THE ANALYSIS OF THE RISKS OF RENEWABLE ENERGY RESOURCES BY USING FUZZY FMEA TECHNIQUE

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Abstract

In the modern societies, one of the most important indicators of the economical growth is the energy resources. The energy demand is increasing continuously due to the rapid population growth and industrialization and this demand can not be satisfied with the available limited resources. Consequently, the gap between the production and the consumption of the energy is growing rapidly. Thus, it is gaining much more importance to benefit from the renewable energy resources in a more effective manner. Failure Mode and Effects Analysis (FMEA) is a quality improvement technique that prevents the formation of a failure or that determines and resolves the failure types existing in a system and in the functions or the components of a system as early as possible. In this study, a risk analysis is done to improve, overcome and determine the risks in the solar, geothermal and wind power plants by using FMEA and Fuzzy FMEA techniques. In the study, the risks in wind, solar and geothermal power plants are classified according to the economical and financial, social and environmental, construction and management, political and technological aspects. By using FMEA and Fuzzy FMEA techniques, the risk priority numbers of power plants are calculated and a risk table is constructed. The three power plant types are rated according to the results obtained by using the two techniques and they are compared in terms of the risks that they produce.

Keywords: Renewable Energy Resources, Fuzzy FMEA, Risk Analysis

JEL Classification: C10

YENİLENEBİLİR ENERJİ KAYNAKLARI RİSKLERİNİN BULANIK HTEA TEKNİĞİ İLE ANALİZİ

Özet

Günümüz toplumlarında ekonomik büyümenin en önemli göstergelerinden biri enerji kaynaklarıdır. Hızlı nüfus artışının ve sanayileşmenin beraberinde getirdiği enerji ihtiyacı hızla artmakta ve kısıtlı kaynaklarla karşılanamamaktadır. Dolayısıyla enerji üretimi ve tüketimi arasındaki açık hızla büyümektedir. Bu nedenle çevre dostu, yenilenebilir enerji kaynaklarından daha verimli bir şekilde yararlanmak son derece önem kazanmaktadır. Hata Türleri ve Etkileri Analizi (HTEA), bir sistemde, sistem bileşenlerinde ya da fonksiyonlarında varolan hata türlerinin, mümkün olduğunca erken aşamada belirlenmesini, çözümlenmesini ya da hata oluşumunun engellenmesini sağlayan bir kalite geliştirme yöntemidir. Bu çalışmada: Yenilenebilir enerji kaynaklarından rüzgâr, jeotermal ve güneş enerjisi santrallerine ilişkin risklerin tespiti, giderilmesi veya iyileştirilmesi amacıyla, HTEA ve Bulanık HTEA teknikleri kullanılarak risk analizleri yapılmıştır. Çalışmada; rüzgâr, jeotermal ve güneş enerjisi santrallerine ilişkin riskler, ekonomik ve finansal, sosyal ve çevresel, inşaat ve işletme, politik ve teknolojik açılardan sınıflandırılmış ve 5 ayrı ana başlık altında toplanmıştır. HTEA ve Bulanık HTEA teknikleri kullanılarak enerji santrallerinin risk öncelik sayıları hesaplanmış ve risk tablosu oluşturulmuştur. Oluşturulan risk tablosuna göre çalışmamızda ele aldığımız 3 tip enerji santrali her iki teknik kullanılarak elde edilen sonuçlara göre değerlendirilmiş ve meydana getirdikleri riskler yönünden karşılaştırılmıştır.

Anahtar Kelimeler: Yenilenebilir Enerji Kaynakları, Bulanık HTEA, Risk Analizi

JEL Kodu: C10

1. Introduction

Nowadays, energy is described as an economic input, the driving force for sustainable development and a key element to improve the level of social welfare (Agacbicer, 2010). Fossil fuels used for energy production are petroleum, natural gas and coal. Released gases during consumption of fossil fuels cause acid rains, the greenhouse effect, air pollution and climate change. Thus the world tend to reduce the use of fossil fuels. Therefore, energy policy giving emphasis and priority to renewable energy sources such as fossil fuels is replaced by environmentally friendly and sustainable energy policies. The International Energy Agency, defines renewable energy as the energy sources which can be obtained naturally and renew itself. Typically energy investments carry serious risks due to their size and their dependency on nature and human factors. Energy companies should pay serious attention on risk management in order to survive in current competitive business environment and continue the long-term profitability (Dagli, 2010). Failure Modes and Effects Analysis (FMEA) is a systematic process which determines the types of errors in a system function or in a system component. . Furthermore, decision makers analyze and assess impact of these risks by using FMEA. In this study, FMEA and Fuzzy FMEA techniques have been applied in order to assess the risks related to wind, geothermal and solar power plants. Additionally, the risk table has been generated by evaluating the results of the two techniques for the three types of power plants and by comparing them for the risks they have.

