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Renewable Energy Power Plant Ranking in Iran Considering the Sustainable Development Aims via Passive Defense Viewpoint

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Abstract: *Custodians in energy field need some tools for decision-making support, for the best alternative classic power plant selection with renewable fuel. In the study a tool has been presented, supporting the custodians, that economic, biologic and social side of power plant construction with renewable fuels will be studied. Then a study method will be presented, using the combining of modified digital logic method and VIKOR method for the solvation of multi-criteria problem, ranking and weighting the electricity generation power plant; considering the quantitative and qualitative criteria. For better understanding of suggested method, a case study will be presented for Iran, and five power plants will be evaluated and ranked, considering the country capacities. The aim of suggested model is the assessment of different power plant and finding the best power plant via the passive defense viewpoint.*

Keywords- *VIKOR, modified digital logic, renewable, sustainable development, multi-criteria decision making.*

I. INTRODUCTION

Water, air and soil pollution and climate change make a negative effect on people life style especially in the developing countries (Kan et al, 2012). Fossil feuls have a considerable share of this negative effect such as CO_2 that is expected to increase the air tempreature to 3.6 C° in long time (IEA, 2012). While the ending and nonrenewable property of fossil fuels mentioned as a crisis. Therefore, the alternative energy sources have been turned important. Responding the needs, the World Commission on Environment and Development (WCED) defined the sustainable development as a development that the current needs of people is responded now without elimination the productions for next generations (WCED, 1987). For this aim, using the renewable energies is a crucial issue. They are developing and covering about 11% of universal energy resources (IEA, 2011). These kind of energies rely on clean and almost without ending fuels (Goldemberg, 2000). It forcasted that the renewable energy generation will improve during the next decads and reach to 40% in 2040 (Kralova & Sjöblom, 2010). This article focuses on economic, environmental and social sides with renewable fuels. A hybrid model presented, combining the Modified Digital Logic Method and VIKOR for the ranking and weighting the power plants. For the better recognition of suggested method, a case study about the renewable energy providers in Iran will be evaluated and ranked, considering two novel criteria containing the expandability and ease of access to technology. The main contributions of this paper are as follows:

1) Ranking power plants with renewable energy in Iran using a hybrid decision making model based on modified digital logic and Vikor methods, considering the environmental, economic and social aspects.
2) Introduction of two novel qualitative criteria, expandability and ease of access to technology.

II. LITERATURE REVIEW

Sustainable development of energy systems, for decision makers around the world, get more important day after day. The main targets of universal policy in this field contain the economic development, energy providing security and reduction of climate changes (IEA & OECD, 2008). For these aims, it needs to consider all sides of energy systems that recognized by the decision makers and strategists (Jeswani et al, 2010; Ness et al, 2007; Valdivia et al, 2011). Table 1 shows the details of these researches. In this article, an integrate evaluation system has been presented for sustainability assessment of renewable power plant. This system caused a model presentation about the ranking of various power plant constructions, considering the economic, environmental and social aspects.

III. MATERIAL AND METHODS

1. Data gathering method

As stated before, this paper addresses the evaluation of renewable energy power plants with consideration of sustainable development aims. Therefore, some criteria and sub-criteria with direct effect on decision-making are indetified by reviewing the literature and using the experts' knowledge. Then two questionnaires are used, first one for the importance and weight determination via the modified digital logic method and the second one via the VIKOR method for the power plant ranking. Finally, a novel hybrid method is presented for power plant ranking based on determined indices.

2. Suggested method

In this article, at first the needed criteria for the power plant ranking will be determined. Using the modified digital logic method the considered weight of criteria has been recognized and then the power plants ranked by the VIKOR method, via this procedure the benefits of both methods are utilized.

The Modified Digital Logic Method

For the applicable programs, which the designing properties are relatively high, the weight determination is so difficult for the multiple criteria simultaneously. For this problem solving, the modified digital logic has been developed via the binary comparison. Dehghan-Manshadi et al. (2007) presented the modified digital logic that scoring has been cahnged from 0 and 1 to 1, 2 and 3. For the criteria with lower, equal and higher importance the 1, 2 and 3 will be assumed. The benefit of this method is the scoring prosedure. After the binary comparison the wights are calculated by relation 1:

$$W_j = \sum_{j=1}^{n} C_{jk} \Big/ \sum_{j=1}^{n} \sum_{k=1}^{n} C_{jk} \quad ; \quad j,k = 1,2,\dots,n \quad \text{و} \quad j \neq k \tag{1}$$

Where the n is the number of criteria, W_j is the weight of criteria j. also, we have:

- ❖ If the j and k have same importance then $C_{jk} = C_{kj} = 2$
- ❖ If the j is more important than k, then $C_{kj} = 1$ and $C_{jk} = 3$
- ❖ If the k is more important than j, then $C_{kj} = 3$ and $C_{jk} = 1$

Table 1. Previous studies

Paper	Scope	Sustainable development index							Index integration method
		EN	EC	SO	TE	EC & SO	EC & TE	Sum	
Chatzimouratidis and Pilavachi (2009)	Sustainability assessment of 10 types of power plants							9	Analytic Hierarchical Process
Evans et al. (2009)	Sustainable development indices for technologies of renewable energies (Geothermal, wind, hydropower, solar)							7	Weighted sum
Jacobson (2009)	Power technologies ranking							11	Multiple value theory
Kowalski et al. (2009)	Scenarios of sustainable electricity power for Austria (Local and National levels)	4	1	12				17	SIMOS and PROMETHEE
Roth et al. (2009)	Sustainability assessment of electricity supplying technologies	11	31	33				75	Multiple value theory
Schenler et al. (2009)	Sustainability assessment of current and future electricity technology (Technology roadmap)	11	9	16				36	Dominating-alternative algorithm
Onat and Bayar (2010)	Sustainable development indices in electricity supplying systems							8	Weighted sum
La Rovere et al. (2010)	Analysis method for sustainability in electricity expansion	5	3	3	4			15	Data envelopment analysis
Dorini et al. (2011)	Biomass vs. Coal (Comparison of two alternatives for electricity power)	13			9			22	Compromise programming
Maxim (2014)	Sustainability assessment of electricity supplying technologies	2		4			4	10	Swing
Ahmad and Tahar (2014)	Selection of renewable energy sources for sustainable development of electricity power: Malaysia	3	4	2	3			12	AHP
Li et al. (2015)	Comparison between wind, solar and geothermal energies							20	Not -Applied
Şengül et al. (2015)	Fuzzy-TOPSIS method for ranking of energy supplying systems: Turkey	2	3	1	3			9	Fuzzy-TOPSIS

VIKOR Method

VIKOR method is one of the applicable models in decision making and selecting the best choice. This method developed by Aprykovich in 1998 and based on collective agreement method. It is applicable in discrete problem solvation and developed for the optimization of complex multi-criteria systems. This method focuses on selecting method and choosing from a set of choices. It determines the adaptive responses for a problem with opposite criteria. It can aid decision makers for reaching to a final decision.

Indeed the VIKOR model ranks and prioritizes the choices via the choices assessment based on criteria. In this model, the criteria do not weighted but the criteria assessed via the other methods, then the choices will be assessed and ranked based on criteria and combining to their values. The main difference of this model with AHP or Network models is that in this model there is no binary comparison between the criteria and choices and each choice will be assessed by a criteria independently.

Case Study

Iran has many fossil fuel resources. The approved oil resources contains gas liquids is more than 137 billion barrels or about 11% of all resources around the world. While the natural gas resources are more than 26.7 trillion cubic meters or 15% of the total resources of the world in 2004 (GLOBAL, 2014). Therefore it is obvious that fossil fuels in Iran are the main base of economy. The custodians are tarrying to diversify the energy consumption and enter nuclear energy and other renewable kinds to the energy basket. The energy security is so important in energy politician viewpoint. Different renewable energies such as solar, geothermal, biomass and hydropower energies show the high potential capacity of power generation in Iran. Bahrami and Abbaszadeh (2013) showed that there is capacity in Iran for the construction of 5 power plant with renewable fuel. In present study the obtained choices of their research have been used (Tabel 2). The needed criteria also determined by the Wang et al (2009) literature review and expert idea. Sub-criteria such as efficiency, investment cost, upkeep cost, service age, the amount of NOx and CO2 gas emissions, landusing, job creating, local development and finally security have been extracted from a review study, while the expandability and ease of access to thechnology have been selected by expert opinin. Table 3 shows the 12 recognized criteria.

