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Applying Imperialist Competitive Algorithm for Optimal Placement of Unified Power Flow Controller in Power System

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Abstract

This paper presents a Imperialist Competitive Algorithm (ICA) to seek the optimal number and location of FACTS devices in a power system. Unified Power Flow Controller (UPFC) has great flexibility that can control the active and reactive power flow and bus voltages, simultaneously. Decoupled model of the UPFC is applied to maximize the system loadability subject to the transmission line capacity limits and specified voltage level. Imperialist Competitive Algorithm is a new heuristic algorithm with efficient mathematical function and global search capability. Optimal placement of UPFC in power system by Imperialist Competitive Algorithm, it leads to a flat voltage profile and increased stability and capacity of the power transmission in lines. At the end, the proof is performed by simulating and testing the 14-bus network and placement of the UPFC appropriately. The results show that the steady state performance of power system can be effectively enhanced due to the optimal location and parameters of the UPFC.

Keywords: Imperialist Competitive Algorithm (ICA); UPFC; Power Flow; Optimal Location

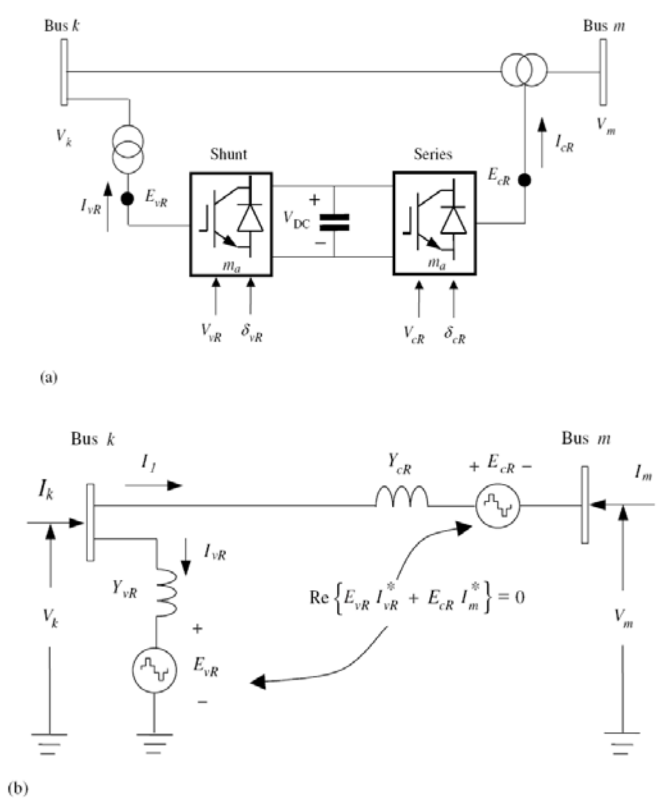
I. Introduction

Recently, the steady state performance of power system has become a matter of grave concern in system operation and planning. As the power system becomes more complex and more heavily loaded, it can be operated in unstable or insecure situations like the cascading thermal overloads, the frequency and voltage collapse. For a secure operation of the power system, it is essential to maintain the required level of security margin [1-3]. Then, power system controllability is required in order to utilize the available network capacitance adequately. The development of FACTS devices based on the advance of semiconductor technology opens up new opportunities for controlling the load flow and extending the loadability of the available transmission network. The UPFC is one of the family members of FACTS devices for load flow control, since it can either simultaneously or selectively control the active and reactive power flow along the lines [4, 5]. Several papers have been published about finding the optimal location of the UPFC with respect to different purposes and methods [6, 7]. In [6], augmented Lagrange multiplier method is applied to determine the optimal location of the UPFC to be installed. Although multi operating conditions can simultaneously be taken into consideration, the operating condition must be preassigned. Gerbex *et al* [7] provides the genetic algorithm to optimize three parameters of the multi-type FACTS devices including TCSC, TCPST, TCVR and SVC: the location of the devices, their types and their values, but another kind of FACTS device -UPFC has not been considered. The main objective of this paper is to develop an algorithm for finding and choosing the optimal location of the UPFC in order to maximizing the system loadability while simultaneously satisfying system operating constraints including transmission line capacity and voltage level limits. The optimal location problem of a given number of FACTS is converted to an optimization problem which is solved by the Imperialist Competitive Algorithm (ICA) that has a strong ability to find the most optimistic results. In the following, the main results of tests on the IEEE 14-bus power systems for the proposed ICA method are shown to demonstrate the effectiveness of the proposed method.

II. Mathematical Model of UPFC

The UPFC may be seen to consist of two voltage source converters sharing a common capacitor on their DC side and a unified control system. A simplified schematic representation together with its equivalent circuit of the UPFC is given in Fig. 1. The UPFC allows simultaneous control of the active and reactive power flow, and voltage magnitude at the UPFC terminals. Alternatively, the controller may be set to control one or more of these parameters in any combination or to control none of them [2].

