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Imperialistic Competitive Algorithm based solution to optimize both Real Power Loss and Voltage Stability Limit

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Abstract:- Voltage stability is an essential feature of a good power transmission system. Optimizing power losses and voltage stability can bring about quality in power transmission systems. Transformer taps are tuned along with unified power flow controller and optimal location. This problem is considered to be a problem having both equality and inequality constrained where the objective function involves voltage stability limit and power loss. The existing solution to this problem is an evolutionary algorithm known as bacteria forging. Evolutionary algorithms (EAs) have been around for many years for solving optimization problems. EAs are inspired by the biological evolution. In this paper we proposed a novel Evolution Algorithm known as "Imperialistic Competition Algorithm (ICA)"to solve the problem. Multiple variables and objective functions are involved in this algorithm. The variables include transformer tap positions, series injected voltage, and the location of unified power flow controller. The simulations are made in MATLAB. The empirical results revealed that the proposed algorithm is effective.

Index Terms:- Imperialistic competition algorithm, evolutionary algorithm, linear programming

I. INTRODUCTION

With respect to power transmission systems optimal power flow (OPF) meant for controlling the power by optimizing real power loss. This is done with various constraints and security requirement in mind. The problem of OPF involved from various perspectives based on the real world problems and the variables that cause problem. In order to minimize power loss controls like VAR sources, shunts, and taps can be considered. There were many methods used to solve the OPF problem. They include Interior Point Methods (IMPs) , and , Newton-based Nonlinear Programming method and Successive Linear Programming (SLP) [5]. The problem of OPF has been greatly solved using the FACTS (Flexible AC Transmission Systems) technology. This has avoided the complexities involved in OPF as there is no need for topology changes, and generation rescheduling. UPFC is the most advanced controller that is flexible in solving the problem of OPF as it injects shunt compensation and controlled series . The UPFC also leverages the power coordination in deregulated power environment besides securing the power transmission systems securing from something known as voltage collapse. Active power loss was minimized in by using many FACTS devices in coordination. Provided OPF solution, other aspect can be considered that is continuation power flow (CPF) as explored in [8] that gives the statistics on overload of the system that can be withstood by the system without causing voltage collapse.

CPF was incorporated successfully in. The traditional solutions to the problem of OPF are highly sensitive to starting points and therefore they usually result in monotonic solution. In order to overcome this problem, evolutionary algorithm is used. Genetic algorithms are an example for evolutionary algorithms that evaluate complex scenarios and provide solutions that will be more accurate when compared with traditional solutions.. To the problem of OPF Particle Swarm Optimization (PSO) has been applied in that worked out food searching behavior of animals of birds. They also computed the best positional locally and globally at any given point of time in order to find out the best options for searching.

This paper focuses on building a new evolutionary algorithm for solving OPF-CPF problem. The algorithm is named as "Imperialistic Competition Algorithm". This algorithm is used to demonstrate the real power loss minimization and maximization of VSL of the power transmission systems. ICA has been applied earlier in power transmission systems for harmonic estimation problem The forging behavior of E. coli (bacteria) has been used in . ICA has been around for few years. Recently it was explored in and later used for harmonic estimation problem in power transmission systems as discussed in Foraging behavior of E.coli is used to build the algorithm. These bacteria live in human intestine. Many variables are simultaneously optimized. The variables include transformer tap positions, injection voltage, and UPFC location and so on. The overview of UPFC is as shown in figure 1. These variables are used along with other constraints necessary. The experimental results revealed that the proposed method has strength and can be used in solving real world problems pertaining to highly non-linear epistemic. Optimization of the said variables for real power loss minimization and VSL maximization.

