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Selection of the Best Artificial Lift Method for One of the Iranian Oil Field Using Multiple Attribute Decision Making Methods

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ABSTRACT

Production rate from oil fields is reduced due to various parameters with time. So it is needed to use some methods to compensate the reduction of production rate. Artificial lift method is the most suitable way to increase production rate. Artificial lift is one of the methods that increase the production rate by means of down hole pressure reduction. Artificial lift includes five methods and it is very important to select the best method, considering field conditions. In this paper, the best artificial lift is selected, using multiple criteria decision making models, such as; Technique for order preference by similarity to ideal solution (TOPSIS) and Elimination Et Choix Traduisant He realite(ELECTRE). In this research, 25 effective parameters are used for the method selection in one of the Iranian oil field. Comparing the obtained results from multiple criteria decision making methods, the best artificial lift method in the corresponding field is selected.

Keywords: *Artificial lift, multiple criteria decision making, Gas lift, Down hole pump, ELECTRE, TOPSIS*

NOMENCLATURE

ESP= Electrical submersible pump
PCP= Progressive cavity pump
SRP= Sucker rod pump
HP= Hydraulic jet pump
GL=Gas lift
MADM= Multiple Attribute Decision Making
TOPSIS= Technique for order preference by similarity to ideal solution
ELECTRE= Elimination Et Choix Traduisant He realite

1. INTRODUCTION

The selected oil field is located in the North West of Lorestan with the length of 35 Km and width of 5 Km. Drilling the first well in this field in 1968 showed that the initial temperature and pressure of the reservoir is 144 F^o and 1688 Psi respectively. Producing about 1340 barrel per day of oil has reduced the reservoir pressure to its current value of 1500 Psi.

The system that adds energy to the fluid column in a wellbore to initiate or enhance production from the well is called an Artificial Lift. When a reservoir lacks sufficient energy for oil, gas and water to flow from wells at desired rates, supplemental production methods can help. Lift processes transfer energy down hole or decrease fluid density in wellbore to reduce the hydrostatic load on formation. Major types of artificial Lift are Gas Lift (GL) design (Continuous gas lift, intermittent gas lift) and pumping (electrical submersible pump (ESP), progressive cavity pump (PCP), sucker rod pump (SRP), hydraulic jet type pump (HP).As the well is produced, the potential energy is converted to kinetic energy associated with the fluid movement. This dissipates the potential energy of the reservoir, thereby causing the flow rate to decrease and the flow to eventually cease. It may be economical at any point in the life of a well to maintain or even to increase the production rate by the use of artificial lift to offset the dissipation of reservoir energy. MCDM refers to making decisions in the presence of multiple, usually conflicting criteria. The problems of MCDM can be broadly classified into two categories: multiple attribute decision making (MADM) and multiple objective decision making (MODM), depending on whether the problem is a selection problem or a design problem.

2. PREVIOUS ARTIFICIAL LIFT SELECTION PROCEDURES

Valentine et al. (1988) used optimal pumping unit search (OPUS) for Artificial Lift selection. Indeed OPUS was a smart integrated system possessing the characteristics of artificial lift methods. OPUS had the capability to control the technical and financial aspects of Artificial Lift methods. It can be said that the production system was consisted of the down hole pump up to the surface facilities (stock tank). The technical and financial evaluation of this procedure was done by means of some specific computer algorithms. Therefore, knowing the primary required investment value, costs (maintenance, equipment) and technical ability of each Artificial Lift method, Artificial Lift selection was done (Valentine etal., 1988).Clegg (1988) mentioned some economic factors such as: revenue, operational and investment costs as the basis for Artificial Lift selection. He believed that the selected Artificial Lift method could have the best production rate with the least value of operational costs .Clegg et al. (1988), studied on some operational and designing characteristics of Artificial Lift methods and found that the operational costs and production rate is affected by these factors.

