



A New Methods for Improved Voltage in Radial Distribution System

Mahdi Mozaffari Legha¹, Reza Seyfi²

¹Department of Power Engineering, Kahnooj Branch, Islamic Azad University, Kahnooj, Iran.

Email: mozaffarilegha.m@gmail.com

²Electricity Distribution Company, South of Kerman, Jiroft, Iran.

Email: Mafshar100@yahoo.com

Abstract: This research is aimed to optimal place and capacity of DGs to reduce losses, improve voltage profile and reduce network. To obtain these goals the resources capacity and the installation place are of a crucial importance. In this paper a new method is proposed to find the optimal and simultaneous place and capacity of these resources to reduce losses, improve voltage profile and reduce network harmonics and reduce network harmonics. The advantage of Fireworks Algorithm (FWA) is that it does not require external parameters such as cross over rate and mutation rate as in case of genetic algorithm and differential evolution and it is hard to determine these parameters in prior. To demonstrate the validity of the proposed algorithm, computer simulations are carried out on power network and the simulation results are presented and discussed.

Key words: Fireworks Algorithm (FWA), voltage profile, DGs

INTRODUCTION

Power loss reduction and voltage profile improvement are goals for electricity utilities. Distribution system reconfiguration and optimal capacitor placement are two of the low Cost available tools for Power loss reduction and voltage profile improvement. Reconfiguring the network means altering its topology by changing the status of normally opened and normally closed switches. This paper propose the optimal place and capacity of DGs to reduce losses, improve voltage profile to actual power distribution network. Distribution system is the final link between high voltage transmission systems and consumers which transport the electric energy from bulk substation to many services or loads, thus causes more power and energy losses. Hence there is a need to reduce the system losses. By minimizing the power losses, the system may acquire longer life span and has greater reliability. Feeder reconfiguration is a very important tool to operate the distribution system at minimum cost and improve the system reliability and security. The reconfiguration of a distribution system is a process, which alters the feeder topological structure by changing the open/close status of the switches in the distribution system. Two types of switches, normally closed switches (sectionalizing switches) and normally open switches (tie switches), are used in primary distribution systems for protection and configuration management. Distribution network reconfiguration for loss reduction is a complicated combinatorial, non-differentiable, constrained optimization problem since the reconfiguration involves many candidate switching combinations. Several papers have considered the problem of optimal network reconfiguration using different optimization techniques.

Merlin and Back [1] introduced the concept of changing the topology of distribution systems for loss minimization. They proposed a branch and bound method. Searching for a minimum loss operating spanning tree configuration for urban power distribution System, is presented in [2]. Branch exchange method and derived a simple formulate to estimate the loss reduction is presented in [3]. The heuristic algorithms that are

based on optimum power flow are reported in [4] and developed in [5]. The power loss reduction and load balancing reconfiguration problem is formulated as an integer programming method presented in [6]. In [7], an algorithm has been proposed to obtain switch pattern as a function of time. Determine a configuration with minimal power losses using a genetic algorithm (GA) has been proposed in [8]. An improved genetic algorithm based on fuzzy multi-objective approach has been suggested in [9] to solve the problem. A method based on binary particle swarm optimization (BPSO) algorithm is presented in [11]. An algorithm based on the heuristic rules and fuzzy multi objective approach for optimizing network configuration is presented in [11]. Ant colony search algorithm (ACSA) to solve the reconfiguration problem presented in [12]. The network reconfiguration problem has been solved by a harmony search algorithm (HSA) presented in [13]. Multi-objective quantum-inspired artificial immune system approach for optimal network reconfiguration in distribution system is presented in [14] and distribution systems reconfiguration using ant colony optimization and harmony search algorithms presented in [15]. In this paper to solve the reconfiguration problem in distribution systems the plant grows simulation algorithm (PGSA), is used

The capacitor placement problem is the determination of the location, number and sizes of capacitors to be placed on a radial distribution system in an optimal manner. Several papers have considered the problem of optimal capacitor placement using different optimization techniques. Grainger and Lee [16–18] formulated the problem using a non-linear programming model and solved it by simple iterative procedures based on gradient search. Dynamic programming was also used to solve the capacitor placement problem in [19]. The optimal placement of fixed and switchable capacitors in radial distribution networks considering time varying load and load uncertainty based on a proposed genetic algorithm (GA) method is presented in [21]. Optimal capacitor placement using modified differential evolution (DE) algorithm is presented in [21]. Attia et al. proposed an approach based on artificial bee colony algorithm to allocate static capacitors along radial distribution networks [22]. Teaching Learning Based Optimization (TLBO) approach to minimize power loss and energy cost by optimal placement of capacitors in radial distribution systems is presented in [23].

