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H_∞ 스위칭 제어 비선형 전력계통안정화장치(NPSS) 설계 및 부하변동 분석

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H_∞ Switching PSS and Load Variation Analysis

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Abstract - This paper presents the nonlinear H_∞ switching power system stabilizer (PSS) based on Lie group and Lie transformation theory. The proposed controller combines the H_∞ switching controller and Lie theory. The proposed power system stabilizer (PSS) is used to improve the transient stability in the time-domain and to solve the problem associated with the inaccessible state variables by measuring only the angular velocity. In the simulation study, the different load conditions, fault periods, and fault locations are considered. The nonlinear time-domain simulation showed that the proposed controller was effective restoring transient stability in a one-machine infinite-bus power system.

1. Introduction

Lie group and Lie algebra, which were generated in the research on the transformation group by Sophus Lie, a Norwegian mathematician, have a central role in various fields of differential geometry, topology, and modern mathematics such as mathematical physics as well as pure algebra [1-4].

In mathematics, algebra is related to vector space about field with a bilinear map. Algebra is associative if the associative law can be applied to all elements.

In this paper, we applied a power system stabilizer based on only the Lie theory of finite dimension [5]. Numerical analysis algorithm used is was modified and reconstructed to be suitable for general simulation using the fourth Runge-Kutta technique. This controller was formed by combining the standard H_∞ estimator with the nonlinear feedback linearization-sliding mode controller (NFL-SMC). Unlike the conventional SMC, it eliminates the need to measure all the state variables in the conventional SMC. The proposed controller is stabilized by the Lyapunove's second theorem adding to sliding surface and estimation error [6-11].

2. Group Theory

The concept of the group that appeared in study on the geometry early in the 19th century and the number theory at the end of 18th century was developed by group theory having definite topological form in the middle of the 19th century by E. Galois' epoch-making research. This concept had a huge impact on all fields of modern mathematics and modern algebra.

In the research of algebraic equation in the 18th century, J. L. Lagrange, A. T. Vandermonde and D. Ruffini recognized the importance of the group consisting of substitutions of the solutions of equation. By using this, N. H. Abel showed that a solution of an algebraic equation cannot be displayed usually by more than the fifth order usually. A. L. Cauchy studied the group of solution substitution of equations independently and especially, E. Galois became starting point of the group theory which examines the relation of an algebraic equation and the group. Then the group was a group of most substitution and A. Cayley (1854).

Justice enabled abstract group's treatment, which escape group of substitution being introduced group's axiom theorem originally by Kronecker (1870). F. Klein (1872) emphasized the importance of group theory in geometrical research. Established in the 1880's by Lie, the Lie group theory studied. In the research of Poincare, Dehn, and Neilsen etc., the development of topology became an important motivation for the research of infinite non-continuous group.

In 1897, the theory of finite order groups written in the W. Burnside's book, became the teaching material of the first group theory, and it has been used to a book of group theory until present. The classification of a finite simple group, which was studied by many mathematicians, was completed by D. Gorenstein's major in early 1980, and it achieved a finite group's delicacy of research. When this finite simple group was classified, it was extended to a single theorem, which was proved in 500 papers written by over 100 mathematicians for about 30 years from the early 1950's to the 1980s. This work provoked field theory, graph theory, and other new many research in finite geometry etc. as well as group theory.

On the other hand, the proof of the finite simple group classification continued, and especially, Steinberg, Curtis, Lustig etc., presented principal research on Lie-type finite group and Alperin, Broue, Puig etc., presented research that leads to a new method of proof.

The results for the finite group and being interested in property research of infinite group respond specially research for infinite non-contiguous group according to development of topology. Combinatorial group theory introduced by W. von Dick and Poincare and the origin on fundamental group of topological space were used to develop the most important field of research of Lie group and infinite group as well as the theory of infinite commutative group.

Specifically, the free group, a generalized free product group, and HNN extension group etc. become the topics of basic research on the fundamental group of space. Bass and Serre developed the commutator analysis, Lie theory, group's variety, linear group, Fuchsian group, Cohomology theory, and 1-relator product, and studied several fields of group acting on tree.

