Performance Improvement of Distribution System by Using PROMETHEE - Multiple Attribute Decision Making Method

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Abstract: Distribution system (DS) delivers electrical power to the end users and is the first interface of the utility with the consumers. Due to deregulation and competition amongst distributors, distribution utilities are under pressure to minimize the losses and to improve reliability to enhance the overall performance. Keeping in view of these aspects the distribution system is reconfigured for the purpose of loss minimization, balancing the load on the feeders, relieving overloads, and maintenance. Each configuration (switching combination) is considered as alternative for the decision makers (DM) with attributes like voltage profile, reliability etc. Multi-attribute decision-making (MADM) is the branch of decision making which deals with assessing the number of alternatives based on some conflicting attributes. In this paper, Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) is proposed for finding the compromised best configuration from available alternatives. MADM methods weighted sum method (WSM), weighted product method (WPM), Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) are applied to sample distribution system and results are compared with PROMETHEE.

Keywords: ***Distribution system reconfiguration, Loss minimization, Multi-attribute decision making, TOPSIS, PROMETHEE.***

1 Introduction

Power system consists of three main components generation, transmission and distribution system. The distribution system consists of the distribution lines and substations. Distribution system losses are in the range of 5-13% and it is considered the weakest link in the power system. Poor management and insufficient investment has increased power demand with increase in losses in distribution system.

After many decades of negligence, distribution system is receiving better focus now-a-days. Utilities are under continuous pressure to improve reliability and supply quality-power to the consumers due to competitive environment. Therefore, utilities must have accurate information concerning system performance to reduce operating cost and meet consumers' expectations. An improved distribution infrastructure and innovative practices can reduce losses and improve system reliability.

Nowadays, the electricity demand is increasing day by day and hence it is very important to reduce power losses of existing distribution system. For the better performance of distribution system, network topology is required to change. System reconfiguration means rearranging the distribution lines which connect various buses (loads) in a power system. Network reconfiguration in distribution system is performed by opening sectionalizing (normally closed) and closing tie (normally open) switches of the network. These switching are performed in such a way that the radiality of the network is maintained and all the loads are energized without violating system constraints.

By changing status of switches, the power flow to loads will be changed and consequently affects the power loss, voltages, harmonic distortion level, as well as the system reliability. Hence, in normal operating condition performance of the distribution system can be improved by selecting the correct status of switches. In past, researchers have proposed various approaches to the network reconfiguration [9-16].

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2 Multiple Criterion decision making (MCDM) methods

Multiple criterion decision making (MCDM) methods are used for decision making in multiple criteria problems. These methods are further classified as Multiple objective decision making (MODM) methods and multiple attribute decision making (MADM) methods.

MODM methods are used when objectives are many, and one has to decide the best while satisfying the constraints and preference priorities. MADM is an approach used to solve problems with limited number of predetermined alternatives. For complex decisions in terms of the consideration of multiple factors, researchers have focused on Multi Attribute Decision Making (MADM) techniques.

In MADM, several alternatives (options) according to some attributes (criteria) are ranked. Ranking is made among decision alternatives described using some criteria (factors) by decision-makers' knowledge and experience.

Each decision table or decision matrix in MADM methods have alternatives, attributes, weight or relative importance of each attribute, and measures of performance of alternatives. The decision matrix is shown in Table 1. The decision table shows alternatives, Ai (for i = 1, 2, ….. , N), attributes, Bj (for j = 1, 2, ….. , M), weights of attributes, wj (for j=1, 2, ….., M) and the measures of performance of alternatives, mij (for i= 1, 2, ….., N; j=1, 2, ….., M)[2].

The job of the decision maker is to select the best alternative from the given alternatives in the form of decision table or matrix. All the elements in the decision table or matrix must be normalized to bring all the attributes on the common platform.

Table 1: Decision table or Matrix in MADM methods [2]

	Attributes					
Alternatives	B1 (w1)	B2 (w2)	B3 (w3)	- (-)	- (-)	BM (wM)
A1	m11	m12	m13	-	-	m1M
A2	m21	m22	m23	-	-	m2M
A3	m31	m32	m33	-	-	m3M
-	-	-	-	-	-	-
-	-	-	-	-	-	-
AN	mN1	mN2	mN3	-	-	mNM

The most commonly used multi criteria decision making techniques are-

- Weighted Sum Method (WSM)
- Weighted Product Method (WPM)
- AHP (Analytic Hierarchy Process)
- TOPSIS (For the Technique for Order Preference by Similarity to Ideal Solution)
- ELECTRE (For Elimination and Choice Translating Reality)
- PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations)

3 Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE)

The Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) was developed by Brans et al. (1984) and falls in the category of outranking methods. In PROMETHEE, pair wise comparison of alternatives is prepared for each single criterion to determine partial binary relations denoting the strength of preference of one alternative over the others. In the evaluation table, the alternatives are evaluated with diverse criteria. To solve the problem by using PROMETHEE some additional information is required like relative importance or the weights of the criteria, and the decision maker's preference function.