2. Failure Modes and Effects Analysis (FMEA)

FMEA is an analytical technique that combines the technology and experience of people in identifying foreseeable failure modes of a product or process and planning for its elimination (Besterfield, 2003). FMEA is widely used in manufacturing industries, such as during various phases of a product life cycle (Lipol and Haq, 2011). The traditional FMEA determines the risk priorities of failure modes through the risk priority number (RPN), which is the product of the occurrence (*O*), severity (*S*) and detection (*D*) of a failure (Wang, Chin, Poon and Yang, 2009). That is RPN = $O \times S \times D$; FMEA uses five scales and the scores of one to ten to measure the chance of occurrence, the chance of non-detection and the severity (Chang, Wei and Lee, 1999). FMEA proves to be one of the most important early preventative actions in system, design, process or service which will prevent failures and errors from occurring and reaching the customer. However, the crisp RPNs have been considerably criticized for a variety of reasons (Wang, Chin, Poon and Yang, 2009). Significant criticisms include but are not limited to the following:

- The relative importance among O, S and D is not taken into consideration. The three risk factors are assumed to be equally important. This may not be the case when considering a practical application of FMEA.
- Different combinations of O, S and D may produce exactly the same value of RPN, but their hidden risk implications may be totally different. For example, two events with the values of 2, 3, 2 and 4, 1, 3 for O, S and D, respectively, have the same RPN value of 12. However, the hidden risk implications of the two events may not necessarily be the same. This may cause a waste of resources and time or in some cases a high risky event unable to be noticed.
- The RPN scale itself has some non-intuitive statistical properties. It is derived from only three factors mainly in terms of safety; and the conventional RPN method has not considered indirect relations between components.

When conducting a FMEA for a safety assessment purpose, precision should not be forced where data is unreliable and scarce. Hence, to ask an analyst or an expert to assign scores ranging from one to ten (as done in the RPN method) for the different factors considered would produce a false and unrealistic impression (Pillay, Wang, Jung, Kwon, Loughran, l'Anson, Wall and

Ruxton, 2001). Although this simplifies the computation, converting the probability into another scoring system and then finding the multiplication of factor scores may cause problems.

3. Fuzzy Approach to FMEA

Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. In fuzzy logic, the degree of truth of a statement can range between 0 and 1 and is not constrained to the two truth values {0,1} or {false,true} as in classical predicate logic (Huang, Jo, Lee, Kang and Bevilacqua, 2009). By providing a basis for approximate reasoning, that is, a mode of reasoning which is not exact nor very inexact, such logic may offer a more realistic framework for human reasoning than the traditional two-valued logic (Zadeh, 1975). The term "fuzzy logic" emerged as a consequence of the development of the theory of fuzzy sets by Lotfi Zadeh. In 1965, Lotfi Zadeh proposed fuzzy set theory (Zadeh, 1965) and later established fuzzy logic based on fuzzy sets.

Fuzzy Logic Algorithm can be explained in the following steps:

1. Define the linguistic variables and terms (initialization)
2. Construct the membership functions (initialization)
3. Construct the rule base (initialization)
4. Convert crisp input data to fuzzy values using the membership functions (fuzzification)
5. Evaluate the rules in the rule base (inference)
6. Combine the results of each rule (inference)
7. Convert the output data to non-fuzzy values (defuzzification)