Espin et al. (1994) used SEDLA software for artificial lift selection. Indeed SEDLA was a computer program possessing the characteristics of artificial lift methods. It was composed of three modules based on an information bank of human activities, the theoretical knowledge of artificial lift methods and the economic evaluation of artificial lift methods respectively. Therefore, the artificial lift selection was done on the basis of profit value (Espin et al., 1994). Heinze et al. (1995), used "the decision tree" for artificial lift selection. The most major factor in it was based on a longtime economic analysis. Also, the Artificial Lift methods evaluation was based on the operational costs, primary investment, lifetime cost and energy efficiency. Ultimately, considering these factors besides the decision maker, the Artificial Lift selection was carried out. Using TOPSIS model, Alemi et al (2010) analyzed one of the Iranian oil fields and found ESP pump employment as the optimum Artificial Lift method.

3. MULTI-ATTRIBUTE DECISION MAKING METHODS (MADM)

The Multiple Attribute Decision Making (MADM) comes to elections, in which mathematical analysis is not needed. This type of MCDM can be used for the election in which there are only a small number of alternative courses. The MADM is used to solve problems in discrete spaces, typically used to solve problems in the assessment and selection of limited number of alternatives. MADM methods, are generally discrete, with a limited number of predetermined alternatives (Kusumadewi et al, 2006).

4. TOPSIS MODEL

The underlying logic of TOPSIS is to define the ideal solution and the negative ideal solution. The ranking of alternatives in TOPSIS is based on 'the relative similarity to the ideal solution', which avoids from the situation of having same similarity to both ideal and negative ideal solutions

The calculation processes of the method are as following:

Step1. Establish a decision matrix for ranking. A MCDM problem can be concisely expressed in matrix format

As:

$$\begin{array}{ccccc} . & c_1 & c_2 & \dots & c_n \\ A_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ A_2 & x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \dots & \vdots \\ A_m & x_{m1} & x_{m2} & \cdots & x_{mn} \end{array} \qquad (1)$$

where A1,A2,…,Am are possible alternatives among which decision makers have to choose, C1,C2,…,C_n are criteria with which alternative performance are measured, $X_{ij}$is the rating of alternative ,Ai with respect to criterionC_i.

Step 2. Calculate the normalized decision matrix. The normalized value n_{ij} is calculated as:

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad j = 1,2, \dots \dots . . n \qquad (2)$$

Step 3. Calculate the weighted normalized decision matrix. The weighted normalized value is v_{ij}calculated as:

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \qquad (3)$$

$$E_j = -\frac{1}{lnm} \sum_{i=1}^{m} [P_{ij} * lnP_{ij}] \qquad (4)$$

$$d_j = 1 - E_j \qquad (5)$$

$$W_j = \frac{d_j}{\sum_1^n d_j} \qquad (6)$$

$$v_{ij} = w_j * n_{ij} \;,\; i = 1,2 \dots . m \;, j = 1,2 \dots . . n \qquad (7)$$

Where w_j is the weight if the *i*th criterion, and $\sum_{j=1}^{n} w_j = 1$

Step 4. Determine the positive ideal solutions and negative ideal solutions respectively:

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$$A^+ = \left\{\left(\left(max_{v_{ij}} \mid j \in j\right), \left(min_{v_{ij}} \mid j \in j'\right)\right) \mid i = 1,2 \dots m\right\} = \{v_1^+, v_2^+, \dots, v_3^+\} \quad (8)$$

$$A^- = \left\{\left(\left(min_{v_{ij}} \mid j \in j\right), \left(max_{v_{ij}} \mid j \in j'\right)\right) \mid i = 1,2 \dots m\right\} = \{v_1^-, v_2^-, \dots, v_3^-\} \quad (9)$$

Where J is associated with the positive criteria and J' is associated with the negative criteria.

Step 5. Calculate the separation measures using the n-dimensional Euclidean distance. The separation of each alternative from the ideal solution is given as:

$$d_i^+ = \sqrt{\sum_{j=1}^{n}\left(v_j^+ - v_{ij}\right)^2} \quad i = 1,2,\dots,m \quad (10)$$

Similarly, the separation from the negative-ideal solution is given as

$$d_i^- = \sqrt{\sum_{j=1}^{n}\left(v_j^- - v_{ij}\right)^2}, \quad \text{i=1,2,…,m} \quad (11)$$

Step 6. Calculate the relative closeness to the ideal solution. The relative closeness of the alternative Ai with respect to $A+$ is defined as:

$$cl_i^+ = \frac{d_i^-}{d_i^- + d_i^+}, \quad i = 1,2 \dots m \quad (12)$$

Step 7. Rank the preference order. A large value of closeness coefficient cl_i^+ indicates a good performance of the alternative Ai .The best alternative is the one with the greatest relative closeness to the ideal solution.