II. Power Loss Reduction

Typically, power losses in distribution system highly regarded for power utility companies because, the losses, reducing the efficiency of energy transfer to the consumers and the economic losses caused by the power losses, imposed on electricity companies. Various solutions have been proposed to reduce the losses in the distribution system. Optimal network reconfiguration is well suited solution to loss reduction [1]. An other practical ways to loss reduction is optimal capacitor installation in the distribution systems [25].

III. Voltage Profile Improvement

Due to the loads variable in the distribution systems and changing time to time, and also due to the radial structure of power distribution system, most consumers in the end of radial systems, has not desired voltage level. One of the main purposes of the distribution system operators is providing desirable voltage level for consumers. DG and capacitor installation in the distribution system can help to improve the voltage profile. Voltage variations in the distribution system must be control in specified range (+7% _ 13%) [26].

IV. Formulation

In this paper, the objective is to minimize the system power loss under a certain load pattern through network optimization while electrical and operational constraints are met, that is the process of altering the topological structures of distribution network by changing the open/closed status of switches so as to minimize total system real power loss. The objective function of the problem is,

$$\text{Minimiz } P_{loss} = \sum_{i=1}^{nl} R_j \frac{P_j^2 + Q_j^2}{V_j^2} \quad (1)$$

The branch's capacity and voltage magnitude at each branch and each bus must be maintained within limits. These constraints are expressed as follows:

For any branch

$$S_j \leq S_{j,max}$$

For any bus : $|V_{i,min}| \leq |V_i| \leq |V_{i,max}|$

The power flows are computed by the following set of simplified recursive equations derived from the single-line diagram depicted in Fig. 1.

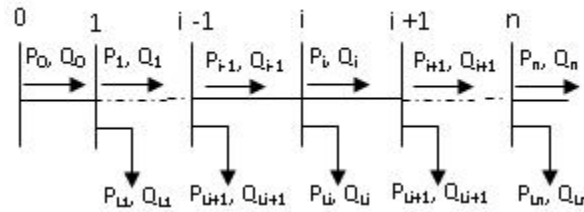


Figure 1: Single line diagram of main feeder

$$P_{i+1} = P_i - P_{Li+1} - R_{ij+1} \frac{P_i^2 + Q_i^2}{|V_i|^2}$$

$$Q_{i+1} = Q_i - Q_{Li+1} - X_{ij+1} \frac{P_i^2 + Q_i^2}{|V_i|^2}$$

$$|V_i|^2 = |V_i|^2 - 2(R_{ij+1} P_i + X_{ij+1} Q_i) + (R_{ij+1}^2 + X_{ij+1}^2) \times \frac{P_i^2 + Q_i^2}{|V_i|^2}$$

Where P_i and Q_i are the real and reactive powers flowing out of bus i , and P_{Li} and Q_{Li} are the real and reactive load powers at bus i . The resistance and reactance of the line section between buses i and $i+1$ are denoted by $R_{i,i+1}$ and $X_{i,i+1}$ respectively. The power loss of the line section connecting buses i and $i+1$ may be computed as

$$P_{Loss}(i, i + 1) = R_{i,i+1} \frac{P_i^2 + Q_i^2}{|V_i|^2}$$

The total power loss of the feeder, P_T^{LOSS} may then be determined by summing up the losses of all line sections of the feeder, which is given as

$$P_T^{LOSS} = \sum_{i=0}^{n-1} P_{Loss}(i, i + 1)$$

Considering the practical capacitors, there exists a finite number of standard sizes which are integer multiples of the smallest size Q_0 . Besides, the cost per Kvar varies from one size to another. In general, capacitors of larger size have lower unit prices. The available capacitor size is usually limited to

$$Q_c^{max} = LQ_c$$

Therefore, for each installation location, there are L capacitor sizes $\{1Q_c, 2Q_c, 3Q_c, \dots, LQ_c\}$ available. Given the annual installation cost for each compensated bus, the total cost due to capacitor placement and power loss change is written as

$$COST = K_p \times P_T^{LOSS} + \sum_i^c (K_{cf} + K_i^c Q_i^c)$$

Where n is number of candidate locations for capacitor placement, K_p is the equivalent annual cost per unit of power loss in $\$/(\text{kW}\cdot\text{year})$; K_{cf} is the fixed cost for the capacitor placement. Constant K_i^c is the annual capacitor installation cost, and, $i = 1, 2, \dots, n$ are the indices of the buses selected for compensation. The bus reactive compensation power is limited to

$$Q_i^c \leq \sum_{i=1}^n Q_{Li}$$

Where $1Q_c$ and LQ_c are the reactive power compensated at bus i and the reactive load power at bus i , respectively. THD index presents the impact of the harmonics on network and is considered in the objective function according to the following equation