Linguistic variables are the input or output variables of the system whose values are words or sentences from a natural language, instead of numerical values. A linguistic variable is generally decomposed into a set of linguistic terms (A short fuzzy logic tutorial, 2010). Membership functions are used in the fuzzification and defuzzification steps of a fuzzy logic system (FLS), to map the non-fuzzy input values to fuzzy linguistic terms and vice versa. A membership function is used to quantify a linguistic term. There are different forms of membership functions such as triangular, trapezoidal, piecewise linear, Gaussian, or singleton (A short fuzzy logic tutorial, 2010). Fuzzy set is defined as a set with fuzzy boundaries. Let X be a nonempty set. A fuzzy set A in X is characterized by its membership function $\mu_A: X \rightarrow [0,1]$ and $\mu_A(x)$ is interpreted as the degree of membership of element x in fuzzy set A for each $x \in X$. It is clear that A is completely determined by the set of pairs $A = \{(u, \mu_A(u)) \mid u \in X\}$. Frequently we will write $A(x)$ instead of $\mu_A(x)$. The family of all fuzzy sets in X is denoted by $F(X)$.

If $X = \{x_1, \ldots, x_n\}$ is a finite set and A is a fuzzy set in X then we often use the notation $A = \mu_1/x_1 + \ldots + \mu_n/x_n$ where the term μ_i/x_i, $i = 1, \ldots, n$ signifies that μ_i is the grade of membership of x_i in A and the plus sign represents the union. From between various membership functions the triangular one is to be exemplified below (Kumru and Kumru, 2013).

A fuzzy set *A* is called triangular fuzzy number with peak (or center) a, left width $\alpha > 0$ and right width $\beta > 0$ if its membership function has the following form (Akerkar and Sajja, 2010).

$$A(t) = \begin{cases} 1 - (a - t)/\alpha & \text{if } a - \alpha \le \mathrm{t} \le a \\ 1 - (t - a)/\beta & \text{if } a \le \mathrm{t} \le a + \beta \\ 0 & \textit{otherwise} \end{cases}$$

and we use the notation $A = (a, \alpha, \beta)$. A triangular fuzzy number with center a may be seen as a fuzzy quantity "x is approximately equal to a" (Figure 1).

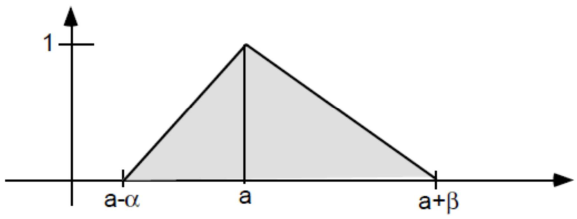

Figure 1. Triangular fuzzy number

In a FLS, a rule base is constructed to control the output variable. A fuzzy rule is a simple IF-THEN rule with a condition and a conclusion (A short fuzzy logic tutorial, 2010). After evaluating the result of each rule, these results should be combined to obtain a final result. This process is called inference. The results of individual rules can be combined in different ways (maximum, bounded sum, normalized sum). Depending on the form of the consequent, two main types of rule-based fuzzy models are distinguished (Babuska, 2002):

1. Mamdani linguistic fuzzy model: Both the antecedent and the consequentare fuzzy propositions.
2. Takagi–Sugeno fuzzy model: The antecedent is a fuzzy proposition; the consequent is a crisp function.

The most commonly used fuzzy inference technique is the so-called Mamdani method (Mamdani, 1977). After the inference step, the overall result is a fuzzy value. This result should be defuzzified to obtain a final crisp output (A short fuzzy logic tutorial, 2010). This is the purpose of the defuzzifier component of a FLS. Defuzzification is performed according to the membership function of the output variable. There are different algorithms for defuzzification too. The mostly used algorithms are Center of Gravity, Center of Gravity for Singletons, Center of Area, Left Most Maximum and Right Most Maximum. There are several defuzzification methods, but probably the most popular one is the centroid technique. It finds the point where a vertical line would slice the aggregate set into two equal masses. Mathematically this centre of gravity (COG) can be expressed as (Kusiak, 2006):

$$COG = \frac{\int_a^b \mu_A(X)x\,dx}{\int_a^b \mu_A(X)\,dx}$$

Centroid defuzzification method finds a point representing the centre of gravity of the fuzzy set, *A*, on the interval, ab. A fuzzy rule base is used to rank the potential causes identified within the FMEA, which would have identical RPN values but different risk implications (Pillay, Wang, 2003). The approach then extends the analysis to include weighting factors for *O, S* and *D* using defuzzified linguistic terms. The advantages of the proposed fuzzy rule base approach for application to FMEA can be summarized as follows (Pillay, Wang, Jung, Kwon, Loughran, l'Anson, Wall and Ruxton, 2001):

- It can be used for systems where safety data is unavailable or unreliable, as it does not force precision.
- It provides an organised method to combine expert knowledge and experience for use in a FMEA.
- The use of linguistic terms in the analysis enables the experts to express their judgements more realistically and hence improving the applicability of the FMEA.
- The flexibility of assigning weight to each factor in the FMEA provides a means of specifically identifying weak areas in the system/component studied.

