ISSN- 2394-5125 VOL 7, ISSUE 01, 2020

Objective Of Multi Highest Quality Power Waft Version For Strength Machine Operation Dispatching

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Abstract—*For the primary requirements of power system operation of protection, excessive , economic system, environmental protection, a multi-intention top of the line energy go with the flow(MOPF) model is hooked up to lessen 3 aim functions of load buses voltage deviations, community lively power loss, pollutants fuel emissions and meanwhile to fulfill the security constraints of energy transmission limits in traces. The everyday boundary intersection approach (NBI) is observed to convert 3-purpose most fulfilling strength waft version into a series of single-objective optimization model, after which the indoors factor technique is used to gain the calmly allocated Pareto frontier in goal capabilities area. according to fuzzy club and entropy weight of numerous goals, the entire compromise foremost answer can be diagnosed from the Pareto frontier floor, that is employed as the operation dispatching scheme of the device. by way of the multi-goal optimization calculation of the IEEE nine-buses tool and the IEEE 39-buses gadget, the effects validate the effectiveness of the proposed model and algorithm, and imply that the complete compromised maximum proper answer can be used as a perfect dispatching scheme of power device operation.*

Index Terms-- ***Pareto frontier, Normal Boundary Intersection method, Multi-objective optimal power flow, optimal dispatching, Power system.***

I. INTRODUCTION

Security, quality, economy and environmental protection are basic requirements of power system operation [1]. To
maintain the security, quality, economy, environmental protection of power system operation is an important job for
system operators, and it is also a significant driving force for the development of electrical science and engineering technology. Modern power grid dispatching control center is the brains of grid operation. Appropriate dispatching or
control strategies executed by operators in dispatching control center contributes to maintain the security, quality, economy, environmental protection operation of power system.

The multi-objective Optimal Power Flow model will be able to describe the above-mentioned optimal operation problems of power system, and its solution is an portent basis for the decision-making of system operators and dispatchers. OPF is an effective tool to achieve the optimal operation state of power grid, and it has developed into a necessary functional module of the EMS system in modern dispatching control center [2]. And for the studies of MOPF, it has gradually caused more interested in recent years [3-5]. Literature [3] established a MOPF model of minimizing the operating costs and maximizing the static voltage stability margin. Literature [4] set up a MOPF model of maximizing both social benefit and load margin. And literature [5] constituted a multi-objective optimal reactive power dispatch model of minimizing both network loss and the voltage deviation of load buses. However, the MOPF model which can fully reflect the four basic requirements of power system operation (security, quality, economy, environmental protection) has not been reported in literatures.

Since the four basic requirements of power system operation (security, quality, economy, environmental protection) have some conflicting nature, an improvement of a goal may lead to a decline performance of another goal.Terefore, under normal condition, all the goals cannot achieve optimal state at the same time, while we can only get a relatively better compromise solution of all the goals instead. Currently, the strategy implemented to deal with the multi-objective optimization problem is to get a series of Pareto optimal solutions, from which we determine the superior ones. There are three common algorithms to get a Pareto optimal solution set: Traditional optimization algorithms, intelligent optimization algorithms and scalar multi-objective optimization algorithms and so on. The traditional optimization algorithms mainly contain the weighted sum method and the ε-constrained method [3-4, 6], by means of which we can only gain a Pareto optimal set which distributes unevenly, and there are a lot of subjectivity in determining the weights or the constraints thresholds. The intelligent optimization algorithms, such as evolutionary algorithm and particle swarm algorithm [7-8], have strong robustness. However, they take too long time for the search process, and the convergence speed is too slow. The scalar multi-objective optimization algorithms include the normal boundary intersection method (NBI) and the normalized normal constraint (NNC) method [9-11], from which the gained Pareto frontier distributes evenly. Moreover it can also form an evenly distributed Pareto frontier even if the objective functions have different dimensions. Therefore it has been widely applied. n this paper, an MOPF model is established to minimize three objective functions of load buses voltage deviation, network loss, pollution gas emissions and meanwhile to meet the security constraints of power transmission limits in lines. This model should be solved by NBI method to obtain the evenly distributed Pareto frontier in the objective functions space. According to Fuzzy membership and Entropy weight Method of various targets, the comprehensive compromise optimal solution can be identified from the Pareto frontier, which is employed as the dispatching scheme of power system operation. Finally, the effectiveness of the proposed model and algorithm is demonstrated by two IEEE standard test systems.

