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# Symbiotic Organisms Search Algorithm Based Solution for Real Power Loss Minimization using OUPFC Device

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***Abstract**: This work employs, SOS algorithm known as meta-heuristic algorithm is employed to deprecate real power loss in the transmission network. Considering RPL deprecation as objective problem, it is solved by sequentially optimizing the OUPFC location and its variables, optimized taps being unchanged. The proposed algorithm under simulated test condition on New England 39 bus test system yields the confirmation of its efficiency, superiority over the results of the FA, as available in the literature.*

***Keywords: SOS algorithm, OUPFC, Firefly algorithm, Meta-heuristic algorithm, Transformer taps.***

## I. INTRODUCTION

Power systems is considered to be in stressed conditions due to frequent increments in load demand, causes the utilities and industries to face many problems like real power loss increase in transmission line ,over loads, load voltage deviation, voltage instability problems[1]-[2]. Such issues are addressed through the adoption of optimum power flow (OPF) methodology as a fundamental tool for organizing, managing, running the power system network by professionals such as power system managers, engineers, researchers and utility people. The OPF, with limitations to be tackled by non-linear programming (NLP) can only be optimized by limiting the power system variables. Key objectives are Real power loss minimization, generation cost minimization (GCM) and voltage stability (VS) with the variation in load. In [3] the optimal power flow problem was mathematically presented. Several researchers, as reported in the literature, have adopted many oft repeated techniques such as Newton based programming (NBP) method [4], Interior point (IP) method [5] to achieve an OPF problem solution.

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Using FACTS software, power flow control for enhancing power system efficiency, avoiding generation rescheduling or topology changes is facilitated. Among the FACTS devices, optimal unified power flow controller (OUPFC) is flexible in treatment during OPF [6]. The traditional techniques being more sensitive to initial points as non monotonic solution surface are unable to achieve the global optimum. To overcome these restrictions various methods have been applied to solve the OPF problem. In [7] Authors succeeded in applying the Firefly Algorithm (FA) and solved the OPF problem, the results of which are compared with the real ceded Genetic algorithm (RCGS) [7].

This paper employs the algorithm developed by Min-yuan cheng, Doddy prayogo, which takes the inspiration from nature, a new meta-heuristic algorithm termed as SOS algorithm, to solve OPF problem of RPL minimization [8] which is a superior algorithm in comparison to others. In [9]-[10] the authors have applied SOS algorithm considering an UPFC device to solve optimal power flow problem. This work has OUPFC location and its variables, optimized by keeping transformer tap positions constant with the SOS algorithm, to optimize the objective function. New England 39-bus system is considered for simulation. The results of the SOS method are compared with the results of FA method to show the superior potential of the proposed algorithm.

## II. OUPFC MODEL

OUPFC, a combination of PST and UPFC, provides voltage through non electronic switches, which change the transmission angle based on the operating conditions [11]-[12]. The per phase arrangement in fig. 1, gives OUPFC which is operated through voltage source converters.