5. ELECTRE MODEL

The ELECTRE (Elimination Et Choix Traduisant He realite) is based on the concept of ranking by paired comparisons between alternatives on the appropriate criteria. An alternative is said to dominate the other alternatives if one or more criteria are met (compared with the criterion of other alternatives) and it is equal to the remaining criteria.

Calculated for the Association of concordance index (s_{kl}) that shows the sum of weights of criteria, according to the formula; According to the equation (7)

$$v_{ij} = w_j * n_{ij} \;, i = 1,2 \dots m \;, j = 1,2 \dots n$$

$$S_{kl} = \{j \mid v_{kj} \geq v_{ij}\}, \; j = 1,2, \dots n \quad (13)$$

Calculating the value set for the matrix discordances associated with the attribute is the following:

$$D_{kl} = \{j \mid v_{kj} < v_{ij}\}, \; j = 1,2, \dots n \quad (14)$$

$I_{k,l}$ concordance matrix elements calculated using the formula:

$$\mathrm{I}_{kl} = \sum_{j \in s_{kl}} w_j \;, \sum_{j=1}^{n} w_j = 1 \quad (15)$$

$NI_{k.l}$ discordance matrix elements calculated using the formula:

$$NI_{k,l} = \frac{\max\,(V_{kj} - V_{lj})_{j \in D_{k,l}}}{\max\,(V_{k.j} - V_{l,j})_{j \in J}} \quad (16)$$

$\bar{\mathrm{I}}$ is calculated using the formula:

$$\bar{\mathrm{I}} = \sum_{k=1}^{\mathrm{m}} \sum_{\mathrm{l}=1}^{\mathrm{m}} \frac{\mathrm{I_{k,l}}}{\mathrm{m(m-1)}} \quad (17)$$

Concordance matrix F calculated based on the dominant,

$$f_{kl} = \begin{Bmatrix} 1 & \rightarrow & f_{kl} \geq \bar{\mathrm{I}} \\ 0 & \rightarrow & f_{kl} < \bar{\mathrm{I}} \end{Bmatrix} \quad (18)$$

Elements of the matrix G is determined as the dominant discordance:

$$g_{kl} = \begin{Bmatrix} 0 & \rightarrow & g_{kl} \geq \bar{\mathrm{I}} \\ 1 & \rightarrow & g_{kl} < \bar{\mathrm{I}} \end{Bmatrix} \quad (19)$$

Aggregation of the dominant matrix (H) showing a partial preference order of alternatives,

Obtained with the formula in Mathlab:

$$h_{kl} = f_{k,l} * g_{k,l} \quad (20)$$

Therefore A_K is an effective choice if,

$h_{k,l} = 1$→for at least one l→ l=1,2,…..m ; $k \neq l$

$h_{k,l} = 0$→for every i→i=1,2,…..m ; i≠k , i≠l

So every column containing at least one unit element can be eliminated because that column is not an effective choice.

Procedure

Two different types of systems are modeled to analyze the various Artificial Lift methods employable for the field. The general criteria and alternative methods used to model the systems are shown in figure1 (Alemi et al. 2010).