This study presents the linear cancellation method, likely group's algebraic method of study, small cancellation theory, and the geometry method of using picture that mark geometrically mark the element of 2 homotopy group with Cayley diagram. The software's need in research of group of CAYLEY, MAGMA, GAP etc. with development of computer from the 1970s leads to active research of computational group theory.

The important of effective algorism and theoretical foundation study more than the conventional research studying on theory was realized and became an important research field of the calculation group theory. Researches were conducted on the calculation group theory connected with automorphism of finite group, finite simple group, transitive permutation group, automorphism of finite group and irreducible representation, Cayley graph, finite geometry etc.

The group's generalized algebraic structures are groupoid structure, ring structure, and semigroup(quasigroup) structure. Several investigators have studied fields of groups in close connection with group research [1-4].

3. Power system model with nonlinearity [12]

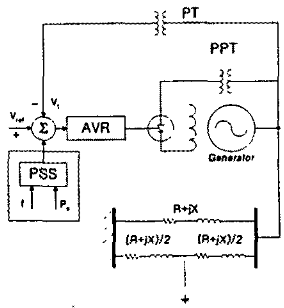
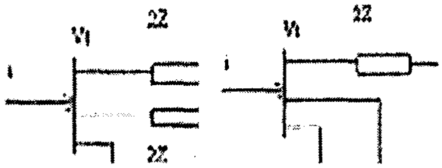


Fig. 1. Power system diagram connected infinite bus



(a) double lines (b) faulted one-line

Fig. 2. Equivalent transmission lines

The nonlinear 4-th order state equations are

$$\dot{\omega}(t)=\frac{1}{M}T_m-\frac{1}{M}T_e(t) \quad (1)$$

$$\dot{\delta}(t)=\omega_o(\omega(t)-1) \quad (2)$$

$$\dot{e}'_q(t)=-\frac{1}{T'_{do}}e'_q(t)-\frac{(x_d-x'_d)}{T'_{do}}i_d(t)+\frac{1}{T'_{do}}e_{fd}(t) \quad (3)$$

$$\dot{e}_{fd}(t)=-\frac{1}{T_A}e_{fd}(t)+\frac{K_A}{T_A}\left(V_{ref}-v_T(t)+u_E(t)\right) \quad (4)$$

$$e_{fd\min}\le e_{fd}\le e_{fd\max} \text{ and } u_{E\min}\le u_E\le u_{E\max} \quad (5)$$

$e_{fd\max}=6.0$, $e_{fd\min}=-6.0$, $u_{E\max}=+0.2$, $u_{E\min}=-0.2$

4. Simulation

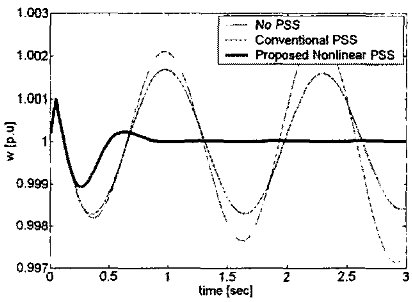


Fig. 3. Normal load under fault

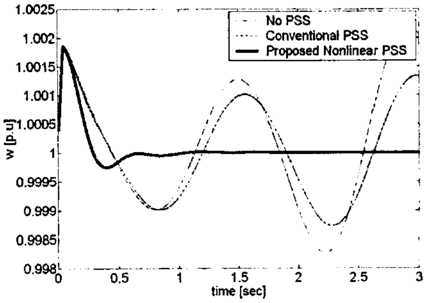


Fig. 4. Heavy load under fault

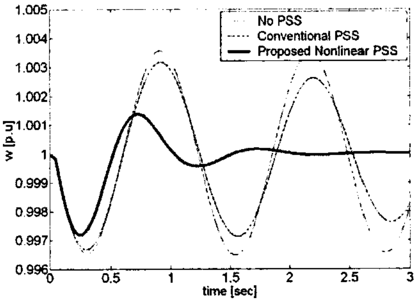


Fig. 5. Light load under fault

4. Conclusion

The case studies of the proposed controller were done by the nonlinear time-domain simulations in three cases of normal load, heavy load and light load conditions under generating 3-cycle line-ground fault for double line transmission. The performance was verified by MATLAB simulation package.

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