# Evolutionary Programming Based Load Tracing Optimization in Deregulated Power System

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*Abstract:* - Tracing the flow of electricity becomes an essential part in transmission fixed cost allocation since the existing methods based on transaction are incapable of providing fair and non-discriminatory transmission service pricing. Conventional power tracing based on matrix inversion confronts with the problem of singular matrix possibility as the solution will be indeterminate and undefined. This is because the existence of singular matrix would lead to the failure of matrix inversion process and as a result, the traced powers are unable to be determined. This paper presents a novel technique for allocating the losses and generated powers to all system loads by means of Evolutionary Programming (EP) algorithm. The developed algorithm has been experimented on IEEE 14-bus RTS and the results revealed that EP can also be a sophisticated tool to be applied in power tracing field with tolerable computation time.

*Key-Words:* - Evolutionary Programming, Load Tracing Optimization

## 1 Introduction

Traditional techniques such as postage stamp allocation, MW-mile methodology and contract path method implemented for assessing transmission cost allocation in deregulated power system have resulted to inefficient allocation of usage capacity charges among customers. According to [1], those methods did not take into account the physical power flow results and appropriate electrical constrains such as power direction, losses and loop flow around closed branches of power system. Because of that tracing the flow of electricity becomes an important analysis tool in determining generators' share contribution to the line flows and load demands or load's extraction factor from generators and transmission lines [2, 3]. It is also applied to determine the percentages of transmission capacity used by generators and loads in the power system [4, 5] and also implemented in congestion analysis [6, 7]. In fact, power flow tracing behaves like a contributor in providing fair and non discriminatory transmission service pricing on generator and load sites by making a transparent transmission cost, losses, and reactive power service allocation [8]. The significance of performing electricity tracing is to know what fractions or percentages of generator's output power are consumed by each particular transmission line and load in the system [8]. In a vertically integrated power system, power flow tracing might be less importance since information like generator's share contribution or load extraction factor cannot give any improvement or recovery on system performance. Nonetheless, in a deregulated power system which has different transmission service charge on loads based on regions, tracing the electricity flow can give transparent information for consumers about how much they will be charged on the associated usage of transmission capacity [9]. Article [10, 11] proposed upstream and downstream algorithm for tracing the electricity from generators, line flows and loads. The method has some limitations since it is based on proportional sharing assumption and requires matrix inversion for tracing process. A method for power flow tracing based on bus impedance matrix has been proposed by [3] where it has been proven that the applied method was capable to increase participation of all generators in supplying output powers to the load sites. Unfortunately, this method has drawback in terms of negative power sharing among generators. An alternative approach for tracing technique has been proposed by [12] where this method performs tracing of electricity via elimination on negative elements in participation factor matrix, which is quite simple and flexible. Nevertheless, from the experiment conducted, it only works for small scale power network. Optimization approach for real power tracing has been explored by [13, 14] where three primary elements of optimization (control variable, constraint, and objective function) have been specified accordingly. The researches have proven that the optimization technique has ability to provide fairness in allocating real powers to generators and loads with simple problem formulation, i.e. without requiring complex mathematical derivation like other conventional methods.

This paper presents a novel method for allocating losses and generated power among system loads via

Evolutionary Programming with acceptable computation time. The proposed method was inspired by the research performed in [13, 14] but there is a little bit advantage of using this technique. The developed technique requires no assumption and can be applied in large scale power system (118-bus system) with tolerable speed of searching mechanism. However, for the purpose of this paper only 14-bus system has been used for validation purpose. The study has revealed that the proposed optimization algorithm has capability in allocating losses and generated power to all loads with satisfaction of power system constraints concurrently.

## 2 Load Tracing Concept

Power tracing composes of two cases, i.e. generation and load tracing. This paper presents a novel technique to allocate losses and generated power among existing loads in a power network via load tracing. Prior to performing power tracing on a network, it is essential to identify the dominion (involved generators and paths) of a load. Fig.1 illustrates a simple power network consisting of 6 buses, 2 generators, 7 branches and 4 loads together with the direction of power flow. From that, the dominion of each load can be identified simply by recognizing power flow direction at each load bus. The line that brings inflow to a load bus means that it is classified as an involved path of that load. Similarly, the generator that is connected to the line is also categorized as an involved generator of that load.