FMEA is a widely used risk assessment tool to identify the potential failure modes of a product or a process. By ranking the priorities for corrective action according to the respective effects of the failures, the chance of the failures can be reduced or eliminated. However, there could be several difficulties during conducting conventional FMEA such as the subjective and qualitative description in natural language, the relative importance among the risk ratings, the difference of risk representation among the same ratings; and the knowledge shared among FMEA team members. Thus, a new risk assessment system based on fuzzy theory is proposed in this paper to deal with these difficulties. Furthermore, an FMEA is conducted for risk of renewable energy resources to demonstrate the proposed fuzzy assessment of FMEA (Hsieh and Yeh, 2007). In the following we introduce the most well-known Renewable Energy Sources (RES).

4. Renewable Energy Resources (RES)

Renewable energy sources (RES) are the sources that are provided from the earth and not needed any production processes. These are not the derivation of fossil sources like coil, oil or carbon based sources. While producing electiricty from renewable sources, CO_2 emission is on the minimum level and comparing to other energy sources, they have less harm to the environment. Typical RESs are; hydrolic energy, wind power, solar power, geothermal power, biomass, biogass, wave power and hydrogen power (Unal, 2006).

4.1. Solar Energy

Solar power is an extremelly big energy source that comes from the core of the sun. This energy created by the fusion reactions the turns hydrogen gas into helium. As a result of this transformation, 4 million tones mass difference occurs in a second and this mass transforms to thermo energy. This thermo energy spread to the Space by radiation. A very little part of this energy comes to the Earth and it causes the live in there. If it is thought that the Sun will live over than 5 billion years, it can be said that the solar energy is an infitive energy source for the Earth (Adiyaman, 2012). In todays world, solar beam that comes to the Earth is used by into two different ways. One is transforming to heat and the other one is transforming it into the electricity. In order to obtain heat power from the Sun, solar panels to heat up water are used in daily life. This panels are placed to the roof and it directly increase the temperature of the water to use in the houses. Production of electricty from the Sun is achieved by one direct and one indirect way. As an indirect way, sun beam is gathered in a point by focus puller mirrors and high temperature is obtained. The liquid heated by this temperature on the collectors is passed on the water vassel and stream is created and mechanic movement for generator is created by the turbines. Therefore, electiricty is produced in an indirect way (Agacbicer, 2010). Photovoltaic bateries are used to produce electricty as a direct method. These bateries are produced by semi conductors that can transform the sun beam directly comes to their surface into electricity. While shape of these bateries can be changed as square, rectangle or circle, area of them are generally 100 cm^2 and thicknesses are between 0.2-0.4 mm (Gunes enerjisinden elektrik nasil elde edilir?, 2007).

4.2. Wind Energy

Wind can be basically described as the movement of the air in the atmosphere. Sun beam comes to the Earth and heats land and water. Since the air on the land heats quickly up comparing to air on the water, the air on the land starts to getting up and the cold air on the water placed on this place (Karadag, 2009). Movement of the wind is always from low pressure area to high pressure area. The pressure difference between these two area determines the speed of air stream. Wind power is the energy of this air movement (Gulay, 2008). Between the renewable energy sources, wind power is the most improved method and it is easier to obtain energy comparing to others. Due to these reasons, usage of this source is growing up. Although wind power uses only %1 of the energy comes from the Sun, the created energy is bigger than 50-100 times from the energy that created by the biomass of all plants in the Earth. The power of the wind will increase in the next years by the technology (Gulay, 2008).

