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Evolutionary Symbiotic Organisms Search Technique in Power Scheduling for Loss Control in Power Transmission System

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ABSTRACT

This paper introduces Evolutionary Symbiotic Organisms Search (ESOS) as an optimizing method for loss minimization in power system. It is inspired by the evolution and interactions between organisms to survive in the ecosystem. Symbiotic Organisms Search (SOS) integrated with Evolutionary Programming (EP) is proposed for solving power scheduling problem in the attempt to control the loss values in electric power system. In this study, SOS algorithm was improvised by adding the element of EP in the determination of best combination of power scheduling in loss minimization. The technique is tested on IEEE 30-Bus Reliability System (RTS) to improve the power loss. To realize the effectiveness of the proposed ESOS technique, several scenarios were considered involving several generator units to participate in the scheduling scheme. Results from the study revealed that the proposed ESOS technique is superior than the traditional EP and SOS. This is quite convincing for further implementation in a larger system or complicated problems such as multi-objective optimization schemes.

Key words: Evolutionary programming, loss minimization, loss control, symbiotic organism search.

1. INTRODUCTION

The progressive increase in electrical demand has resulted to decrease voltage stability and increase in transmission loss in a power system. The system will be forced to operate close to its point of collapse in order to serve the load, making the system to be in a stress condition. It is important to have generator coordination strategy and to adopt optimal plan to utilize the generator efficiently. These problems can be addressed by applying the right solution. Apart from adding distributed generation (DG) module to control system loss [1], system loss can be reduced by performing reactive power planning which involves optimization process to the system. In order to perform optimization, some measures need to be considered to support the reactive power loading so that the minimization process can be executed efficiently. The determination of optimal sizing of the compensating devices involved optimization techniques as reported in [2-7]. The optimization techniques are able to identify the optimal sizing and locations of the related compensating devices, as implemented in power system network. There a few ways to support the reactive power; two popular methods are by Optimal Reactive Power Dispatch (ORPD) and optimal transformer tap changer setting (ORTS).

The word ‘Symbiosis’ originates from Greek words which means ‘living together’ to define the relationship between organisms that are depending on each other for survival [8]. The symbiotic relationship can be generally divided into two types which obligates and facultative. Both types are interdependent. However, facultative type does not necessarily need to depend on other organisms for survival. In nature, there are 3 classes of symbiotic relationship; Mutualism, Commensalism and Parasitism. Mutualism is a relationship that benefits both parties or species, can be known as win-win relationship. Commensalism is a relationship that benefit one side but do not benefit nor harm the other species while Parasitism benefits one side but giving harm to the other species [9-11]. The Symbiotic Organisms Search (SOS) was recently come into the optimization technology development. is an effective meta heuristic algorithm that mimic the symbiotic relationship among living things. In this study, cascaded versions involving evolution-based algorithms in optimizing power system problems such as SOS, AIs and EP is proposed [12-13]. Unlike other meta heuristic algorithms such as PSO, flower pollination algorithm and bat algorithm that also mimic natural phenomena behavior, SOS replicates the relationship or symbiotic interactions between organisms to find the fittest organism in the search space. SOS algorithms commences with an initial population of organisms of the ecosystem. Each organism will be considered as candidate to the specified problem and correlated to a certain fitness value which represents degree of adaptation to the desired objective. The symbiotic interactions between two organisms in the ecosystem which includes mutualism, commensalism and parasitism, new solutions led to the production of result in this process. Each organism in the ecosystem will be made randomly interact with each other through all classes of symbiotic relations and this process of interactions will be repeated until the termination criterion is fulfilled.

Evolutionary programming is one of the optimization techniques in solving optimization problem popularly employed in power system [14-16]. It is a fraction of Evolutionary Computation under Artificial Intelligence field. Evolutionary Programming (EP), Genetic Algorithm (GA), Genetic Programming and Evolutionary Strategy (ES) are optimization methods under Evolutionary Computation [16]. All of these techniques could solve Reactive Power Planning (RPP) problem but this particular study will be focusing on cascading EP with other techniques to see the outcome of the combined techniques.