II. THE MULTI-OBJECTIVE OPTIMAL POWER FLOW MODEL OF POWER SYSTEM OPERATION DISPATCHING

In the optimization model which described four basic requirements (security, quality, economic, environmental protection) of power system operation, security is an essential condition in normal operation, which is forbidden to violate, and therefore it should be described as the constraints. For example, the active power transmitted in lines must be limited below a certain value in order to prevent overheating which may result in burned wires. Quality refers to the voltage and frequency which can maintain in a certain operating range and it is better to stay closer to the rated values, thus we can limit the operating range by the constraints. And the deviation between the operating values and the rated values can be minimized by the objective functions, which can make it closer to the rated values. Economy and environmental protection, which means the less power loss of system operation and the fewer amounts of pollution gas emissions, will be described by minimizing the objective functions apparently. The MOPF model of power system operation dispatching which takes security, quality, economy, environmental protection into consideration can be described as follows:

$$\begin{cases} \min & \{ f_1(x), f_2(x), f_3(x) \} \\ \text{s.t.} & h(x)=0 \\ & \underline{g} \le g(x) \le \overline{g} \end{cases} \qquad (1)$$

Where, $\boldsymbol{x}$ is the control variables and state variables in power system. The control variables are the active power and reactive power output of the generators $\boldsymbol{P_G}$ and $\boldsymbol{Q_G}$. The state variables include the real part of each node voltage $\boldsymbol{e}$, and the imaginary part of each node voltage $\boldsymbol{f}$ except the referenced node. Assuming that the system has n nodes and the n-th node is the referenced node, whose imaginary par of voltage is $f_n=0$. The objective function $f_1(\boldsymbol{x})$ is the sum of square of the voltage deviation of load buses, which is revealed below:

$$f_1(x) = \sum_{i=1}^{N_L} \left(\sqrt{e_i^2 + f_i^2} - V_{iN}\right)^2 \qquad (2)$$

Where, NL is the total number of load buses in the system, ViN is the rated voltage of i-th load bus. $f2(\boldsymbol{x})$ is active power loss of the network, that is the sum of all the active power output of all the generators minus the active power absorbed by all the loads, which is expressed as:

$$f_2(x) = \sum_{i=1}^{N_G} P_{Gi} - \sum_{i=1}^{N_L} P_{Li} \qquad (3)$$

Where, NG is total number of generators in the system, PGi is the active power output of i-th generator, PLi is the active power absorbed by i-th load. $f3(\boldsymbol{x})$ is the amount of pollution gases emissions, which can be represented below：

$$f_3(x) = \sum_{i=1}^{N_g} (a_{2i} P_{Gi}^2 + a_{1i} P_{Gi} + a_{0i}) \qquad (4)$$

Where, a_{2i}、a_{1i} *and* a_{0i} are the characteristics coefficients of the pollution gases emission of the i-th generator.

$\boldsymbol{h}(\boldsymbol{x})$ is the injected power balance equation of each node, hich can be stated as:

$$\begin{cases}\Delta P_i = P_{Gi} - P_{Li} - e_i\sum_{j=1}^{n}(G_{ij}e_j - B_{ij}f_j) - f_i\sum_{j=1}^{n}(G_{ij}f_j + B_{ij}e_j) = 0 \\ \Delta Q_i = Q_{Gi} - Q_{Li} - f_i\sum_{j=1}^{n}(G_{ij}e_j - B_{ij}f_j) + e_i\sum_{j=1}^{n}(G_{ij}f_j + B_{ij}e_j) = 0\end{cases}$$

$$i=1,\ 2,\ \ldots,\ n \qquad (5)$$

Where, G_{ij} and B_{ij} are the real part and imaginary part of the i-th row, the j-th column element of the node admittance
matrix of network. The inequality constraints $\boldsymbol{g}(\boldsymbol{x})$ consist of the upper and lower bounds which contain the active power and reactive power output of generators as well as the bus voltage magnitude, and the security constraints of the active power transmission limit of lines. And all of them can be described below:

$$\begin{cases}\underline{P_{Gi}} \le P_{Gi} \le \overline{P_{Gi}} \\ \underline{Q_{Gi}} \le Q_{Gi} \le \overline{Q_{Gi}} \\ \underline{V_i} \le \sqrt{e_i^2 + f_i^2} \le \overline{V_i} \\ -\overline{P_{ij}} \le P_{ij} \le \overline{P_{ij}}\end{cases} \qquad (6)$$

Where, P_{ij} is the active power transmission of the line between i-th node and j-th node.