UPFC model and operation

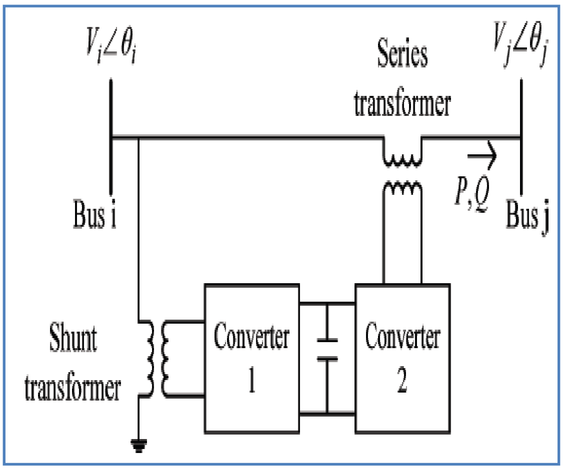

Fig. 1 –Overview of UPFC

As can be seen in figure 1, the UPFC is a device which is unique among the devices pertaining to FACTS. The shunt connected converters and series converters are used in the device. The injection model of UPFC is as shown in figure 2.

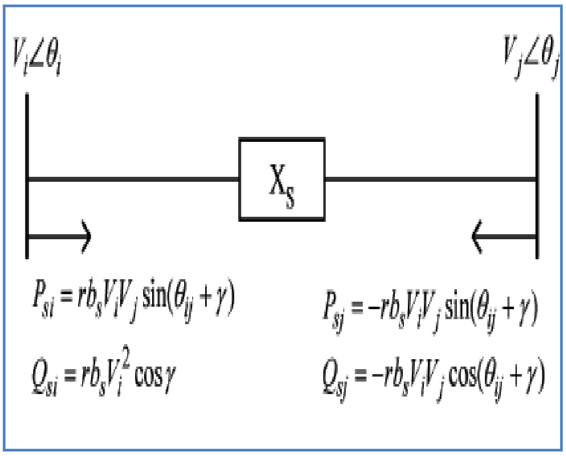

Fig. 2 –UPFC injection model

As seen in figure the injection model of UPFC has been used in [6] and proved to be efficient. This is connected in the overall system at appropriate location. This is capable of controlling both reactive and real powers of power transmission lines. The remainder of the paper is structured as follows. Section II presents problem statement. Section III provides details of proposed system. Section IV presents experimental results while section IV concludes the paper.

II. PROBLEM STATEMENT

The problem considered in this paper is power transmission system. We considered New English power system layout as shown in figure 4. We also considered the usage of UPFC device and its injection model which are as shown in figure 1 and 2. The optimization of real power loss and Voltage Stability Limit (VSL) are the two problems considered in this paper. The final optimization problem is represented as follows.

$$F(x, u, \lambda_{\max}) = \mathrm{G}(x, u) + \mathrm{V}(\lambda_{\max})$$

where

$$\mathrm{G}(x, u) = \text{Real Power Loss}$$

$$\mathrm{V}(\lambda_{max}) = (1/\lambda_{max}).$$

Both objective functions are considered for optimization. The proposed algorithm as presented in the ensuing section is used to solve the problem. The ICA algorithm that has been adapted in this paper is capable of achieving both the objective functions using evolutionary algorithm approaches. The subsequent sections throw more light into the solution and how the objective functions are converged.

III. PROPOSED ALGORITHM

Our proposed algorithm is twofold in its functionality. It is meant for minimization of real power loss and also enhancing the voltage stability. The dual purpose is served using a novel algorithm which is inspired by Evolutionary Algorithms (EAs). EAs have been good candidates to solve real world complex problems. Our algorithm is known as Imperialist Competitive Algorithm. This algorithm was originally conceived by Atashpaz-Gargari and Lucas [15] which is as shown in **figure 2.**