Optimization is an important process to find the suitable system operation and planning particularly to maintain voltage stability in a power system. Other than EC, there are many techniques proposed by other researchers to perform optimization in solving RPP in power system. Examples of these techniques are Simulated Annealing (SA) and Particle Swarm Optimization (PSO) [17-18]. In reference [28], hybrid of PSO and SA was proposed to improve the simulation timing and premature convergence suffered by PSO. The difference between other techniques and EC is that EC is based on natural evolution.

Reference [2] proposed Quantum Genetic Algorithm (QGA) as reactive power optimization technique using Genetic Algorithm based on Quantum Computing (QC). It uses quantum bit coding, whole interference crossover and quantum gate as update operator to complete the evolution. Other than that, reference proposed to use Multi-Objective Particle Swarm Optimization algorithm to improve active power loss and voltage divergence. MOPSO have a special mutation that could enhance the exploration of the algorithm and improve the diversity of Pareto solutions. Reference [22-26] proposed an evolutionary programming method to solve the reactive power planning problem and comparing it to a nonlinear programming method. The results of the comparative study show that EP was better for power system planning compared to nonlinear programming by using traditional gradient-based optimization method.

Simulation can be conducted using IEEE Reliability Test System (RTS) to exhibit the effectiveness of the programming and repetitive load flow program was put into practice for fitness computation of EP. In Evolutionary approaches to multi-objective optimization, a study conducted by Carlos, M. Fonseca and Fleming stated the differences between Pareto and non-Pareto concept. Pareto concept is vectors that their components cannot be all simultaneously improved. Whereas the opposite of this will be known as non-Pareto concept. Pareto optimal solutions also known as non-dominated, non-inferior solution [3].

Pareto based optimization was first introduced by Goldberg (1989), the idea was to assign equal probability of reproduction to all non-dominated individuals in the population by assigning rank 1 to the non-dominated individuals and removing them from contention then proceed with finding new individuals. Then the new set will be classified as rank 2 and so on and so forth. Fonseca and Fleming proposed that an individual rank corresponds to the number of individuals in the particular population by which it dominated. Combining Pareto with partial difference information in the form of goal vector. While the basic ranking scheme remains unaltered [26]. Non-pareto based optimization on the other hand, the first introduction to optimizing objectives separately in EA was introduced by Schaffer in his approach known as the Vector Evaluated Genetic Algorithm (VEGA). Next generation that were selected from a whole of old generation with appropriate fractions according to each of the objectives separately. Fourman *et al.* [9] stated that, selection process was performed by comparing pair individuals, each pair according to one of the objectives. Research study made by Kursawe in [19], formulated a multi-objective version of Evolutionary Strategies (ES). Selection consists as many steps as number of objectives. At each step, one objective was selected randomly according to a probability vector and used to dictate the deletion of an appropriate fraction of the current population [17]. After selection, survivors become parents for next generation. This paper presents Evolutionary Symbiotic Organisms Search Technique in Power Scheduling for Loss Control in Power Transmission System. Optimal Power Scheduling is implemented for loss control in power system. Symbiotic Organisms Search (SOS) is integrated with Evolutionary Programming (EP) to derive the Evolutionary Symbiotic Organisms Search (ESOS). The proposed technique was implemented in the loss control scheme; conducted on the IEEE 30-Bus reliability test system (RTS). Results obtained from the study, compared with the traditional EP and SOS revealed that the proposed ESOS is reliable and feasible for loss control scheme.

2. RESEARCH METHODOLOGY

In this study, the traditional Evolutionary Programming (EP) was embedded into the main Symbiotic Organism Search

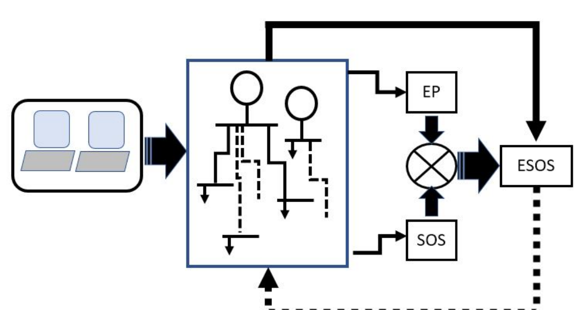

Figure 1: The proposed Configuration of ESOS for Power Transmission Control Centre