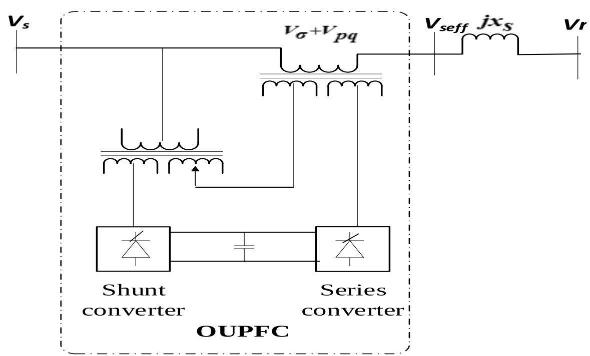


**Fig.1. Per phase schematic diagram of OUPFC**

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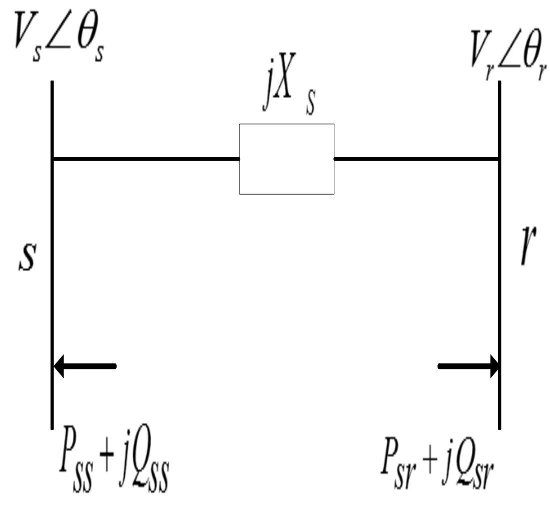


**Fig.2. Model OUPFC injection power**

The power injection OUPC model is shown in figure 2, where:

$$P_{ss} = -b_s k V_s V_r \sin(\delta+\sigma) - b_s r V_s V_r \sin(\delta+\rho) \quad (1)$$

$$Q_{ss} = -b_s V_s^2 (k^2 + r^2) - 2b_s k r V_s^2 \cos(\sigma-\rho) - 2b_s k V_s^2 \cos(\sigma)$$
$$-2b_s r V_s^2 \cos(\rho) + b_s k V_s V_r \cos(\delta+\sigma) + b_s r V_s V_r \cos(\delta+\rho) \quad (2)$$

$$P_{sr} = -P_{ss} \quad (3)$$

$$Q_{sr} = b_s k V_s V_r \cos(\delta+\sigma) + b_s r V_s V_r \cos(\delta+\rho) \quad (4)$$

## III. PROBLEM FORMULATION

The OPF problem with RPL minimization mathematically is expressed as follows:

$$\text{Minimize} \quad F(x,u,\lambda_{max}) \quad (5)$$
$$\text{subject to} \quad g(x,u)=0$$
$$h(x,u)\le 0$$

A set of control variables Vector $u$ i.e. OUPFC control parameters $r, \gamma$, and $\sigma$ i.e. UPFC series injected voltage, UPFC series injected voltage angle, and PST phase angle, respectively

## IV. SOS ALGORITHM

Introduced by Min-Yuan Cheng and Doddy Prayogo in 2014, solves different numerical optimization and engineering design problems [9]. Symbiosis conveys a relationship of cohabitants between two or more different types of biological species. The optimization strategy with SOS algorithm is shown in figure 3 as a flow chart.

