Discussions and Closures

Discussion of "An Efficient Method to Compute Transfer Function of a Transformer From Its Equivalent Circuit"

Marjan Popov, Lou van der Sluis, and Gerardus Christopher Paap

The authors [1] presented an interesting method to extract the transfer function from the equivalent circuit of a two-winding transformer. The equivalent circuit is based on the nodal conductance matrix G, nodal reciprocal inductance matrix \( \Gamma \), and nodal capacitance matrix C. So far, there were many articles published so that the transfer function of a particular transformer was extracted from the measured transformer terminal impedance. The method presented here is clear and easily applicable by making use of the powerful Matlab functions. Furthermore, one can determine the resonance frequencies of a particular transformer more accurately.

To show the applicability, a lightning impulse at the transformer terminal is applied and a response at the end of the first pi-section (Fig. 1) is computed. These results are according to the expectations. We would appreciate an answer to the following questions:

- In the particular case, it is not clearly defined whether a pi-section corresponds to a coil, a group of coils, or a turn (Fig. 2). In most cases, the transformer might suffer from steep interturn voltages. The authors claim that by using this method, there is no limit on the size of the network. To preserve reasonable calculation times and memory usage in today’s personal computers, can the authors comment on the size of the network model when all interturn voltages need to be calculated?
- For short-time intervals (1 \( \mu s \)) within peak voltages, the effect of the losses is not significant [2]. However, for longer time intervals (a few hundreds of microseconds), not only might the winding losses have a significant influence but also the core losses due to the flux penetration inside the core [3]. How do the authors represent the losses \([r']\) in their case? How do they calculate the inductances, the reciprocal inductance matrix \( \Gamma \), and the capacitance matrix \( C \)?

Closure of "An Efficient Method to Compute Transfer Function of a Transformer From Its Equivalent Circuit"

K. Ragavan and L. Satish

We thank Profs. Popov, van der Sluis, and Paap for writing a discussion on our paper [1]. We trust that they will find our response acceptable.

Generally, a study on transformer windings essentially consists of two important phases, viz:

1) Representation of windings by their equivalent circuit.
2) Efficient solution of equivalent circuit.

The primary objective of our paper [1] concerns the second phase alone, under the presumption that an equivalent circuit representation is made available. However, both questions posed by the discussers pertain to matters related to the first phase (i.e., how the equivalent circuit originated, how the size of the network is chosen when all interturn voltages need to be calculated, what the extent of influence is of losses on circuit elements, etc.). Nonetheless, we provide answers.

- Item 1
  1) The results presented in [1] pertain to a two-winding transformer structure, with the circuit elements chosen to satisfy conditions given in Section 1 of the paper, as well as being close to practically encountered values. The validity of this equivalent circuit has been established over several decades as seen from the agreement between calculated and measured natural frequencies. It must be emphasized that the extension of such a network to enable the calculation of interturn voltages is not yet established theoretically and is even more difficult to experimentally verify.
  2) The proposed solution imposes, practically, no limit on the size of a network that can be modeled. This is not merely a "claim" as remarked by the discussers, but has adequately been supported by results, see [1, Table 1]. We believe that the ability to compute the poles and zeros of transfer function of a two-winding transformer with 250 sections per winding within 709 s is an adequate proof of achieved time efficiency.
  3) Regarding the size of network when all interturn voltages need to be calculated, no specific answers can be provided. However, a generally accepted rule of thumb specified by Abetti [2] might be appropriate to quote, where it states "it would be sufficient to choose the number of sections somewhat larger than the required number of natural frequencies."

- Item 2
  1) It has been clearly mentioned in [1, Sec. 1] that the elements of the equivalent circuit are determined using quasistatic approximations. In the example considered, a constant loss (i.e., fixed \( r \) and \( r' \)) has been assumed and other elements were chosen, as already explained.