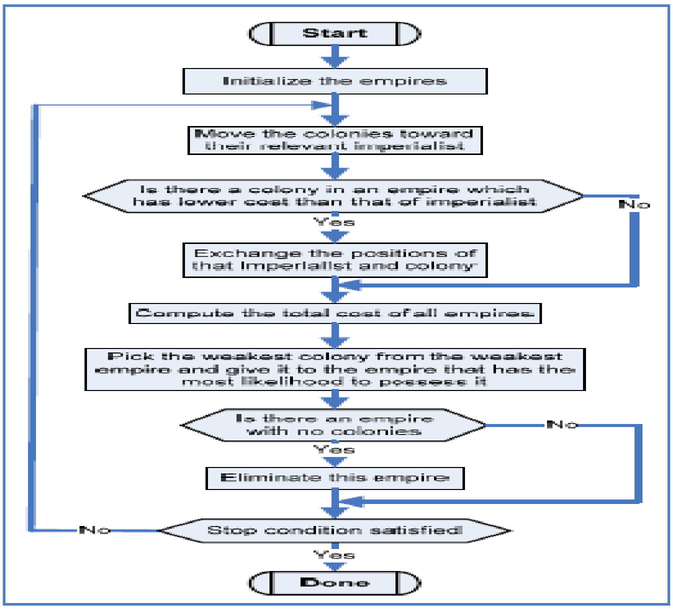

Fig. 3–Flowchart of the algorithm [15]

Evolutionary algorithms (EAs) have been around for many years for solving optimization problems. EAs are inspired by the biological evolution. In [15] an optimization was proposed which has been inspired by imperialistic competition. Accordingly the algorithm takes the entire world as input. It assumes that all countries are classified into two kinds known as colonies and imperialist states. The proposed algorithm considers a situation where imperialistic competition prevails among the empires. The aim of the algorithm is to converge into a state where only one empire along with its colonies exists. Moreover the empire and the colonies do have same state and cost. The algorithm is tested using real time datasets available. The empirical results revealed that the proposed algorithm is effective and can solve various kinds of optimization problems.

Applying ICA for Optimization of Real Power Loss and VSL Problem

The ICA algorithm has been exploited in this paper or achieving its goals. As the ICA is one of the EAs, it is found suitable for solving the optimization problems specified in this paper. The algorithm has an iterative process that takes care of optimizing two variables i.e., real power loss and voltage stability limit. These two variables are considered appropriately in the form of empires and colonies. By treating them as part of objective functions, the algorithm finally converges and optimized the said parameters in power transmission systems. The ICA applied to this project has the steps given in listing 1.

```
Algorithm: Imperialistic Competitive Algorithm
Inputs: Transformer tap positions, series injected voltage, location of UPFC, penalty factors
Outputs: Optimized VSL and Real Power Loss
Step 1
Initialization of variables
Repeat
    Input variables and penalty factors to ICA base line algorithm
    Compute objective function for real power loss
    Optimize Real Power Loss
Until Real Power Loss is Completely Optimized
Repeat
    Input variables and penalty factors to ICA base line algorithm
    Compute objective function for VSL
    Optimize VSL
Until VSL is Completely Optimized
```

Listing 1 –Steps to optimize real power loss and VSL

As can be seen in the listing 1, the algorithm runs in two separate optimization loops. The first loop optimizes real power loss. It does mean that it reduces real power loss while the second loop focuses on increasing the VSL. The more in VSL, the more stable the power transmissin system should be. The underlying algorithm is ICA that has been adapted from [15].

IV. EXPERIMENTAL RESULTS

Experiments have been made with simulations for real power loss minimization, and optimizing voltage stability limit. Penalty factors are also introduced for limit voilations of tranmission lines, transformer MVA, and voltage. These penalty factors are applied to thetotal power loss optimization problem as follows.

$$F = pf_1 + pf_2 + pf_3 + of, \text{ where}$$
$$of = \text{Real Power Loss}$$
$$pf_1 = 10 * abs\left(sign(V_{\min} - 0.9) - 1\right) + 10 * abs\left(sign(V_{\max} - 1.1) + 1\right)$$
$$pf_2 = 10 * abs\left(sign(trans_{\max} - 15) + 1\right)$$
$$pf_3 = 10 * abs\left(sign(line_{\max} - 20) + 1\right)$$

Where of is the real power loss while pf stands for penalty factor. The real power loss otpimization and voltage stabilkity limit have been optimized using the propsoed imperialist competitive algorithm. The algorithm has been adopted to sove the optimization problems proposed in this paper.Experiments are made using simulations. The resutls are presented in figure 5 and 6. Our algorithm has been testing using the layout of New England power system which is as shown in figure 4.