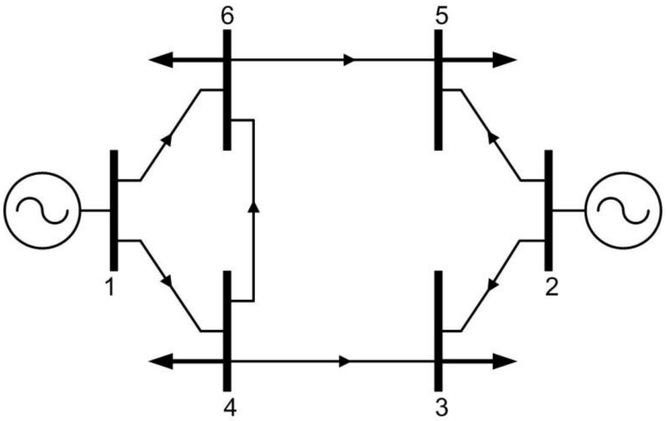

Fig. 1 IEEE 6-bus system with power flow direction

By inspection, the dominion of each load is tabulated in Table 1. The involved generators and lines can be interpreted as the source and path used by a load in extracting real power from generation to consumer site, whereas the unused generators and lines which is not indicated by capital 'Y' in Table 1 denote that they are not part of the elements in the extraction of real power by the load. According to [13], the component of a load with power $P_{Li}$ in line flow and generated power can be expressed as a fraction $x^i$ of $P_{Li}$, that is:

$$P_{fl}{}^{i} = x_{fl}{}^{i}.P_{Li} \qquad (1)$$

$$P_{gk}{}^{i} = x_{gk}{}^{i}.P_{Li} \qquad (2)$$

TABLE I
THE DOMINION OF EACH LOAD

| Line | | Load Bus | | | |
|---|---|---|---|---|---|
| From | To | 3 | 4 | 5 | 6 |
| 1 | 6 | | | Y | Y |
| 1 | 4 | Y | Y | Y | Y |
| 4 | 6 | | | Y | Y |
| 6 | 5 | | | Y | |
| 2 | 5 | | | Y | |
| 2 | 3 | Y | | | |
| 4 | 3 | Y | | | |
| Generator Bus | | | | | |
| 1 | | Y | Y | Y | Y |
| 2 | | Y | | Y | |

Capital 'Y' means the lines and generators are the involved elements of each load.

where

$P_{fl}{}^{i}$ : $l$-th line flow extracted by $i$-th load

$x_{fl}{}^{i}$ : $l$-th line flow fraction extracted by $i$-th load

$P_{gk}{}^{i}$ : $k$-th generated power extracted by $i$-th load

$x_{gk}{}^{i}$ : $k$-th generated power fraction extracted by $i$-th load

Thus, any lines or generators that are unused by a load should have zero value of fraction, for example by looking at Table 1 of load at bus 3, the fraction of first, third, fourth and fifth line flow (i.e. $x_{f1}{}^{3}, x_{f3}{}^{3}, x_{f4}{}^{3}$ and $x_{f5}{}^{3}$ ) should be nil since they are not part of the dominion of the load. The line flow of $l$-th line can be expressed as a summation of load extraction powers:

$$P_{fl} = P_{fl}{}^{1} + P_{fl}{}^{2} + \cdots + P_{fl}{}^{nload} \qquad (3)$$

Substituting (1) into (3) :

$$P_{fl} = x_{fl}{}^{1}.P_{L1} + x_{fl}{}^{2}.P_{L2} + \cdots + x_{fl}{}^{nload}.P_{L,nload} \qquad (4)$$

$$\text{i.e. } P_{fl} = \sum_{i=1}^{nload} x_{fl}{}^{i}.P_{Li} \qquad (5)$$

By using similar mathematical derivation, the following equation is obtained for $k$-th generated power:

$$\text{i.e. } P_{gk} = \sum_{i=1}^{nload} x_{gk}{}^{i}.P_{Li} \qquad (6)$$

where '*nload*' in (3) to (6) represents the number of load in the system.