(SOS) algorithm to alleviate the setback experienced in the traditional SOS. The integrated EP-SOS derives ESOS and will be used to control the transmission system loss as depicted in Figure 1. Apparently, power system data are collected by the power system control centre for monitoring and data collection. Input data are also sent to the EP, SOS and ESOS algorithms for performing the offline studies of power system compensation. Figure 2 shows the flowchart of the methodology of Evolutionary Symbiotic Organisms Search in loss study being carried out.

Figure 3 shows the SOS flowchart without Parasitism phase. It begins with pre-optimization of the system to recognize the pre-optimized losses. In this technique, the conventional SOS algorithm is implemented to solve the power scheduling as an independent technique; without any modification. This is used as the first benchmark technique so that the setback or weakness of it can be highlighted.

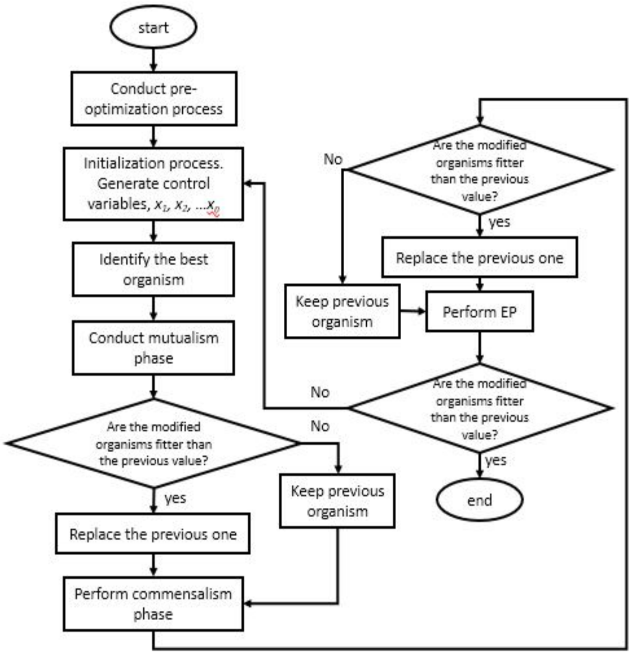

Figure 2: Flowchart of Evolutionary SOS

2.1. Mutualism Phase

Mutualism in ecosystem is a type of relationship that benefits two or more organisms that involved in the relationship. In this program X_i is selected as i^{th} organism in the ecosystem which will interact with X_i, an organism selected randomly from the ecosystem. In order to exhibit the mutual survival advantage between the organism, the mutual vector can be calculated as shown in (1):

$$Mutual\ vector = \frac{X_i + X_j}{2} \quad (1)$$

The product of new organisms *i* and *j* depend on the value of Mutual Vector and Benefit Factor. Benefit Factors evaluate the level of benefit to each organism whether the organisms benefit partially or fully from the relationship. These new