4.3. Geothermal Energy

Geothermal energy is created by the heat under the Earth's crust by moving this heat up to the surface thanks to the meteoric water. The temperature of water and stream that are the what geothermal energy is are always up to the atmospherical average and they contain much more minerals, salt and many gases comparing to the underground and overground waters around them (Kocak, 2001). Geothermal energy is a new, renewable, sustainable, cheap, reliable, environment friendly energy type (Jeotermal Enerji, 2010). The undergraund reservuars created by rain, snow, sea and magmatic waters will be renewable if geologic conditions will continue, reenjection will be done and consumption-production balance will be stable. In addition to these, geothermal energy cannot affected by the atmospheric conditions (Dagistan, 2006). Geothermal energy is carried to the power centrals by stream and hot water pipes in order to create electricity production. In addition to that, they are used to heat houses by pumping these stream and hot water. Furthermore, this energy is used for cooling systems, agriculture and industrial purposes.

5.Renewable Energy Resources Risks

5.1. Economical and Financial Risks

Foreign Exchange Risk can be described as the possibility of losing value/money due to changes of the national currency compared to its value against foreign currencies. Foreign exchange risk results as profit or loss on firms' balance sheets or investment portfolios due to the changes in foreign exchange rates.

Credit Risk is the possibility of failure of the borrower to fulfill his obligations. Borrower’s payment capacity should be calculated according to terms of the loan; estimating how much credit borrower can pay back. Especially investors in energy sector generally have difficulty to pay their credits back due to the risks arising from natural/climatic events in particular.

Inflation Risk refers the likelihood of an undesirable real rate of return with respect to the investors. The decrease in purchasing power of money due to the rise in the general level of prices reduces the efficiency of investments in stocks.

Electricity Price Risk is the risk state set prices for renewable energy power plants also guarantee buying power of investors at this price. However there is a possibility of change in price or invalidation of guarantee although unlikely. The major effect of this is the credit payment failure risk.

5.2. Political Risks

Terrorism is related to take precautions for mitigating the effects of possible terrorist attacks on renewable energy plants as well as preventing them. Thus, in theory; renewable energy plants must be unappealing and deterrent for terrorist acts and assaults.

Civil Unrest and War is a risk related to expropriate and nationalize policies of the countries always intimidate the foreign investors. Also, global political conflicts and wars influence investors' behaviors. Energy sector is not only important due to national politics, but also global politics. Wars are fought, military coupes have been plotted and countries are occupied for dominating energy sources over the world, which is known as a common fact. Strike, civil unrest, rebellion, political recession, change of government and even civil war are examples of the related risks.

Change of Law and Regulations is a risk related to withdrawal of the governmental support for loans, capital subventions and renewable energy plant financial aids. Thus, future changes in Turkish laws related to renewable energy sources must be monitored and analyzed thoroughly. Especially the stability of electricity price rates is of utmost importance for renewable energy plants.

5.3. Technological Risks

Technical and Engineering Design Mistakes is generally occur before the construction during the design process. These defects are detected during overall performance test process and activation of facilities. If defects are detected in the final stage, they may cause notable delays and extend construction time.

Advancement of Alternative Technologies may Render Other Energy Sources More Feasible *is* the risk of affecting all energy plants producing same or different types of energy. Those investors that develop or utilize better technology will have certain competitive advantages over their rivals.

5.4. Construction and Management Risks

Worker Accidents and Mistakes During Construction and Operation Phases is the risk related to results as physical damage and losses due to human error. Plants in construction are subject to these types of risks more than those in operation.

Unexpected Maintenance and Repair includes unplanned maintenance and repairs occurring due to incorrect planning or worker accidents and mistakes. Energy production may be interrupted and/or plant may be shut down temporarily due to unplanned maintenance.

Unexpected Extension of Periodic Maintenance Periods is a risk related to the extension of maintenance periods due to technical and design errors or worker accidents and mistakes. Energy plants undergo maintenance on planned schedules and time lengths.

Business Costs are Higher than Expected is a risk related to increased expenditure due to unplanned maintenance and repairs, extension of planned maintenance times and other similar reasons.

Extension of Construction Times is a risk of inability to meet construction deadlines due to natural disasters, worker accidents, technical and engineering errors and delays in acquiring plant specific machines and equipments.

Delay in Procurement of Equipment is a kind of risk that may cause lag in time of construction, due to different reasons about delay in procurement of imported machine and/or equipment.

Natural Disaster is a kind of risk defined as physical damages and loses that may happen during construction or operating of energy plants due to natural disaster such as earthquake, flood, hurricane, storm.