The procedure of decision making for solving distribution system problem using PROMETHEE method is as follows:

Step1: Identify and short-list the alternatives on the basis of the identified criteria.

Step2: Prepare a decision table or decision matrix.

Step3: Get the information on the decision maker preference function. The preference function (Pi) translates the difference between the evaluations obtained by two alternatives (a1 and a2) in terms of a particular attribute, into range from 0 to 1. Let Pi, $a1a2$ be the preference function associated to the attribute bj.

$$Pi, a1a2 = Gi[ci(a1) - ci(a2)] \qquad (1)$$

$$0 \leq Pi, a1a2 \leq 1 \qquad (2)$$

If the decision maker specifies a preference function Pi and weight wi for each attribute 'bj' of the problem, then the multiple attribute preference index *Ga1a2* can be calculated as the weighted average of the preference functions Pj.

$$\prod a1a2 = \sum_{i=1}^{M} wi\ Pi, a1a2 \qquad (3)$$

Step 4: Calculate the leaving flow $\varphi^{+}(a)$.

$$\varphi^{+}(a) = \sum_{x\, \varepsilon\, A} \prod xa \qquad (4)$$

Step 5: Calculate the entering flow $\varphi^{-}(a)$.

$$\varphi^{-}(a) = \sum_{x\, \varepsilon\, A} \prod ax \qquad (5)$$

Step 6: Calculate the net flow φ (a).

$$\varphi(a) = \varphi^{+}(a) - \varphi^{-}(a) \qquad (6)$$

Step 7: Decide the ranking based on the scores of net flow.

The PROMETHEE method provides a ranking of the alternatives from the best to the worst one using the net flows.

4 Implementation and Results

The example of 12.66 kV, 33-node system is taken into consideration as a case study. This has many possible radial configurations, but only non-dominated solutions [1] are taken as shown in Table 2. The weights of the attributes considered in [1] are 0.3 for the active power losses, 0.35 for system average interruption frequency index (SAIFI) (failures/year) and 0.35 for average energy not supplied (AENS) (kWh/customer/year).
The available alternatives for DM are 14, and attributes considered are 3, active power losses, SAIFI and AENS, all the attributes are required to be minimized for the benefit of the distribution system.

Table 2: Example from Reference [1]

Solution	Losses	SAIFI	AENS
1	**139.5513**	1.1048	0.4422
2	139.9780	1.0327	0.4118
3	141.9160	1.0173	0.4056
4	142.4292	1.0162	0.4054
5	146.2891	1.0042	0.3998
6	146.5133	1.0031	0.3995
7	146.6658	1.0021	0.3999
8	148.6078	0.9982	0.3991
9	150.2031	1.0003	0.3984
10	150.2483	0.9991	0.3982
11	150.9774	0.9910	0.3952
12	152.5900	0.9871	0.3943
13	156.0999	0.9847	0.3936
14	161.5802	**0.9841**	**0.3935**

Table 3: Normalized values

Solution	Losses	SAIFI	AENS
1	1.0000	0.8907	0.8899
2	0.9970	0.9529	0.9556
3	0.9833	0.9674	0.9702
4	0.9798	0.9684	0.9706
5	0.9539	0.9800	0.9842
6	0.9525	0.9811	0.9850
7	0.9515	0.9820	0.9840
8	0.9391	0.9859	0.9860
9	0.9291	0.9838	0.9877
10	0.9288	0.9850	0.9882
11	0.9243	0.9930	0.9957
12	0.9146	0.9970	0.9980
13	0.8940	0.9994	0.9997
14	0.8637	1.0000	1.0000