Figure 1: Block diagram of the UPFC system: (a) Two back-to-back voltage source converters (b) Equivalent circuit of a UPFC.

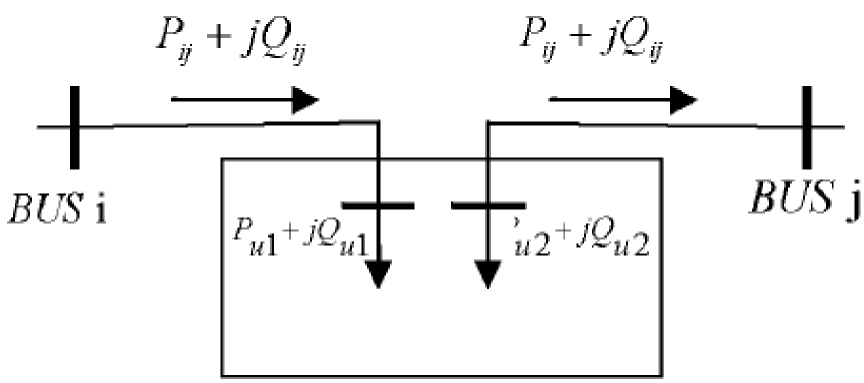


The active power demanded by the series converter is drawn by the shunt converter from the AC network and supplied to bus m through the DC link. The output voltage of the series converter is added to the nodal voltage, say bus k, to boost the nodal voltage at bus m. The voltage magnitude of the output voltage V_{CR} provides voltage regulation, and the phase angle δ_{CR} determines the mode of power flow control [3].

III. Implemented Model for Optimizing Location of the UPFC

Two types of UPFC model is represented in the papers. One is a coupled model and the other is decoupled model [2]. In the first type a UPFC is modeled with a voltage source series with impedance in the transmission line. In the second type a UPFC is model with two separated buses. The first type is more difficult compared with the second one and the modification of the Jacobean matrix of the system should be applied if it is used. On the other hand, the decoupled model can be easily used in conventional power flow methods without changing the Jacobean matrix of the system. In this paper the decoupled model, as shown in Fig. 2, is used for the power flow study.

Figure 2: The decoupled model of UPFC



If the UPFC is assumed to be lossless, the real power flow P_{ij} that flows from bus *i* to bus *j* can be written as:

$$P_{ij} = P_{U1} \tag{7}$$

Although a UPFC can control the power flow, but cannot generate the real power. So equation (8) should be considered in the model.

$$P_{U1} + P_{U2} = 0 \tag{8}$$

The values of Q_{U1}, Q_{U2} can be set to an arbitrary value within the capacity of the UPFC to maintain the bus voltage. In the same way if multiple UPFCs are installed in the power system, the control variables for the k_{th} installed UPFC are shown as follows:

$$UPFC_{k-th} = \left[P_{K1}^{U}, Q_{K1}^{U}, P_{K2}^{U}, Q_{K2}^{U} \right] \tag{9}$$

So that:

$$P_{K1} + P_{K2} = 0 \tag{10}$$

IV. Optimization Strategy

The aim of the optimization is to perform a best utilization of the existing transmission lines. In this respect, UPFC device is located in order to maximize the system loadability while observing thermal and voltage constraints. In other words, it was tried to increase the power transmitted by power system as much as possible to the costumers with holding power system in security state in terms of branch loading and voltage levels. The objective function is made in order to penalize configurations of the UPFC which lead to overload transmissions lines and over or under voltage at busses. The objective function is defined as the sum of two terms. The first one is related to the branch loading which penalizes overloads in lines. This term is called LF and is computed for all lines of the power system, if branch loading is less than 100% its value is equal to 1; otherwise, it decreases exponentionally with respect to the overload. To accelerate the convergence, product of values for all objective functions is calculated. The second part of the objective function is for voltage levels that are named BF. This function is calculated for all buses of power system. For voltage levels between 0.95 and 1.05, values of the objective functions is equal to 1. Outside this range, value decreases exponentionally with the voltage deviations. Therefore, for a configuration of UPFCs, objective function is given as:

$$LF = \begin{cases} 1 & , \ BL < 100 \\ \exp[0.0461(100 - BL)] & , \ BL \geq 100 \end{cases} \tag{11}$$

$$BF = \begin{cases} 1 & , \ 0 \leq V_L \leq 100 \\ \exp[-23.0259 |1 - V_L| - 0.05] & , \ 1.05 \leq V_L \leq 1.25 \\ & or\, 0.75 \leq V_L \leq 0.95 \end{cases} \tag{12}$$

$$Objective\, Function \quad OF = \prod_{i=line} LF_i + \prod_{j=buses} BF_i \tag{13}$$

The Cost Function for the ICA is computed by minimizing the inverse of the Objective Function, defined as follows:

$$Cost\ Function = \frac{1}{OF} = \frac{1}{\prod_{i=line} LF_i + \prod_{j=buses} BF_i} \tag{14}$$

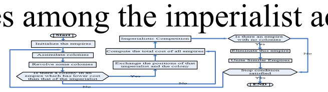
Where, *LF* is the line flow index and *BL* is the Branch Loading (Percentage of the line flow with respect to the line capacity rate). *BF* is bus voltage index and V_L is per unit value of the bus voltages.