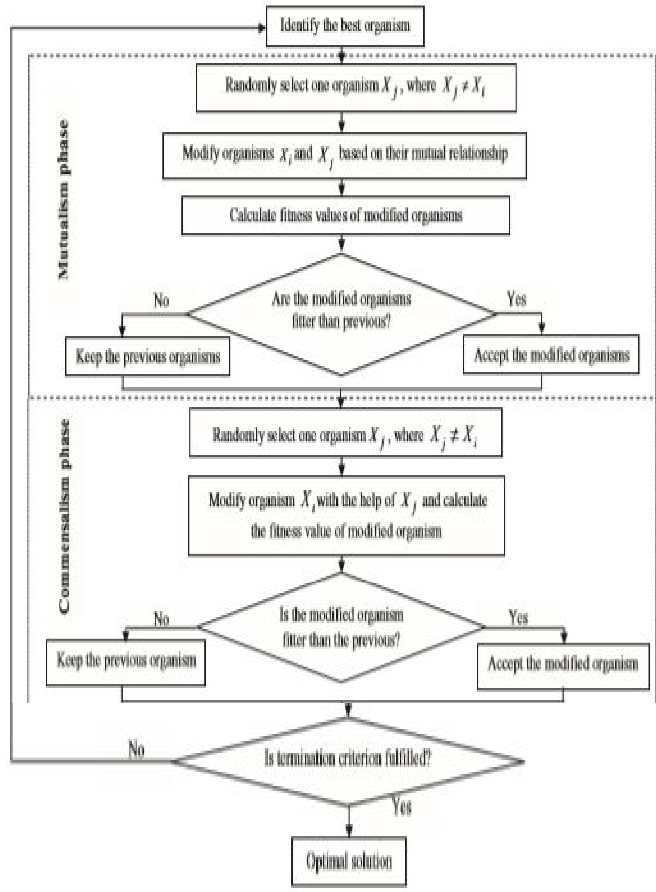

Figure 3: Flowchart of the modified SOS (without Parasitism Phase)

organisms will be tested to see whether they produce better fitness or not. If they produce better fitness, the new organisms will replace the old one. If they do not improve the fitness, the

old organisms will be kept. The production of new organisms in mutualism phase can be represented below:

$$X_{i\_new} = X_i + rand(0,1) \times (X_{best} - Mutual\_Vector \times BF_1) \quad (2)$$

$$X_{j\_new} = X_j + rand(0,1) \times (X_{best} - Mutual\_Vector \times BF_2) \quad (3)$$

2.2. Commensalism Phase

Commensalism relationship offers benefits to only one side of a relationship without causing harm to the other or will not be affected. Example, the relationship between a spider and tree or herbs. Spiders can build their web on the tree to trap insects. This way the spider could get its food and at the same time the spider's web will not cause any disadvantages or advantages towards the tree or herbs. The new individual of X_i will be generated using the following formula:

$$X_{i\_new} = X_i + rand(-1,1) \times (X_{best} - X_j) \quad (4)$$

2.3. Evolutionary Programming

Evolutionary Programming provides solution by evolving a population of candidates over several generations. The process involved in Evolutionary Programming are mutation and selection tournament. Fitness computation is conducted twice; which makes use the parents and offspring populations in 2 independents processes. The computations of fitness values depend on the number individuals generated during the initialization process. In the earlier initialization process, control variables are randomly generated based on the normal gaussian distribution. The number of control variables determine how many generators to be scheduled in this study. 20 individuals are the size of population as far as EP is concerned.

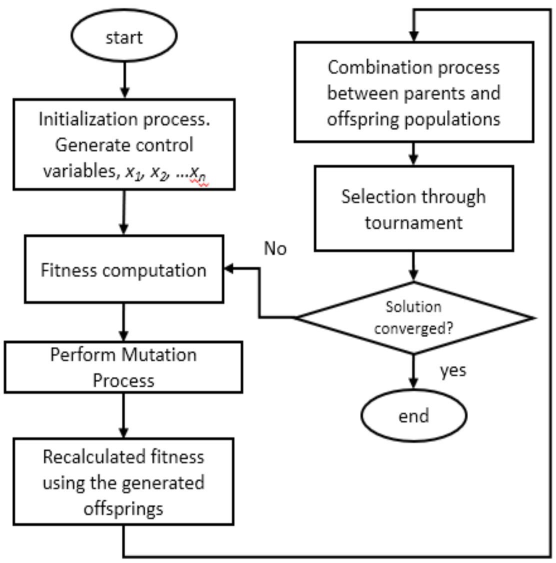

Figure 4: General Flowchart of Traditional EP

EP was added to replace parasitism phase. This adds the evolution elements in the system. As evolution is a part of survival, the addition of this element was expected to produce better results. The process continues from commensalism phase, and the candidates are referred as parents. In EP, the parents will go through mutation process and produce new sets of solution referred as offspring. The fitness of these offspring will then be tested. The mutation of the parents can be conducted as follow:

$$X_{mutated\_parents} = X_{parents} + N(0,\beta\,(X_{jmax} - X_{jmin}) \times (fitness\_i \div fitness\_max) \quad (5)$$

N is the gaussian random variable number, β is the mutation scale where $0<\beta<1$. The value of mutation scale can be adjusted to achieve better convergence.