III. NBI METHOD OF SOLVING THE MOPF MODEL

For the MOPF model above, since there are usually certain conflicts between different objectives, which cannot achieve
optimal point simultaneously. However, the Pareto optimal
solutions can reflect the compromise information between
various objectives, which is defined as: Giving a
multi-objective optimization problem min $\{f_1(x), f_2(x), \cdots, f_r(x)\}$, whose feasible region is $\boldsymbol{\Omega}$. If $\boldsymbol{x}^*\in\boldsymbol{\Omega}$, and there is no other $x2\in\boldsymbol{\Omega}$ which satisfies $f_i(x') \le f_i(x^*)$, in which there is at least one strict inequality is satisfied. Therefore we can call $\boldsymbol{x}^*$ the Pareto optimal solution of the problem. Obviously, there are often a set of optimal solutions (that is more than one Pareto optimal solution which can meet the definition), which is known as Pareto frontier. For the three-objective OPF model (1), when we only minimize $f_1(\boldsymbol{x})$ for single-objective optimization, and get the optimal solution $\boldsymbol{x}^{1*}$. Correspondingly, $f^{1*}(f_1(x^{1*}), f_2(x^{1*}), f_3(x^{1*}))$ is the gained point in the three-dimensional coordinate system which is composed of three objective functions. Similarly, we can obtain two optimal solutions $\boldsymbol{x}^{2*}$ and $\boldsymbol{x}^{3*}$ when we only minimize $f_2(x)$ or $f_3(x)$, respectively, and thus we can gain $f^{2*}(f_1(x^{2*}), f_2(x^{2*}), f_3(x^{2*}))$ and $f^{3*}(f_1(x^{3*}), f_2(x^{3*}), f_3(x^{3*}))$ two corresponding points. In the space whose coordinate system is constituted by three objective functions, $\boldsymbol{f}^{1*}$、 $\boldsymbol{f}^{2*}$ and $\boldsymbol{f}^{3*}$ make up the endpoints of the Pareto frontier, which define a plane called Utopia plane. $f^*(f_1(x^{1*}), f_2(x^{2*}), f_3(x^{3*}))$ is the point composed of the minimum values of the three objective functions, which is unattainable in general, and we call it the Utopia point. In addition, the Pareto frontier is located between the Utopia point and the Utopia plane, as in figure 1

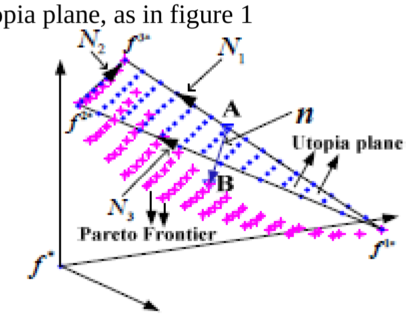

Figure 1. Utopia plane and Pareto optimal frontier for a three-objective case

The procedure of forming Pareto frontier is as follows:

A. Normalization transformation for objective functions In order to avoid the differences of dimensions and magnitudes between different objective functions, the objective functions need to be implemented the normalization
transformation [9]. As a result, the objective functions can be limited into the interval [0, 1] or less. Besides, the normalized variables can be distinguished by the line"—" overhead. Take i-th objective function for an example:

$$\overline{f}_i = (f_i - f_i^U)/(f_i^N - f_i^U) \qquad i=1,2,3 \qquad (7)$$

Where,

$\mathbf{F}^U = (f_1^U, f_2^U, f_3^U) = (f_1(\mathbf{x}^{1*}), f_2(\mathbf{x}^{2*}), f_3(\mathbf{x}^{3*}))$ is the Utopia point, which consists of the minimum voltage deviation of load buses, the minimum transmission loss and the minimum amount of pollution gases emissions. $\mathbf{F}N$ is the supposed worst point called the nadir point, which is composed by the maximum voltage deviation, the maximum transmission loss and maximum amount of pollution gases emissions in the value of three objective functions corresponding to three single-objective optimal point ***x***1*、***x***2* and ***x***3* respectively. And **F***N* is expressed below:

$$\mathbf{F}^N = (f_1^N, f_2^N, f_3^N) \quad (8)$$

$$f_i^N = \max\{f_i(x^{1*}), f_i(x^{2*}), f_i(x^{3*})\} \quad i = 1,2,3 \quad (9)$$

It can be seen that the normalized the Utopia point is located in original point after normalization transformation.