V. ICA Algorithm Introduction

In this article the imposed algorithm for optimization, that is inspired from mathematics modeling of imperialist competition, has been introduced and its different component will be explained. We want find the argoman x in the way its analogous cost be optimum, with having function in optimization. In this article, new algorithm is introduced for general searching that is inspired from imperialist competition. In sum this algorithm starts in several countries at the early stage. In fact countries are possible answers of problems and are chromosome equals in genetic algorithm and particle in optimization of particle group. All the countries are divided into two parts: imperialist and colony. Imperialistic countries absorb colony countries with applying simulation policies parallel with different axis of optimization. Imperialist competition along with assimilation policy forms the main nucleus of this algorithm and causes the countries to move in the absolute minimum of function.

V.1. ICA Algorithm

Fig 1 shows ICA algorithm flowchart. This algorithm, such as other evolutionary algorithms begins with some accidental primary crowds that each of them has been called a "country". Some of best elements of crowds are selected as imperialist (equal with elites in genetic algorithms) .the remaining crowds have been considered as colony. Imperialist, with their power, absorb these colonies to themselves with special trend that will be discussed at future. Power of each empire depends on its two constitutive part namely imperialist country (as central nucleus) and its colonies. In mathematics this dependence models with empire power definition in the form of power sum of imperialist country plus percents of average power of its colonies. The imperialist competition between them begins with forming early empires. Each empire that cannot be successful in imperialist competition and increases its power, will be removed from imperialist competition scene .therefore the survival of each empire depends on its power in absorption of revival empire's colonies and ruling over them. As a result, in imperialist competition streams, the power of greater empires will be increased and weak empires will be removed. Empire will be obliged improve their colonies for increasing their power. Colonies gradually near the empires and we can observe some sort of convergence. Final extent of imperial extent is when we have had unit empire in the world, with colonies which are close to the imperialist country accordance with their position.For starting the algorithm , we create N numbers of early countries .we select N imp of the best members of this crowd as imperialist (the countries including minimum amount of cost function) , the remains forms N col of colonies countries in which each of them belongs to one empire. We give some of these colonies to each imperialist for dividing the early colonies among the imperialist accordance with their power. consider their normalized cost as follow:



(9)

Where c_n imperialist cost max (c_i) is highest cost among imperialist and C_n is normalized cost of this imperialist.

Each imperialist which have had more cost (be weaker imperialist), includes less normalized costs. Normalized respective power of each imperialist, with having normalized costs, has been calculated as follow and accordance with it, colonies countries have been divided between imperialist.

$$P_n = \frac{C_n}{\sum_{i=1}^{N_{imp}} C_i} \quad (10)$$

From other respect, normalized power of an imperialist is colonies proportion that are controlled by that imperialist.Therefore the early number of an imperialist's colonies equals with:

$$N.C.n = round\{P_n.(N_{col})\} \quad (11)$$

Where $N.C.n$ is early number of empire 's colonies and N_{col} is the total number of existing colonies countries in the early countries crowds . Round is also function that give closest integer t a decimal number. We select accidentally some of these primary colonies countries, with considering N.C for each empire an give it to N imperialist, the imperialist competitive algorithm begins with having primary status of all empires. Evolutionary trend which located in a segment that continues till the stop condition fulfillment. Fig 2 shows the manner of early empires forming . Bigger empires have more colonies. In this Fig, imperialist number 1 creates the strongest empire and have most number of colonies.

IV.2. Absorption Policy Modeling

Colonies movement toward the assimilation policy of imperialist has done with the purpose of analyzing the culture and social structure of colonies in central government culture. Imperialist countries began to creating development (building transportation substructure , university establishing ,…).