V. Power Flow

The Backward Sweep calculates the current injected into each branch as a function of the end node voltages. It performs a current summation while updating voltages. Bus voltages at the end nodes are initialized for the first iteration. Starting at the end buses, each branch is traversed toward the source bus updating the voltage and calculating the current injected into each bus. These calculated currents are stored and used in the subsequent Forward Sweep calculations. The calculated source voltage is used for mismatch calculation as the termination criteria by comparing it to the specified source voltage. The Forward Sweep calculates node voltages as a function of the currents injected into each bus. The Forward Sweep is a voltage drop calculation with the constraint that the source voltage used is the specified nominal voltage at the beginning of each forward sweep. The voltage is calculated at each bus, beginning at the source bus and traversing out to the end buses using the currents calculated in previous the Backward Sweep [12]. Single line diagram of main feeder depicted in Fig 2.

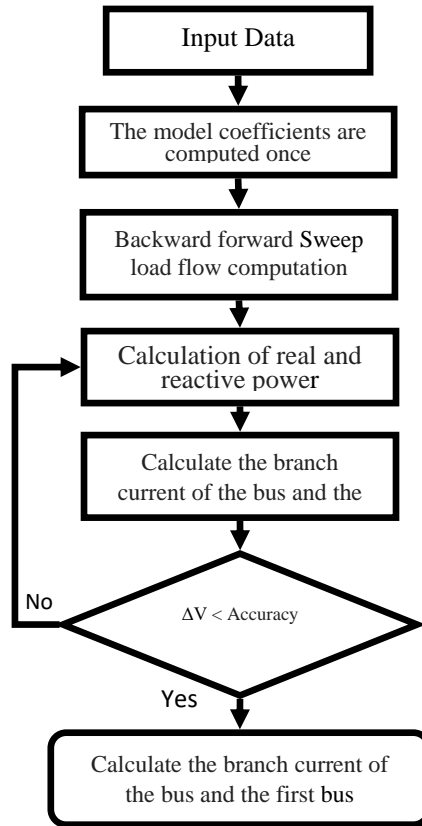


Fig 2. Single line diagram of main feeder

VI. Fireworks Algorithm (FWA)

Optimization Problems have being one of major problems and can be found everywhere, especially in the academy field and industrial world. To solve these kind problems, many methods have been proposed. Recently Swarm Intelligence (SI) optimization has been a very hot subject and method for optimization problems and showed its great success. James Kennedy defined it as follows: " Swarm intelligence refers to a kind of problem-solving ability that emerges in the interactions of simple information-processing units.[3]" The units that build up the swarm can be living creature and also can be lifeless bodies. In the years since the introduction of Swarm Intelligence, SI has a number of branches with a number of researchers exploring the concepts, behavior, cognition underlie the nature and made great contribution to these fields, such as, Particle Swarm Optimization (PSO)[4], Ant Colony Optimization (ACO)[5], Genetic Algorithm (GA)[6] and Fish School Search (FSS)[7]. In PSO algorithms, it simulates the behavior of" searching food among flocks" who share the social information, previous experiences among the swarm and individuals.

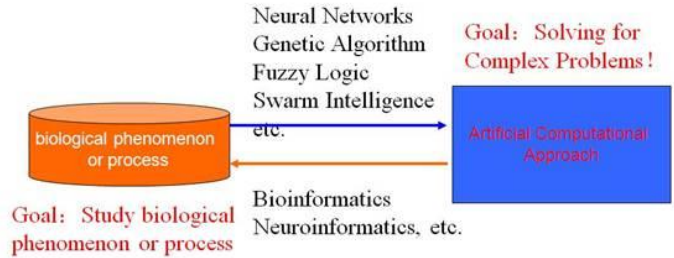


Fig 3. From Biological phenomenon or process to Artificial Computational Approach

