Application of TLBOA Algorithm for Environmental-Friendly Power Flow Studies

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Abstract

Electric energy sources have been diversifying such as lignite, hard coal, oil, natural gas, hydroelectricity, geothermal, wood, animal and plant wastes, solar and wind. Each of these energy power generating units has specific features. These features affect the electric energy power flow. Power flow (PF) studies aim some features such as more cost-effect, more environmentally, more effective and less loss in dispatching electrical energy. For this aim, some electrical energy PF algorithms are used. The purpose of the research is to calculate better electrical energy fuel cost (FC) and less CO_2 emissions. Better FC means cheaper, more environmental friendly energy generation. To obtain a better FC, a proposed Teaching-Learning Based Optimization Algorithm (PTLBOA) is used and compared to Equal Embedded Algorithm (EEA). As a result, better and more environmental-friendly FC is calculated for a 40 bus electrical power system.

Key words: Power flow (PF), Proposed Teaching Learning Based Algorithm (PTLBOA), fuel cost (FC), environmental-friendly

1. Introduction

Nowadays, environmental impacts of energy production are evaluated by many countries [1]. Carbondioxide and other harmful gas emissions are tried to be brought under control. Generating energy more efficiently will result less emissions and other economic gains.

Electrical generation units are operated as $/h. Every improvement at cost of energy will contribute an extra lifetime for energy generating units such as generators and less working times. It will also decrease the cost of labour. Less working times for energy generating units will decrease global warming effect of energy generation. Optimal Power Flow (OPF) is an important issue for the interconnected electrical systems for planning, operation, exchange of power between utilities and dispatch of energy with a minimum cost [2].

Abbreviations

PTLBOA	Proposed Teaching Learning Based Optimization Algorithm
EEA	Equal Embedded Algorithm
PF	Power Flow
OPF	Optimal Power Flow
FC	Fuel Cost
PA	Proposed Algorithm

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There are many different objectives for OPF. Some of them are FC minimization, power loss minimization, reactive power optimization, less carbon emission, chemical reaction [3,4]. The FC is directly associated with active power generation and optimization.

The main aim of this paper is to determine the effect of TLBOA on FC with generator limits. OPF results with PTLBOA are compared to EEA for nonlinear analysis. The results show that OPF with PTLBOA is a more efficient technique for the solution of PF problems.

2. Materials and Method

To show the effectiveness of PA, a 40 bus Taiwan Tai-power energy production system is chosen. Tai-power system consists of a 40 bus energy generation system and different thermal energy generation units such as coal-fired, oil-fired, gas-fired, diesel and combined cycle generation units. Total load capacity for the system is 10500 MW [5]. 40 bus power system is a realistic large scale power system in Taiwan. Specific α, β and γ coefficients and limits of generators for each generator for the 40 bus power system are taken from reference [5]. In this study, PTLBOA and EEA are used for comparison. The PTLBOA is regulated by optimum student number and iteration number between limits as a result of multiple trials. The main difference from classical TLBOA is determining student, iteration numbers and minimum and maximum weighing limits.

2.1. Teaching Learning Based Optimization Algorithm (TLBOA)

TLBOA is a social based optimization algorithm which is introduced by R.V. Rao et al. [6]. It depends on interaction between students and teachers in a class. The learning capacity of students is related to ability of teacher. At every step of algorithm, successful students are elected and the best students have been determined.

TLBOA has three parameters which is the number of students, number of classes and iteration number. The algorithm has two phases. These are Teacher’s phase and Student’s phase.

2.1.1. Teacher’s Phase

At that phase of the algorithm, students learn from the teacher by imitating. A teacher gives the information between students and tries to increase the average of his class. Teacher is the most experienced and the most informed person so the best student can learn as much as the teacher.

Between teacher and student’s learning capacity, there is an average difference called difference mean and it is defined as equation (1)

$$Difference\_Mean_{j,i} = r_i(X_{j,kbest,i} - T_f M_{j,i}) \tag{1}$$

where r_i is a random number between 0 and 1, $X_{j,kbest,i}$ is the result of teacher (the best result) and T_f is teaching factor between 1 and 2.

T_f is defined as equation (2)

$$T_f = round[1 + rand(0,1)\ \{1,2\}] \quad (2)$$

If difference mean is better than present result, equation (1) is arranged as (3)

$$X'_{j,k,i} = X_{j,k,i} + Difference\_Mean_{j,k,i} \quad (3)$$

where $X'_{j,k,i}$ is the best function result accepted.

After teacher's phase, all best function values are kept to use at student's phase.

