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Selection of the Best Artificial Lift Method in One of the Iranian Oil Field by the Employment of ELECTRE Model

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Research Article

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ABSTRACT

Production rate from oil fields is reduced due to various parameters with time. So it is necessary to use some methods to compensate the reduction of production rate. Artificial lift refers to use of artificial means to increase the flow of liquids, such as crude oil or water, from a production well and is the most suitable way to increase production rate. It is achieved by the reduction of downhole pressure. Artificial lift includes five methods and it is very important to select the best method, considering the field conditions. In this paper, the best artificial lift is selected, using multiple criteria decision making models, such as; Elimination Et Choix Traduisant He realite (ELECTRE). For this reason, 25 effective field parameters were used from the Malekoh oil field for analyzing. Comparing the obtained results from the multiple criteria decision making methods, the best artificial lift method in the corresponding field was selected.

Keywords: *Artificial lift; multiple criteria decision making; gas lift; down hole pump; ELECTRE;*

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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; ELECTRE= Elimination Et Choix Traduisant He realite

1. INTRODUCTION

The Malehkouh is an oil field 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 to be 144 F and 1688 Psi. 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 decrease the fluid density in wellbore and accordingly reduce the hydrostatic pressure against the 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), and 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. MODM methods have decision variable values that are determined in a continuous or integer domain, with either an infinitive or a large number of choices, the best of which should satisfy the decision maker's constraints and preference priorities. MADM methods, on the other hand, are generally discrete, with a limited number of predetermined alternatives (Kusumadewi et al, 2006). By now, the application of the each Artificial Lift methods throughout of the world has been in a manner that for GL,ESP, SRP, PCP, HP as different Artificial Lift methods has been equal to 50, 30, 17, > 2 and < 2% respectively (Taheri 2006).

2. PREVIOUS ARTIFICIAL LIFT SELECTION PROCEDURES

Neely et al. (1981) designated some Artificial Lift methods such as: SRP, ESP, HP, GL and studied about the application circumstances, advantages, disadvantages and constraints of each method. The geographical and environmental circumstances as the dominant factors for Artificial Lift selection and also some other subordinate factors such as: reservoir pressure, productivity index, reservoir fluid properties and inflow performance relationship were considered by him (Neely et al., 1981).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 et al., 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 (1988), also 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 affected factor 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 done (Heinze et al., 1995). Using TOPSIS model, Alemi et al (2010) analyzed one of the Iranian oilfields 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 (Kusumadewi 2006). The calculation processes of the method are as following:

3.1 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.

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

$$\begin{array}{cccccc}
 & & c_1 & c_2 & \dots & c_n \\
 A_1 & x_{11} & x_{12} & \dots & x_{1n} & \\
 A_2 & x_{21} & x_{22} & \dots & x_{2n} & \\
 \vdots & \vdots & \vdots & \dots & \vdots & \\
 A_m & x_{m1} & x_{m2} & \dots & x_{mn} &
 \end{array} \tag{1}$$

where A_1, A_2, \dots, A_m are possible alternatives among which decision makers have to choose, C_1, C_2, \dots, C_n are criteria with which alternative performance are measured, X_{ij} is the rating of alternative A_i with respect to criterion C_j .

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

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

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

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

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

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

$$W_j = \frac{d_j}{\sum_{j=1}^n d_j} \quad (6)$$

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

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

Calculation for the Association of concordance index (s_{kl}) that shows the sum of weights of criteria, according to the following formula. According to the equation (7) (Mohamadi et.al 2011).

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

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

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

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

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

$$I_{kl} = \sum_{j \in S_{kl}} w_j \quad , \quad \sum_{j=1}^n w_j = 1 \quad (15)$$

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

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

\bar{I} is calculated using the formula:

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

Concordance matrix F calculated based on the dominant elements;

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

The matrix G is determined as the dominant discordance:

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

Aggregation of the dominant matrix (H) showing a partial preference in order of alternatives (Ermaitita et al., 2011), obtained with the formula in Matlab:

$$h_{kl} = f_{k,l} * g_{k,l} \tag{20}$$

So every column containing at least one unit element can be eliminated because that column is not an effective choice (Asgharpour 2010).

4. RESULTS AND DISCUSSION

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 figure 1.