# 3 Evolutionary Programming in Load Tracing

This section describes the technique applied in formulating Evolutionary Programming (EP) algorithm into load tracing problem. The main elements of optimization technique such as control variables, equality and non equality constraints, and the objective function should be specified accordingly. Nevertheless, prior to performing optimization, an algorithm that can identify automatically the involved lines and generators for all size of power network should be fully developed so as to provide a valid and reliable traced powers. For the purpose of this paper, only the overall EP algorithm is presented.

## 3.1 Fundamental of Evolutionary Programming

There is a lot of stochastic optimization techniques applied in power and energy field and the most common algorithms employed by many researchers are Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Evolutionary Programming (EP) and Ant Colony Optimization (ACO). The invention of EP is pioneered by D. Fogel in 1962 and is further upgraded for optimization purpose by Burgin [15]. The fundamental algorithm of EP begins with random number generation, fitness evaluation of each candidate, mutation of parents for offspring generation, and selection of new generation [15]. The control variable is represented by the generated random number and is limited by a set of specified constraints. The objective function is used to guide the searching process so as to provide a finite converged solution with tolerable computation time.

## 3.2 Formulation of EP into Load Tracing Problem

The crucial part in optimization is to find the most effective way in formulating the algorithm with our case study. Here, the control variables, constraints and the objective function have been identified accordingly.

### 3.2.1 Control variables

$$\boldsymbol{X} = \begin{bmatrix} x_{r1}{}^{1} & \cdots & x_{r1}{}^{i} & \cdots & x_{r1}{}^{nload} \\ x_{r2}{}^{1} & & x_{r2}{}^{i} & & x_{r2}{}^{nload} \\ \vdots & & \vdots & & \vdots \\ x_{rl}{}^{1} & \ddots & x_{rl}{}^{i} & \ddots & x_{rl}{}^{nload} \\ \vdots & & \vdots & & \vdots \\ x_{r,nbr}{}^{1} & \cdots & x_{r,nbr}{}^{i} & \cdots & x_{r,nbr}{}^{nload} \\ x_{g1}{}^{1} & & x_{g1}{}^{i} & & x_{g1}{}^{nload} \\ x_{g2}{}^{1} & \ddots & x_{g2}{}^{i} & \ddots & x_{g2}{}^{nload} \\ \vdots & & \vdots & & \vdots \\ x_{gk}{}^{1} & & x_{gk}{}^{i} & & x_{gk}{}^{nload} \\ \vdots & & \vdots & & \vdots \\ x_{g,ngen}{}^{1} & \cdots & x_{g,ngen}{}^{i} & \cdots & x_{g,ngen}{}^{nload} \end{bmatrix} \quad (7)$$

The line flow and generated power fraction (i.e. $x_{fl}{}^{i}$ and $x_{gk}{}^{i}$ respectively) being the control variables in load tracing optimization. Each individual in EP represents a matrix ***X*** of order (*nbr* + *ngen*) x *nload*, where *nbr*, *ngen*, and *nload* represent the number of lines, generators and loads in the system respectively. The elements inside the matrix ***X*** represent the fractions of line flow and generated power for all loads, as shown in (7). The fraction of line flow composes of two parts, sending and receiving end fraction (i.e. $x_{sl}{}^{i}$ and $x_{rl}{}^{i}$ respectively). Because of too many control variables involved, the EP algorithm might be burdensome in terms of time consumption. Hence, only one of the line flow fraction should be selected either $x_{sl}{}^{i}$ or $x_{rl}{}^{i}$. For the load tracing optimization, it is suitable to select $x_{rl}{}^{i}$ as the control variable since receiving end power goes directly to the load. The sending end and losses fraction due to *i*-th load can be alternatively determined via (8) [13] and (9) respectively:

$$x_{sl}{}^{i} = \frac{P_{sl}}{P_{rl}} . x_{rl}{}^{i} \quad (8)$$

$$x_{loss,l}{}^{i} = x_{sl}{}^{i} - x_{rl}{}^{i} \quad (9)$$

where $P_{sl}$ and $P_{rl}$ represent the sending and receiving end power of *l*-th line respectively. The reason why (9) has been established because of its ability to speed up the EP searching mechanism as compared to the method proposed by [14], which representing $x_{loss,l}{}^{i}$ as the control variable in matrix ***X***.

### 3.2.2 Constraints

The equality and non equality constraints specified in this paper are as followed:

i) $$P_{sl} = \sum_{i=1}^{nload} x_{sl}{}^{i} . P_{Li} \quad (10)$$

ii) $$P_{rl} = \sum_{i=1}^{nload} x_{rl}{}^{i} . P_{Li} \quad (11)$$

iii) $$P_{gk} = \sum_{i=1}^{nload} x_{gk}{}^{i} . P_{Li} \quad (12)$$

iv) $$x_{sl}{}^{i}, x_{rl}{}^{i}, x_{loss,l}{}^{i}, x_{gk}{}^{i} \geq 0 \quad (13)$$

The constraint (13) ensures there will be no negative share of power among loads in the system, which enhancing the effectiveness of using optimization technique.

### 3.2.3 Objective function

A hypothetical equation has been derived to be utilized as the fitness for guiding the EP algorithm in searching mechanism. Logically, power consumed by a load should be equal to the total extracted generator power minus with the total losses due to that load, or mathematically:

$$P_{Li} = \sum_{k=1}^{ngen} P_{gk}{}^{i} - \sum_{l=1}^{nbr} P_{loss,l}{}^{i} \qquad (14)$$

After several mathematical substitutions and derivations:

$$E_i = \sum_{k=1}^{ngen} x_{gk}{}^{i} - \sum_{l=1}^{nbr} x_{loss,l}{}^{i} - 1 \qquad (15)$$

or

$$\min(E_i) = \sum_{k=1}^{ngen} x_{gk}{}^{i} - \sum_{l=1}^{nbr} x_{loss,l}{}^{i} - 1 \qquad (16)$$

The objective of EP is to minimize the error $E_i$ as low as possible by finding stochastically the best values of fraction.

### 3.3 Overall EP Algorithm for Load Tracing Optimization

Fig. 2 illustrates the process involved in finding the best generated power and losses fractions to be allocated on each load. Prior to executing the searching mechanism via EP, the power flow solution and identification of involved paths and generators are primarily performed. Subsequently, EP algorithm shall take place.

Step 1: *EP initialization*
The essential EP parameters such as mutation scale $\beta$ (which ranges between 0 and 1), number of population and required iterations are specified.

Step 2: *Random number generation*
Initially, the line flow and generator power fraction (i.e. $x_{rl}{}^{i}$ or $x_{gk}{}^{i}$ respectively) of each load are randomly generated via constraint handling technique algorithm, which is not shown in this paper. The random generation will be terminated after all individuals (the matrices ***X***'s) have been filled with fraction values.

Step 3: *Fitness evaluation*
After determining the minimum and maximum values of each fraction from all matrices ***X***'s, the error of each load is computed via (16). The maximum error among the loads is chosen for representing the fitness of an individual ***X***.