B. Generating evenly distributed points on Utopia plane Assuming that the vector N_1 is from point f_{1*} to point f_*, the vector N_2 is from point f_{2*} to point f_{3*}, the vector N_3 is from point f_{1*} to point f_{2*}, which are presented in figure 1. The vector N_k is divided into $_k m$ equal line segments, and thus the unit length of each line segment is $\delta_k = 1/m_k$, $k = 1,2,3$. Any point on the Utopia plane may be expressed by a linear combination of three endpoint f_{1*}、f_{2*} and f_{3*}. Take *j*-th point **A** as an example:

$$p_j = \sum_{i=1}^{3} \beta_{ij} \overline{f}^{i*} \quad (10)$$

Where, $_1 f_*$、$_2 f^*$ and $_3 f_*$ are the normalization of three endpoints, and the expressions of β is listed below:

$$\begin{cases} \beta_{1j} = [0,1,\ldots,m_1]\delta_1 \\ \beta_{2j} = [0,1,\ldots,m_2']\delta_2 \\ \beta_{3j} = 1 - \beta_{1j} - \beta_{2j} \end{cases} \quad (11)$$

It can seen from the expressions that $m_2' = \mathrm{Int}((1-\beta_{1j})/\delta_2)$, and Int(**.**) is a integer function. The value of parameter β
determines the distribution of points on the utopia plane When $\delta_1 = \delta_2 = 0.2$, , the value of β can be illustrated in figure 2

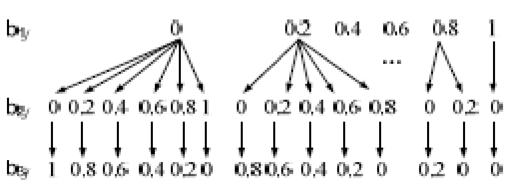

Figure 2. Values of vector ***β*** used in equal points of division

p can also be expressed in the form of multiplication of payoff matrix √ and vector ***β*** of equal division points, which is as follows:

$$p_j = \overline{\Phi}\beta = \begin{bmatrix} \overline{f}_1(x^{1*}) & \overline{f}_1(x^{2*}) & \overline{f}_1(x^{3*}) \\ \overline{f}_2(x^{1*}) & \overline{f}_2(x^{2*}) & \overline{f}_2(x^{3*}) \\ \overline{f}_3(x^{1*}) & \overline{f}_3(x^{2*}) & \overline{f}_3(x^{3*}) \end{bmatrix} \begin{bmatrix} \beta_{1j} \\ \beta_{2j} \\ \beta_{3j} \end{bmatrix} \quad (12)$$

C. Solving the optimal solution of Pareto frontier

In the NBI method, we can obtain evenly distributed Pareto frontier surface by finding the intersection points of the
Normal vector of utopian plane and the feasible region boundary in the objective functions space. However the expression of normal vector of utopian plane in three-dimension space is too complex and not easy to calculate. Apparently, as long as there is a group of evenly spaced parallel lines which intersect with utopian plane and is close to the normal direction, evenly distributed Pareto frontier can also be gained by intersection points of these lines with the feasible region boundary in the objective functions space. So we can make use of quasi-normal method in the literature [10] to simplify the calculation. The expression of quasi-normal vector ***n*** is expressed as (13). According to figure 1, ***n*** is a vector from point **A** on the utopian plane to point **B** on corresponding Pareto frontier surface.

$$n = -\overline{\Phi} e \quad (13)$$

Where $e = [1,1,\cdots,1]^{\mathrm{T}}$ is given.

