Optimization Assisted Load Tracing via Hybrid Ant Colony Algorithm for Deregulated Power System

[1]Z. HAMID[**], [2]I. MUSIRIN[*], M. N. A. RAHIM, N. A. M. KAMARI
[*]Centre for Electrical Power Engineering Studies (CEPES), Faculty of Electrical Engineering,
Universiti Teknologi MARA,
40450 Shah Alam, Selangor,
MALAYSIA
[1]zulcromok086@gmail.com, [2]ismailbm@salam.uitm.edu.my,

Abstract: - The development of electricity tracing theory is to solve the problem concerning fair and non-discriminatory transmission service pricing of a deregulated power system. As the traditional methods such as postage stamp allocation and megawatts-mile methodology neglect the consideration of physical power system constraints, the allocation of service charge is said to be unreliable and rather biasing. At the same time, proportional sharing principle (PSP) based power tracing techniques necessitate for matrix inversion process; in which sometimes cannot be performed due to singularity property of the matrix. As a result, the tracing results are unable to be obtained due to error in mathematical operation. To try a new approach, this paper demonstrates the technique to implement Artificial Intelligence (AI) based optimization for performing load tracing, that is, by means of a new hybrid algorithm; Blended Crossover Continuous Ant Colony Optimization (BX-CACO) with simple and easy formulation steps. Experiment on IEEE 30-bus system together with comparative studies justifies the capability of the proposed technique for real system application.

Key-Words: - BIM, BX-CACO, Load Tracing, Matrix Singularity Property, PSP, TLDF

1 Introduction

In the business concerning transmission service pricing of a deregulated power system, losses charge allocation to consumers has been performed through various approaches; however, it is still in debate among researchers as there are several methods that lack of fairness and free-discrimination when allocating the charge. Traditional methods like postage stamp allocation, megawatts-mile methodology, and contractual path method perform the charge allocation by means of transaction, that is, without taking into account the physical constraints of power system like generation-demand balance and current flow direction [1] – [2]. This results to unsatisfactory service and hence leading to discriminatory business on consumers. Later, another approach known as power tracing has been developed to solve the weakness encountered by the previous discriminatory methods; by adopting the consideration of physical power system constraints into the developed technique. According to [3] – [6], power tracing has significant role for determining generators' share contribution to the line flows, losses, and loads, making transparent charge allocation, assessing congestion in power system, and also behaves like a contributor to establish fair transmission serving pricing.

In a vertically integrated power system, as in Malaysia, performing the electricity tracing is less significant as the information like generator and load participation in line flows and losses cannot contribute to any improvement on system performance. Nevertheless, for a deregulated environment as in European countries, tracing the powers contributed by generators and loads is very important for a transparent charge allocation, that is, each consumer will be able to know how much they will be charged on the associated usage of transmission capacity [7]. In [8] – [9], *proportional sharing principle* (PSP) based power tracing has been proposed, which is called as Topological Generation and Load Distribution Factors (TGLDF). Although it is a pioneer method, there are still disadvantages as it necessitates for matrix inversion (which sometimes cannot be performed if the matrix to be inversed is singular) and also, the power system ought to be treated as lossless, which adds hesitation on the tracing results. A circuit theory based power tracing has been proposed by [10], where the basic Ohm's Law was utilized to obtain the traced complex powers. However, this method still confronts with negative sharing problem and hence unable to provide reliable charge allocation. Other methods that implemented matrix operation for electricity tracing can be explored in [11] – [13].

Electrical Power and Energy System, Vol. 26, 2004, pp. 509 – 518.

[3] P. Barcia, R. Pestana, Tracing the Flows of Electricity, *Electrical Power and Energy Systems*, Vol. 32, 2010, pp. 329 – 332.

[4] M. S. S. Rao, S. A. Soman, P. Chitkara, R. K. Gajbhiye, N. Hemachandr, B. L. Menezes, Min-Max Fair Power Flow Tracing for Transmission System Usage Cost Allocation: A Large System Perspective, *IEEE Transactions on Power Systems*, Vol. 25, 2010, pp. 1457 – 1468.

[5] Y. C. Chang, C. N. Lu, An Electricity Tracing Method with Application to Power Loss Allocation, *Electrical Power and Energy Systems*, Vol. 23, 2001, pp. 13 – 17.