Step 4: *Mutation process*
The next step is to modify the current solution (parent) to a new updated solution (offspring) via mutation process. The mechanism for mutation can be mathematically represented by the following equation [15]:

$$x_{new}{}^{i} = x_{current}{}^{i} + N(0,\gamma^2) \qquad (17)$$

$$\gamma^2 = \beta\left(x_{max}{}^{i} - x_{min}{}^{i}\right)\left(\frac{f}{f_{max}}\right) \qquad (18)$$

Where

| | | |
|---|---|---|
| $x_{current}{}^{i}$ | : | represent the parent's line flow and generated power fraction ($x_{rl}{}^{i}$ or $x_{gk}{}^{i}$) respectively. |
| $x_{new}{}^{i}$ | : | represent the offspring's line flow and generated power fraction ($x_{rl}{}^{i}$ or $x_{gk}{}^{i}$) respectively. |
| $x_{min}{}^{i}$<br>$x_{max}{}^{i}$ | : | represent the minimum and maximum value of every variable in matrix ***X***. |
| $N(0,\gamma^2)$ | : | Gaussian random number with zero mean and variance of $\gamma^2$. |
| $f$ | : | fitness ($E_i$) of an individual ***X***. |
| $f_{max}$ | : | maximum fitness among all individuals. |

Step 5: *Combine and sort*
After evaluating the fitness of all offspring, both of the parent and offspring population are combined and sorted according to their quality of fitness.

Step 6: *Assigning new generation*
Subsequently, half of the combined population is selected as the new generation for the next iteration.

Step 7: *Convergence test*
Eventually, the algorithm will stop if all individuals ***X***'s have a tolerable difference of fitness.