Table 2. The properties of power plant in Iran (Bahrami & Abbaszadeh, 2013)

Alternative	Power Plant Type	Location
A1	Hydropower Plant	Around watery rivers and dams
A2	Wind Power Plant	Roodbar, Zabol, Tabriz, Shiraz, Mahshahr
A3	Photovoltaic Power Plant	Yazd, Semnan, Tehran, Taleghan, Khorasan
A4	Biomass	Fars, Shiraz, Khorasan
A5	Geothermal Power Plant	Meshkin-Shahr, Sabalan, Sarein, Damavand, Sahand, Khoy, Makoo

Table 3. Recognized criteria and sub-criteria for power plant construction in Iran (Wang et al., 2009)

Sub-criteria	Description	Sub-criteria	Description
C1	Safety	C7	Fuel cost
C2	Maturity	C8	Maintenance cost
C3	Ease of access to technology	C9	Service period
C4	Social acceptability	C10	Greenhouse gas emissions
C5	Productivity	C11	Degree of earth occupation
C6	Investment cost	C12	Job creation

Each criterion weight determination

The modified digital logic has been used for the determination of criteria weights after the recognition of assessment criteria. The needed data for the problem solvation via this method has been extracted from the first questionnaire. In this questionnaire, considered criteria compared to each other by the binary comparison and valuated by the modified digital logic method. Each criterion weight normalized by the hour normalization (Chen & Yang, 2011). Table 4 shows the normalized weight of criteria.

Table 4. Criteria normalized weight

Safety	Maturity	Ease of access to technology	Social acceptability	Productivity	Investment cost	Fuel cost	Maintenance cost	Service period	Greenhouse gas emissions	Earth occupation	Job creation
.112	.076	.082	.070	.081	.096	.083	.080	.073	.083	.0682	.089

Generation of Decision making matrix

Considering the various and different criteria existence, the VIKOR method has been chosen for decision making about them. For this aim, the expert ideas have been used by the second questionnaire. The decision matrix then generated. Figure 1 shows the general framework of decision matrix.

	C_1	C_2		C_m
A_1	x_{11}	x_{12}		x_{1m}
A_2	x_{21}	x_{22}		x_{2m}
A_n	x_{n1}	x_{n2}		x_{nm}

Fig 1. Decision making matrix

Then the normalized decision matrix generated, using the relation 2 and initial decision matrix (Figure 2).

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

	C_1	C_2		C_m
A_1	f_{11}	f_{12}		f_{1m}
A_2	f_{21}	f_{22}		f_{2m}
A_n	f_{n1}	f_{n2}		f_{nm}

Fig 2. Normalized decision matrix

The main decision matrix of case study and its normalized form are presented in Tables 5 and 6, respectively.

Table 5. Decision matrix

Criteria / Alternative	Safety	Maturity	Ease of access to technology	Social acceptability	Productivity	Investment cost	Fuel cost	Maintenance cost	Service period	Greenhouse gas emissions	Earth occupation	Job creation
Hydropower Plant	1	9	7	5	0.800	1750	0	0.3	50	15	750	5
Wind Power Plant	3	7	7	9	0.350	1100	0	4.5	30	16	100	11
Photovoltaic Power Plant	9	3	7	7	0.094	5000	0	4	20	12	35	10
Biomass	10	7	5	5	0.280	1488	24.2	1.2	30	20	5000	72
Geothermal Power Plant	10	5	6	7	0.060	2000	0	0.3	30	15	18	54

Table 6. Normalized Decision matrix

Criteria / Alternative	Safety	Maturity	Ease of access to technology	Social acceptability	Productivity	Investment cost	Fuel cost	Maintenance cost	Service period	Greenhouse gas emissions	Earth occupation	Job creation
Hydropower Plant	0.059	0.617	0.485	0.330	0.866	0.294	0	0.049	0.668	0.424	0.148	0.055
Wind Power Plant	0.176	0.480	0.485	0.595	0.379	0.185	0	0.731	0.401	0.453	0.020	0.120
Photovoltaic Power Plant	0.528	0.206	0.485	0.463	0.102	0.839	0	0.650	0.267	0.339	0.007	0.109
Biomass	0.586	0.480	0.347	0.330	0.303	0.250	1	0.195	0.401	0.566	0.989	0.788
Geothermal Power Plant	0.586	0.343	0.416	0.463	0.065	0.336	0	0.049	0.401	0.424	0.004	0.591

In Figure 2, f_{ij} is the normalized form of C_j criteria for A_i alternative. VIKOR technique is based on a density function (L_{pj}).

$$L_{pi} = \left\{ \sum_{j=1}^{m} \left[w_j . \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \right]^p \right\}^{1/p} \quad ; \quad 1 \le p \le \infty \quad ; \quad i = 1,2, \dots, n \tag{3}$$

Where m and n are the number of criteria and alternatives respectively. w_j is the weight of j criterion. Also f_{ij} is the value of Ith choice at jth criterion while f_j^* and f_j^- are the positive and negative ideal response for jth criterion.

$$A^+ = \left\{ \left(max\, f_{ij} \mid j \in J \right) or \left(min\, f_{ij} \mid j \in J' \right) \middle| \, i = 1,2, \dots, n \right\} = \{ f_1^*, f_2^*, \dots f_m^* \} \tag{4}$$

$$A^- = \left\{ \left(min\, f_{ij} \mid j \in J \right) or \left(max\, f_{ij} \mid j \in J' \right) \mid i = 1,2, \dots, n \right\} = \{ f_1^-, f_2^-, \dots f_m^- \} \tag{5}$$

For the criteria with positive side (J), the positive and negative ideals are the maximum and minimum of amounts respectively. Whereas it is opposite for the J' (Table7).

