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New Concept of Percentage Total Deviation Method for Multi-Objective Optimization

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Abstract: ***Real time problems faced in day to day life are involving proper decision making with many objectives.. There are many effective methods for optimizing single objective function. The problem has n objectives ends with n solutions having different values of design variables. The need for common single objective function by combining all the n objective functions is needed for obtaining the best solution for design variables. weightages added to each objective function for the formation of single objective function. There are many more methods to develop single objective function for the problem. This paper presents a very simple new concept of percentage deviation method. It combines multi objectives in to a single objective function for the best solution. In this approach, the solution of single optimization is required by any optimization method before going for the application. Simple dc circuit having two sources and one load is considered as an example. Three objectives are present in the example which illustrates the application of the method. The actual plot of variation in the value of objective functions with respect to single design variable is shown to demonstrate the effectiveness of the method.***

Keywords: Percentage deviation, Single optimization, Total deviation, Multi objective, Fuel cost, Network loss, Emission, Cost function, emission function, Optimal value, Design variables, minimization, parametric, quadratic

1. Introduction

Optimization is the art of obtaining the best result under given circumstances. Optimization can be defined as the process of finding the conditions that give the maximum or minimum of a function.The optimum seeking methods are also known as *mathematical programming techniques* and are generally studied as a part of operations research. *Operations research* is a branch of mathematics concerned with the application of scientific methods and techniques [3] for decision making problems by establishing the best or optimal solutions. Solving single objective for a real time problem involves finding the best solution for a specific criterion. The Multi Objective (MO) problems are needed scaling which reformulates the problem in to a parametric single objective optimization. There are many kinds of Optimization, classified based on continuous function and discrete data.The continous function further classified as constrained and unconstrained[1]. Some of the papers [2,5] focused on particular suitable methods for MO problems where as the papers [3] and [4] discribes the algorithems and procedure for MO problems in Power systems. In all these methods optimization is performed after combining multiple certeria into a single objective function with out finding optimal solution for every objective function. The new basic conept presented in this paper is finding the optimal solution of each objective function, and then finding the percentage deviation of each function value from its optmal vaue at various design variables.Adding all the deviations forms the single objective function called Total Percentage Deviation(T_d). T_d is minimised by any single optimization method for finding the best optimum value of design variable. Simple electrical dc circut with two sources and one load considered as an example for proving the TPD concept effectively .The quadratic cost and emission functions are considered which are depending on source powers.Actual pilots are presented for finding the correct optimal values without applying any optimization method which proves the effectiveness of the TPD mthod.The method can be adopted with any single optimization gives the best solution.

2. Mathematical Explanation

Conventional

With multiple objectives there arises a possibility of conflict, and one simple way to handle the problem is to construct an overall objective function as a linear combination of the conflicting multiple objective functions.

Thus, if $f_1(X)$, $f_2(X)$ **...** $f_n(x)$ denote n objective functions with design variables X then construct a new (overall) objective function for optimization as:

$$f(X) = k_1 f_1(X) + k_2 f_2(X) + \text{-------} k_n f_n(X) \text{ ------------(1)}$$

where k_1 to k_n are weightages whose values indicate the relative importance of one objective function to the other.

Prposed TD method:

Find the optimal value of each objective function f_{ia} i = 1to n,

Determine the percentage deviation of each objective function

$$Td_i = \frac{[f_i(X) - f_{ia}]}{f_{ia}} X100 \qquad i = 1\ to\ n - (2)$$

Then construct a new over all objective function by adding all the deviations;

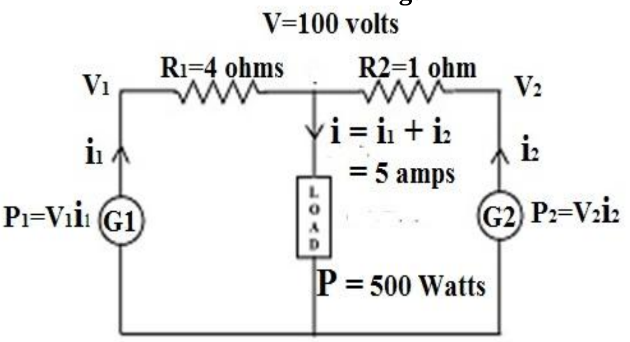
$$Td = \sum_{i=1}^{n} Td_i \sum_{i=1}^{n} \frac{[f_i(X) - f_{ia}]}{fia} X100 \qquad -(3)$$

Equation (3) is a single objective function can be optimized by any method.

In this approach no need for finding weightages or scaling factor. The equation (3) gives best solution directly for any number of objective functions for a particular problem. The application of the method is demonstrated in the following example.