The expression of quasi-normal method is much simpler than that of normal vector of the Utopia plane, and it is beneficial to simplify the calculation. Thus point **B** on the Pareto frontier can be determined by the following formula:

$$\overline{F}(x) = \overline{\Phi}\beta + dn = \overline{\Phi}(\beta - de) \quad (14)$$

Where, *d* is a distance parameter. With the increase of *d*, the objective functions of the feasible solution determined by Φ***β*** + *d****n*** are gradually improved. When *d* achieves maximum value max *d* , the point Φ***β*** + *d****n*** in the objective functions space is the Pareto optimal solution. Therefore, if a vector ***β*** of equal diversion points is given, the original multi-objective optimization problem (1) is converted into a series of parameterized single-objective optimization problems with the objective to maximize the distance *d*, which are as follows:

$$\min \ (-d) \quad (15)$$

$$\text{s.t.} \ \overline{F}(x) = \overline{\Phi}\beta + dn = \overline{\Phi}(\beta - de) \quad (16)$$

$$h(x) = 0 \quad (17)$$

$$\underline{g}(x) \le g(x) \le \overline{g}(x) \quad (18)$$

ISSN- 2394-5125 VOL 7, ISSUE 01, 2020

Given all the diverse values of vector $\boldsymbol{\beta}$, the multi-objective optimization problem is transformed into a series of single-objective optimization problems, which can be solved by Primal-dual interior point method [12]. And then, we can acquire a series of evenly distributed Pareto optimal solution by solving a series of single-objective optimization problems.

IV. DISPATCHING DECISIONS BASED ON PARETO FRONTIER

After obtaining the Pareto optimal solution set of MOPF problems, system operators can select the corresponding optimal solution as the decision-making scheme according to diverse operating states and various operational requirements of the system. However, in general, how to choose a solution in which each objective are relatively better from Pareto frontier as the decision-making guidance of dispatchers? This paper adopts Fuzzy membership and Entropy weight method to determine the solution.

The value of the membership can reflect the optimizing degree of objective functions. And we choose the trapezoid function as the fuzzy membership functions of three objectives. The fuzzy membership of the i-th objective function which is corresponding to the j-th Pareto optimal solution can be expressed as:

$$\mu_{ij} = \frac{f_{i\max} - f_{ij}}{f_{i\max} - f_{i\min}} \quad i = 1,2,3 \quad j = 1,2,\cdots,m \qquad (19)$$

Where, m is the number of solutions on the Pareto frontier, f_{ij} is the value of the i-th objective function which is corresponding to the j-th Pareto optimal solution, $f_{i\max}$ and $f_{i\min}$ is the maximum and minimum of the i-th objective function on the Pareto frontier respectively.

A large extend of subjectivity is mainly due to human determining the weight of each objective, so we use Entropy weight method to calculate the weight of each objective function. The value of entropy weight is determined by the difference degree of various solutions in this objective, which represents the amount of information provided by this objective. Entropy weight is calculated as follows

$$\begin{cases} \omega_i = \dfrac{1-e_i}{(1-e_1)+(1-e_2)+(1-e_3)} \\ e_i = -\dfrac{1}{\ln m}\displaystyle\sum_{j=1}^{m} p_{ij}\ln p_{ij} \qquad i=1,2,3 \quad j=1,2,\cdots,m \\ p_{ij} = \mu_{ij} \Big/ \displaystyle\sum_{j=1}^{m}\mu_{ij} \end{cases} \qquad (20)$$

Where, p_{ij} is the specific weight of the j-th Pareto optimal solution in the i-th objective function, e_i indicates the value of entropy of the i-th objective function, ω_i means the entropy weight of the i-th objective function. Apparently, we can know that $\sum_{i=1}^{3}\omega_i = 1$.

After determining the fuzzy membership and the entropy weight of each objective, we can acquire the degree of comprehensive optimization of the j-th Pareto optimal solution by calculating the weighted sum of the membership, which is revealed as follows:

$$\lambda_j = \sum_{i=1}^{3}\omega_i\mu_{ij} \qquad (21)$$

Obviously, the maximum value of λ_j among all the Pareto optimal solutions is the comprehensive compromised optimal solution (CCOS) by the coordinated optimization of three objective functions, which can be employed as the dispatching scheme of power system operation.

V. CASE STUDIES

A. IEEE 9-bus system

IEEE 9-bus system is shown in Figure 3, assuming node 1 as the reference node, and the initial state of the system and the parameters of the lines and transformers can be seen from MATPOWER [13]. The upper and lower limits of the generator output and the characteristic coefficients of pollution gas emissions are indicated in TABLE I. The upper and lower limits of the node voltage are 1.10 p.u. and 0.90 p.u. while the maximum transmission power of each line is in TABLE II.