Figure 1: Flowchart of the Imperialist Competitive Algorithm

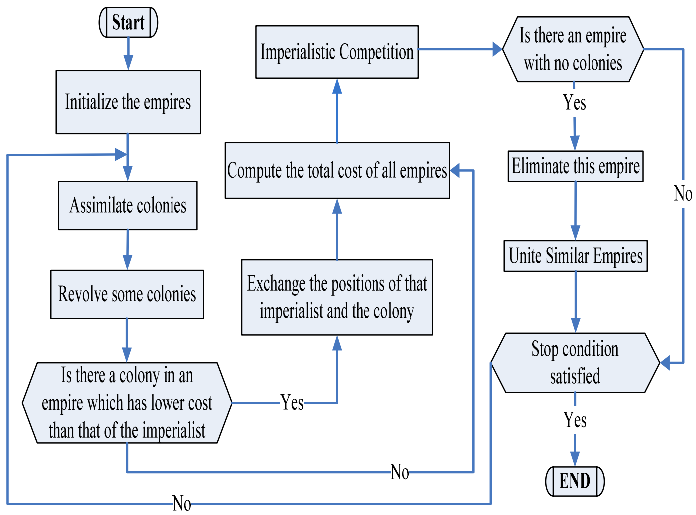
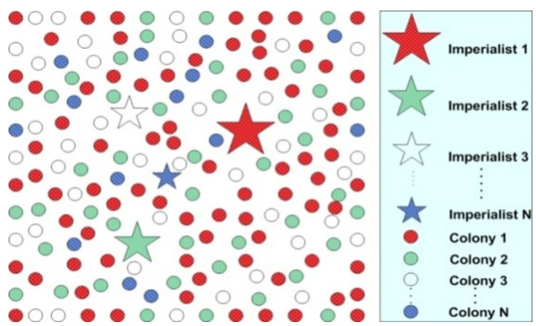


Figure 2: Manner of forming primary empire, imperialist number 1 creates strongest empire and has maximum number of colonies.



In fact this central government tries to close colony country to its self by applying attraction policy, in different political and social dimensions, with considering showing manner of country in solving optimization problem. This section of imperialistic process in optimization algorithm has been modeled in the form of colonies movement toward the imperialist country. The Fig 3 shows total image of this movement. According with this Fig, imperialist country attract to itself parallel with culture and language axis. As shown in this Fig, colony country moves in x unit size toward the attachment line of colony to the imperialist and drawn to new situation. In this Fig, distance between imperialist and colony is shown by D, and x is accidental number with steady distribution.

It means for x, we have:

$$x \sim U(0, \beta \times d) \tag{12}$$

Where β is a number bigger than 1 and nears to 2. A good selection can be β=2. The existence of coefficient β >1 causes the colony country closes to the imperialist country from different aspects while moving. With historical survey of assimilation phenomena, one clear fact in this field is in spite that imperialist countries followed seriously the attraction policy but facts did not follow totally accordance with applied policy and there were deviances in the work results. In introduced algorithm, this probable deviation has done with adding an accidental angle to the attraction path of colonies. For this purpose, in the colonies movement toward the imperialist, we add an accidental angle toward the colony movement ,Fig 4 shows this state . this time we continue our path in stead of x movement toward the imperialist and in toward the vector and colony maxim to the imperialist in the same extent, but with θ deviation in the path, and consider θ accidentally and with constant distribution (but any ideal and proper distribution can be used), then $\theta \sim U(-\gamma, \gamma)$.

Figure 3: Total image of colony movement toward imperialist.

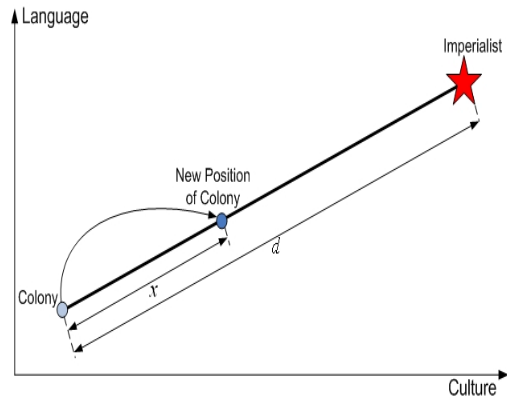
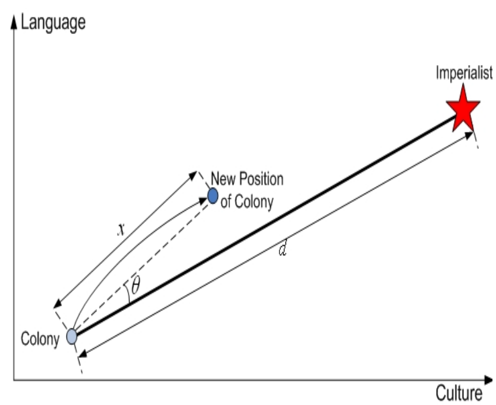


Figure 4: Real movement of colonies toward the imperialist.



In this relation y is ideal parameter that its increasing causes increasing searching around imperialist and its decreasing causes colonies close possibly to the vector of connecting colony to the imperialist. With considering the radian unit for θ, a number close to $\pi/4$ was proper selection in the most depletion.