Fire and Explosion is a kind of risk that may happen due to human triggered accidents and mistakes, natural disasters, terrorist attacks etc. during constructional or operational steps.

Altering of Wind Speed is a kind of risk that may occur when average wind speeds where the wind tribunes are constructed cannot produce effective power outputs in economical aspects and the power output is below the threshold required to generate electricity.

Choosing an Inappropriate Tribune is a kind of risk that may occur, when a tribune which is an uneconomic or not full filling criteria for the place where the plant is constructed, is chosen.

Discovery Risk is the risk that geothermal resources discovered to generate electricity do not provide us with appropriate flow rate and temperature.

Drilling Risk may happen if the depth of well is much deeper than expected depth. Geothermal energy production is done directly or indirectly using the thermal fluids in depths of ground by drilling. Cost is directly proportional to the depth of the well.

Fluctuation of Strength of Sunlight is a risk that may occur when total time opposed to sunlight and sunlight radiation amount is below the average values to obtain feasible power outputs.

Stealing is a kind of risk that people may steal machineries and equipment in the energy plants.

5.5. Social and Environmental Risks

Harming of Third Parties is a risk that may happen when fire and explosions, terrorist attacks, natural disasters in energy plants may give physical or financial harm to third parties.

Noise is a risk that may result from mechanic or aerodynamic noise created by wind turbines.

Bird Deaths is a risk that may occur when wind turbines are placed upon immigration paths of immigrant birds.

Gas Emission Risk may result in global warming and disturbing the ecosystem since geothermal energy plants emits small amounts of CO_2, NO_x, SO_x.

Geothermal Waste Risk may occur when wastes of geothermal plants are at a level that may give harm to earth and cause environmental problems. Since geothermal fluids contain various chemical materials within their content due to high level of temperature and pressure.

Waste Risk may occur when wastes in photovoltaic systems that contain small amount of poisoning materials are emitted to environment and may result in a fire even if it has a small possibility.

Diminishing of Cultivatable Areas is a kind of risk that may occur when large areas are occupied by photovoltaic panels. Since the efficiency of energy that is obtained from photovoltaic panels requires large areas.

6. Renewable Energy Resources Risk Evaluation

On behalf of surviving in today's competitive environment and the long-term profitability of companies operating in the electricity generation and distribution industry, risk management and damage control are critical issues which are prominent all over the world. When added international energy markets, new technologies, price uncertainty, compliance, environment, privatization, mergers, complex political fluctuations and risks brought about by globalization to the liberalization of markets in Turkey, gas and electricity price fluctuations, creditor claims, gas supply and electricity sales agreements, integration process with the European Union, original equipment manufacturers and maintenance companies in the international demand brought about by the complex responsibilities of agreements, risk management and damage control issues should be handled with utmost care on the creation of new risk management models. In this study, the potential risks of solar, geothermal and wind power plants which to be used for power generation, grouped and explained under five main headings. Relationships between main risks and lower risks are shown in Figure 2.