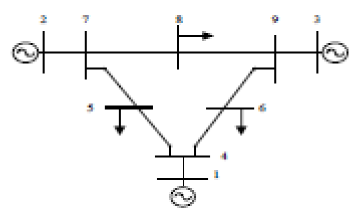

Figure 3. Structure of IEEE 9-bus system

TABLE I. OPERATING PARAMETERS OF GENERATORS

G	$\overline{P}_{Gi}$ /MW	$\underline{P}_{Gi}$ /MW	$\overline{Q}_{Gi}$ /Mvar	$\underline{Q}_{Gi}$ /Mvar	a_2/ (t/(MW)^2·h)	a_1/ (t/(MW·h))	a_0/ (t/h)
1	250	10	300	-300	0.003375	1.800	56.25
2	300	10	300	-300	0.001125	0.600	18.77
3	270	10	300	-300	0.001689	0.897	28.17

TABLE II. TABLE 2 MAXIMUM POWER TRANSMISSION OF LINES

i-end node	j-end node	Maximum power/MW
4	6	250
6	9	150
9	8	150
8	7	250
7	5	250
5	4	250

The NBI method is used for three-objective optimization calculations of the system, and let $\delta_1 = \delta_2 = 0.1$, where there is a total of 66 points. And then we can get the Pareto frontier which is shown in Figure 4. It can be seen from Figure 4 that the 66 Pareto optimal solutions are evenly distributed on the Pareto frontier by NBI method, which contain comprehensive and abundant information of the optimal operation of the power system. The system operators can choose the corresponding optimal solutions from Pareto frontier as the dispatching decision scheme according to the operation state and operation requirements of the system.

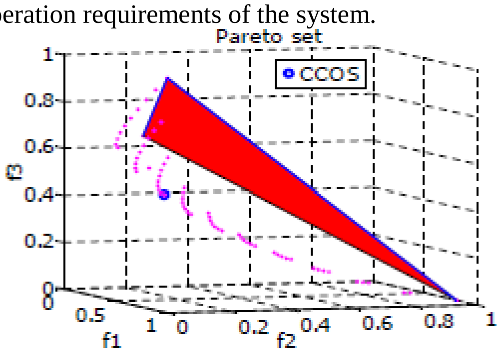

Figure 4. Pareto frontier for 3 objectives optimization in IEEE 9-bus system

The values of the objective functions of three endpoints on the Pareto frontier are expressed in TABLE III. As we can see from the table, the amount of pollution gas emissions corresponding to the solution from “Minimize voltage deviation” is relatively larger. In addition, the root mean square value of voltage deviation of load buses corresponding to the solutions from “Minimize the network loss” and “Minimize the emissions” are both more than 7%. Obviously,

These three single-objective optimization solutions are not good decision points for operation, which is due to the fact that in the single-objective optimization, we only take the corresponding objective into consideration rather than pay respect to other objectives.

TABLE III. PARETO EXTREME POINTS

Endpoint	root mean square value of voltage deviation	Network loss /MW	Amount of emissions /t
Minimize voltage deviation	2.97822×10^{-7}	3.68498	533.7902
Minimize network loss	0.0843405	2.31580	605.2819
Minimize emissions	0.0756432	7.64540	404.4440

Next, we calculate the fuzzy membership of three objective functions corresponding to each Pareto optimal
solution according to formula (19), and coefficients of entropy weight of three objective functions computed from the entropy weight method are 0.33287, 0.33405 and 0.33308, respectively. As we can see, the diversity of the optimal points caused by the objective of network loss is the most evident. As a result, this objective plays the most significant role in the comprehensive evaluation, and we tend to select the point with relatively less network loss as the compromised optimal solution. Moreover, we can calculate the weighted sum of the membership of each point according to formula (21), and then select the point corresponding to the maximum value of λj as the CCOS, the location of CCOS on the Pareto frontier is as Figure 4, and the values of three objective functions of CCOS are showed in TABLE IV. Form what we can see, the root mean square value of voltage deviation of load buses corresponding to the CCOS is 1.47%, and the network loss as well as the amount of emissions are both relatively small compared to the values of endpoints, so it can be used as decision making reference for dispatchers.