V.3. Position Displacement of Colony and Imperialist

In some cases attraction policy has had possitive result for them, in spite of destroying political-economical structures of colony countries . some of countries with appling this policy accessed to general self confidence and after awhile it was the educated people who combat with the nation leadership for escaping from imperialist . We can find various cases of these in enland and france' s colonies . from other perspective , looking at up and downs of power circulation in the countries shows truly that the countries in which were at the peak of politic military power , after awhile declined and contrary the countries reached to the power that before were not into the power. This historical movement in the modelling in the algorithm has been applied in the way of colony movement toward the imperialist country , some of these colonies may reach to a better condition than imperialist (reaching to the points in cost function that generate less costs than cost function extent) . In this state , the imperialist country and colony change their position and algorithm continues with imperialist counry in new situation and this time it is the new imperialist country in which begin to applying assimilation policy for its colonies. The colony and imperialist displacement is shown in the Fig 5. In this Fig the best empire's colony in which has less costs than imperialist, is shown with dark colour. Fig 6 shows the whole empire after position changing.

Figure 5: Displacement of colony and imperialist

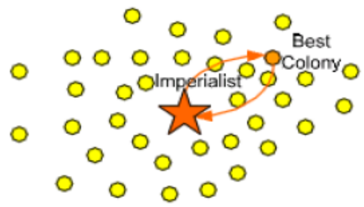
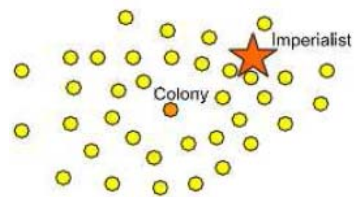


Figure 6: The whole empire after displacement



IV.4. Total Power of an Empire

The power of an empire equals with the power of imperialist country in addtion to some perceptage of total power of whole colonies , in this case the total cost of an empire calculate as follow:

$$T.C. = Cost(imprialist_n) + \xi mean\{Cost(colonies\ of\ empire_n)\} \tag{13}$$

Where T.C.n is the empire's total cost and ζ is possitive number that is usually between zero and one and near to zero.This low considering of ζ cause total cost of empire be nearry equal with its central government and inreasing ζ causes increasing the colonies's costs measure infulunce of an empire in determining the its total costs. In generic state ζ =0/ 05 in the most cases reulted to proper answers.

IV.4.1. Imperial Competition

Each empire which cannot increase its power and looses its competiton power, will be removed from imperialistic competitions. This removing forms gradually. It means that with passing the time , weak empire give up their colonies and the strong empire take possession of these colonies and increase their power . for modelling this fact ,we assume the empire at the time of deleting ,is the weakest existing empire . So in the algghorithm repetition, we take some of weakest colonies of the empire and create a competition between the whole empires. mentioned colonies will not nessesarily be possessed the strongest empire. But this is the stonger empire which has more chance for its ownership. Fig 9 shows total image of this part of alghorithm.

Figure 7: Exchanging the positions of a colony and the imperialist

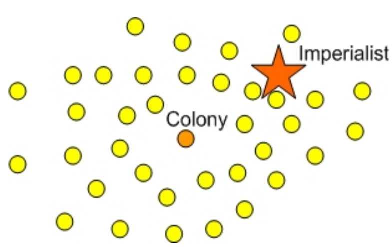
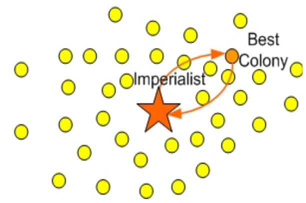


Figure 8: The entire empire after position exchange

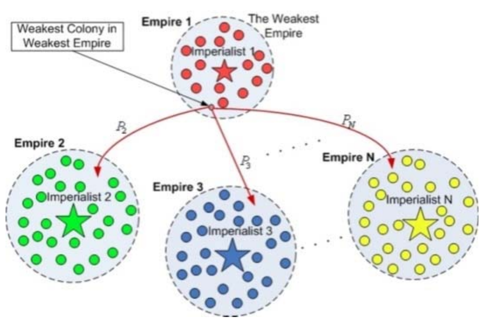


For modelling the competition between the empires for possessing these colonies , first of all we calculate the owenership probability of each empire(that be fit with the power of that empire) with considering total cost of each empire , as follow: first we determine total costs of empire based on its nnormalized costs:

$$N.T.C._{n} = T.C._{n} - \max_{i}\{T.C._{i}\} \tag{14}$$

Where T.C.N is n total cost of empire and N.T.C.n is normalized costof that empire. Each emire which have had less T.C.N ,has more n.t.cn . infact T.C .n equals total cost of an empire and N.T.C. N equalsits total power.

Figure 9: Total image of imperialistic competition : bigger empire take the possession oof the other emire's colonies with more liklihood.