2.1.2. Student's Phase

At this stage, students learn the knowledge by interacting and by discussing between them. If a student is more knowledgeable, the other is updating himself by interaction.

P and Q are the random students

$$X'_{total-P,i} \neq X'_{total-Q,i} \quad (4)$$

where $X'_{total-P,i}$ and $X'_{total-Q,i}$ are updated values of $X_{total-P,i}$ and $X_{total-Q,i}$

If

$$X'_{total-P,i} > X'_{total-Q,i}$$

$$X''_{j,P,i} = X'_{j,P,i} + r_i(X'_{j,P,i} - X'_{j,Q,i}) \quad (5)$$

and if $X'_{total-Q,i} > X'_{total-P,i}$

$$X''_{j,P,i} = X'_{j,P,i} + r_i(X'_{j,Q,i} - X'_{j,P,i}) \quad (6)$$

$X''_{j,P,i}$ is accepted as the best function value [6].

2.2. Equal Embedded Algorithm (EEA)

EEA is also known as Muller's Method. It is iterative and quadratically converged and based on interpolation. There are three starting points and a parabola passes through them [7].

In Muller's method f(x)=0 and where f(x) is a non-linear function. It doesn't have function derivative. The roots of quadratic equation assumed to be approximately equal to be the roots of the equation of f(x)=0.

x_{i-2}, x_{i-1}, x_i are three approximations to a root of f(x)=0 and y_{i-2}, y_{i-1} and y_i are related values of $y = f(x)$.

Relationship between y and x

$$y = A.(x - x_i)^2 + B.(x - x_i) + y_i \tag{7}$$

where A, B are the interpolation coefficients and computed as [8]

$$A = \frac{(x_{i-2} - x_{i-1}).(y_{i-1} - y_i) - (x_{i-1} - x_i).(y_{i-2} - y_i)}{(x_{i-1} - x_{i-2}).(x_{i-1} - x_i).(x_{i-2} - x_i)} \tag{8}$$

$$B = \frac{(x_{i-2} - x_i)^2.(y_{i-1} - y_i) - (x_{i-1} - x_i)^2.(y_{i-2} - y_i)}{(x_{i-1} - x_{i-2}).(x_{i-1} - x_i).(x_{i-2} - x_i)} \tag{9}$$

$$x_{i-1}^{(1)} = x_{i-1}^{(0)} - \frac{2y_i}{B \pm \sqrt{B^2 - 4Ay_i}} \tag{10}$$

Lambda values for all generators changes between minimum to maximum values under different load demands. For selected power demand, one value of lambda between all values are selected to provide optimum solution. All lambda values are embedded to optimum one hence it is named as ”equal embedded algorithm” [8].

Proper lambda values are selected such that

$$\lambda_i = \frac{b_i + 2c_i P_i}{1 - 2\sum_{i=1}^{n_g} B_{ij} P_j + B_{i0}} \tag{11}$$

where $\lambda_i = \lambda_i^{min}$ at $P_i = P_i^{min}$ and $\lambda_i = \lambda_i^{max}$at $P_i = P_i^{max}$.

All lambda values, output powers, transmission loss, sum of output power (SOP), minus transmission loss are computed at pre-prepared power demand (PPD) table.

2.3. Theory/calculation

PF studies are based on the FC calculation. A lesser FC result means better environmental-friendly PF analysis. The FC can be expressed as the sum of each generator cost:

$$F_{cost} = \sum_{i=1}^{ng}(\alpha_i + \beta_i Pg_i + \gamma_i Pg_i^2)\ \$/h \tag{12}$$

where α_i, β_i and γ_i are the FC coefficients and Pg_i is the active power for the ith generator and n_g is the number of generators in the system.

Each power generating unit has a typical operating cost curve which consists of $a_{i,}$ b_i and c_i parameters. These parameters are specialized for every power generating unit by design manufacture to determine the heat rate.

For a 10500 MW electrical production system, difference between two compared EEA and PTLBOA algorithms is 72094,8 $ annual and 2883792 $ for a 40 years' lifetime which is an accepted period for thermal power plants. The economic save is 17852045,71 American Dollars for Turkey's 65000 MW installed power. This is an important saving for energy production processes in every respect.

2.3.1. Equality Constraints

As equality constraints, generated and consumed power is defined in the following equations [9]

$$P_{load} - \sum Pg_i - \sum P_L = 0 \tag{13}$$

$$Q_{load} - \sum Qg_i - \sum Q_L = 0 \tag{14}$$

where P_{load} and Q_{load} is the active and reactive power demanded by the system and $\sum Pg_i$ and $\sum Qg_i$is the total active and reactive power generated by all generators and $\sum P_L$ and $\sum Q_L$ are total active and reactive line losses respectively.

