

July 2011

Network Reconfiguration for Electrical Loss Minimization

Suman Nath

Department of Electrical Engineering Bengal Engineering & Science University, Shibpur, India,
suman.therebel@gmail.com

Somnath Rana

Department of Electrical Engineering Bengal Engineering & Science University, Shibpur, India,
somnath.besu.ee@gmail.com

Follow this and additional works at: <https://www.interscience.in/ijica>



Part of the [Aerospace Engineering Commons](#), and the [Mechanical Engineering Commons](#)

Recommended Citation

Nath, Suman and Rana, Somnath (2011) "Network Reconfiguration for Electrical Loss Minimization," *International Journal of Instrumentation Control and Automation*: Vol. 1 : Iss. 2 , Article 11.

DOI: 10.47893/IJICA.2011.1024

Available at: <https://www.interscience.in/ijica/vol1/iss2/11>

This Article is brought to you for free and open access by the Interscience Journals at Interscience Research Network. It has been accepted for inclusion in International Journal of Instrumentation Control and Automation by an authorized editor of Interscience Research Network. For more information, please contact sritampatnaik@gmail.com.

Network Reconfiguration for Electrical Loss Minimization

Suman Nath & Somnath Rana

Deptt. of Electrical Engineering, Bengal Engineering & Science University, Shibpur, India
E-mail: suman.theRebel@gmail.com, somnath.besu.ee@gmail.com

Abstract - Increasing requirements of urbanization, industrialization and modernization demands further expansion and development of the national power grid and nonetheless, with a better efficiency and an enhanced voltage stability. The aim of this project is to conceptualize and realize an electric transmission and distribution network with improved efficiency and voltage stability that will contribute to the substantial reduction in the involved operational costs. Network Reconfiguration Methodology has been used. The study of this work was conducted on IEEE 14 bus network with Matlab tool using Newton-Raphson Method. The study also deals with how this technique can practically be implemented using Artificial Neural Network and sensors.

Keywords - Artificial Neural Network (ANN), L-Index value, Load-flow study, Network Reconfiguration, Newton – Raphson method, MATLAB.

I. INTRODUCTION

Ideally, losses in an electric system should be around 3 to 6%. In developed countries it is not more than 10%. However, in developing countries like India, the percentage of active losses is around 20%; therefore the utilities in the electric sector are presently interested in reducing it in order to have an edge in the competition; since the electricity prices in the deregulated markets are related to the system losses. In India, collective of all states, in 2008 the technical and non- technical losses are accounted as 23% of the total input energy.

To manage a loss reduction program in a transmission and distribution system, it is necessary to use efficient and effective computational tools like MATLAB, Artificial Neural Network (ANN) etc. that allow quantifying the loss in each different network element for system losses reduction.

II. CONCEPT OF NETWORK RECONFIGURATION

Electric Transmission network losses are one of the major concerns for electric power system. There are several approaches are available for improvement of Electric Transmission. This work deals with the improvement of efficiency of Electric Transmission of a power network by network reconfiguration. Network reconfiguration is performed by reconfiguring the power network. System reconfiguration means restructuring

the power lines which connect various buses in a power system. Restructuring of specific lines leads to alternate system configurations. System reconfiguration can be accomplished by placing line interconnection switches into network. Opening and closing a switch connects or disconnect a line to the existing network. If there are N switches in a network, there are 2^N possible switching combinations. Improving transmission efficiency by network reconfiguration involve study of switching options which enhances voltage stability under a given loading and generation condition. The improvement of efficiency is achieved only by altering topological structure of the power lines and does not involve any additional hardware like installation of SVC, capacitor bank, tap-changing transformers etc. The challenge in the proposed method however lies with the task of finding the optimum switching pattern that would maximize the overall voltage stability of the system and minimize the losses. The major benefits of network reconfiguration are-

- A. Efficient Electric Transmission.
- B. Network reconfiguration improves the voltage stability of the system.
- C. Network reconfiguration also smoothens out the peak demands, improving the voltage profile in the feeders and increases network reliability.
- D. Enhancement of voltage stability can be achieved without any additional cost involved for installation of capacitors, tap changing transformers and the related switching equipment.