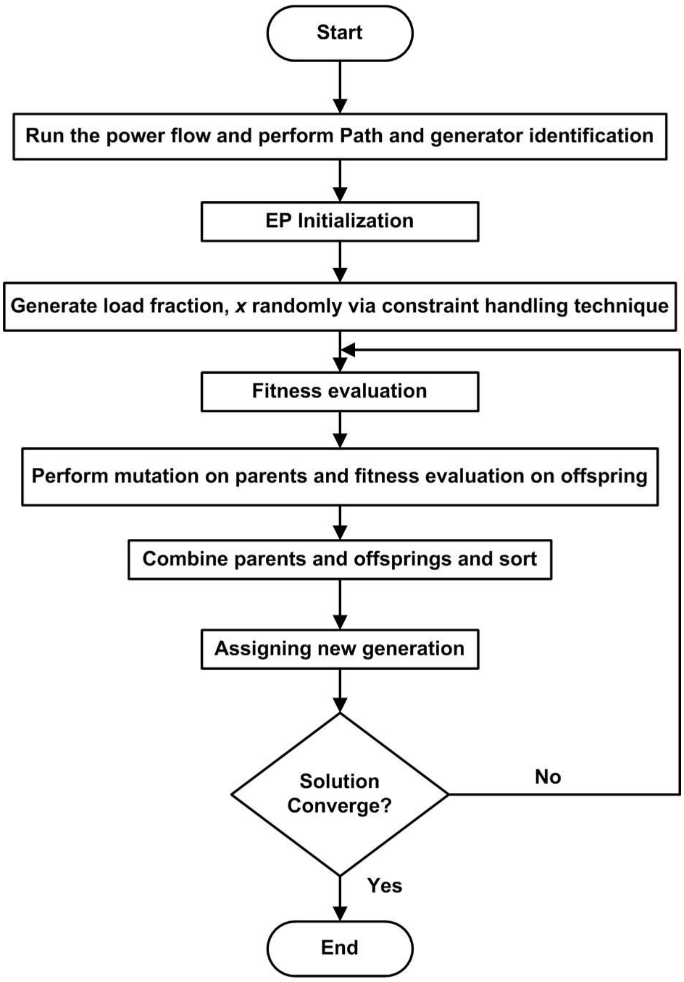

Fig. 2. Overall EP algorithm for load tracing optimization

TABLE 2
LOAD TRACING VIA EVOLUTIONARY PROGRAMMING

| Line |  | Load Bus |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From | To | 2 | 3 | 4 | 6 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Total |
| 1 | 2 | 0.0160 | 2.8838 | 0.0544 | 2.1641 | 0.1366 | 0.0074 | 0.0308 | 0.0049 | 0.0449 | 0.0181 | 0.0399 | 5.4008 |
| 1 | 8 | 0.0000 | 0.0000 | 0.4739 | 0.6534 | 0.6830 | 0.0806 | 0.3343 | 0.3041 | 0.0253 | 0.0551 | 1.8464 | 4.4560 |
| 2 | 3 | 0.0000 | 0.9601 | 0.0000 | 0.1478 | 0.0000 | 0.0966 | 0.0734 | 0.0000 | 0.0000 | 0.0000 | 0.0545 | 1.3324 |
| 2 | 6 | 0.0000 | 0.0000 | 0.0000 | 0.7874 | 0.0000 | 0.7603 | 0.4262 | 0.0000 | 0.0000 | 0.0000 | 0.3974 | 2.3713 |
| 2 | 8 | 0.0000 | 0.0000 | 0.0329 | 0.2627 | 1.4601 | 0.0522 | 0.0158 | 0.0160 | 0.0488 | 0.0222 | 0.0252 | 1.9359 |
| 3 | 6 | 0.0000 | 0.0000 | 0.0000 | 0.0424 | 0.0000 | 0.0041 | 0.0051 | 0.0000 | 0.0000 | 0.0000 | 0.0019 | 0.0535 |
| 8 | 6 | 0.0000 | 0.0000 | 0.0000 | 0.0944 | 0.0000 | 0.0070 | 0.0023 | 0.0000 | 0.0000 | 0.0000 | 0.0030 | 0.1067 |
| 6 | 7 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 6 | 9 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 8 | 4 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 4 | 11 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0269 | 0.0709 | 0.0000 | 0.0000 | 0.0000 | 0.0978 |
| 4 | 12 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0233 | 0.0213 | 0.0348 | 0.0794 |
| 4 | 13 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1023 | 0.1384 | 0.2408 |
| 7 | 5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 7 | 9 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 9 | 10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0128 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0128 |
| 9 | 14 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1260 | 0.1260 |
| 11 | 10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0382 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0382 |
| 12 | 13 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0058 | 0.0072 | 0.0130 |
| 13 | 14 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0854 | 0.0854 |
| Total Losses |  | 0.0160 | 3.8439 | 0.5612 | 4.1522 | 2.2797 | 1.0082 | 0.9658 | 0.3959 | 0.1423 | 0.2248 | 2.7600 | 16.3499 |
| Gen. Bus |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 |  | 18.8507 | 33.2195 | 10.9288 | 48.4124 | 77.4815 | 20.1408 | 7.5185 | 3.6518 | 6.0938 | 13.5327 | 13.9159 | 253.7464 |
| 2 |  | 2.8652 | 29.8446 | 0.8324 | 1.3251 | 0.7973 | 2.1571 | 0.1844 | 0.2440 | 0.1485 | 0.1920 | 1.4094 | 40.0000 |
| 3 |  | 0.0000 | 34.9786 | 0.0000 | 2.2139 | 0.0000 | 8.2099 | 2.2628 | 0.0000 | 0.0000 | 0.0000 | 2.3347 | 50.0000 |
| Total |  | 21.7160 | 98.0427 | 11.7612 | 51.9515 | 78.2788 | 30.5078 | 9.9658 | 3.8958 | 6.2423 | 13.7246 | 17.6600 | 343.7464 |

TABLE 3
LOAD TRACING VIA BIALEK'S METHOD

|  | Load Bus |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | 2 | 3 | 4 | 6 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Total Losses |
| Losses | 0.5949 | 2.5807 | 0.6244 | 2.9975 | 4.2373 | 1.8499 | 0.6449 | 0.2531 | 0.4057 | 0.9591 | 1.2025 | 16.3499 |
| Gen. Bus |  |  |  |  |  |  |  |  |  |  |  | Total |
| 1 | 17.2941 | 38.1660 | 10.3041 | 38.1481 | 69.9206 | 23.5433 | 7.5123 | 3.2200 | 5.6120 | 12.4201 | 12.5171 | 238.6578 |
| 2 | 4.4059 | 9.7233 | 0.8959 | 7.7793 | 6.0794 | 4.8010 | 1.2410 | 0.2800 | 0.4880 | 1.0799 | 2.0002 | 38.7739 |
| 3 | 0.0000 | 46.3106 | 0.0000 | 1.8726 | 0.0000 | 1.1557 | 0.2467 | 0.0000 | 0.0000 | 0.0000 | 0.3827 | 49.9683 |
| Total | 21.7000 | 94.2000 | 11.2000 | 47.8000 | 76.0000 | 29.5000 | 9.0000 | 3.5000 | 6.1000 | 13.5000 | 14.9000 | 327.4000 |