Example:
Optimization of cost, emmission and network loss is one of the MO problem in Power System Engineering.A simple circuit consisting of two sources (Generators), two lines of having resistances
R_1=4Ω,
R_2=1Ω and a load of 500 watts is considered as shown in the Figure1 to demonstrate the TPD method effectively. Load voltage V is constant at 100 volts

Figure 1



Since the load voltage is constant at 100 volts, load current i is equal to load 500 watts divided by 100 volts equal to 5 amps

$i = i_1 + i_2 = 5$ amps --------------------- (4)

Generator 1 output power = $P_1 = V_1 \times i_1$ watts ------- (5)
Generator 2 output power = $P_2 = V_2 \times i_2 = V_2 \times (5 - i_1)$ watts -(6)

Cost Equations
Generator 1 $f_1 = 0.01\ P_1^2 + P_1 + 100$ Rs/hr ---- (7)
Generator 2 $f_2 = 0.005\ P_2^2 + 5\ P_2 + 100$ Rs/hr ---- (8)
Where $P_2 = (5 - P_1 / V_1)$ --------- (9)
Total cost $f_T = f_1 + f_2$ Rs/hr ------ (10)

Emission Equations
Generator 1 $e_1 = 0.0045\ P_1^2 + 0.125\ P_1 + 10$ gms/hr -- (11)
Generator 2 $e_2 = 0.0015\ P_2^2 + 0.8\ P_2 + 20$ gms/hr --- (12)
Total emission $e_T = e_1 + e_2$ gms/hr - (13)

Network loss Equations
Loss $P_L = i_1^2 R_1 + i_2^2 R_2$ watts -- (14)
$P_L = ((P_1 / V_1)^2 \times R_1 + (5 - P_1/V_1)^2 \times R_2)$ watts -- (15)

Total Percentage Deviation method
Total fuel cost f_T from the equations (9),(10),Total emission T_d from the equations (9),(13) and Total network loss P_L from the equation (15) are in terms of Generator 1 output power

At first, find the optimal value (minimum) of cost f_{Ta}, optimal value of Emission e_{Ta} and optimal value of loss P_{La} from the actual Pilots of respective curves..

Determination of Optimal cost f_{Ta}
The generator 1 cost f_1, generator 2 cost f_2 and total cost f_T variations w.r.t generator 1 output power are shown in Figure 2

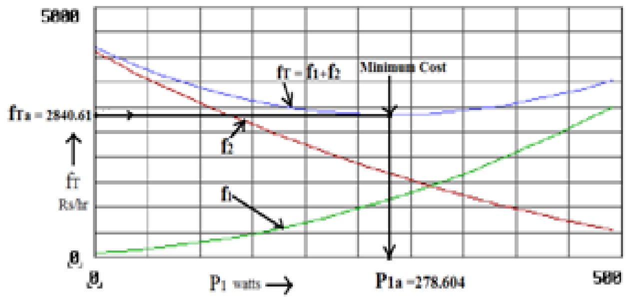


Figure 2

The optimal cost f_{Ta} = 2840.61 Rs/hr
Generator 1 output power P_{1a} = 278.604 watts
Generator 2 output power P_{2a} = 253.101 watts

Determination of Optimal Emission e_{Ta}
The generator 1 emission e_1, generator 2 emission e_2 and total emission e_T variations w.r.t generator 1 output power are shown in Figure 3

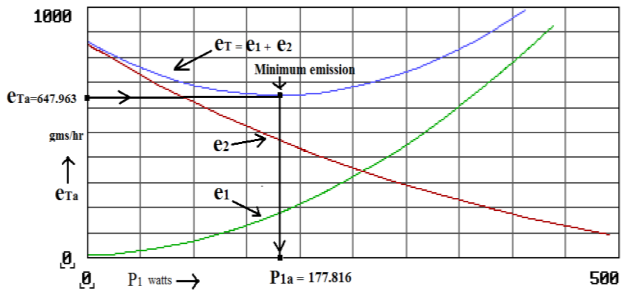


Figure 3

Generator 1 output power P_{1a} = 177.816 gms/hr

Generator 2 output power P_{2a} = 344.409 gms.hr

The optimal emission e_{Ta} = 647.963 gms/hr

Determination of Optimal Loss P_{La}
The Line loss in 4 ohms L_1, line loss in 1 ohm L_2 and total loss P_L variations w.r.t generator 1 output power are shown in Figure 4.

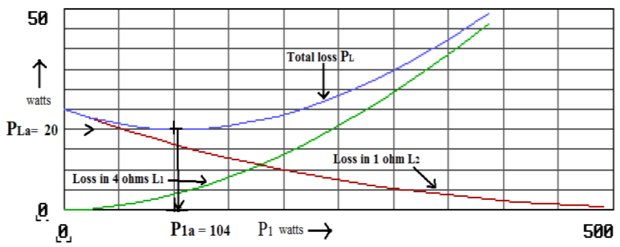


Figure 4

The optimal total loss = P_{La} = 20 watts
Generator 1 output power P_{1a} = 104 watts
Generator 2 output power P_{2a} = 416 watts

Determination of Minimum Total Deviation T_{da}

The cost % deviation $dc = (f_T - f_{Ta})100/f_{Ta}$ ----(16)

$dc = (f_T - 2840.61)\times 100/2840.61$

The emission % deviation $de = (e_T - e_{Ta})\times 100/e_{Ta}$ ---- (17)

$de = (e_T - 647.963)\times 100/647.963$

The Loss % deviation $dL = (P_L - P_{La})\times 100/P_{La}$ --- (18)

$dL = (P_L - 20)\times 100/20$ --(19)

Total % Deviation $T_d = dc+de+dL$ ---(20)

The % deviation in cost, emission, loss and total deviation w.r.t generator 1 output power are shown in Figure 5.