TABLE IV. COMPREHENSIVE COMPROMISED OPTIMAL SOLUTION

root mean square values of voltage deviation	Network loss /MW	Amount of emissions /t
0.0147407	3.993213	484.071783

B. IEEE 39 bus system

IEEE 39-bus system is shown in Figure 5, assuming node 31 as the reference node, and the initial state of the system, the parameters of transformers and lines, the upper and lower limits of the optimal models and the coefficients of pollution gas emission can be seen from MAT POWERThe Pareto frontier which is calculated from the three objectives optimization by NBI method is illustrated in figure 6. The values of three objective functions corresponding to three endpoints on the Pareto frontier are showed in TABLE V. As we can see from the table, the network loss and the amount of emissions corresponding to the solution from “Minimize voltage deviation” are both relatively larger. In addition, the root mean square value of voltage deviation of load buses corresponding to the solutions from “Minimize network loss” and “Minimize emissions” are both approximately 5%. Obviously, these three single-objective optimization solution are not good decision points for operation, which is due to the fact that single-objective optimization only take the

ISSN- 2394-5125 VOL 7, ISSUE 01, 2020

corresponding objective into consideration rather than other objectives.

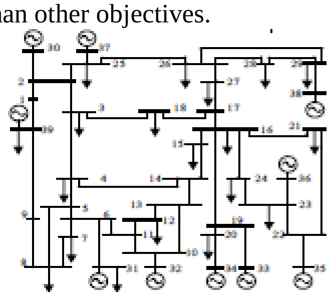

Figure 5. Structure of the IEEE 39-bus system

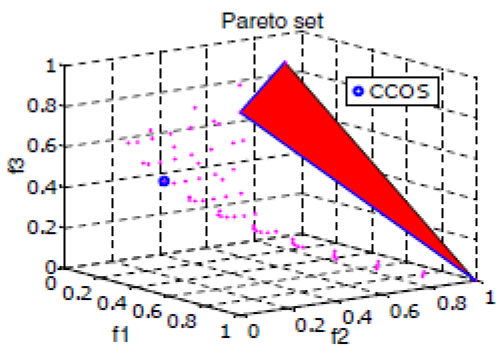

Figure 6. Pareto frontier for 3 objectives optimization in IEEE 39-bus system

TABLE V. PARETO EXTREME POINTS

Endpoint	*Root mean square values of voltage deviation*	*Network loss /MW*	*Amoun emissio*
Minimize voltage deviation	0.002877	43.66576	9240.3
Minimize network loss	0.0466467	27.51785	9369.0
Minimize emissions	0.046336	44.96214	8251.9

we can calculate the weighted sum of the membership of each point on the Pareto frontier by the fuzzy membership method and entropy weight method, and then select the point corresponding to the maximum value of λ_j as the CCOS, the location of CCOS on the Pareto frontier is as Figure 6, and the values of three objective functions of CCOS are showed in TABLE VI. Form what we can see, the root mean square value of voltage deviation of load buses corresponding to the CCOS is 0.83%, and the network loss as well as the amount of emissions are both relatively small compared to the values of endpoints, so it can be used as decision making reference for dispatchers.

TABLE VI. COMPREHENSIVE COMPROMISED OPTIMAL SOLUTION

Root mean square values of voltage deviation	*Network loss /MW*	*Amount of emissions /t*
0.008300	34.466578	8665.272809

VI. CONCLUSIONS

This paper searches a method for dispatching and decision making which is able to satisfy the basic requirements of security, quality, economic, environmental protection of power system operation, and conclusions gained from which are as follows:

1) A MOPF model with the objectives of minimizing the voltage deviation of load buses, network loss, the amount of emissions of pollution gas and meanwhile satisfying the security constraints of power transmission in lines is established, which can reflect the basic requirements of security, quality, economy, environmental protection of power system operation.

2) By using NBI method and interior point method to solve the three-objective OPF model, the evenly distributed Pareto frontier in the objective functions space can be gained.

3) By using fuzzy membership method and entropy weight method, the obtained CCOS on the Pareto frontier has relative superiority in the indexes of security, quality, economy, environmental protection, which can be applied as the dispatching scheme of power system operation.

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