III. CALCULATION OF LOSSES REDUCED SINGLE LINE EQUIVALENT NETWORK

Consider the single-line system

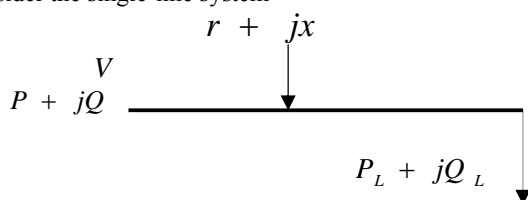


Fig. 1: Single-line system

Parameters are,

- p= injected real power
- Q= injected reactive power
- v= sending end voltage
- r = resistance of the line
- x = reactance of line
- Q = reactive load
- P_L = real load

$$P = \frac{r(P^2 + Q^2)}{V^2} + P_L \tag{1}$$

$$Q = \frac{x(P^2 + Q^2)}{V^2} + Q_L \tag{2}$$

From equation (1) & (2), we can eliminate $\frac{r(P^2 + Q^2)}{V^2}$ terms by rearranging the equations and obtain,

$$x(P - P_L) = r(Q - Q_L) \tag{3}$$

The voltage at sending is the reference voltage, and its magnitude is kept constant. Hence, the sending end voltage is assumed as 1 per unit.

On rearranging equation (3) and eliminating Q from equation (1), a quadratic equation of P is obtained as

$$(r^2 + x^2)P^2 - (2x^2P_L - 2rxQ_L)P + (x^2P_L^2 + r^2Q_L^2 - 2rxP_LQ_L + rP_L) = 0 \tag{4}$$

And eliminating P from equation (1), a quadratic equation in Q is obtained as

$$(r^2 + x^2)Q^2 - (2x^2Q_L - 2rxP_L)Q + (x^2P_L^2 + r^2Q_L^2 - 2rxP_LQ_L + rQ_L) = 0 \tag{5}$$

As equations (4) and (5) are in quadratic form, for P and Q to have real roots, the discriminants of equations (4)

and (5), respectively, must be greater than or equal to zero. Thus,

$$(2x^2P_L - 2rxQ_L + r)^2 - 4(r^2 + x^2) * (x^2P_L^2 + r^2Q_L^2 - 2rxP_LQ_L + rP_L) \geq 0 \tag{6}$$

$$(2x^2Q_L - 2rxP_L + x)^2 - 4(r^2 + x^2) * (x^2P_L^2 + r^2Q_L^2 - 2rxP_LQ_L + xQ_L) \geq 0 \tag{7}$$

Simplifying equation (6) or (7), we obtain

$$4[(xP_L - rQ_L)^2 + xQ_L + rP_L] \leq 1 \tag{8}$$

For a given radial distribution net work, the total real and reactive power can be computed as

$$P = \sum P_{LOSS} + \sum P_{LI} \tag{9}$$

$$Q = \sum Q_{LOSS} + \sum Q_{LI} \tag{10}$$

Where $\sum P_{LOSS}$ and $\sum Q_{LOSS}$ are the total real and reactive power losses in the system and $\sum P_{LI}$ & $\sum Q_{LI}$ are the total real and reactive loads, respectively.

By applying the single-line method for the reduction of distribution network, the occurrence of voltage collapse can be studied easily, and it is not necessary to consider every line of the network separately. By using the single-line method, the total real and reactive powers can be found as

$$P = r_{REQ}(P^2 + Q^2) + \sum P_{LI} \tag{11}$$

$$Q = x_{REQ}(P^2 + Q^2) + \sum Q_{LI} \tag{12}$$

Where r_{EQ} and x_{EQ} are the equivalent resistance and reactance, respectively, in the single line.

Recalling equation (8), the stability index L can be defined as

$$L = 4[(xP_L - rQ_L)^2 + xQ_L + rP_L]. \quad (13)$$

Hence, for a reduced single-line network, equation (13) can be rewritten as

$$L = 4[(x_{EQ}P_{EQ} - r_{EQ}Q_{EQ})^2 + x_{EQ}Q_{EQ} + r_{EQ}P_{EQ}]. \quad (14)$$

Where P_{leq} and Q_{leq} are the total real and reactive loads, respectively, in the distribution network. From equations (9) to (12), the equivalent resistance and reactance of a reduced single line network can be defined as

$$r_{EQ} = \frac{\sum P_{LOSS}}{\{(P_{EQ} + \sum P_{LOSS})^2 + (Q_{EQ} + \sum Q_{LOSS})^2\}} \quad (15)$$

$$x_{EQ} = \frac{\sum Q_{LOSS}}{\{(P_{EQ} + \sum P_{LOSS})^2 + (Q_{EQ} + \sum Q_{LOSS})^2\}} \quad (16)$$

It is noted that for a stable system, the value of stability index, L is very much less than 1; however, if the value of L approaches 1, this would indicate that the system is close to voltage collapse. If the network is loaded beyond this critical limit, the power becomes imaginary, and it is at this point that the voltage collapse occurs.

