博士学位論文審査要旨

２０１５年2月１７日

論 文 題 目： A Study on Impedance Measurement of Small-Capacitance Circuit using Transient Waveforms (過渡波形を用いた微小容量からなる回路インピーダンス測定法の一研究)

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要　　旨：

合理的絶縁設計に必須である雷サージの予測計算には，僅か数 pF であっても対象機器の浮遊容量を表現する必要がある。本論文では，信号電圧が小でノイズ耐性も低く難があった定常状態インピーダンス測定に代わり，過渡現象を用いた微小容量を含む回路インピーダンス測定法を提案している。

本論文は全 6 章で構成されている。第 1 章では，本研究の電力システムにおける過渡電圧と高速過渡現象解析に要するモデリング法について述べている。第 2 章では，本研究の応用分野である雷サージ過電圧と高速過渡現象の概要を説明している。第 3 章では，インピーダンス測定の基礎をなす定常測定法について説明している。第 4 章では，過渡電圧・電流を周波数変換しこの比からインピーダンスを求める従来手法は高インピーダンス回路に対しては電圧測定器の浮遊容量により必要とする電圧測定精度が得られないことを示し，電圧測定が可能となる電圧源開放電圧と回路に流入する電流測定のみからなる測定手法を開発している。木材に埋め込んだ電極間のインピーダンス測定では電極間容量，浮遊容量のみならず，電極と木材との接触抵抗，電極間の絶縁抵抗も知ることができることを明らかとしている。第 5 章では，提案法の応用について実例を交え説明している。配電用遮断器の測定では，接点間容量，浮遊容量を求め，直接電圧測定が困難な誘導電圧を，ガス放電アレスタを用いて間接測定し，その精度を確認している。第 6 章では，本論文の成果をまとめている。

本論文の結果は，高精度な配電系統雷サージ解析に応用できるのみならず，通信系統を含め幅広い微小容量を含む回路の解析，絶縁設計に応用でき，安定な電力供給に貢献するもので，これらの成果はこの分野の発展に多大なる貢献をなすものである。よって本論文は博士 (工学) (同志社大学) の学位論文として十分な価値を有するものと認められる。

総合試験結果の要旨

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要　　旨：

博士論文提出者はインドネシア共和国の Bandung Institute of Technology の Master's Program を 1999 年 9 月に修了し，2011 年 9 月に本学大学院工学研究科電気電子工学専攻博士課程（後期課程）に入学し，現在在籍中である。

本論文の主たる内容は，電気学会共通英文論文誌 IEEJ Transactions on Electrical and Electronic Engineering, Vol. 9, Issue S1, pp. S37–S43 に掲載，同志社大学理工学研究報告に 2 件掲載が決定しており，十分な評価を得ている。

2015 年 1 月 17 日午前 10 時より約 2 時間にわたり，提出論文に関する学術講演会が開かれ，種々の質疑・討論が行われ，提出者の説明により十分な理解が得られた。

さらに，公聴会終了後，審査委員により学位論文に関連した諸問題につき口頭試問を実施した結果，論文提出者の十分な学力を確認できた。なお，提出者は本論文を英語で執筆しており，英語によるその他の論文発表や学会で発表を行っていることから，十分な語学力を有しているものと認められる。

よって総合試験の結果は合格であると認める。

博 士 学 位 論 文 要 旨

論 文 題 目 : A Study on Impedance Measurement of Small-Capacitance Circuit using Transient Waveforms (過渡波形を用いた微小容量からなる回路インピーダンス測定法の一研究)

氏　　名 : Diah Permata

要　　旨 :

Predictive calculations of overvoltages generated due to lightning are most essential for a reasonable insulation design of power system. For an accurate lightning surge analysis, power system apparatus should be represented with its stray capacitors even if its capacitance is some picofarads, because the surge includes high frequency components. An accurate measurement of the small capacitance becomes indispensable. A measurement method of small-capacitance using transient waveforms is proposed in this thesis. A pi-circuit is used to express the stray capacitors between terminals and those from each terminal to ground. Two measuring modes, differential and common modes, are required to obtain the parameters of the circuit. The parameters are determined by transient current waveforms of the modes with an applied voltage, i.e., the open circuited voltage at the end of the current injection cable.