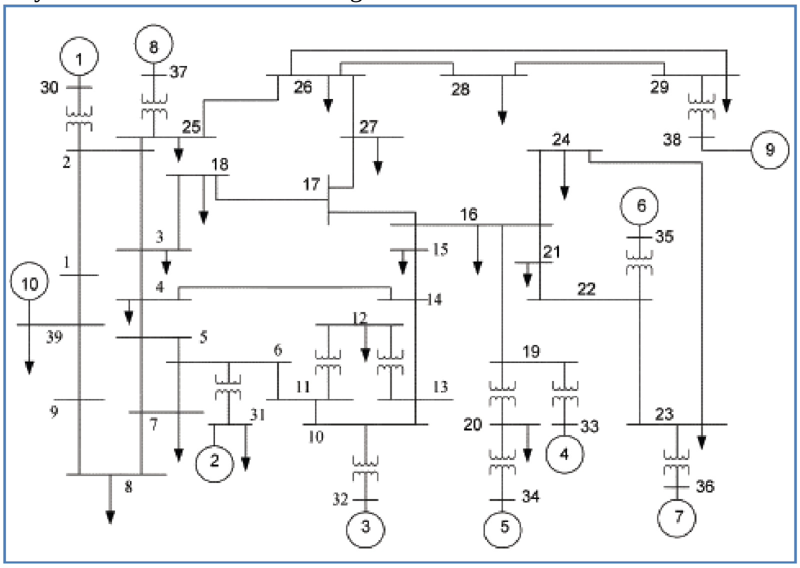

Fig. 4–Power system layout (New England)

As can be seen in figure 4, it is evident that the New England power system's layout has been considered for our experiments. It has 39-bus layout including 12 transformers and corresponding tap values. More details of this layout can be found in . Table1 shows the simulation results for multi-objective optimization problem.

Optimized Taps And UPFC Parameters For Multi Objective Of Real Power Losses And Voltage Stability Limit					
S.NO	Line No	Transformer Taps	Injected Voltage	Real Power Losses	Voltage Stability Limit
1	2-30	1.00	$\lvert V_{se}\rvert$=0.005000p.u $\langle\delta_{se}$ = 3.140000rad UPFC location=1-2	0.396474	1.029987
2	10-32	1.13			
3	12-11	1.02			
4	12-13	1.11			
5	19-33	1.14			
6	19-20	1.00			
7	20-34	1.08			
8	22-35	1.07			
9	23-36	0.95			
10	25-37	1.06			
11	29-38	1.11			
12	6-31	1.15			

Table 1 – simultaneous optimized values of UPFC and transformer taps for BFAM

As shown in table 1, the transformer tap values are used. Other information pertaining to experiments is as described here. UPFC Locations considered are 1 – 2. Series injected voltage = 0.060000 p.u. The angle of series injected voltage = 0.000000. The optimized real power loss is 0.321986 p.u. The optimized voltage Stability limit is 0.950000. Table 2 shows the comparison of the results of ICA and the prior work named "BFA".

Optimized taps and UPFC parameters for multi-objective of real power loss and VSL					
S.NO	Line no	Taps	Injected voltage	Real power losses	Voltage stability limit
1	2-30	0.950	$\lvert v_{se} \rvert = 0.06$ p.u $\delta_{se} = 0.000$ UPFC location 1-2	0.3219p.u	0.95
2	10-32	1.070			
3	12-11	0.950			
4	12-13	0.994			
5	19-33	0.950			
6	19-20	1.011			
7	20-34	0.953			
8	22-35	1.016			
9	23-36	0.950			
10	25-37	0.950			
11	29-38	1.011			
12	31-6	1.132			

Table2: simultaneous optimized values of UPFC and transformer taps for ICA

As can be seen in table 2, it is evident that the performance of ICA is better than that of BFA in terms of optimization of real power loss and VSL. The experimental results are presented in figure 5 and 6.