2.3.2. Inequality Constraints

Inequality constraints can be classified into generator constraints, transformer constraints and security constraints. In active PF analysis, generator constraints are only taken into account.

2.3.2.1. Generator Constraints

OPF must be realized at some limits of physical devices. Here the problem and also solution is to determine the optimum power generation values between minimum and maximum power limits and to determine the total load demand for the generators.

The optimum power for ith generator is given by equation (15)

$$P_{min} \leq Pg_i \leq P_{max} \tag{15}$$

where P_{min} is minimum value of ith generator, $Pg_i$is optimum generated power, P_{max} is maximum value of ith generator [9].

3. Results

In this study, for 40 bus generation system, a PTLBOA applied with 20 students, 40 variables (40 buses) and 100000 iterations. The PA is implemented in MATLAB R2008b platform on a 2.16 GHz 3 GB Ram personal computer.

In the algorithm, weighing is important parameter to select successful students fast. The weighing is taken between 0 and 1. In this study, maximum weighing is taken 0.999 and minimum of it is 0.0000001. The PA has 100000 iterations because of variable students' number and weighing values. In table 1, minimum, maximum and optimum power values for each generators are given respectively for 10500 MW load demand and the best FC for the PA are calculated.

Table 1. Optimum Pi values for 40 bus power system for PA

Generator No	$P_i^{optimum}$ (MW)	Generator No	$P_i^{optimum}$ (MW)	Generator No	$P_i^{optimum}$ (MW)
1	**79.99998**	12	**304.2838**	27	**550**
2	**119.9999**	13	**446.9049**	28	**12.36451**
3	**190**	14	**492.6107**	29	**12.43234**
4	**42**	15	**499.9992**	30	**12.3433**
5	**41.99989**	16	**499.8636**	31	**20.00011**
6	**140**	17-18-19	**500**	32-33-34	**20**
7	**299.9998**	20-21	**550**	35	**18**
8-9	**300**	22-23	**549.9999**	36	**18.0001**
10	**276.5169**	24-25	**550**	37	**20**
11	**317.6815**	26	**549.9999**	38-39-40	**25**

Also, reference [8]'s result and calculated CO_2 emission decrease are given in Table 2 for comparison to our study. According to reference [10], CO_2 emission decreases as 0.0274 tons/h.

Table 2. Comparison of the algorithms according to fuel cost and CO_2 emission

Optimization Method	**Fuel Cost ($/h)**
Equal Embedded Algorithm (EEA) [8]	143934,67
Proposed Teaching Learning Based Optimization Algorithm (PTLBOA)	143926,44
Approximate decreased CO_2 Emission amount	0.0274 tons/h

4. Discussion

Every improvement at FC will result significant savings economically. Lifetime of the system is taken as 40 years here [11]. For a 40 years' period, using our PA, the economic save is 17852045,71 American Dollars for Turkey's 65000 MW installed power [12]. This saving means less working times and longer product lifetime for energy production systems so they will be more environmental-friendly. Saving as a result of using our PA annually and for 40 years is given in Table 3.

The PA gives the investors valuable information in power systems on planning different thermal energy generating units. The PA can be applied for a great number of different thermal units. As electrical generation system is being complexed, more efficient algorithms can also developed.

Table 3. Economic and Environmental Comparison of the PA for two power systems

Installed Power	Annual Saving ($)	Total save for 40 years ($)	Total CO_2 Decrease for 40 years (tons)
10500 MW Tai-Power System	72094,8	2883792	9600,96
65000 MW Turkey Power System	312407,3	17852045,71	59434,51

Conclusions

In this paper, for a 40 bus active generation system, a PTLBOA is applied under constraints. Total FC with EEA is 143934,67 $/h. It is 143926,42 $/h with the PA for 10500 MW load demand. The PA has a better result from EEA. So, total generation cost is reduced by obtaining the optimum power generation values for each bus by using PA. Calculations were done for 40 years which is an average lifetime of a thermal power plant. The results were calculated for Turkey's 65000 MW whole electrical production systems. Saving for all electrical system of Turkey is 17852045,71 $ for 40 years. This means saving from transportation and labor costs. Total CO2 emission decrease is 59434,51 tons. Saving in FC of the electricity also affects the environment first and lifetime of electrical, mechanical components of power plants. It will also affect the energy prices positively.

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