[6] P. Nallagownden, R. N. Mukerjee, S. Masri, Power Tracing and Prediction of Losses for Deregulated Transmission System, *International Journal of Electrical & Computer Sciences*, Vol. 10, 2010, pp. 97 – 103.

[7] K. Xiea, J. Zhoua, W. Li, Analytical Model and Algorithm for Tracing Active Power Flow Based on Extended Incidence Matrix, *Electric Power Systems Research*, Vol. 79, 2009, pp. 399 – 405.

[8] J. Bialek, Topological Generation and Load Distribution Factors for Supplement Charge Allocation in Transmission Open Access, *IEEE Transactions on Power Systems*, Vol. 12, 1997, pp. 1185 – 1193.

[9] J. Bialek, Tracing The Flow of Electricity, *Generation, Transmission and Distribution, IEE Proceedings*, Vol. 143, 1996, pp. 313 – 320.

[10] J. H. Teng, Power Flow and Loss Allocation for Deregulated Transmission Systems, *Electrical Power and Energy Systems*, Vol. 27, 2005, pp. 327 – 333.

[11] P. Wei, Y. Ni, F. F. Wu, Load Flow Tracing in Power Systems with Circulating Power, *Electrical Power and Energy Systems*, Vol. 24, 2002, pp. 807 – 813.

[12] P. Wei, B. Yuan, Y. Ni, F. F. Wu, Power Flow Tracing for Transmission Open Access, *International Conference on Electric Utility Deregulation and Restructuring and Power Technologies* (DRPT), 2000, pp. 476 – 481.

[13] S. M. Abdelkader, Complex Power Flow Tracing For Transmission Loss Allocation Considering Loop Flows, *IEEE Power & Energy Society General Meeting* (PES), 2009, pp. 1 – 9.

[14] A. R. Abhyankar, S. A. Soman, and S. A. Khaparde, Optimization Approach to Real Power Tracing: An Application to Transmission Fixed Cost Allocation, *IEEE Transactions on Power Systems*, Vol. 21, 2006, pp. 1350 – 1361.

[15] M. H. Sulaiman, M. W. Mustafa, H. Shareef, S. N. A. Khalid, O. Aliman, Real and Reactive Power Flow Allocation in Deregulated Power System Utilizing Genetic-Support Vector Machine Technique, *International Review of Electrical Engineering (IREE)*, Vol. 5, No. 5, 2010, pp. 2199 – 2208.

[16] M. H. Sulaiman, M. W. Mustafa, H. Shareef, S. N. A. Khalid, An Application of Artificial Bee Colony Algorithm with Least Squares Support Vector Machine for Real and Reactive Power Tracing in Deregulated Power System, *International Journal of Electrical Power and Energy Systems* , Vol. 37, 2012, pp. 67 – 77.

[17] M. Dorigo, *Optimization, Learning and Natural Algorithms*, Ph.D Thesis, Dipartimento, Politecnico di Milano, Italy, 1992.

[18] M. Dorigo, T. Stutzle, *Ant Colony Optimization*, Massachusetts Institute of Technology, 2004.

[19] V. Aristidis, An Ant Colony Optimization (ACO) Algorithm Solution to Economic Load Dispatch (ELD) Problem, *WSEAS Transactions on Systems*, Vol. 5, No. 8, 2006, pp. 1763 – 1770.

[20] J. Nikoukar, M. Gandomkar, Capacitor Placement in Distribution Networks Using Ant Colony Algorithm, *WSEAS Transactions on Systems*, Vol. 4, No. 1, 2005, pp. 38 – 42.

[21] C. F. Juang, C. M. Lu, C. Lo, and C. Y. Wang, Ant Colony Optimization Algorithm for Fuzzy Controller Design and Its FPGA Implementation, *IEEE Transactions on Industrial Electronics*, Vol. 55, 2008, pp. 1453 – 1462.

[22] C. F. Juang and C. H. Hsu, Reinforcement Interval Type-2 Fuzzy Controller Design by Online Rule Generation and Q-Value-Aided Ant Colony Optimization, *IEEE Transactions on Systems, Man, and Cybernetics, Part B: Cybernetics*, Vol. 39, 2009, pp. 1528 – 1542.