Table 7. The positive and negative ideal amounts

Index	Safety	Maturity	Ease of access to technology	Social acceptability	Productivity	Investment cost	Fuel cost	Maintenance cost	Service period	Greenhouse gas emissions	Earth occupation	Job creation
Positive Ideal	0.586	0.617	0.485	0.595	0.866	0.185	0	0.049	0.668	0.339	0.004	0.788
Negative Ideal	0.059	0.206	0.347	0.0330	0.065	0.839	1	0.731	0.267	0.566	0.989	0.055

After the f_j^* and f_j^- calculation for all criteria, the amount of S_i and R_i for all alternatives determine as below:

$$S_i = \sum_{j=1}^{m} w_j . \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \quad ; \quad i = 1,2,\dots,n \tag{8}$$

$$R_i = \max_{j=1,2,\dots,m} \left(w_j . \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \right) \quad ; \quad i = 1,2,\dots,n \tag{9}$$

The related values are showed in Table 8:

Table 8. The S_j and R_j value calculation

Alternative	S_j	R_j
Hydropower Plant	0.328	0.112
Wind Power Plant	0.414	0.087
Photovoltaic Power Plant	0.523	0.096
Biomass	0.544	0.083
Geothermal Power Plant	0.334	0.081

The VIKOR index (Q) is calculated as below:

$$S^* = \min_{i=1,2,\dots,n} S_i \tag{10}$$

$$S^- = \max_{i=1,2,\dots,n} S_i \tag{11}$$

$$R^* = \min_{i=1,2,\dots,n} R_i \tag{12}$$

$$R^- = \max_{i=1,2,\dots,n} R_i \tag{13}$$

$$Q_i = v . \left[\frac{S_i - S_i^*}{S^- - S^*} \right] + (1 - v) . \left[\frac{R_i - R_i^*}{R^- - R^*} \right] \tag{14}$$

In relation (14), v parameter is the maximum weight of group utility ($0 \leq v \leq 1$) and considered as 0.5. The best possible choice among the alternatives is a choice that VIKOR index be lesser than other choices. Table 9 shows the results of VIKOR index calculation for the power plants.

Table 9. The VIKOR index for the renewable fuel power plant with MDL-VIKOR

Alternative	Q_i	Rank
Hydropower Plant	0.500	3
Wind Power Plant	0.298	2
Photovoltaic Power Plant	0.693	5
Biomass	0.532	4
Geothermal Power Plant	0.012	1

IV. RESULTS ANALYSIS

The criteria assessment show that the security, investment cost, job making, fuel cost, gas emission, ease of accessing to technology and efficiency have the highest priority respectively. According to the problem results, the geothermal power plant has the highest rank in terms of compatibility with all aims of sustainable development. The results show that experts consider the most importance to the high secure, low cost and risk for the environment technology. In addition, the results show that electricity production from the geothermal and hydropower energies has the most priority for the fossil fuel replacement. Geothermal and wind energies in high scale can reduce the dependency to the fossil fuel and caused the energy security. There are many villages without electricity in Iran and all other choices can be used in these areas. However, it should be said that an alternative technology is not suitable for the whole country and in every especial area can be different, considering the geographic capacity. For example in desert parts, the solar energy is a considerable resource for the power providing. Conjugating the diverse kind of energies will cause the Self-sufficiency in energy and sustainable development.

V. CONCLUSION

The most important problem about the current fossil fuel is their ending nature and nonrenewable property. Beside this problem, wide and enormous consumption of fossil fuels cause the pollution emission and consequent results. Therefore, the renewable energies has the more share in the world energy providing day by day. Therefore in the international policies and programs given to the renewable energy resources.

In this regard, a new model has been presented, conjugating the VICOR and Modified digital logic techniques for the choices ranking, using the qualitative and quantitative sub-criteria simultaneously. The suggested method has two benefit at first it has less complexity and bewilderment than the other applicable methods such as AHP; second benefit is its application for both quantitative and qualitative indices. In this article, 12 criteria have been recognized and it determined that geothermal, wind and hydropower energies have the most priority, considering the country capacities for the fossil fuels replacement.

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