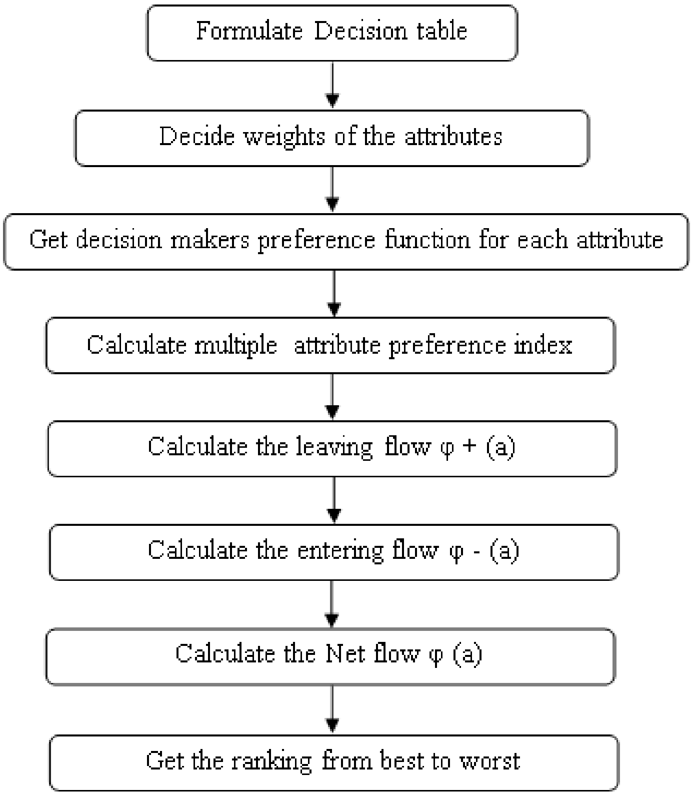

Fig. 1: Flow chart for PROMETHEE method

Table 4: Result Table of PROMETHEE method

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	Net Dominance	Ranking
A1	-	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	-7.90	14
A2	0.7	-	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	-7.10	13
A3	0.7	0.7	-	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	-6.30	12
A4	0.7	0.7	0.7	-	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	-5.50	11
A5	0.7	0.7	0.7	0.7	-	0.3	0.65	0.3	0.3	0.3	0.3	0.3	0.3	0.3	-4.00	10
A6	1	1	1	1	1	-	1.65	1.3	1.3	1.3	1.3	1.3	1.3	1.3	6.60	1
A7	1	1	1	1	0.65	0.65	-	1.3	1.3	1.3	1.3	1.3	1.3	1.3	3.90	3
A8	1	1	1	1	1	1	1	-	1.65	1.65	1.3	1.3	1.3	1.3	6.10	2
A9	1	1	1	1	1	1	1	0.65	-	1.3	1.3	1.3	1.3	1.3	3.40	4
A10	1	1	1	1	1	1	1	0.65	1	-	1.3	1.3	1.3	1.3	2.80	6
A11	1	1	1	1	1	1	1	1	1	1	-	1.3	1.3	1.3	2.90	5
A12	1	1	1	1	1	1	1	1	1	1	1	-	1.3	1.3	2.30	7
A13	1	1	1	1	1	1	1	1	1	1	1	1	-	1.3	1.70	8
A14	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1.10	9

Table 5: Comparison of MADM methods with ranking obtained

Solution	WSM	WPM	AHP	TOPSIS [1]	PROMETHEE
1	14	14	14	14	14
2	13	11	12	10	13
3	5	4	5	2	12
4	6	6	6	4	11
5	2	2	2	**1**	10
6	**1**	**1**	**1**	3	**1**
7	3	3	3	5	3
8	8	8	8	6	2
9	10	10	10	9	4
10	9	9	9	8	6
11	4	5	4	7	5
12	6	7	7	11	7
13	11	12	11	12	8
14	13	13	13	13	9

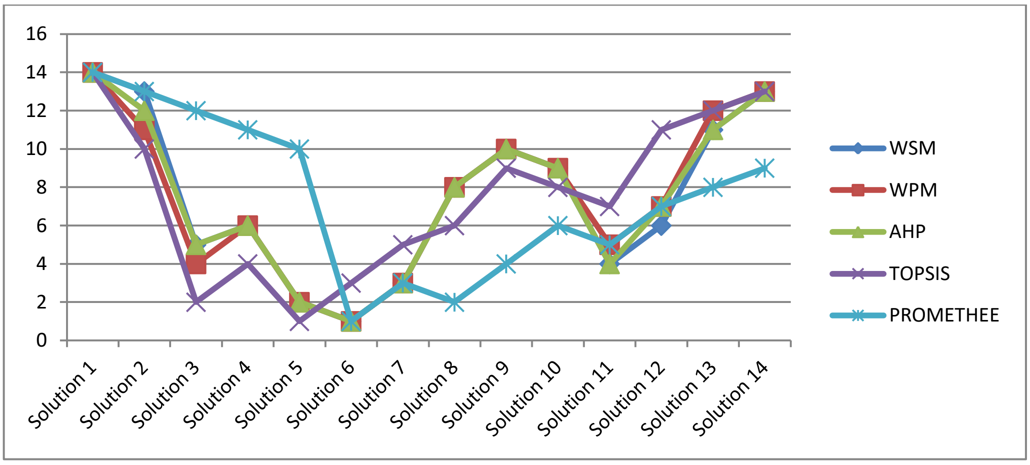

Fig. 2: Graphical representation of comparison of various MADM methods for example [1]

5 Conclusion

In this paper, MADM technique PROMETHEE is discussed in detail and WSM, WPM, AHP, TOPSIS, and PROMETHEE are implemented for the sample distribution system for decision making. The attributes considered are the minimization of the active power losses and the minimization of reliability indices (SAIFI, AENS). Weights considered are 0.3 for losses and 0.35 for SAIFI and 0.35 for AENS for all the methods.

The purpose of this paper is to find the optimal configuration by comparing different switching combinations with given attributes i.e. losses, SAIFI and AENS.

The results obtained by all the MADM methods are compared and solution number 6 has obtained rank 1 in WSM, WPM, AHP and PROMETHEE. The PROMETHEE method takes into account values of the criteria and their relative importance together. This results in better evaluation of the alternatives as compared to other methods and proves to be a good method for performance improvement of distribution system and its reconfiguration.

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