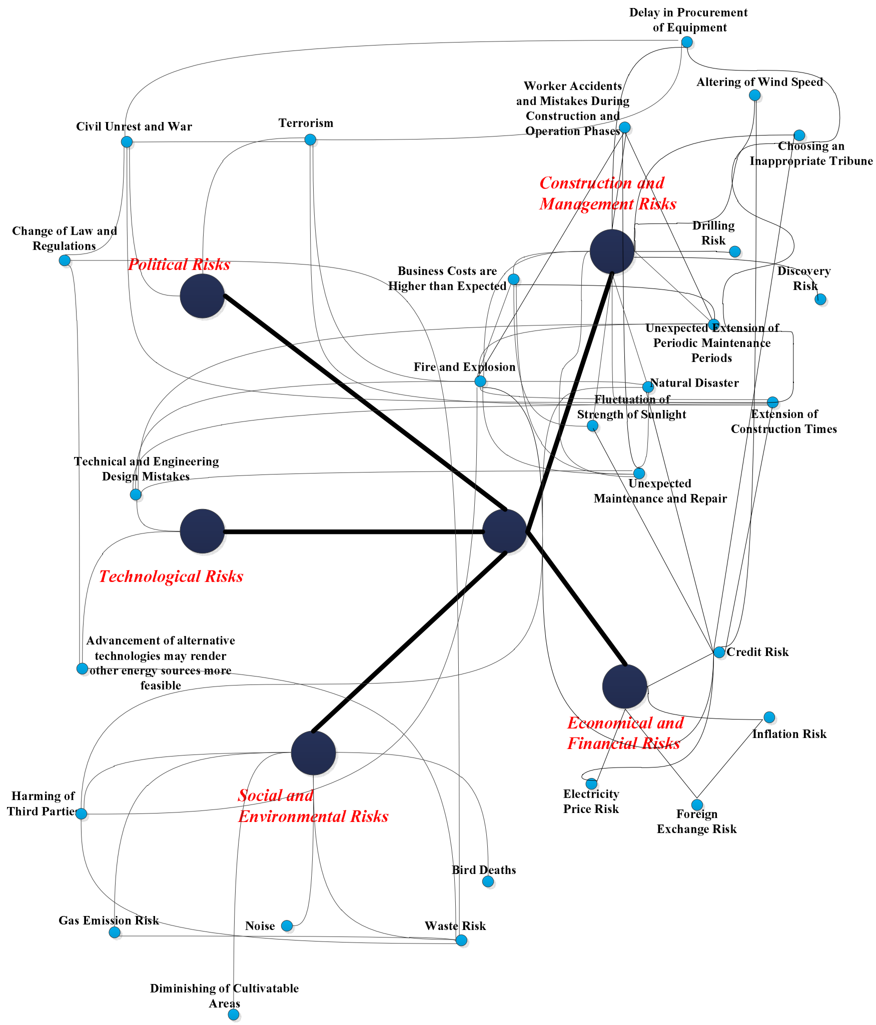

Figure 2 Relationship between main risks and lower risks

As can be seen in Table 1, fuzzy sets are defined for effects of occurrence, severity and detection. Intervals are established by taking rating scale of five and ten which is used in FMEA technique as a standard.

Table 1 Values and Category of Occurrence, Severity and Detection

VALUES			CATEGORY
D	F	G	
1	1	1	VL
2,3	2,3	2,3	L
4,5,6	4,5,6	4,5,6	M
7,8	7,8	7,8	H
9,10	9,10	9,10	VH

Three inputs and one output variable is determined by using triangular membership function, ranges for FMEA. These functions are assigned to be evaluated on five-scale for severity, occurrence and detection and on decimal-scale for the output variable. Each value is compared with each other and their degree of relationship is evaluated five-scale for input and decimal-scale for output. So the rule is established by determining the value of RPN score. The rating values are entered and the RPN value is calculated for each criterion by using MATLAB. Traditional FMEA and fuzzy FMEA values are given in Table 2. In Table 2, first reference condition (normal condition) values are set, then for each risks possibility, optimistic and pessimistic scenarios were created by 1 point approach. Because of some risks are connected, when approaching each risk possibility, affected risks possibilities are changed in the same way. While existence of risk only affects the probability of the risk, assumption is made that it had no effect on the severity and discernibility of the risks. Also by approaching lower risks in the main heading, it is determined that how effects of change in the main risks will influence power plants.