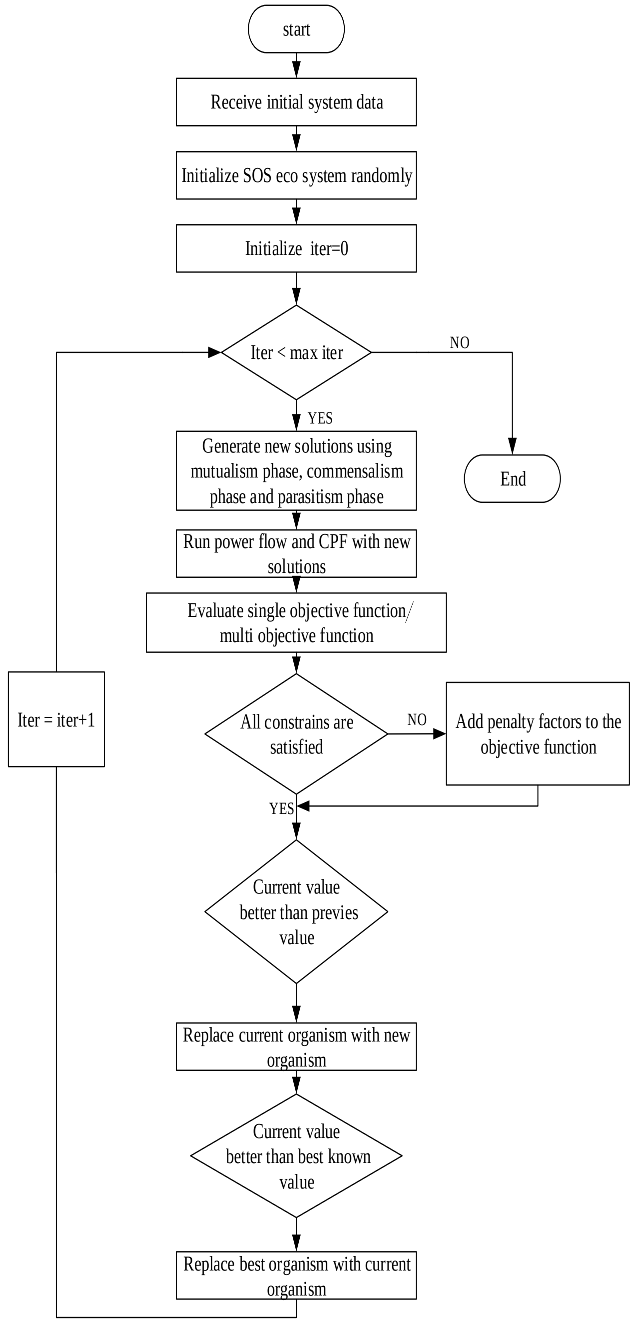


**Fig. 3. Optimization strategy with SOS algorithm**

## V. RESULTS AND DISCUSSION

New England 39 bus test system [9] consists of 10generator buses, 12 transformers and 46 transmission lines. Power flow with nominal values of taps is run and for this test system, the RPL is 0.4378 p.u.

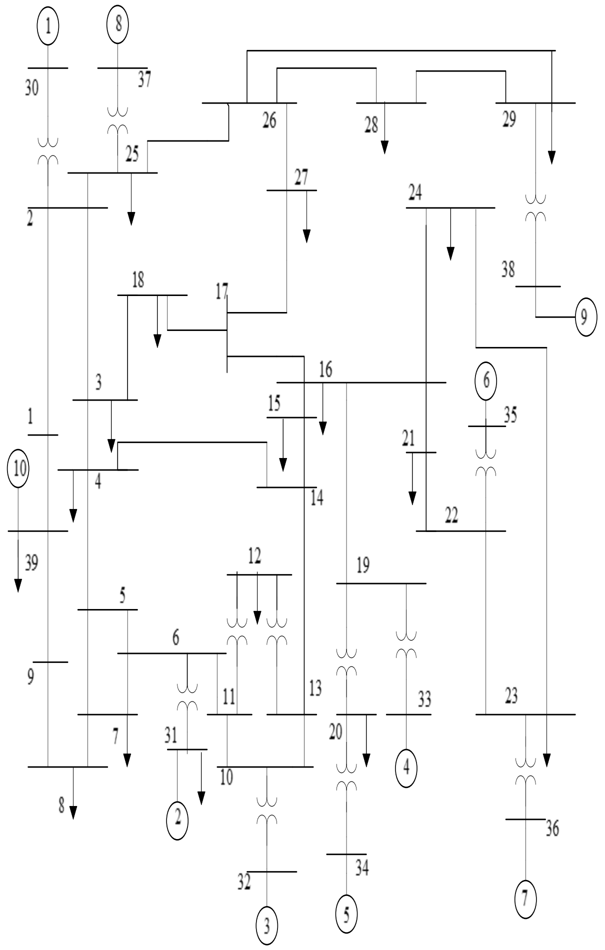

**Fig 4: New England 39 bus system**

The optimized OUPFC location, parameters, RPL with proposed technique is given in table 1. From the results it is clear that when more nonlinear equipment like OUPFC is inducted into the system, the fitness function has successfully converged with SOS.

**Table 1. New England 39 bus system case study –** Results

| S.No | Control variables | Optimized control settings with SOS algorithm |
|---|---|---|
| **1** | UPFC series Injected voltage $V_{se}$(p.u.) | 0.020675 |
| **2** | UPFC series Injected voltage angle ρ, (deg.) | -16.265388 |
| **3** | PST phase angle, σ, (deg.) | -3.420569 |
| **4** | UPFC location | 4-14 |
| **5** | RPL (p.u.) | 0.345202 |

## VI. RESULTS COMPARISON

The simulation results on comparison, with the results reported in literature, as given in table2, indicates RPL reduction with SOS compared to FA, with UPFC and OUPFC. This shows the potential of solving the non-liner optimization problem particularly the RPL minimization problem when OUPFC is introduced, by means of the proposed algorithm.