2.4. Pseudo Codes

The computational procedure of the flowchart can be written in pseudo-code below:

```
%% Pseudo code of Evolutionary SOS algorithm
Define objective function f(x); x = (x1, x2,…, xd)
Initialize an ecosystem of n organisms with random solutions
While iter < max_iter
   For i = 1:n
    Find the best organism Xbest in the ecosystem
   % mutualism phase
   Randomly select one organism Xj, where Xj ≠ Xi
          Determine Mutual Vector and Benefit Factor
   Modify organisms Xi and Xj.
          If modified organisms give better fitness values then
          update them in the ecosystem.
   % commensalism phase
   Randomly select one organism Xj, where Xj ≠ Xi
   Modify organisms Xi and Xj.
          If modified organisms give better fitness values then
          update them in the ecosystem.
  % evolutionary programming
          The updated ecosystem will go through mutation
          process
   Calculate fitness value of offspring
   Combine parents and offspring to do selection
   Define new generation and do convergence test
   end for
end while
```

3. RESULTS AND DISCUSSION

The proposed ESOS power scheduling scheme was validated to a standard reliability test system (RTS). In this study, the IEEE 30-Bus RTS was used as the test specimen. With 6 generators including the swing bus, this test system is a suitable system, normally employed as the test specimen. It has 30 buses, 6 generators and 41 transmission lines. The generators are located at buses 1, 2, 5, 8, 11 and 13. There are also connecting intermediate buses in this system. The single line diagram of the system is illustrated in Figure 5. Prior to the implementation of ESOS, pre-optimization process was conducted to give the initial status of the system.

Table 1 tabulates the results for losses values during the pre-optimization and after optimization processes. In case 1, the losses value is 17.5985 MW before optimization was conducted in the system. This value reduces significantly to 3.2429 MW with the implementation ESOS, when power scheduling was conducted to the system involving generators at buses 2, 5 and 8. This implies 81.57% losses reduction. It is worth to mention that, the implementation of ESOS for power scheduling is worth. For case 2, the losses value reduces to 5.3404 MW implying 69.65% losses reduction. These results can be beneficial to power system operators for attempting the losses control in this system. With these results, other variations can be done to other buses with any desired combinations.

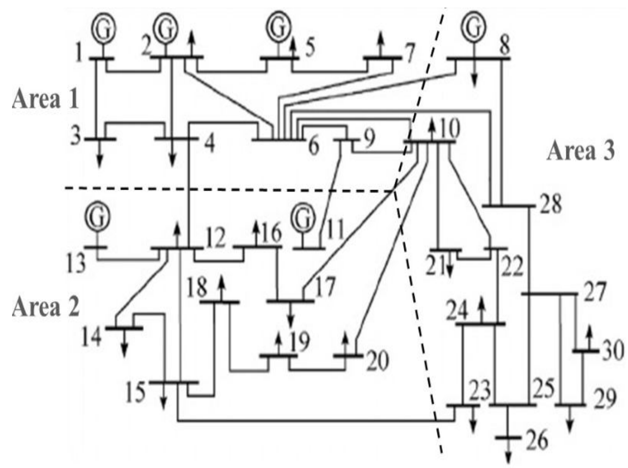

Figure 5: IEEE 30-Bus Reliability Test System (RTS)

Table 1: Results for Loss Values with 3 Generators participation

Cases	Participating Generator Buses	Losses Value (MW)	
		Before	After
Case 1	Bus 2, Bus 5 Bus 8	17.5985	3.2429
Case 2	Bus 8, Bus 11 and Bus 13	17.5985	5.3404

Table 2 tabulates the results for comparative studies of the proposed ESOS with respect to EP and SOS. The pre-optimized loss value is 17.5985 MW, while the total generated power, P_G is 40.00 MW.