The probability of colony ownership in competition by each empire calculates as follow:

$$p_{p_n} = \left| \frac{N.T.C._{n}}{\sum_{i=1}^{N_{imp}} N.T.C._{i}} \right| \tag{15}$$

with ownership probability of each empire, we divide the mentioned colonies accidentally between the empires, but with related probability to ownership probability of each empire. Then we form vector P based on above probabiliy extents as follow:

$$\mathbf{P} = \left[p_{p_1}, p_{p_2}, p_{p_3}, ..., p_{p_{N_{imp}}} \right] \tag{16}$$

vector P' s size is 1×nimp and is consituted based on probability amounts of empires ownership. Then we form the accidental vector R as equal as vector P , the arrays of this vector are accidental number with the same distribution in [0,1].

$$R = \left[r_1, r_2, r_3, ..., r_{N_{imp}} \right]$$

$$r_1, r_2, r_3, ..., r_{N_{imp}} \sim U(0,1) \tag{17}$$

Then we form vector D as follow:

$$\mathbf{D}=\mathbf{P}-\mathbf{R}=\left[D_1, D_2, D_3, \ldots, D_{N_{imp}}\right]$$
$$=\left[p_{p_1}-r_1,\ p_{p_2}-r_2,\ p_{p_3}-r_3, \ldots, p_{p_{N_{imp}}}-r_{N_{imp}}\right] \qquad (18)$$

we give the mentioned colonies to the empires with having cector D so that related andis in vector D be bigger than others. The empire which has more ownership probability , has the highest extent ,with more chances in related andis in vector D.

IV. 4.2. Declining the Weak Impires

Weak empires gradually decline in imperialistic competition and strong empires take the possession of their colonies. There are different conditions for declining an empire. In suggested empire , when an empire loose its colonies ,it assumped deleted.

IV.4.3. Convergency

The mentioned alghorithm continues till fulfillment of one convergency condition or afinishing the number of whole repitition. After awhile all the empires will decline and we have only one empire and other countries are under the control of this united empire. In this new ideal world all the colonies are controled bye an united empire and the colonies 's cost and situations equals with the empirilaist 's cost and situation . in this new world, there are no difference not only between colonies but also between colonies and imperialist country . in other words, all the countries are both colony and imperialist at the same time. In such situation the imperialistic competition have been finished and stops as one stop codition of algorithm.

IV.5. ICA Alghorithm

Assimilation : this function applies assimilation part or in other word attraction policy . Primary empires : it forms primary empires with proper dividing of colonies among them , with concidering situation and cost of primary countries. Imperialistic competition: The imperialistic competition between the emipres in order to attract each other colonies is done by this function . removing the weak empires is also in this function. Imperialist and colony displacement: Displacement of imperialist and colony is done in this function. If a colony reach to a better position than imperialistt ,it immediately take the control of emperor and continues the work with applying the attraction policy on them.The colonies revolution: Revelution , that is main counterweight of discovery balance and exploitation and is useful for discovery, applies in this function . sudden changes happens in some countries and in some cases leads to discovery of minimum indiscernible point in function.

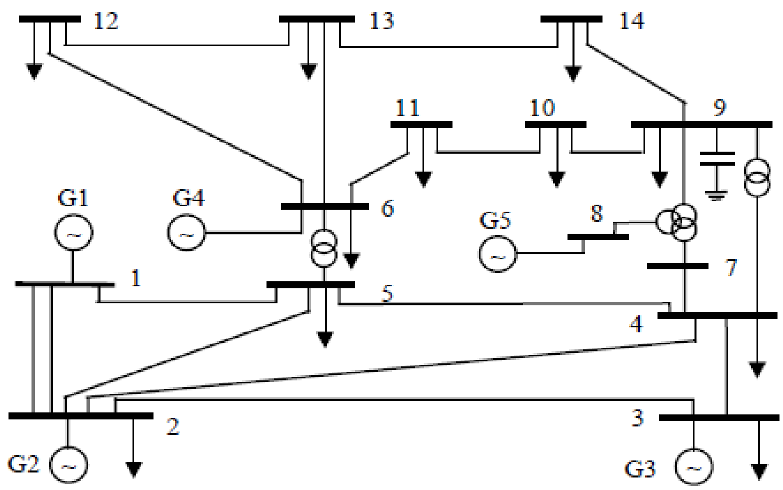
IV. 5. 1. ICA Alghorithm's Similar_Code

1. Select some accidental point on the function and form the primirary empires . we mean the powerhouses power that are concidered as primary guess .
2. Move the colonies toward the imperialist country (assimilation policy).
3. If there are an empire that has less costs than imperialist ,change the position of colony and imperialist .
4. Calculate total costs of an empire(with pay attention to imperialist and its colonies's costs).
5. Select one colony from weakest empires an give it to the empire which has more chance for ownership .
6. Delete weak empires .
7. Stop if there are only one remained empire , otherwise go to 2.