Table 2: Comparison of simulation results

| Method | FACTS device | RPL (p.u) |
|---|---|---|
| SOS | With OUPFC | **0.345202** |
| SOS[9] | With UPFC | 0.3500 |
| FA[12] | With OUPFC | 0.348356 |
| FA[12] | With UPFC | 0.3545 |

## VII. CONCLUSION

The RPL of the transmission network as optimized by a newly developed SOS algorithm based technique is proposed in this paper, with the control variables like OUPFC location, corresponding series injected voltage magnitude and phase angle , with the optimized transformers tap setting values constant. Comparing the Simulation results with the FA method as reported in the literature, it is clearly observed that, the proposed method provides significant improvement in terms of loss minimization.

## APPENDIX

New England 39 bus system data is given below:

**LINE DATA**:

| Bus nl | Bus nr | R p.u | X p.u | ½ B p.u | Line code/ Tr. tap |
|---|---|---|---|---|---|
| 1 | 2 | 0.0035 | 0.0411 | 0.34935 | 1 |
| 1 | 39 | 0.0010 | 0.0250 | 0.375 | 1 |
| 2 | 3 | 0.0013 | 0.0151 | 0.1286 | 1 |
| 2 | 25 | 0.0070 | 0.0086 | 0.073 | 1 |
| 3 | 4 | 0.0013 | 0.0213 | 0.1107 | 1 |
| 3 | 18 | 0.0011 | 0.0133 | 0.1069 | 1 |
| 4 | 5 | 0.0008 | 0.0128 | 0.0671 | 1 |

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|---|---|---|---|---|---|
| 4 | 14 | 0.0008 | 0.0129 | 0.0691 | 1 |
| 5 | 6 | 0.0002 | 0.0026 | 0.0217 | 1 |
| 5 | 8 | 0.0008 | 0.0112 | 0.0738 | 1 |
| 6 | 7 | 0.0006 | 0.0092 | 0.0565 | 1 |
| 6 | 11 | 0.0007 | 0.0082 | 0.06945 | 1 |
| 7 | 8 | 0.0004 | 0.0046 | 0.039 | 1 |
| 8 | 9 | 0.0023 | 0.0363 | 0.1902 | 1 |
| 9 | 39 | 0.0010 | 0.0250 | 0.600 | 1 |
| 10 | 11 | 0.0004 | 0.0043 | 0.03645 | 1 |
| 10 | 13 | 0.0004 | 0.0043 | 0.03645 | 1 |
| 13 | 14 | 0.0009 | 0.0101 | 0.08615 | 1 |
| 14 | 15 | 0.0018 | 0.0217 | 0.183 | 1 |
| 15 | 16 | 0.0009 | 0.0094 | 0.0855 | 1 |
| 16 | 17 | 0.0007 | 0.0089 | 0.0671 | 1 |
| 16 | 19 | 0.0016 | 0.0195 | 0.152 | 1 |
| 16 | 21 | 0.0008 | 0.0135 | 0.1274 | 1 |
| 16 | 24 | 0.0003 | 0.0059 | 0.034 | 1 |
| 17 | 18 | 0.0007 | 0.0082 | 0.06595 | 1 |
| 17 | 27 | 0.0013 | 0.0173 | 0.1608 | 1 |
| 21 | 22 | 0.0008 | 0.0140 | 0.12825 | 1 |
| 22 | 23 | 0.0006 | 0.0096 | 0.0923 | 1 |
| 23 | 24 | 0.0022 | 0.0350 | 0.1805 | 1 |
| 25 | 26 | 0.0032 | 0.0323 | 0.2565 | 1 |
| 26 | 27 | 0.0014 | 0.0147 | 0.1198 | 1 |
| 26 | 28 | 0.0043 | 0.0474 | 0.3901 | 1 |
| 26 | 29 | 0.0057 | 0.0625 | 0.5145 | 1 |
| 28 | 29 | 0.0014 | 0.0151 | 0.1245 | 1 |
| 12 | 11 | 0.0016 | 0.0435 | 0.000 | 1.006 |
| 12 | 13 | 0.0016 | 0.0435 | 0.000 | 1.006 |
| 6 | 31 | 0.0000 | 0.0250 | 0.000 | 1.070 |
| 10 | 32 | 0.0000 | 0.0200 | 0.000 | 1.070 |
| 19 | 33 | 0.0007 | 0.0142 | 0.000 | 1.070 |
| 20 | 34 | 0.0009 | 0.0180 | 0.000 | 1.009 |
| 22 | 35 | 0.0000 | 0.0143 | 0.000 | 1.025 |
| 23 | 36 | 0.0005 | 0.0272 | 0.000 | 1.000 |
| 25 | 37 | 0.0006 | 0.0232 | 0.000 | 1.025 |
| 2 | 30 | 0.0000 | 0.0181 | 0.000 | 1.025 |
| 29 | 38 | 0.0008 | 0.0156 | 0.000 | 1.025 |
| 19 | 20 | 0.0007 | 0.0138 | 0.000 | 1.060 |