The efficient method of calculating L-index is by reducing the given power system network to a single line equivalent system. The basic algorithm can be described as follows:

1. Run the Load flow analysis program to obtain the values of bus voltages and complex powers.

2. Estimate:

$$r_{EQ} = \frac{\sum P_{LOSS}}{\{(P_{LEQ} + \sum P_{LOSS})^2 + (Q_{LEQ} + \sum Q_{LOSS})^2\}}$$

$$x_{EQ} = \frac{\sum Q_{LOSS}}{\{(P_{LEQ} + \sum P_{LOSS})^2 + (Q_{LEQ} + \sum Q_{LOSS})^2\}}$$

3. From the above values of r_{REQ} and x_{REQ} Estimate:

$$L = 4[(x_{EQ}P_{LEQ} - r_{EQ}Q_{LEQ})^2 + x_{EQ}Q_{LEQ} + r_{EQ}P_{LEQ}]$$

4. Estimate L for each switching combination.
5. Analyze the results and find out which switching combination gives the lowest value of L, i.e. the best voltage stability.

The main advantages of this algorithm is computation L-index involves losses so, if there any change in switching combination or if there is any load variation the losses will be affected and hence stability of the system will change.

IV. ARTIFICIAL NEURAL NETWORK

Neural networks include the capability to map the perplexed and extremely non-linear relationship between the load levels of zone and system topologies. This study adopts the multilayer feed forward which has the ability of not only handling the analog/binary input but also mapping complex input-output relationship with hidden layer.

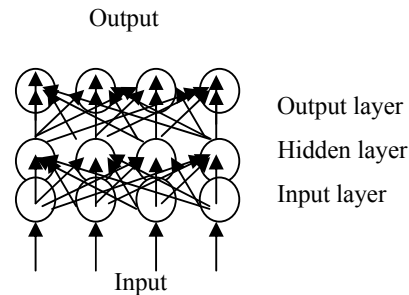


Fig2: Three Layer Feed-Forward Neural Network

Operation: $y_i = wx_i + b$

Its adaptation is defined through a cost function (error metric) of the residual $e = d_i - (b + wx_i)$ where d_i is the desired input. With the MSE error metric,

$$E = \frac{1}{2N} \sum_i^N e_i^2$$

The adapted weight and bias become:

$$b = \frac{\sum_i X_i^2 \sum_i d_i - \sum_i X_i \sum_i X_i d_i}{N(\sum_i (X_i - \bar{X})^2)}$$

and

$$W = \frac{\sum_i (X_i - \bar{X})(d_i - \bar{d})}{\sum_i (X_i - \bar{X})^2}$$

This is best utilized in the controls area. A single neuron with tap delayed inputs (the number of inputs is bounded by the lowest frequency present and the Nyquist rate) can be used to determine the higher order transfer function of a physical system via the bi-linear z-transform.

V. NETWORK RECONFIGURATION TECHNIQUE ON A STANDARD IEEE-14 BUS SYSTEM

Case study has been conducted on a modified IEEE-14 bus system. The standard IEEE-14 bus system has been modified with the addition of power lines which connect various buses in the power system by connection/disconnection switches. Also connection / disconnection switches have been placed in series with the existing lines. The system data are given in table1 and table2. The system under study is illustrated in fig1. By closing or opening a switch, a line can be added or removed from the system respectively. '0' indicate switch is open, '1' indicate switch is closed.

Network reconfiguration is done by two ways. One way is that, the original power system network is not changed but extra power lines are added to power network by connection/ disconnection switches. Another way of network reconfiguration is connection/ disconnection of already existing lines within the power network. Present work deals with addition of extra lines to the network.