VII. Case Study

The load increasing studies on the real power system are done for different aims in planning and operation process of the system. For long-term studies of the power system, it is necessary to consider both active and reactive load increasing. The standard IEEE 14-bus test system is shown in Fig. 4 to demonstrate the effectiveness and validity of the proposed method. The numerical data and parameters are taken from [7]. In this way, new values of voltages and active and reactive powers of the net and also the value of the objective function are obtained. By iterating this process and a comparison between fitness values, the best chromosome meaning best found solution is introduced.

Figure 4: A standard IEEE 14 bus system



Suppose that the given number of UPFCs is set to 2. The dynamic optimization performance of the solution method is shown in Fig. 5. In case of using just one UPFC in the system, the proposed algorithm yields a seven-segmented result as the optimal solution. In Table 1 the numbers one and four express the bus number which one UPFC is located between them. The second and third numbers show the values of injective active and reactive powers, respectively into the bus 9 and the fifth and sixth numbers, respectively show the injective active and reactive powers into the bus 4. Seventh number also gives the fitness value defined in the Eq. (14) for the UPFC. In case of using two UPFC in the power system simultaneously, the proposed algorithm represents the optimum solution by thirteen segmented chromosome. The first UPFC is set between the buses number 3 and 4 and the second UPFC is set between the buses number 5 and 6. The simulation result is shown in Table 2. The numerical results before and after UPFC placement in the network is shown in Tables III-XI. It is observed form the simulation results that the voltages of buses of the network are in authorized range and the profile of the voltage is satisfactorily flat.

For 1 UPFC:

Table I: The best results for 1 UPFC

1	2	3	4	5	6	7
Bus Number	P_i	Q_i	***Bus Number***	P_j	Q_j	***Fitness***
9	***67.34***	***-53.71***	***4***	***185.9***	***-95.6***	***0.0414***

For 2 UPFC:

Table II: The best results for 2 UPFC

1	2	3	4	5	6	7	8	9	10	11	12	13
Bus Number	P_i	Q_i	***Bus Number***	P_j	Q_j	***Bus Number***	P_i	Q_i	***Bus Number***	P_j	Q_j	***Fitness***
3	***161***	***83***	***4***	***213***	***-138.6***	***5***	***31.3***	***-25.37***	***6***	***51.43***	***-43.54***	***0.1189***

Table III: The result of buses voltages of power flow without UPFC

Bus Number	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***
Voltage	**1.05**	***1.05***	**1.036**	**0.985**	**1.000**	**1.050**	**0.955**	**1.050**	**0.901**	**0.888**	**0.957**	**0.947**	**0.953**	**0.859**

Table IV: The Result of buses voltages of power flow with one UPFC

Bus Number	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***
Voltage	**1.050**	**1.050**	**1.031**	**1.021**	**1.022**	**1.052**	**0.981**	**1.050**	**1.051**	**0.970**	**1.008**	**1.015**	**1.023**	**0.987**

Table V: The result of buses voltages of power flow with two UPFC

Bus Number	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***
Voltage	**1.050**	**1.050**	**1.011**	**1.005**	**1.014**	**1.048**	**1.005**	**1.050**	**1.068**	**0.999**	**1.002**	**0.995**	**1.006**	**0.998**

Table VI: The result of active power flow without UPFC

Line Numbezr	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***	***19***	***20***
Power Flow	***0.907***	***0.123***	***0.035***	***0.288***	***0.170***	***0.115***	***0.014***	***0.086***	***-0.12***	***0.420***	***-3.71***	***-1.29***	***-0.02***	***1.621***	***1.494***	***1.278***	***0.093***	***0.739***	***0.420***	***0.002***

Table VII: The result of reactive power flow without UPFC

Line Number	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***	***19***	***20***
Power Flow	***0.406***	***0.055***	***0.028***	***0.186***	***0.207***	***0.169***	***-0.08***	***-0.03***	***-0.10***	***0.210***	***-0.56***	***0.286***	***0.655***	***0.443***	***0.344***	***0.539***	***-0.06***	***-0.16***	***-0.28***	***0.613***

Table VIII: The result of active power flow with one UPFC

Line Number	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***	***19***	***20***
Power Flow	***0.467***	***0.141***	***0.053***	***0.340***	***0.257***	***0.187***	***-0.04***	***0.136***	***-0.17***	***0.326***	***-0.95***	***-0.98***	***0.163***	***0.894***	***1.019***	***1.059***	***0.178***	***0.895***	***0.626***	***0.003***

Table IX: The result of reactive power flow with one UPFC

Line Number	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***	***19***	***20***

Power Flow	***0.589***	***0.055***	***0.028***	***0.188***	***0.210***	***0.170***	***-0.08***	***-0.03***	***-0.10***	***0.214***	***-0.45***	***0.254***	***0.711***	***0.566***	***0.222***	***0.583***	***-0.06***	***-0.18***	***-0.29***	***0.62 4***