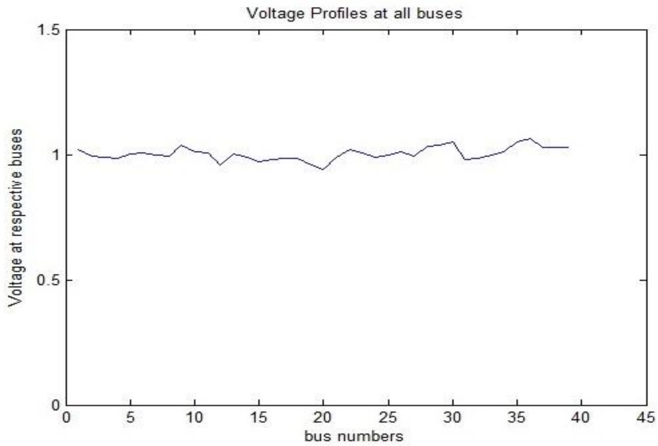

Fig. 5–Voltage profiles of all the buses at nominal load

As can be seen in figure it is evident that the horizontal axis represents the bus numbers while the vetical axis represents voltage at respective buses. The voltage buses at all profiles are presented as well. The resutls revealed that the proposed algorithm is capable of improving VSL.

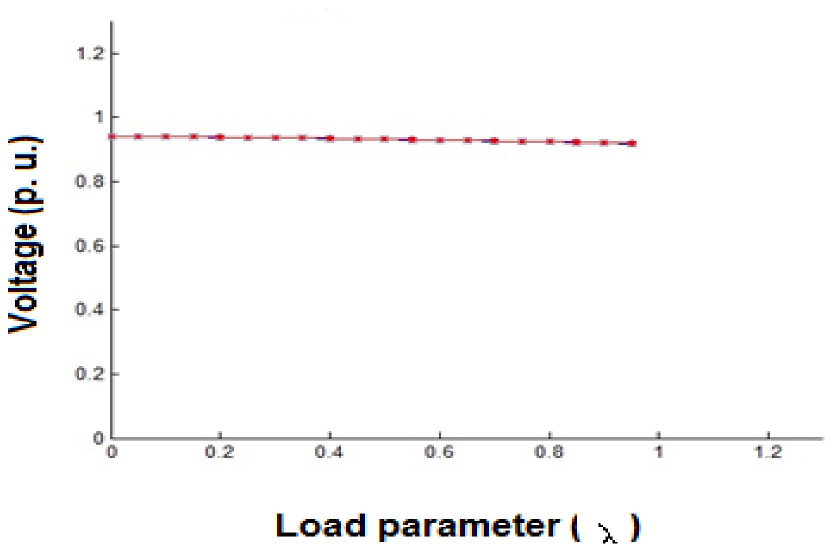

Fig. 6 – PV curve of weakest bus (simultaneous UPFC and taps)

As seen in figure 6, it is evident that the resutls reveal the Vm at bus 20with respect to load at bus 20. The resutls revealed that the prosoped protocol is capble of achieving its dual goal including the enhancement voltage stability limit.

V. CONCLUSION

In this paper we studied two problems that frequently occur in power Transmission systems. The problems include enhnacemnt of voltage stability limit and minimization of real power loss. The dual purpose is achieved by an EA known as Imperilistic Competition Algorithm (ICA) that was originally proposed in. However, this algorithm has been adapted by us to achieve our goals in this paper. The former goal is to improve stablity of voltage while the latter's goal is to minimize real power loss. The evolutinalry algorithm ICA takes UPFC, transformer taps, and other variabels as input and converges the system into optimial solution where we can achieve the optimized VSL and real power loss. So the results obtained by the proposed algorithm is better compared to the bacteria foraging algorithm.

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