays. However, if it is transmitted over the Internet, one may expect a much lower quality of service, especially with respect to delays. In cases which require low latency (such as power safety control systems) such delays are inacceptable, which leads to a conclusion that such applications require using a separate telecommunication infrastructure. On the other hand, there are applications of synchrophasor measurement units which do not require low latencies. In such cases, which include power line parameters estimation or short-circuit localization, even very long latencies (in order of seconds or even minutes) are acceptable and existing telecommunication networks may be used successfully.

IV. Problem formulation

Basing on the proposed power line model (figure 1) one can formulate the following equations derived from the 1st Kirchhoff's circuit law:

$$\begin{aligned} I_A &= I_{A0} + I_{AB} - I_{AC} + I_\alpha \\ I_B &= I_{B0} + I_{BC} - I_{AB} + I_\beta \\ I_C &= I_{C0} + I_{CA} - I_{BC} + I_\gamma \end{aligned} \tag{1}$$

and

$$\begin{aligned} I_a &= I_{a0} + I_{ab} - I_{ac} - I_\alpha \\ I_b &= I_{b0} + I_{bc} - I_{ab} - I_\beta \\ I_c &= I_{c0} + I_{ca} - I_{bc} - I_\gamma \end{aligned} \tag{2}$$

By analyzing (1) and (2) one can reach a conclusion that to determine some of the admittances (Y_{A0}, Y_{B0}, Y_{C0}, Y_{a0}, Y_{b0}, Y_{c0}, Y_α, Y_β, Y_γ) all of the voltages in respect to the ground must be known.

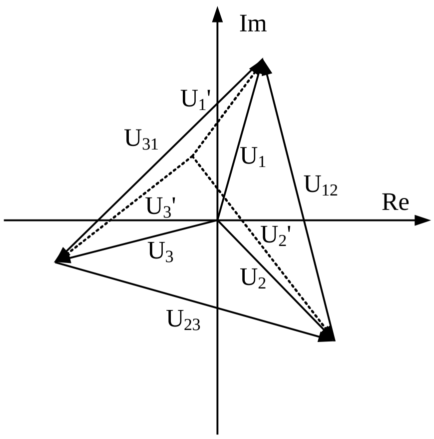

Fig. 2 Two possible sets of phase voltages for a sample set of inter-phase voltages

$$\begin{bmatrix} I_A \\ I_B \\ I_C \\ I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} V_A & 0 & 0 & V_A - V_B & 0 & V_A - V_C & V_A - V_a & 0 & 0 \\ 0 & V_B & 0 & V_B - V_A & V_B - V_C & 0 & 0 & V_B - V_b & 0 \\ 0 & 0 & V_C & 0 & V_C - V_B & V_C - V_A & 0 & 0 & V_C - V_c \\ V_a & 0 & 0 & V_a - V_b & 0 & V_a - V_c & V_a - V_A & 0 & 0 \\ 0 & V_b & 0 & V_b - V_a & V_b - V_c & 0 & 0 & V_b - V_B & 0 \\ 0 & 0 & V_c & 0 & V_c - V_b & V_c - V_a & 0 & 0 & V_c - V_C \end{bmatrix} \begin{bmatrix} Y_A \\ Y_B \\ Y_C \\ Y_{AB} \\ Y_{BC} \\ Y_{CA} \\ Y_\alpha \\ Y_\beta \\ Y_\gamma \end{bmatrix} \tag{3}$$

A synchrophasor measurement unit provides information on voltages between lines and phase currents. Unfortunately, there is an infinite set of phase voltages which may be composed into expected inter-phase voltages, as we have to deal with an underdetermined system of linear equations. Solving this system results with one of many possible sets of phase voltages, which may be used in further computations dealing with the problem of estimation of power line parameters (figure 2). The problem may be described as a system of equations (3), whose numerical solution in respect to the **Y** vector (obtained via the least squares method) makes up a set of power line's parameters estimation.

V. Numerical experiment

As a part of the research process the Author has developed a computer application. The application makes use of a library of subroutines solving systems of linear equations using the least squares method [1].

A few different sets of input data have been prepared and processed by the application, and the obtained results have been verified in two steps:

- automatically, by checking the norm $\|\mathbf{VY} - \mathbf{I}\|$,
- manually, by comparing the results with reference data.

Valid results have been obtained for all test cases. Average computation time was 38,2 μs.

VI. Conclusion

In case of power lines with synchrophasor measurement units already installed on both ends of a line, the parameter estimation method proposed by the Author in this paper imposes no additional costs. The method is independent of data acquisition time, so existing telecommunication infrastructures (such as the Internet) may be used.

Estimating parameters of power lines in various states (depending on the line's load and weather conditions) improves reality of power system simulations and makes it possible to fully utilize power lines' capabilities.

The algorithm researched by the Author and the numerical experiment performed by him are a first step in the direction of performing more complex computations utilizing the power line parameters estimations.

VII. References

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