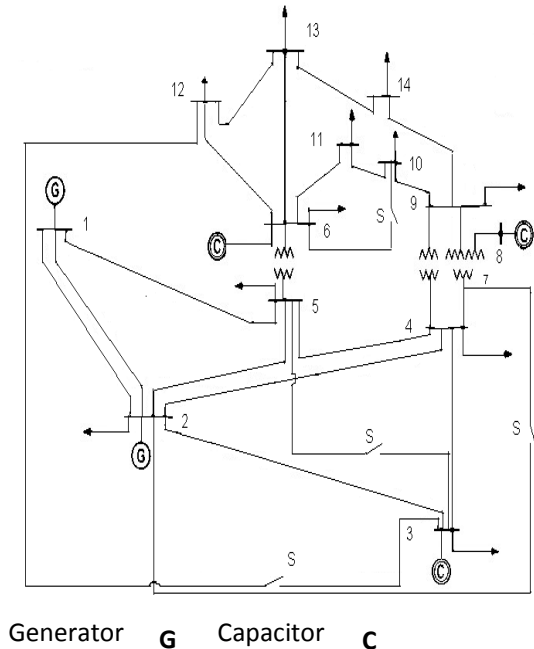


Fig3: Modified IEEE-14 Bus system

'S' Connection/disconnection switches (Additional power lines connected to the system for the purpose of network reconfiguration).

PROPOSED RECONFIGURATION SCHEME

Reconfiguration is the process of operating connection/disconnection switches(S) to change the circuit topology. Network reconfiguration is an operation in configuration management that determines the switching operations for improvement of the voltage stability with minimum loss condition. System reconfiguration means restructuring the power lines which connect various buses in the power system. Reconfiguration has been achieved by addition of three power lines to the existing network. The number of additional lines has been restricted to three owing to economic considerations as increasing the number of lines increases cost.

VI. DISCUSSION OF RESULTS

In normal condition or base configuration of the given system $S_1=0, S_2=0, S_3=0$ i.e. all the connection/disconnection switches are open. When $N=3$ nos. additional power lines are available, there may be $2^N=8$ different switching cases. All of these eight possible switching combinations have been studied, and each combination has been designated by a unique configuration number. For example the configuration code '1' indicates normal condition .In all cases of lines and switching combinations, their corresponding system configuration code with computed values of active power loss, reactive power loss and L-index values have been presented in the Chart1.

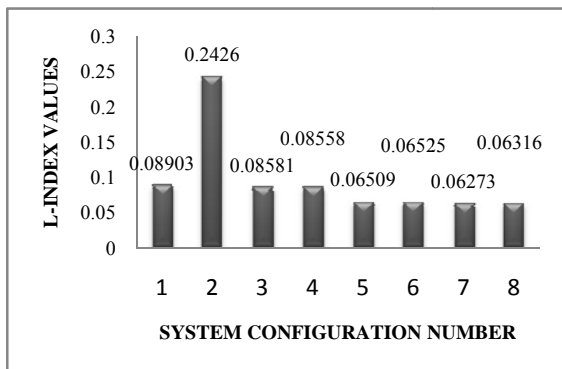
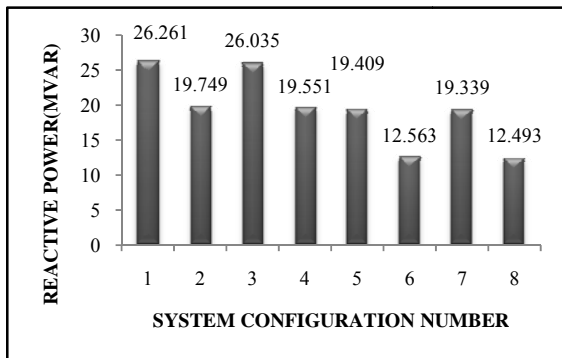
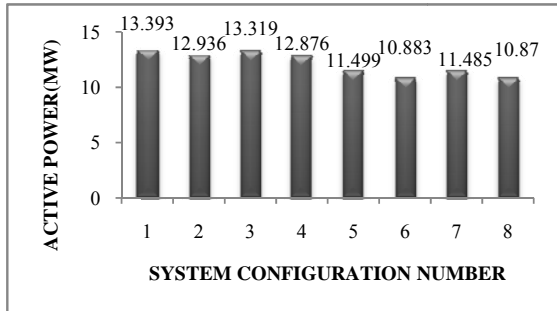
The computed L-index value for normal system configuration (configuration no. : 1), as observed from the Chart1 is 0.08903. Many alternative system configurations result lower value of L-index compared to the normal configuration, and hence can improve overall voltage stability. With simultaneous addition of all the three power lines ($S_1=1, S_2=1, S_3=1$; configuration no.: 8) the L-index value is reduced to 0.06316. With variation of load, the optimum switching combination also changes. The active and Reactive power losses are minimized to a great extent as seen from Tab.1.

