Radioelectronics and Communications Systems
Vol. 48, No. 7, pp. 12–19, 2005

Izvestiya VUZ. Radioelektronika
Vol. 48, No. 7, pp. 18–29, 2005
UDC 621.372.061

DESIGN OF ANALOG NETWORKS IN THE CONTROL THEORY FORMULATION. PART 1: THE THEORY

A. M. Zemlyak

Autonomous University, city of Puebla, Mexico

Formulation of the process of analog network design is given based on the control theory concepts. The new approach generalizes the design process and defines its various strategies within the common optimization procedure. The problem of generation of the optimal (in terms of its speed) design algorithm can be formulated as minimization of a functional in the control theory. Numerical results presented in the second part of the work demonstrate the advantages of the suggested approach.

One of the basic problems in the design of large systems is how to reduce the amount of computer time spent for attaining the optimal point of the objective function during the design process. The traditional approach to designing includes two main parts: (a) selection of the system model, which can be described by some algebraic or integro-differential equations; and (b) the parametric optimization procedure for finding the objective function optimum. The time required for analysis of the model of an electric system, and the time related to evaluation of characteristics of the optimization procedure grows rapidly as the system complexity increases.

The traditional measures for reduction of the time necessary for system analysis are widely known. The sparse structure of conductance matrices of electronic networks gave impetus to practical application of ideas for sparse matrix processing [1]. Another way to diminishing the number of operations for electronic network analysis is based on the idea of diacoptics, i.e., breaking a large system into a number of subsystems followed by their analysis and sewing the results together to obtain the ultimate solution. The pioneering works devoted to this approach appeared in the middle seventies and were based on decomposition and subsequent sewing as applied to network's branches [2] or nodes [3]. Extension of the straightforward solution methods was obtained with the aid of hierarchical decomposition and macromodel representation [4].

The optimization tools, used for optimization and design of electronic networks, also make a considerable impact on the overall number of operations and on processor running time. The numerical methods, both for unconstrained and constrained optimization, are still evolving [5]. Practical applications of these methods to electronic network design are developed with regard for optimization based on various criteria [6, 7]. The fundamental issues of development, design of structures, and CAD-system adaptation are considered in [8–11]. These concepts, being well elaborated, formed the basis of a number of training and professional packages of electronic network analysis and design [12–18].

By convention, the above concepts of network design will be called the traditional strategy of design, meaning that the method of analysis is based on Kirchhoff's laws. A new formulation of the network optimization problem without strict adherence to Kirchhoff's laws was suggested in [19, 20]. This process was called the generalized optimization and used the idea of ignoring the Kirchhoff laws for the whole network or some part of it. In this case, apart from minimization of the previously defined objective function, we also had to minimize the residual of the equation system describing the network model. In the extreme case, when the residual function included all equations of the network mathematical model, this idea

REFERENCES

1. O. Osterby and Z. Zlatev, Direct Methods for Sparse Matrices, Springer-Verlag, N. Y., 1983.

2. F. F. Wu, Solution of Large-Scale Networks by Tearing, IEEE Trans. Circuits Syst., Vol. CAS-23, No. 12, pp. 706–713, 1976.

3. A. Sangiovanni-Vincentelli, L. K. Chen, and L. O. Chua, IEEE Trans. Circuits Syst., Vol. CAS-24, No. 12, pp. 709–717, 1977.

4. A. Ruehli, A. Sangiovanni-Vincentelli, and G. Rabbat, IEEE Trans. Circuits Syst., Vol. CAS-29, No. 3, pp. 185–191, 1982.

5. R. Fletcher, Practical Methods of Optimization, John Wiley and Sons, N. Y., 1980.

6. R. K. Brayton, G. D. Hachtel, and A. L. Sangiovanni-Vincentelli, Proc. IEEE, Vol. 69, pp. 1334–1362, 1981.

7. R. E. Massara, Optimization Methods in Electronic Circuit Design, Longman Scientific & Technical, Harlow, 1991.

8. V. I. Il'in, Izv. VUZ. Radioelektronika, Vol. 30, No. 6, pp. 5–13, 1987.

9. V. P. Sigorskii, Izv. VUZ. Radioelektronika, Vol. 31, No. 6, pp. 5–22, 1988.

10. A. I. Petrenko, Izv. VUZ. Radioelektronika, Vol. 31, No. 6, pp. 27–31, 1988.

11. I. P. Norenkov, Izv. VUZ. Radioelektronika, Vol. 32, No. 6, pp. 25–29, 1989.

12. L. W. Nagel, SPICE2: A computer program to simulate semiconductor circuits. Electronic Research Laboratory, Rep. No. ERL-M520, University of California, Berkeley, 1975.

13. N. N. Kazandzhan, Yu. M. Kalnibolotskii, Ye. A. Romamenko, and L. P. Gogoleva, Izv. VUZ. Radioelektronika, Vol. 23, No. 6, pp. 99–101, 1980.

14. V. N. Il'in, V. A. Bakhov, N. Yu. Kamneva, V. L. Kogan, and M. A. Kotul'skii, Izv. VUZ. Radioelektronika, Vol. 25, No. 6, pp. 65–69, 1982.

15. Ya. K. Yrokhimenko, V. K. Lovkii, N. I. Yastrebov, and N. V. Greben'kov, Izv. VUZ. Radioelektronika, Vol. 27, No. 6, pp. 95–96, 1984.

16. A. I. Petrenko, A. P. Timchenko, V. V. Ladogubets, and V. S. Machugovskii, The PRAM-01 ES subsystem for analysis and optimization of electronic devices [in Russian], In: Applied and Theoretical Issues of Development, Introduction and Maintenance of Electronic Equipment CAD-Systems, pp. 62–63, Moscow Aviation Institute, 1984.

17. I. F. Ogorodneichuk, B. I. Borzenkov et al., Izv. VUZ. Radioelektronika, Vol. 30, No. 6, pp. 73–75, 1987.

18. S. V. Afinogenov, A. V. Basha et al., Izv. VUZ. Radioelektronika, Vol. 30, No. 6, pp. 80–82, 1987.

19. I. S. Kashirskii, Izv. VUZ. Radioelektronika, Vol. 18, No. 5, pp. 88–92, 1975.

20. I. S. Kashirskii and Ya. K. Trokhimenko, The Generalized Optimization of Electronic Networks [in Russian], Tekhnika, Kiev, 1979.

21. V. Rizzoli, A. Costanzo, and C. Cecchetti, Numerical optimization of broadband nonlinear microwave circuits, IEEE MTT-S Int. Symp., Vol. 1, pp. 335–338, 1990.

22. E. S. Ochotta, R. A. Rutenbar, and L. R. Carley, IEEE Trans. on CAD, Vol. 15, No. 3, pp. 273–294, 1996.

23. A. M. Zemlyak, Analog System Design Problem Formulation by Optimum Control Theory, IEICE Trans. Fundamentals Electron. Communic. and Computer Sciences, Vol. E84-A, No. 8, pp. 2029–2041, 2001.

24. L. S. Pontryagin, V. G. Boltyanskii, R. V. Gamkrelidze, and Ye. F. Mishchenko, Mathematical Theory of Optimal Processes [in Russian], Nauka, Moscow, 1969.

25. R. P. Fedorenko, Approximate Solution of Optimal Control Problems [in Russian], Nauka, Moscow, 1969.

26. R. Pytlak, Numerical Methods for Optimal Control Problems with State Constraints, Springer-Verlag, Berlin, 1999.

26 March 2005