Table 2: Studies of Results Solved Using EP, SOS and ESOS

	Pre-optimize	EP	SOS	ESOS
Total Loss (MW)	17.5985	2.820	2.725	2.015
Computational time (s)	N/A	243.7	485.2	1200.2
V_m(p.u)		1.06	1.06	1.06
Total P_G (MW)	40.00	286.22	286.12	256.552

From the table, ESOS gives 2.105 MW as the new loss value; while EP exhibits 2.820 MW, while SOS gives 2.725 MW. This indicates that ESOS outperformed SOS and EP in terms of achieving low losses value. ESOS managed to achieve 88.55% loss reduction; while SOS achieved 84.52% and EP achieved 84.00% losses reductions. ESOS significantly performed much better than both EP and SOS. The total generated power solved using ESOS is the minimum among the three techniques worth 256.552 MW. The minimum voltage are comparable among others worth 1.06 p.u..

Table 3: Power Scheduling Solved Using ESOS at Different Cases

Scenarios	Power Scheduling Schemes
Power Scheduling for 2 Generators	P_{G2} = 89.7245 MW, P_{G5} = 99.2419 MW, P_{GTotal}= 188.9664 MW, P_{loss} = 5.8781 MW
Power Scheduling for 3 Generators	P_{G2} = 38.4766 MW, P_{G5} = 75.9196 MW, P_{G8} = 81.4225 MW, P_{GTotal}= 195.8187 MW, P_{loss} = 2.8893 MW
Power Scheduling for 4 Generators	P_{G2} = 60.1638 MW, P_{G5} = 72.3836, P_{G8} = 51.9337 MW, P_{G11} = 49.0817 MW, P_{GTotal} = 233.5628 MW, P_{loss} = 2.1567 MW
Power Scheduling for 5 Generators	P_{G2} = 17.1586 MW, P_{G5} = 85.1936 MW, P_{G8} = 48.3427 MW, P_{G11} = 95.6571 MW, P_{G13} = 9.60075 MW, P_{GTotal}= 255.9528 MW, P_{loss} = 2.0041 MW

Table 3 tabulates the results power scheduling solved using ESOS at different scenarios. These scenarios are categorized based on participating generators for power scheduling schemes. For power scheduling involving 2 generators; generators at buses 2 and 5; the values are P_{G2} = 89.7245 MW, P_{G5} = 99.2419 MW, P_{GTotal}= 188.9664 MW, P_{loss} = 5.8781 MW. On the other hand, in power scheduling involving 3 generators, P_{G2} = 38.4766 MW, P_{G5} = 75.9196 MW, P_{G8} = 81.4225 MW, P_{GTotal}= 195.8187 MW, P_{loss} = 2.8893 MW. In this scenario, generators at buses 2, 5 and 8 are the participating buses for power scheduling scheme. For power scheduling involving 4 generators, buses 2, 5, 8 and 11 are the participating buses. In this scenario, P_{G2} = 60.1638 MW, P_{G5} = 72.3836, P_{G8} = 51.9337 MW, P_{G11} = 49.0817 MW, P_{GTotal} = 233.5628 MW, P_{loss} = 2.1567 MW. In the scenario with 5 participating buses, P_{G2} = 17.1586 MW, P_{G5} = 85.1936 MW, P_{G8} = 48.3427 MW, P_{G11} = 95.6571 MW, P_{G13} = 9.60075 MW, P_{GTotal}= 255.9528 MW, P_{loss} = 2.0041 MW. It is discovered that, power scheduling involving 5 generators has managed to achieve the lowest loss value worth 2.0041 MW. This indicates that it is a good remedial action through power scheduling at all generators in the system in the attempt of controlling losses in the system.

4. CONCLUSION

This paper has presented evolutionary symbiotic organisms search (ESOS) technique in power scheduling for loss control in power transmission system. In this study, evolutionary programming (EP) is integrated with the symbiosis organism search (SOS) to develop evolutionary symbiosis organism search (ESOS) for solving power scheduling problem to control losses in a power transmission system. Results obtained from the study revealed that the proposed ESOS technique performed better than EP and SOS in achieving low losses in a power system. It is also discovered that, power scheduling schemes at all generators can help achieve the lowest losses in a system. The proposed technique can be further utilized for solving other power system problems which require optimization process.

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