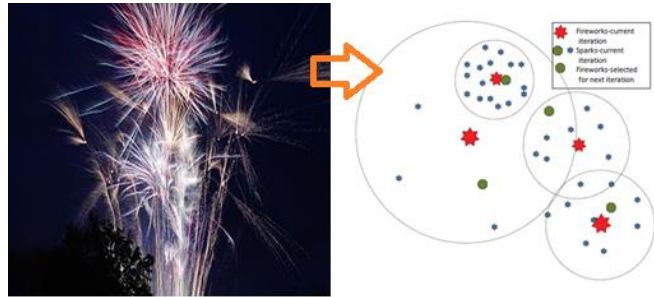


Fig 4. Mathematical Modeling Process of Fireworks Algorithm

When a firework is set off, a shower of sparks will fill the local space around the firework. In our opinion, the explosion process of a firework can be viewed as a search in the local space around a specific point where the firework is set off through the sparks generated in the explosion. Mimicking the process of setting fireworks, a rough framework of the FA is depicted in Fig. 5.

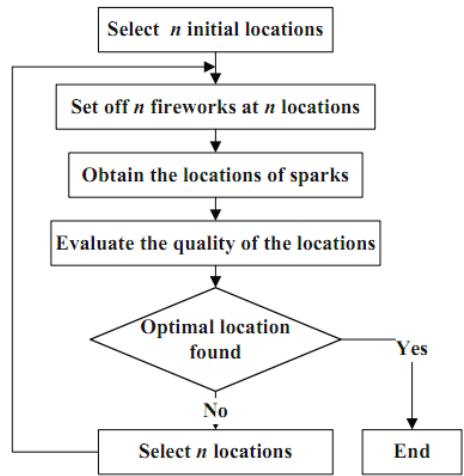


Fig 5. Framework of fireworks algorithm

VII. Test Results

To study the proposed method, power network. Figure 6 illustrates the single-line diagram of this network.

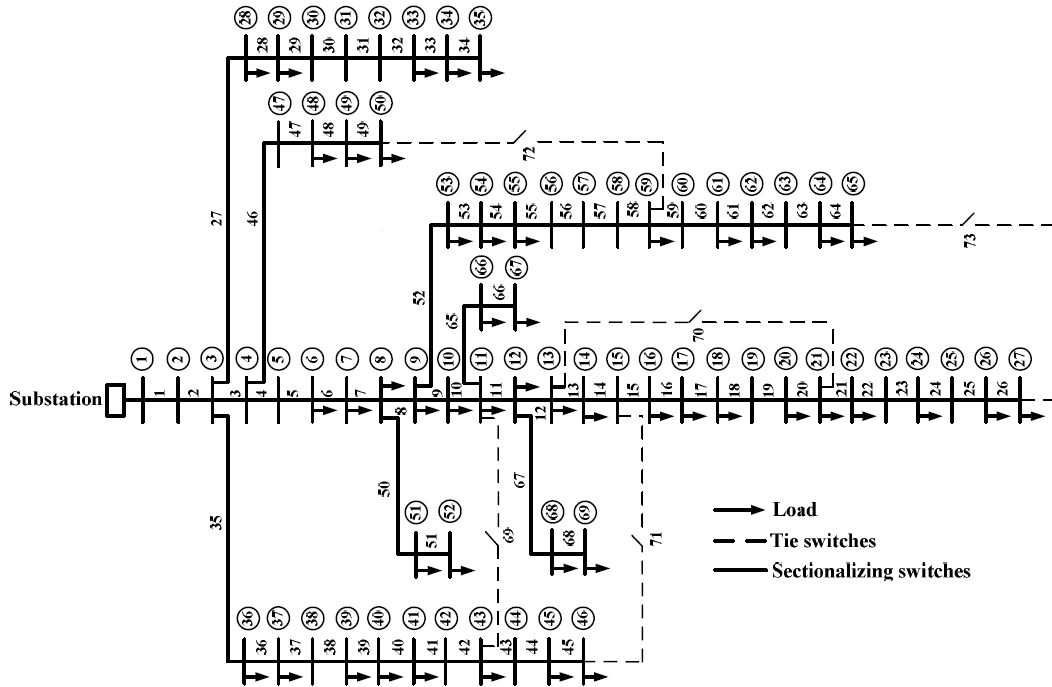


Figure 6: Single-line diagram of actual power network

Initially, a load flow was run for the case study in both fundamental frequency and harmonics frequencies without installation of capacitor. The base values of the system are taken as 20kV and 45MVA. The results of conductor selection are shown in Figure 7 and 8.