## 4 Results and Discussion

The EP engine has been implemented via MATLAB and has been validated using IEEE 14-bus RTS with 3 synchronous generators, 20 branches and 11 loads. From the experiment, it is justified that the algorithm is capable of producing a reliable and feasible result with acceptable computation time of 240 seconds, as shown in Table 2. The converged error $E_i$ is 1.44 x $10^{-5}$ with final number of iterations of 2000, as illustrated in Fig. 3. Alongside with the results, another tracing technique via Bialek's method has also been conducted and the result is tabulated in Table 3. As can be seen, both of the methods provide reasonable outputs with satisfaction of all power system constraints and concurrently provide fairness in the allocation of losses and generated power among loads. Looking at Table 2, all of the allocated losses coming from each transmission line can be traced effectively by using EP, which provides detail information about where the losses allocated to a load come from. In contrast to the EP, load tracing via Bialek's method can only provide the total losses allocated to each load but is incapable to trace where the losses come from. This is strictly a major drawback since the method cannot identify which transmission line causes the highest losses to the load. Moreover, in spite of having systematic mathematical steps for obtaining the traced powers and no computation time is required, the method still necessitate for the inversion of matrix which depends mainly on the matrix singularity. This is another

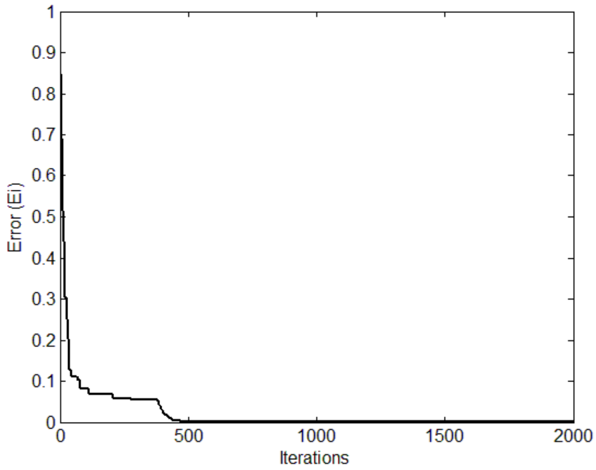

Fig. 3. Convergence of objective function

limitation since the load tracing results will be indeterminate if the matrix is non-square (singular). Nonetheless, EP based load tracing does not require the condition of matrix, i.e. there is no perturbation on having a singular matrix as the EP works free from matrix inversion in allocating the traced powers to the loads. This implies that optimization technique can be applied in any condition of power system, either under base case or stress condition and simultaneously enhancing the usage of this method in voltage stability field.

## 5 Conclusion

An optimization based power tracing technique by means of Evolutionary Programming has been proposed in this paper with complete algorithm and tested on IEEE 14-bus RTS for validation purpose. It is proven that instead of applying conventional methods that require matrix inversion during tracing process, stochastic optimization via Artificial Intelligence (AI) can also be the alternative way in providing a fair and non-discriminatory losses and generated power allocation to system loads. EP based load tracing is an analogous to black box problem, where only the input (fraction $x$) should be specified and fed to the black box system. Subsequently, the developed algorithm will handle all of the process involved inside the system for delivering the outputs, i.e. the traced powers. This entails that the proposed technique create an easiness in formulating the load tracing problem since there is no assumption is needed as what the other methods did.

For future research, it is recommended to extend the capability of the developed algorithm to be applied in large scale power system and provides reactive power tracing results concurrently. It is also aspired that the developed technique should be able to solve problems which is not only related to power system economics, but also in voltage stability field.

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