REFERENCES


Manuscript received May 8, 2005. Paper no. TPWRD-00563-2003. The authors are with the Delft University of Technology, Delft 2628 CD, The Netherlands (e-mail: M.Popov@tudelft.nl). Digital Object Identifier 10.1109/TPWRD.2007.893952
2) If the effect of core nonlinearity, increased damping or loss at higher frequencies, the influence of frequency on circuit elements, etc. has also to be incorporated into the model; then, a more complicated circuit would be required. The direct extension of the proposed method of solution to such cases does not appear straightforward, and obtaining a generalized closed-form solution seems impossible. Alternatively, instead of a single equivalent circuit, the winding could be represented by a number of equivalent circuits (depending on the desired resolution), where each one is valid within a frequency interval. The individual circuits are solved in the usual way, but finding answers to newer questions such as, how the individual transfer functions are to be combined, how transfer function discontinuity at frequency transitions can be avoided, etc., would require further work.

• Initially, the discussers make a comment on the existence of many articles that describe the “extraction of transfer function from measured transformer terminal impedance.” This remark appears surprising and is incorrect. Our response on this matter is as follows.

The transfer function (i.e., transfer impedance) and driving-point (terminal) impedance function are different quantities, having only their poles (which are the same as open-circuit natural frequencies of the network) as common, while their respective zeros are totally unrelated [3]. Therefore, it is not possible to extract the transfer function using a measured transformer terminal impedance. As no reference has been cited, further discussion is not possible.

REFERENCES


Discussion of “Are Harmonic Recommendations According to IEEE and IEC Too Restrictive?”

Dingsheng Lin

This discusser would like to ask the authors [1] to answer the following questions.

1) Having taught Maxwell’s equations for a long time [2], this discusser would like to propose that the authors extend their analysis to the propagation of harmonic fields in space. This question is related to the well-established telephone interference factor (TIF) that the authors have neither mentioned nor employed. Is the TIF still a useful concept?

2) Capacitor placement alters the harmonic environment through possible series and parallel resonances. Do the authors have experience in controlling such resonant conditions through constrained optimization?

3) In [5] of the paper, the impact of inter and subharmonic voltages on television screens of vacuum-tube-type monitors is discussed. Do such harmonic voltages also cause disturbances in flat-plate television or computer monitors?

4) The increase of power-electronic components, such as pulse-width-modulated (PWM) current-source converters [3]–[6] has led to increased insulation failures in cables, transformers, and rotating machines. The reason for such failures are the current spikes which have a short rise time (μs range) resulting in large induced voltages in magnetic devices due to ever-present inductances and parasitic capacitances. The discontinuities of the winding or cable parameters (e.g., L and C) lead to locally large interturn or turn-to-ground voltages. Such PWM current-source waveshapes should be limited in a similar manner as the amplitudes of sub, inter, and integer harmonic currents. Can the authors comment on this problem?

5) Distortion power D was defined by Budeanu [7], [8] but has not found any useful application. With the increase of the harmonics in distribution systems due to distributed generation (DG) and greater reliance on power-electronic loads (e.g., rectifiers, inverters), distortion power could be used to measure the harmonic contribution of consumers and power (distributed) generators. That is, harmonic generators would have to pay for distortion power D as it is done for peak power consumption $P_{peak}$, real power $P$, and reactive power $Q$.

6) In some cases, spatial harmonics create time sub, inter, and integer harmonics in electrical machines and cause power system disturbances. Could the authors comment on this issue? Are there pertinent references available on this topic?

7) Reference [9] indicates that the losses of saturated transformers depend also on the harmonic phase shifts. Do the authors believe that a revised Standard IEEE-519 should also address the issue of harmonic phase shifts?

Guidelines of existing harmonic IEEE and IEC standards appear to be based on the observation of electrical apparatus performance during the past 20 years and are not derived from specific measurements and calculation as presented in this paper. It is certainly wise to impose restrictive guidelines. However, it does not seem justified to not investigate harmonic voltage and current limits of electrical apparatus. This paper makes a long-needed contribution in this direction for residential power distribution systems. It is hoped that a similar study will be published for industrial and commercial (three-phase) power systems.

REFERENCES