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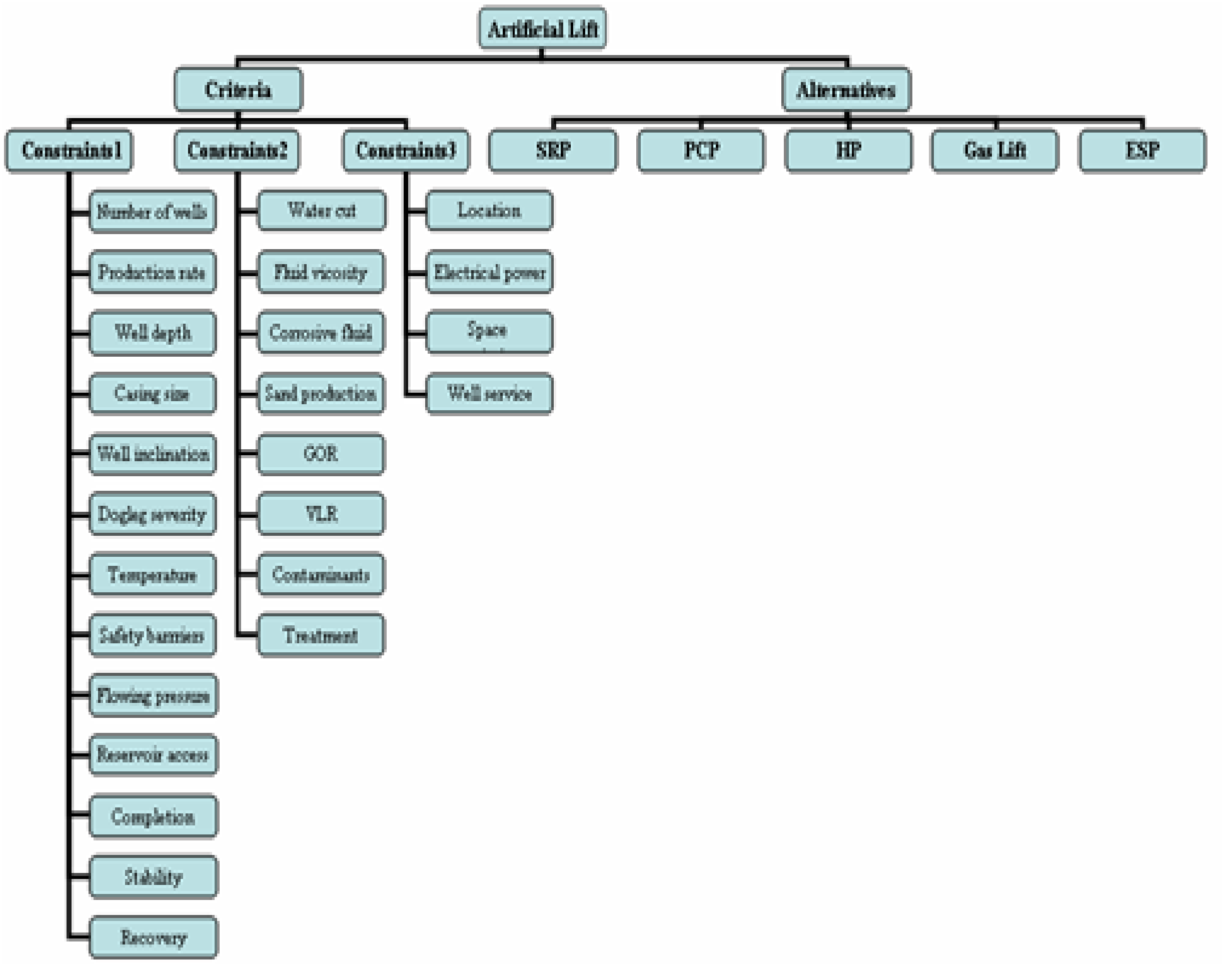

Figure 1. The Alternatives and criteria for artificial lift selection

MATLAB language is used to write the program codes for each model. In order to select the best Artificial Lift method using TOPSIS and ELECTRE models, the existing oil field parameters are compared with the values in the standard table for Artificial Lift selection developed by Shlumberger Company.

Table 1 shows the conditions of the oil field used for selection of the best Artificial Lift method by Multiple Attribute Decision Making.

As stated before, (Equation 6) the corresponding weight vector of the field would be,

$$W = \{.03 \quad .05 \quad .05 \quad .05 \quad 0 \quad 0 \quad 0 \quad .03 \quad .03 \quad .27 \quad .21 \quad 0 \quad 0 \quad .03 \quad 0 \quad .04 \quad 0 \quad .05 \quad .03 \quad .04 \quad .04 \quad 0 \quad 0 \quad 0 \quad 0\}$$