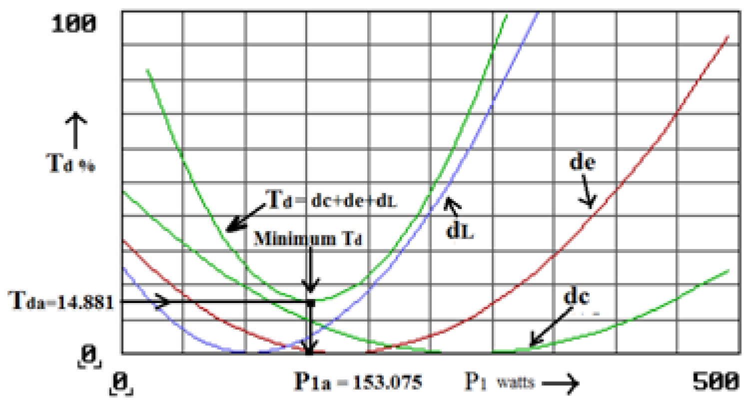


Figure 5

The Minimum Total deviation T_{da} = 14.881 %
This is the best solution for the Example.
Generator 1 output power P_{1a} = 153.075 watts
Generator 2 output power P_{2a} = 367.924 watts
The results are given in the following table

Results

Single Objective	P1 Watts	P2 Watts	
Cost Optimization	278.604	253.101	2840.61 Rs/hr
Emission Optimization	177.816	344.409	647.963 gms/hr
Loss Minimization	104 .00	416.00	20.00 Watts
Multi- Objective Optimization			
With all the three Objectives	153.075	367.924	14.880 %
Cost deviation from the minimum cost			dc = 9.267 %
Emission deviation from the minimum emission			de = 0.618 %
Loss deviation from the minimum loss			dL = 4.995 %
The Total % Minimum deviation			Td = 14.880 %

Conatraint on degin variable: Generator 2 output Power is maximum of 300 Watts and set at the maximum.
Then Generator 1 output Power =225.889 watts
The cost % deviation dc =1.602
The emission % deviation de =2.297
The loss % deviation dL = 29.431
Total % deviation T_d = 33.33

Only cost % deviation is reduced from the best. But emission, loss and total % deviations are increased from the best to a larger value.

Similarly any deign variable change will increase the deviations from the best solution.

3. Conclusion

A novel approach `Total Percentage Deviation Method 'is presented for finding the best solution to Optimization of Multi –Objective problems. Actual plots are used for validating the exactness of the method by considering a simple electrical network. The best solution is given in the table. Determination of optimal value for each objective is needed for the proposed novel method. Most of the conventional methods/algorithms are finding the best solution without finding the individual optimal value. In such cases, the best solution for the design values may give the lesser value of any one of the optimal value of a objective function which is not feasible. If constraint on design value is considered in the proposed method, The solution gives the higher percentage deviation values from the best solution. If the higher deviations from the optimal value are acceptable, then the solution can be considered for the best along with the constraint. The proposed method is based on a new simple concept for solving MO problems; it may be introduced in the technical curriculum by the Universities and Institutions for further development.

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Dr. P. S.Kannan obtained BE degree in electrical and electronics engineering (EEE), M.Sc (Engg.) in Power Systems and Ph.D in Power System optimization from Madurai Kamaraj University during the years 1976,1979 1996 respectively. He worked 32 years in Thiagarajar college of Engineering, Madurai, Tamil Nadu, India as Professor and Head of EEE Department and Dean Student affairs. First Principal of Vaigai Engineering college at Madurai and served as Professor Emeritus in Kings Engg, College near Thanjavur . He guided PG students & research scholars more than 25 years and produced 12 Ph.D. Served as Chief investigator in the project of Defense Research Development Laboratory, Hyderabad. Published 35 papers in National/ International Journals and 55 in National/International conferences. Got Indian and German patents (2021 & 2022) for DC Micro-grid application in utilizing solar energy. Received more than 6 best research paper awards. Acted as member in academic councils and research committees of various Universities. Examiner and reviewer for journal papers/Ph.D Thesis Power system optimization & control is his field of interest.

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Er. K. Samuktha studied in Thiagarajar college of Engineering Madurai and got BE degree in EEE from Madurai Kamaraj University 2006 and studied ME power electronics in PGP Engineering College ,Namakal and got the degree from Anna University 2012 ,Chennai. She worked two years as Assistant Professor in Electrical engineering department of Raja college of Engineering, Madurai and nine years as senior Assistant Professor in EEE department of Profession College of Engineering, Coimbatore. She is an electrical consultant now for the design and installation of Electrical main and Sub main control panels for Vilas, Apartments and Multi store buildings. Her field of interest is the Power Electronics.