Table X: The result of active power flow with two UPFC

Line Number	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***	***19***	***20***
Power Flow	***0.695***	***0.403***	***0.086***	***0.41***	***0.186***	***0.191***	***-0.01***	***0.195***	***-0.68***	***0.415***	***-0.90***	***-0.83***	***0.18***	***1.123***	***1.092***	***1.133***	***0.091***	***0.947***	***0.715***	***0.001***

Table XI: The result of reactive power flow with two UPFC

Line Number	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***	***19***	***20***
Power Flow	***0.486***	***0.268***	***0.011***	***0.188***	***0.188***	***0.150***	***-0.06***	***-0.06***	***-0.59***	***0.206***	***-0.61***	***0.254***	***0.711***	***0.596***	***0.222***	***0.583***	***-0.06***	***-0.18***	***-0.29***	***0.624***

VIII. Conclusion

In this paper, the optimal UPFC placement on an unstable power system because of load increasing has been investigated. A mathematical model for simultaneously optimizing location and parameters of the UPFCs is presented in this paper. A Imperialist Competitive Algorithm is used to solve this nonlinear programming problem. The computation process are discussed in detail such as the construction of the chromosome, handling of equality and inequality constraints, the location of UPFC to be embedded and the load flow computation etc. The case study of the IEEE 14-busbar system has confirmed that the developed algorithm is correct and effective.The results of the simulations suggest a further use of the proposed tool in the planning field. With the proposed methodology, it can be seen that the FACTS device candidate should give the best locations with respect to various future load duration curves of the transmission system. Such information is of strategic importance to analyze the variation of the system parameters with respect to the number and optimal placement of the UPFC and consequently, with respect to the increase of the power transfers.

References

[1] J. Hao, L. B. Shi and C. Chen, "Optimizing location of unified power flow controllers by means of improved evolutionary programming", IEE Proc. Gen, Trans. Dist. Vol. 151, No. 6, pp. 705–712, 2004.

[2] N. G. Hingorani and L. Gyugyi, Understanding FACTS: Concepts and technology of flexible AC transmission systems, Wiley-IEEE Press**;** 1999.

[3] S.N., Singh, and A.K. David: "Optimal location of FACTS devices for congestion management", Electr. Power Syst. Res., 58, pp. 71–79, 2001.

[4] A.Nabavi-Niaki and M.R.Iravani, "Steady-state and dynamic models of unified power flow controller (UPFC) for power system studies", IEEE Trans. Power Syst. 11(4): 1937–43, 1996.

[5] M. Noroozian, L. Angquist, M. Ghandhari and GAndertson, "Use of UPFC for optimal power flow control", IEEE Trans. on Power Delivery, Vol.12, No.4,1997.

[6] W.L.Fang,., and H.W. Ngan,: "Optimizing location of unified power flow controllers using the method of augmented Lagrange multipliers", IEE Proc., Gener, Transm, Distrib., 146, (5), pp. 428–434, 1999.

[7] Gerbex, R.Cherkaoui, , and A.J.Germond,: "Optimal location of multi-type FACTS devices in a power system by means of genetic algorithms", IEEE Trans.Power Systs., 16, (3), pp. 537–544,2001.

[8] Atashpaz-Gargari, E., Hashemzadeh, F., Rajabioun, R. and Lucas, C. (2008). Colonial Competitive Algorithm, a novel approach for PID controller design in MIMO distillation

column process, *International Journal of Intelligent Computing and Cybernetics,* 1 (3), 337–355.

[9] Atashpaz-Gargari, E., Lucas, C. (2007). Imperialist Competitive Algorithm: An algorithm for optimization inspired by imperialistic competition, *IEEE Congress on Evolutionary Computation*, 4661–4667.

[10] Biabangard-Oskouyi, A., Atashpaz-Gargari, E., Soltani, N., Lucas, C. (2008). Application of Imperialist Competitive Algorithm for materials property characterization from sharp indentation test. *To be appeared in the International Journal of Engineering Simulation*.

[11] Rajabioun, R., Hashemzadeh, F., Atashpaz-Gargari, E., Mesgari, B., Rajaei Salmasi, F. (2008). Identification of a MIMO evaporator and its decentralized PID controller tuning using Colonial Competitive Algorithm. *Accepted to be presented in IFAC World Congress*.

[12] Rajabioun, R., Atashpaz-Gargari, E., and Lucas, C. (2008). Colonial Competitive Algorithm as a Tool for Nash Equilibrium Point Achievement. *Lecture notes in computer science,* 5073, 680-695.

[13] Sepehri Rad, H., Lucas, C. (2008). Application of Imperialistic Competition Algorithm in Recommender Systems. In: 13th Int'l CSI Computer Conference (CSICC'08), Kish Island, Iran.