Tab.1: Active and Reactive Power Losses in Optimum Condition

Under normal condition		After reconfiguration	
Real losses (MW)	Reactive losses (Mvar)	Real losses (MW)	Reactive losses (Mvar)
13.393	26.261	10.870	12.493

Optimum condition :System Configuration 8

Chart1:Active ,Reactive Power Loss and L-Index Values for Different System Configurations



VII. FEEDER RESTRUCTURING

Distribution systems are normally configured radially. From time to time, modifying the radial structure of the feeders by changing the ON/OFF status of the sectionalizing and tie switches to transfer loads from one feeder to another may significantly REDUCE the Distribution losses. Distribution systems normally have a combination of industrial, commercial,

residential and lighting loads. So, the peak load on the substation and feeders occurs at different times of the day, the systems become heavily loaded at certain times of the day, and lightly loaded at some other times. If the distribution loads are rescheduled more efficiently by network reconfiguration, efficiency of Distribution system can be improved. Reconfiguration also allows smoothening out the peak demands, improving the voltage profiles at the buses and increasing the network reliability.

VIII. APPLICATIONS

The concept of network reconfiguration can be successfully implemented in the existing real life electric transmission networks (at different voltage levels) as it was done for the standard IEEE 14 bus system (which yielded encouraging results;) in this project. When implemented, it shall reduce both the transmission line active and reactive power losses substantially and enhance the voltage stability of the system as well.

The network reconfiguration concept can be somewhat extended to conceive the concept of feeder reconfiguration in electric distribution networks to improve the reliability indices. It will be inconvenient to use load flow analysis here. However simulations to obtain the optimal configuration can be carried out using software like ETAP etc. There are other methods as well where efficient and effective computational tools like Genetic Algorithm, Artificial Neural Network (ANN), heuristic algorithms etc. are used for arriving to the optimal solution.

The results obtained from the load flow analysis demonstrate that corresponding to the various load conditions, there exist a unique optimal switching condition. Hence, sensors with in- built artificial intelligence incorporated in the electric system, shall continuously monitor the varying load conditions and give the command to the series- parallel combination of the load- sectionalizing and tie switches to select and operate the optimal switching condition.

Artificial Neural Networks are designed to two groups. The first level is to estimate the proper load level from the load data of each zone, and the second is to determine the appropriate system topology from the input load level.

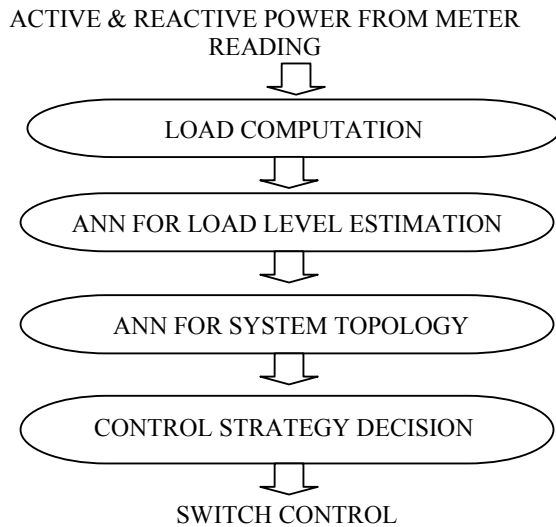


Fig. 4 : Control Strategy

IX. FUTURE WORK

Large scale implementations of network reconfiguration and feeder reconfiguration in power system. Small scale isolated power generation at the primary and secondary distribution levels to compensate for the losses incurred in transmission and distribution. Non – conventional sources of energy like solar energy, Small Hydro Projects (SHPs), Magneto Hydro Dynamic (MHD) generation can be utilized for providing the compensating electrical power. Extensive amount of power electronic devices can be used to minimize losses. Find out way to use of superconducting cables such as comprising an insulated superconducting wire cooled by liquid nitrogen. Methods for cooling superconducting materials include a method in which the superconducting material is formed into a braided wire having a structure similar to that of a coaxial cable, and the coolant is sealed inside the central hollow space of the superconducting material. This can no doubt bring a revolutionary change in the field of efficient electrical distribution of power. Losses will become negligible. Improved designs of the joints used in an electric system (like splice joints) to minimize the thermal losses that occur in the system. Aluminum alloys having improved electrical properties like lower resistivity, lower temperature- coefficient of resistance etc. to minimize the thermal losses in the ACSR and AAAC conductors.