[23] M. Craus, C. Bulancea, An Improved Load Balance Strategy Using ACO Meta-heuristics, *WSEAS Transactions on Computers*, Vol. 4, No. 8, 2005, pp. 960 – 965.

[24] C. F. Juang and C. H. Hsu, Reinforcement Ant Optimized Fuzzy Controller for Mobile-Robot Wall-Following Control, *IEEE Transactions on Industrial Electronics*, Vol. 56, 2009, pp. 3931 – 3940.

[25] K. Saleem, N. Fisal, M. A. Baharudin, A. A. Ahmed, S. Hafizah, S. Kamilah, Ant Colony Inspired Self-Optimized Routing Protocol Based on Cross Layer Architecture for Wireless Sensor Networks, *WSEAS Transactions on Communications*, Vol. 9, No. 10, 2010, pp. 669 – 678.

[26] K. Socha and M. Dorigo, Ant Colony Optimization for Continuous Domains, *European Journal of Operational Research*, Vol. 185, 2008, pp. 1155 – 1173.

[27] Z. Hamid, I. Musirin, M. M. Othman, M. N. A. Rahim, New Formulation Technique for Generation Tracing via Evolutionary Programming, *International Review of Electrical Engineering (IREE)*, Vol. 6, 2011, pp. 1946 – 1959.

[28] S. S. Reddy, M. S. Kumari, M. Sydulu, Congestion Management in Deregulated Power System by Optimal Choice and Allocation of FACTS Controllers Using Multi-Objective Genetic Algorithm, *The IEEE PES Transmission and Distribution Conference and Exposition*, 2010, pp. 1 – 7.

[29] K. Deb, *Multi-Objective Optimization using Evolutionary Algorithms*, John Wiley and Sons, 2001.

[30] Z. Hamid, I. Musirin, M. N. A. Rahim, Blended Crossover Continuous Ant Colony Optimization and Stability Index Tracing for Effective FACTS Devices Installation, *International Review of Electrical Engineering (IREE)*, Vol. 7, No. 1, 2012.

[31] Z. Hamid, I. Musirin, M. M. Othman, M. N. A. Rahim, Efficient Power Scheduling via Stability Index Based Tracing Technique and Blended Crossover Continuous Ant Colony Optimization, *Australian Journal of Basic and Applied Sciences (AJBAS)*, Vol. 5, No. 9, 2011, pp. 1335 – 1347.

[32] M. H. Sulaiman, M. W. Mustafa, O. Aliman, Transmission Loss and Load Flow Allocations via Genetic Algorithm Technique, IEEE Region 10 Conference (TENCON), 2009, pp. 1 – 5.

[33] J. A. Momoh, *Electric Power System Applications of Optimization*, CRC Press HQ Marcel Dekker, 2001.

Bibliographies

Zulkiffli Abdul Hamid was born in Kedah, Malaysia in 1986. He obtained Diploma in Electrical Engineering (Electronics) in 2007 and Bachelor in Electrical Engineering (Hons) in 2010 from Universiti Teknologi MARA, Malaysia. His research interest includes sizing FACTS devices, Artificial Intelligence (AI) base optimization technique, power tracing and voltage stability field. Currently he is pursuing his Ph.D in power tracing field at the same university.

Ismail Musirin obtained Diploma of Electrical Power Engineering in 1987, Bachelor of Electrical Engineering (Hons) in 1990; both from Universiti Teknologi Malaysia, MSc in Pulsed Power Technology in 1992 from University of Strathclyde, United Kingdom and PhD in Electrical Engineering from Universiti Teknologi MARA, Malaysia in 2004. Assoc. Prof. Dr. Ismail Musirin has published 2 books and more than 80 technical papers in the international and national conferences, and also in the international journals. He is a reviewer of IEEE transactions and IET journals. He is also appointed as the permanent reviewer for the World Scientific and Engineering Academy and Society (WSEAS) centered in Greece. His research interest includes power system stability, optimization techniques, distributed generator and artificial intelligence. He is also a member of IEEE, IEEE Power Engineering Society and Artificial Immune System Society (ARTIST).