**BUS DATA**

| Bus No | Bus Code | Voltage Mag. | Angle Degree | Load | |
|---|---|---|---|---|---|
| | | | | Mw | Mvar |
| 1 | 0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0 | 1.0 | 0.0 | 322.0 | 2.4 |
| 4 | 0 | 1.0 | 0.0 | 500.0 | 184.0 |
| 5 | 0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 6 | 0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 7 | 0 | 1.0 | 0.0 | 233.8 | 84.0 |
| 8 | 0 | 1.0 | 0.0 | 522.0 | 176.0 |
| 9 | 0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 10 | 0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 11 | 0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 12 | 0 | 1.0 | 0.0 | 7.5 | 88.0 |
| 13 | 0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 14 | 0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 15 | 0 | 1.0 | 0.0 | 320.0 | 153.0 |
| 16 | 0 | 1.0 | 0.0 | 329.0 | 32.3 |
| 17 | 0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 18 | 0 | 1.0 | 0.0 | 158.0 | 30.0 |
| 19 | 0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 20 | 0 | 1.0 | 0.0 | 628.0 | 103.0 |

| | | | | | |
|---|---|---|---|---|---|
| 21 | 0 | 1.0 | 0.0 | 274.0 | 115.0 |
| 22 | 0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 23 | 0 | 1.0 | 0.0 | 247.5 | 84.6 |
| 24 | 0 | 1.0 | 0.0 | 308.6 | -92.20 |
| 25 | 0 | 1.0 | 0.0 | 224.0 | 47.2 |
| 26 | 0 | 1.0 | 0.0 | 139.0 | 17.0 |
| 27 | 0 | 1.0 | 0.0 | 281.0 | 75.5 |
| 28 | 0 | 1.0 | 0.0 | 206.0 | 27.6 |
| 29 | 0 | 1.0 | 0.0 | 283.5 | 26.9 |
| 30 | 0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 31 | 2 | 1.0475 | 0.0 | 9.2 | 4.6 |
| 2 | 1 | 0.9820 | 0.0 | 0.0 | 0.0 |
| 33 | 2 | 0.9831 | 0.0 | 0.0 | 0.0 |
| 34 | 2 | 0.9972 | 0.0 | 0.0 | 0.0 |
| 35 | 2 | 1.0123 | 0.0 | 0.0 | 0.0 |
| 36 | 2 | 1.0493 | 0.0 | 0.0 | 0.0 |
| 37 | 2 | 1.0635 | 0.0 | 0.0 | 0.0 |
| 38 | 2 | 1.0278 | 0.0 | 0.0 | 0.0 |
| 39 | 2 | 1.0300 | 0.0 | 1104.0 | 250.0 |

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