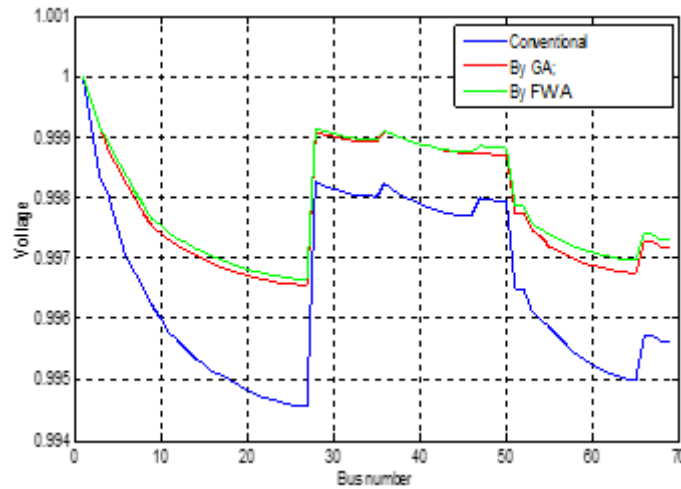


Figure 7: Voltage profiles of 69-bus system

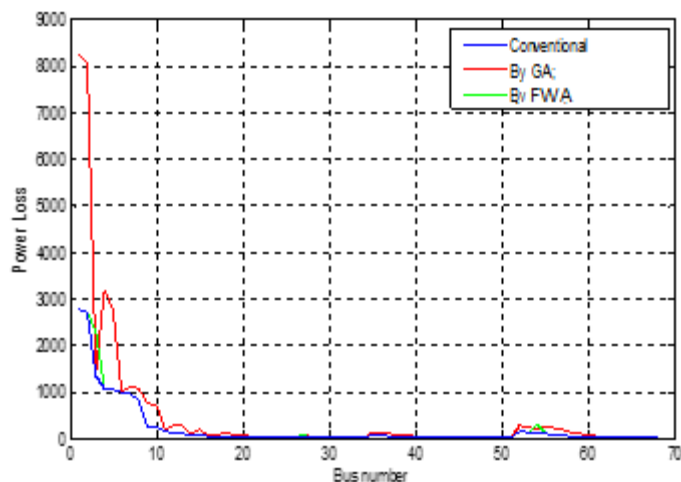


Figure 8: Peak power loss profiles in each branch

In addition, capacity produced of all the units are less than the reactive load of the network. The following figure depicts the voltage of distribution buses, before and after installing five DG resources and clarifies the impact of these resources on voltage profile.

VIII. Conclusion

In the present paper, a new population based fireworks algorithm (FWA) has been proposed to solve capacitor placement problem in distribution system. Simulations are carried on actual power network of Kerman Province, Iran. The results obtained by the proposed method outperform the other methods in terms of quality of the solution and computation efficiency. The main advantage of FWA algorithm is that it does not require external parameters such as cross over rate and mutation rate etc, as in case of genetic algorithms, differential evolution and other evolutionary algorithms and these are hard to determine in prior. The other advantage is that the global search ability in the algorithm is implemented by introducing neighborhood source production mechanism which is a similar to mutation process.

References

- [1]A. Merlin and H. Back. (1975). Search for a minimum loss operating spanning tree configuration for urban power distribution System. Proc1975 2th Power Syst. Computation Conf. (PSCC). Cambridge, U.K. Paper 1,2/6
- [2]D.Shirmohammadi and H. W. Hong (1989). Reconfiguration of electric distribution networks for resistive line loss reduction. IEEE Trans. Power Del. Vol. 4. No. 1. pp. 1492-1498
- [3]S. Civanlar et al. (1992). Distribution feeder reconfiguration for loss reduction. IEEE Trans. Power Del. Vol. 3. pp. 1217-1223
- [4]S. K. Goswami AND S. K. Basu. (1992). A new algorithm for the reconfiguration of distribution feeders for loss minimization. IEEE Trans. Power Del. Vol. 7. No. 3. pp. 1484-1491
- [5]F. V. Gomes et al.(2002). A new distribution system reconfiguration approach using optimum power flow and sensitivity analysis for loss reduction. IEEE Trans. Power Syst. Vol. 21. No. 4. pp. 1616-1623
- [6]Baran et al. (1989). Network reconfiguration in distribution systems for loss reduction and load balancing. IEEE Trans. Power Deliv. 4(2). 1401-1407
- [7]Broadwater et al. (1993).Time varying load analysis to reduce distribution losses through reconfiguration. IEEE Trans. Power Deliv. 8(1). 294-300
- [8]Nara et al. (1992). Implementation of genetic algorithm for distribution systems loss minimum reconfiguration. IEEE Trans. Power Syst. 7. 1044-1051
- [9]Huang And Y.-C. (2002). Enhanced genetic algorithm-based fuzzy multi objective approach to distribution network reconfiguration. Gen Transm. Distrib. IEEE Proc.149(5).615-620