At first, a measurement using an impedance measuring instrument, which is categorized as a steady state method, is investigated. Although the method is applicable in a laboratory test, it is difficult to apply to practical systems due to instability by radio interference.

On the other hand, the transient measuring method, which gives the impedance as a ratio between the voltage and current frequency responses transformed from time domain, can be easily applied to the power system apparatus. However, the measurement of the small stray capacitance is difficult due to the low impedance of the voltage probe, which is indispensable to the transient voltage measurement. The parasitic capacitance of the voltage probe obscures the small capacitance.

A current injection cable is indispensable to the transient measurement. Investigation of the effect of the sheath surge impedance clarifies that stray capacitor grounding from a terminal is short-circuited by the low impedance of the sheath surge impedance in the differential mode. A correcting method of the effect of the sheath surge impedance is proposed in this thesis.

The parameters of the pi-type circuit are obtained from a slope of the transient current waveforms or a waveform fitting by a nonlinear method. These methods enable the derivation without a voltage measurement by a probe connecting across the small capacitance. The first method has high resistance to extraneous noise, because the numerical time to frequency transformation, which is sensitive to noise, is not required. The parameter estimation can be carried without any numerical simulation. In the nonlinear fitting method, the time to frequency transformation is simply in the form of analytical equations. Since the analytic method is a closed form solution, it is insensitive to noise in comparison with numerical transformation. Although the nonlinear method requires numerical calculations, the accuracy is higher than that of the former method. The former method is useful to determine the initial values for the nonlinear

fitting calculation.

The transient measuring methods are applied to define the circuit parameter of the equivalent pi-circuit of the following elements: (1) impedance between electrodes implanted into a piece of wood, (2) a gas arrester (GA) and (3) a miniature circuit breaker (MCB).

The contact and leakage resistances between the electrode and the wood and the capacitance between the electrodes are simultaneously obtained with the stray capacitances to ground by the proposed methods. The methods are applicable to measure not only the small stray capacitances but also the resistances. The transient methods can be applied to a measurement of a high impedance circuit. The wood model is useful for an insulation design of wooden insulators such as a wooden pole.

The GA is a basic device for protecting a circuit from a lightning surge. It can be used as a voltage sensor to evaluate the voltage across a small-capacitance circuit, because its internal capacitance is smaller than that of the conventional voltage probe. The breakdown voltage of GA can be known from a current measurement.

Characteristic of MCB can be simply expressed by a switch at a power frequency. However, the transient characteristic of MCB has to be expressed by some capacitors. For example, even if the MCB is turned off, some voltage is induced from a surge-entering terminal on the other terminal via the stray capacitor between its contacts. The contact capacitance with the stray capacitances determines the penetrating surge.

The accuracies of the models are confirmed by numerical simulations using Electromagnetic Transients Program. Good agreements between the measured and calculated results show the high reliability of the proposed methods.

To illustrate the usefulness of the proposed method and the equivalent circuit, an MCB is used as an example. Because the induced voltage across a small stray capacitance cannot be directly measured, the induced voltage is indirectly measured by a flashover of a GA connected to the terminal. In addition, the circuit of the MCB with the GA enables a prediction of the applied voltage from the flashover. If the stray capacitances of the MCB as well as the GA are accurately known, the ratio between input and output voltage can be theoretically obtained. The voltage dividing ratio is useful to estimate and design the insulation level of distribution power system. The ratio obtained by a theoretical calculation agrees well with that between the voltage across the incoming-terminal of the MCB and that of the GA just before the flashover obtained by EMTP simulation.

A circuit-parameter derivation method of the models of a wood as an insulator, a switch (MCB) and a gas-arrester for a fast transient simulation have been developed in this thesis. These components are basic elements not only for power system but also electronic and/or communication system. In addition to this, the proposed method is applicable to the other elements, whose capacitance cannot be accurately measured by conventional methods. This thesis will open up a new field in a transient simulation.