Table 2 Risk Table of Energy Types

Energy Types		**Wind(W)**					**Geothermal(G)**					**Solar(S)**				
Risks		**O**	**D**	**S**	**RPN**	**FRPN**	**O**	**D**	**S**	**RPN**	**FRPN**	**O**	**D**	**S**	**RPN**	**FRPN**
Economical and Financial Risks	Electricity Price Risk	4	5	7	140	32,2	4	4	6	96	25	3	4	8	96	37,1
	Credit Risk	3	4	7	84	25	5	4	7	140	32,2	3	4	8	96	37,1
	Inflation Risk	4	4	7	112	28,8	4	4	6	96	25	3	4	6	72	22,9
	Foreign Currency Exchange Risk	5	5	7	175	34,5	4	5	6	120	30,2	4	4	6	96	25
Political Risks	Terrorism	2	6	7	84	27,1	2	7	7	98	30,5	3	6	7	126	33,7
	Civil Unrest and War	2	5	7	70	22	3	5	7	105	28	2	5	7	70	22
	Change of Law and Regulations	3	4	8	96	37,1	4	5	8	160	39	4	3	7	84	25
Technological Risks	Technical and Engineering Design Mistakes	4	7	6	168	48,1	5	7	5	175	34,5	5	7	5	175	34,5
	Advancement of alternative technologies may render other energy sources more feasible	5	2	5	50	22	6	3	5	90	28,3	7	2	4	56	21,7
Construction and Management Risks	Worker Accidents and Mistakes During Construction and Operation Phases	6	3	5	90	28,3	7	3	5	105	28	7	2	5	70	22
	Unexpected Maintenance and Repair	4	7	5	140	32,2	3	8	5	120	28	3	6	4	72	22,9
	Unexpected Extension of Periodic Maintenance Periods	3	6	4	72	22,9	3	6	5	90	28,3	3	6	5	90	28,3
	Business Costs are Higher than Expected	3	8	4	96	28,3	3	8	5	120	28	3	8	4	96	28,3
	Extension of Construction Times	3	7	3	63	25	3	7	4	84	25	3	7	4	84	25
	Fluctuation of Strength of Sunlight											9	5	9	405	71,2
	Discovery Risk	-	-	-	-	-	7	6	8	336	59,2	-	-	-	-	-
	Drilling Risk	-	-	-	-	-	7	5	7	245	19,8	-	-	-	-	-
	Choosing an Inappropriate Tribune	2	3	8	48	37,2	-	-	-	-	-	-	-	-	-	-
	Altering of Wind Speed	8	5	8	320	59,8	-	-	-	-	-	-	-	-	-	-
	Delay in Procurement of Equipment	5	6	4	120	30,2	4	5	4	80	19,8	3	6	4	72	22,9
	Natural Disaster	5	7	6	210	39,6	4	7	8	224	48,1	5	7	6	210	39,6
	Fire and Explosion	3	7	8	168	45,4	5	7	6	210	53,6	4	7	8	224	48,1
	Stealing	-	-	-	-	-	-	-	-	-	-	1	8	2	16	17,4
Social and Environmental Risks	Diminishing of Cultivatable Areas	-	-	-	-	-	-	-	-	-	-	8	1	2	16	17,4
	Waste Risk	-	-	-	-	-	-	-	-	-	-	8	2	4	64	21,7
	Noise	8	1	2	16	17,4	-	-	-	-	-	-	-	-	-	-
	Bird Deaths	8	2	1	16	17,4	-	-	-	-	-	-	-	-	-	-
	Gas Emission Risk	-	-	-	-	-	8	2	2	32	21,5	-	-	-	-	-
	Geothermal Waste Risk	-	-	-	-	-	8	2	3	48	22	-	-	-	-	-
	Harming of Third Parties	4	5	5	100	25	4	5	6	120	30,2	5	5	6	150	30,2
	Response of the Local People's	4	3	4	48	19,8	3	4	4	48	19,8	3	3	4	36	15,9

7.Conclusion

When results in Table 2 are examined on graphic, in graphic which constitutes normal state scenario, percentage distrubution of risks (Table 3) which can rise in wind, geothermal and solar energy stations were constituted. When generated results are evaluated, highest risks are; technology risk for wind stations with %35.1 percentage, construction/enterprise risk for geothermal stations with %33.8 percentage and again construction/enterprise risk for solar stations with %32.6 percentage. Social and environmental risks constitute lowest risks, that is one of the main reasons of world's leaning to renewable energy.

Table 3 Percentage Distribution

	Average RPN			**% Risk (Traditional)**			**%Risk (Fuzzy)**		
	W	**G**	**S**	**W**	**G**	**S**	**W**	**G**	**S**
Financial and Economical Risks	127,8	113	90	25,66	19,16	18,03	30,1	28,1	30,5
Political Risks	83,33	121	93,3	16,74	20,51	18,7	28,7	32,5	26,9
Technological Risk	109	133	116	21,9	22,46	23,14	35,1	31,4	28,1
Construction and Management Risks	132,7	161	134	26,66	27,36	26,82	34,9	33,8	32,6
Social and Environmental Risk	45	62	66,5	9,04%	10,51%	13,32%	19,9	23,4	21,3

Also, for us in terms of financial and economic risks, it is seen that solar energy is the most risky energy group. The reason of this is first investment cost of solar energy stations is more according to other groups and they work with very low load factor (%6-20). To achieve a good risk management in energy stations precautions for these specified risks should be discussed and they should be applied.

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