- [10] Jin et al. (2004). Distribution network reconfiguration for load balancing using binary particle swarm optimization. International Conference on power system technology (POWERCON 2004). Singapore. pp. 507-510
- [11] M. Mozaffari Legha, (2011) Determination of exhaustion and junction of in distribution network and its loss maximum, due to geographical condition, MS.c Thesis. Islamic Azad University, Saveh Branch, Markazi Province, Iran.
- [12] M. Sharafi, H. Samet, Abdollah Kavousifard, Mahdi Sharafi, Mohammad Reza Rahmati; "Optimal Conductor Selection of Radial Distribution Networks Using PSO Method" CIRED Regional – Iran, Tehran, 13-14 Jan 2013; Paper No:12-E-500-0317.
- [13] Mahmood Joorabian, Ehsan Afzalan; "Optimal Selection of Conductors Using Colonial Selection Algorithm (CSA) for productivity Improvement Radial Distribution Systems," 28th, Power System Conference - 2013 Tehran, Iran
- [14] M. Mozaffari Legha,; "Optimal Conductor Selection of Radial Distribution Networks Using GA Method" CIRED Regional – Iran, Tehran, 13-14 Jan 2013; Paper No: 12-F-500-0320.
- [18] MAHDI MOZAFFARI LEGHA, ROUHOLLAH ABDOLLAHZADEH SANGROOD, ARDALAN ZARGAR RAEISZADEH, MOHAMMAD MOZAFFARI LEGHA, "A PRACTICAL APPROACH TO THE CONDUCTOR SIZE SELECTION IN PLANNING RADIAL DISTRIBUTION SYSTEMS FOR PRODUCTIVITY IMPROVEMENT USING ICA APPROACH", INTERNATIONAL JOURNAL ON TECHNICAL AND PHYSICAL PROBLEMS OF ENGINEERING (IJTPE), ISSUE 15, VOL. 5, NO. 2, PP. 1-5, JUNE 2013
- [15] D. Das. (2006). A fuzzy multiobjective approach for network reconfiguration of distribution systems. IEEE Trans. Power Del. Vol. 21. No. 1. pp. 202-209
- [16] Su et al. (2005). Distribution network reconfiguration for loss reduction by ant colony search algorithm. Electr. Power Syst. Res. 75(2-3).190-199
- [17] Srinivasa Rao et al. (2011). Optimal network reconfiguration of large-scale distribution system using harmony search algorithm. IEEE Trans. Power Syst. 5. 1080-1088
- [18] N. H. Ahmad et al. (2012). Multi-objective quantum-inspired Artificial Immune System approach for optimal network reconfiguration in distribution system. In 2012 IEEE Int. Power Engineering and Optimization Conf. pp. 384-388
- [19] M. Dorigo, V. Maniezzo and A. Colorni (1996). Ant system: optimization by a colony of cooperating agents. Systems, Man, and Cybernetics, Part B: Cybernetics, IEEE Transactions on, Volume: 26, Issue: 1, pp. 29-41.
- [20] J. Holland (1975). Adaptation in natural and artificial systems. University of Michigan Press, Ann Arbor.
- [21] C. J. A. B. Filho, F. B. de Lima Neto, A. J. C. C. Lins, A. I. S. Nascimento and M. P. Lima (2008). A novel search algorithm based on fish school behavior. Proceedings of the IEEE International Conference on Systems, Man and Cybernetics. pp. 2646-2651
- [22] Andreas Janecek* and Ying Tan, Swarm Intelligence for Non-negative Matrix Factorization, IJSIR 2011
- [23] Andreas Janecek* and Ying Tan, Using population based algorithms for initializing nonnegative matrix factorization, ICSI 2011, Part II, LNCS 6729, pp. 307–316, 2011.