And the corresponding V (equation 7) matrix would be,

$$V = \begin{vmatrix} .01 & .02 & .02 & .02 & 0 & 0 & 0 & .01 & .01 & .08 & .05 & 0 & 0 & .01 & 0 & .01 & 0 & .02 & .01 & .01 & .01 & 0 & 0 & 0 & 0 \\ .01 & .02 & .02 & .02 & 0 & 0 & 0 & .01 & .01 & .08 & .09 & 0 & 0 & .01 & 0 & .01 & 0 & .02 & .01 & .02 & .01 & 0 & 0 & 0 & 0 \\ .01 & .02 & .02 & .02 & 0 & 0 & 0 & .01 & .01 & .08 & .05 & 0 & 0 & .01 & 0 & .01 & 0 & .02 & .01 & .01 & .01 & 0 & 0 & 0 & 0 \\ .01 & .03 & .03 & .03 & 0 & 0 & 0 & .01 & .01 & .19 & .13 & 0 & 0 & .01 & 0 & .02 & 0 & .03 & .01 & .01 & .02 & 0 & 0 & 0 & 0 \\ .01 & .03 & .03 & .03 & 0 & 0 & 0 & .01 & .01 & .13 & .09 & 0 & 0 & .01 & 0 & .01 & 0 & .03 & .01 & .01 & .01 & 0 & 0 & 0 & 0 \end{vmatrix}$$

After calculating the parameters V and W, in the next step for the TOPSIS model, the positive ideal solutions and negative ideal solutions are defined on the basis of relations 8 and 9.

Table 1: Conditions of the selected oil field

Criteria								
Production, reservoir and well constraints			**Produced fluid properties**			**Surface infrastructure**		
1	Number of well	3	14	Water cut%	33.5	22	Location	onshore
2	Production rate(bbl/d)	1340	15	Fluid viscosity(cp)	0.1206	23	Electrical power	utility
3	Well depth(ft)	4513	16	Corrosive fluid	YES	24	Space restrictions	No
4	Casing size(inch)	7	17	Sand production (ppm)	9	25	Well service	Pulling unit
5	Well inclination	vertical	18	GOR(scf/stb)	576			
6	Dog leg severity	2	19	VLR	0.01			
7	Temperature(F)	144	20	Contaminants	Asphaltene			
8	Safety barriers	1	21	Treatment	Acid			
9	Flowing pressure(psi)	425						
10	Reservoir access	required						
11	Completion	Dual						
12	Stability	stable						
13	Recovery	primary						

After calculating the parameters V and W, in the next step for the TOPSIS model, the positive ideal solutions and negative ideal solutions are defined on the basis of relations 8 and 9.

$$A^{+} = \{.01 \quad .03 \quad .03 \quad .03 \quad 0 \quad 0 \quad 0 \quad .01 \quad .01 \quad .19 \quad .13 \quad 0 \quad 0 \quad .01 \quad 0 \quad .02 \quad 0 \quad .03 \quad .01 \quad .02 \quad .02 \quad 0 \quad 0 \quad 0 \quad 0\}$$

$$A^{-} = \{.01 \quad .02 \quad .02 \quad .02 \quad 0 \quad 0 \quad 0 \quad .01 \quad .01 \quad .08 \quad .05 \quad 0 \quad 0 \quad .01 \quad 0 \quad .01 \quad 0 \quad .02 \quad .01 \quad .01 \quad .01 \quad 0 \quad 0 \quad 0 \quad 0\}$$

Then using the results of this stage, the separation measures are calculated (relations 10 and 11). The corresponding values of the separation measures for each of the Artificial Lift methods are shown in table 2.

And finally using relation 12 the relative closeness of each Artificial Lift method to the ideal solution is defined. Table 3 and figure 2 show the final results of the TOPSIS model.

Table 2. Separation measurements for each of the Artificial Lift methods

D_{i-}	D_{i+}	Artificial lift Methods
0.0096	**0.1363**	**RP**
0.0412	**0.1178**	**PCP**
0.0086	**0.1364**	**HP**
0.1362	**0.0110**	**GL**
0.0702	**.0684**	**ESP**

Table 3. The final results of the TOPSIS model

Artificial lift				
RP	**PCP**	**HP**	**GL**	**ESP**
0.0658	**0.2589**	**0.0592**	**0.9255**	**0.5065**

As can be seen from the results, TOPSIS model suggests the gas lift as the best Artificial Lift method for the oil field.