X. ACKNOWLEDGMENTS

- [1] A.Chakrabarti, B.E. (Hons.), M.Tech(Power), Ph.D.(Tech.),C.Eng.,M.I.E. (I), M.I.E.E.E. (USA). Professor, Bengal Engineering & Science University, Shibpur.
- [2] Abhinandan De, B.E. (Electrical Engg.), M.E. (Electrical Engg.), Ph.D. (Engg.). Asst. Professor, Bengal Engineering & Science University, Shibpur.
- [3] Amalendu Bikash Choudhury, M.M.E Asst. Professor, Bengal Engineering & Science University, Shibpur.

REFERENCES

- [1] M.A.kashem, V.Ganapathy, G.B.Jasmon, “On-line Network Reconfiguration for enhancement of voltage stability in distribution systems using artificial neural networks”, *Electric power components and systems*, 29:361-373, 2001, copy right 2001 Taylor & Francis.
- [2] L.Ramesh, S.P.Chowdhury, S.Chowdhury,A.A. Natarajan, C.T.Gaunt “Minimization of Power Loss in Distribution Networks by Different Techniques” *International Journal of Electrical Power and Energy Systems Engineering* 2:1 2009.
- [3] Hugh Rudnick, Ildefonso Harnisch “Reconfiguration of electric distribution systems with a simplified power summation method”
- [4] M.A.kashem, V.Ganapathy, G.B.Jasmon, “Network Reconfiguration for enhancement of voltage stability in distribution systems”, *IEE Proc.-Gener Trunsm Dislrib.*, Vol. 147, No. 3, May 2000.
- [5] A.Y.Abdelaziz, M.M.Abu-Elnaga, M.A.Elsharkawy, “Voltage stability assessment of multi-machine power systems using energy function and neural networks techniques”, *Electric power components and systems*, 34:1313-1330, 2006, copy right Taylor & Francis.
- [6] S.Sivanagaraju, N.Visali, V.Sankar, T.Ramana, “Enhancing voltage stability of radial distribution systems by network reconfiguration”, *Electric power components and systems*, 33:539-550, 2005, copy right Taylor & Francis.
- [7] Ibrahim O.Habiballah, Chokri A.Belhadj, “Corrective schemes for voltage stability using two different indicators”, *Electric power components and systems*, 27:123-138, 1999, copy right 1999 Taylor & Francis, Inc.

- [8] Eaton, H.A.C. and T.L. Oliver (1992), Learning Coefficient Dependence on Training Set Size, *Neural Networks*, vol. 5, pp. 283-288.
- [9] Fahlman, S.E. (1988a), An Empirical Study of Learning Speed in Backpropagation Networks, *Carnegie Mellon Report*, No CMU-Cs, pp 88-162.
- [10] Fahlman, S.E. (1988b), Learning variations of Backpropagation-An Empirical study, *proc. of the 1988 Connectionist Models Summer School*, Morgan Kaufmann, San Mateo, CA.
- [11] Huang, S. and Y. Huang (1991), Bounds on the Number of Hidden Neurons in Multilayer Perceptrons, *IEEE Trans. on Neural Networks*, 2(1), pp. 47-55.
- [12] McInerney, M. and A.P. Dhawan (1993), Use of Genetic Algorithms with Backpropagation in Training of Feedforward Neural Networks, *IEEE Proceedings of the Intl. Conf. on Artificial Neural Networks and Genetic Algorithms*, Innsbruck, Springer-Verlag, Wien, pp. 203-208.
- [13] Rajasekaran, S. and G.A. Vijayalakshmi Pai (2004), *Neural Networks, Fuzzy Logic, and Genetic Algorithms Synthesis and Applications*, Prentice-Hall of India.
- [14] Rajasekaran, S. and G.A. Vijayalakshmi Pai (1996), Genetic Algorithm Based Weight Determination for Backpropagation Networks, *Proc. Trends in Computing*, Tata McGraw-Hill, pp. 73-80.
- [15] Zurada, J. M. (2003), *Introduction to Artificial Neural Systems*, Jaico Publishing House, Mumbai, India.
- [16] Y. Chauvin and D.E. Rumelhart, Eds., *Backpropagation: Theory, Architectures, and Applications*. Hillsdale, NJ: Erlbaum, 1995.
- [17] D. Shirmohammadi and H. W. Hong, "Reconfiguration of electric distribution networks for resistive losses reduction," *IEEE Trans. Power Delivery*, vol. 4, pp. 1402-1498, Apr. 1989.