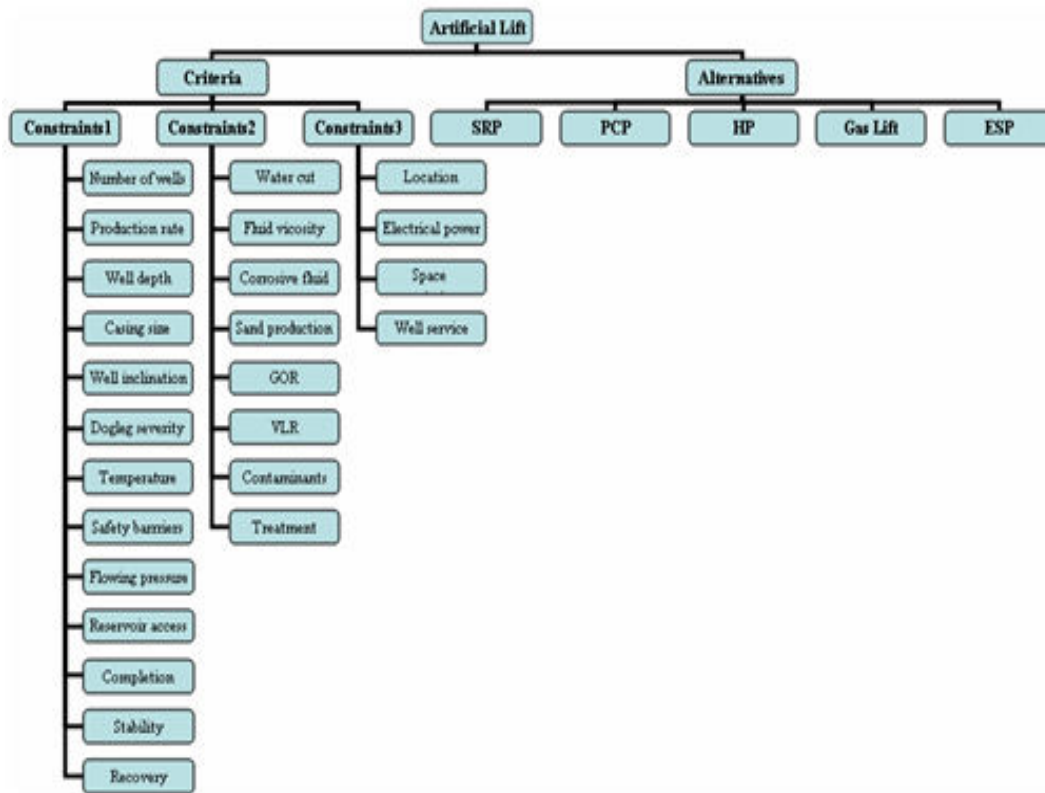


Figure 1: The Alternatives and criteria for artificial lift selection

MATLAB language is used to write the program codes for each model. In order to select the best artificial lift method using 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 Malekoh oil field used for selection of the best artificial lift method by multiple attribute decision making.

Table 1: Conditions of one of the Iranin 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	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						

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

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

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

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

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

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

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

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

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

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

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

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

Using matrix H and assigning an acceptance degree to each method (each column of the matrix), Table 2 and figure 2 are produced as results.

Table 2: The final results of the ELECTRE model for one of the Iranin oil field

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

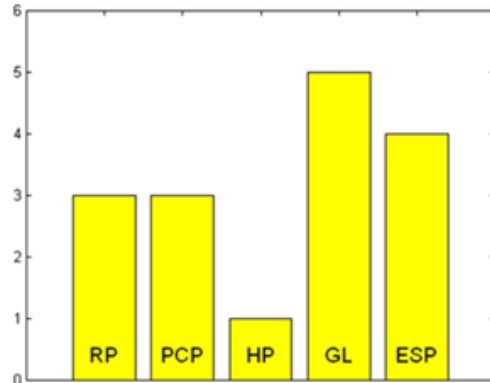


Figure 2. Artificial lift result for one of the Iranin oil field by ELECTRE model

As can be seen from the results, ELECTRE model suggested that the gas lift is the best artificial lift method for the Malekoh oil field.

5. CONCLUSION

In this paper the multiple attribute decision making methods are used to select the best artificial lift method for the Malekoh oil field in Iran. It was found that the selection of Gas lift is the best choice for increasing the production rate in oil field according to the results obtained from the ELECTRE models with acceptance degree of 1 and the hydraulic pumps (HP) are proved to be the worst method with acceptance degree of 0.2. The validity of these methods have been checked and validated with the several certain oil fields artificial lift operations and accurate results were obtained. So it is concluded that the MCDM methods are the most powerful approaches to select the best artificial lift methods.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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