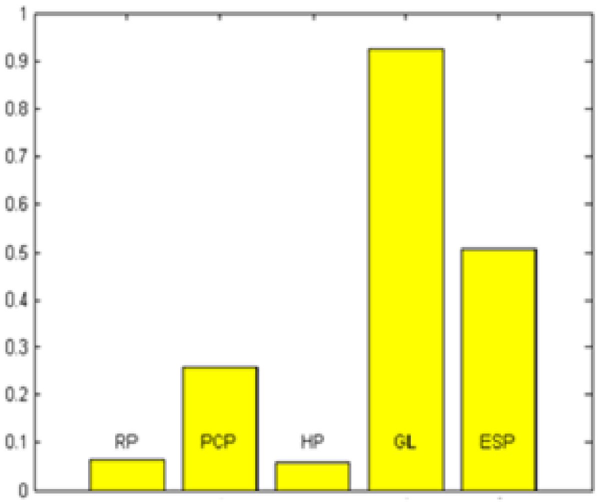

Figure 2 .Artificial lift result for the oil field by TOPSIS model

The second employed system is the ELECTRE model. The basic Matrixes of I, NI used in this model are calculated according to the previously stated relations 15 and 16.

$$I = \begin{vmatrix} 0 & .6572 & .8821 & .1775 & .2511 \\ .3428 & 0 & 1 & .2954 & .4393 \\ .1179 & 0 & 0 & .2673 & .2230 \\ 08225 & .7046 & .7327 & 0 & 0 \\ .7489 & .5607 & .7770 & .2305 & 0 \end{vmatrix}$$

$$NI = \begin{vmatrix} 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 \\ .1853 & 1 & 0 & 1 & 1 \\ .0393 & .0626 & .0393 & 0 & .4244 \\ 0 & .1251 & 0 & 1 & 0 \end{vmatrix}$$

And the matrixes F and G are calculated from the Equations 18 and 19.

$$F = \begin{vmatrix} 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \end{vmatrix}$$

$$G = \begin{vmatrix} 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 0 & 1 \end{vmatrix}$$

Finally matrix H is calculated on the basis of relation 20.

$$H = \begin{vmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 \end{vmatrix}$$

Using the matrix H and assigning an acceptance degree to each method (each column of the matrix), table 4 and figure 3 are produced as results.

Table 4: The final results of the ELECTRE model

Artificial lift methods				
RP	**PCP**	**HP**	**GL**	**ESP**
0.6	**0.6**	**0.2**	**1**	**.8**

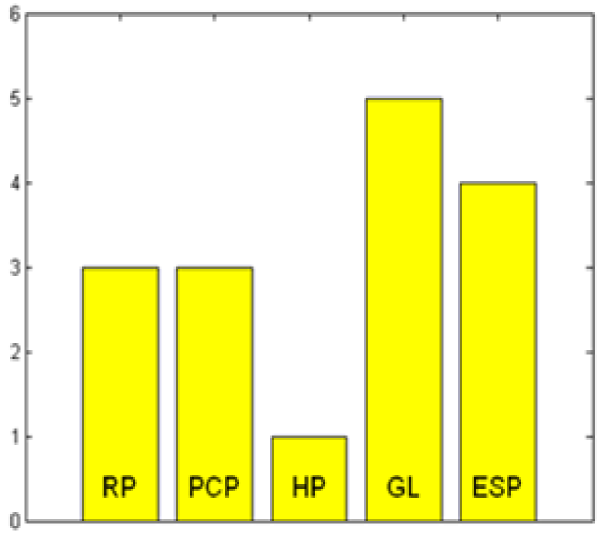

Figure 3. Artificial Lift result for the oil field by ELECTRE model

As can be seen from the results, ELECTRE model suggests the gas lift as the best Artificial Lift method for the oil field.

6. CONCLUSION

In this paper the Multiple Attribute Decision Making methods are used to select the best Artificial Lift method for the oil field in Iran. Gas lift is the best choice for the studied oil field according to the results of TOPSIS and ELECTRE models. The gas lift selection probability for this field by TOPSIS model is estimated greater than ELECTRE model. The validity of these methods have been checked and validated with the several certain oil fields Artificial Lift operations.

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