Ranking of the Solutions of Reducing Electrical Energy Consumption in Isfahan Sepahan Cement Industry by Using Fuzzy TOPSIS Method

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Abstract
Nowadays, energy consumption management is a vital strategy for societies to optimize energy consumption. Considering the widespread functions of electrical energy in human lives,a high proportion of consumption management procedures deals with the management of electrical energy consumption. It is important to study the state of electrical energy and provide managerial and optimal management solutions in this industry. The main purpose of this study is ranking the key solutions of reducing electrical energy consumption in Isfahan Sepahan Cement industry. In this research, firstly, by studying and investigating conducted researches, interviewing with cement industry experts and alsoa researcher-made questionnaire, 20 solutions and 5 indices are chosen. Then by utilizing the indices weight and Fuzzy TOPSIS method, solutions are ranked and in conclusion, after conducting needed calculations, "Hot exhaust gases heat recovery and electricity generation" obtained the highest rank and "Revision of various energy tariffs" scored the lowest rank.

Keywords
Electrical Energy, Isfahan Sepahan Cement Industry, TOPSIS Method, Consumption Reduction Management

1. Introduction

Managing Electrical energy consumption reduction means alteration and optimization of consumption pattern. Shiftingelectric charge in order to manage energy consumption is usually very cheap and demands planning and establishment ofwork discipline. Charge increase, deformation of load curve, using special resources (such as indoor electrical facilities of industries), and saving in electricity in production unit etc. are all related to the mentioned method. By an appropriate plan, most industries can shift a portion of their electricity consumption from peak hours to other times, preferably, to low charge hours and use various fees in such time periods. Energy plays a vital role in daily activities and human development procedure in different societies. Besides, energy is a main factor in economic and social development of different communities. By population increase, industrialization and lining standards enhancement, energy has become more and more prominent.

After the oil crisis back in 1970s, different countries have tried to decrease consumption of natural resources by means of optimization of energy and cost; and therefore, preserve the environment and eventually, achieve a higher economic growth [1].

In recent years, various researches have been conducted in the fields of energy and reduction of electricity consumption. Each of which, have tried to identify and rank the ways of reducing the

consumption of electrical energy. Thus, firstly, a summary of the conducted studies in the field of energy is presented:

Audit group of energy in 7 cement factories in Thailand reports the followings in order to save energy:

1- Discussing about the primary energy consumption of facilities.
2- Comparing current energy user facilities with previous ones.
3- Analyzing thermal energy user facilities.
4- Costs calculation in terms of economy.
5- Investigating and calculating energy fees.
6- Establishing a database as a resource.

In conclusion, in this paper a saving of 2571.6 MWh of electrical energy has been calculated, although some pieces of advice such as definite conduct of annual energy consumption, substitution, and preserving renewable types of energy have been offered [2].

Optimized parameters in order to minimize the consumption of energy in Mexican aluminum industry state that the machines and tools that consume energy are responsible for environmental effects and optimized parameters can lead to minimization of energy consumption. In this research by TAGOCHI method some results are gained that are run by using tests. The results are put into action merely when the process is developed. Some of the results include the amount of energy consumed in each machinery procedure in aluminum industries, patterns engineering control, cutting depth of aluminum and cutting aluminum pace [3].

Savings in energy consumption of transportation in China states that energy consumption in China transportation is approximately one thirds of world's total energy consumption; and that in the recent decade with the continuous development of Chinese economy, energy consumption has increased to a great extent and energy consumption in transportation channels has significantly developed. In the paper after revision of existing reports, theoretical methods and technical patterns in China's transportation, analyses have been conducted regarding the current status of energy consumption in China's transportation. Conclusions include establishment of technologies in saving energy, creating railway and water transportation, air transportation and development of transportation paths [4].

Thai manufacturing industries by analyzing the change in energy intensity and using the logarithmic analysis state that structural and energy changes in Thai industries result in energy optimization development and also help decrease energy intensity [5].

"Experimental Investigation on Energy Efficiency of Electrical Utilities in Process Industries through Standard Energy Conservation Practices" which studies energy and energy preservation opportunities, has been chosen through the method of energy audit power rating, operation time, power factor and other important details of all the machines/equipment collected for the selected industry. The measured data were analyzed to find energy conservation opportunity. Energy saving techniques like energy efficient pumps, stopping of air leakages, air compressor efficiency improvement was considered for energy conservation. Energy saving details were calculated with cost benefit analysis. Besides, profit and costs analyses were conducted to preserve energy. Eventually, It has resulted in a total saving of 2, 29, 369 electric units (kWh/year) and annual energy saving of Rs. 13, 43,670 [6].

China and Japan industries have stated in a study regarding comparison of energy consumption and energy optimization that there is a strong relationship between energy consumption reduction and energy optimization in the industries of the two countries. Thus, structural changes in energy and energy challenges have been stated in the investigation that structural alteration leads to energy added value [7].

In Portugal dairy industries, 67 percent of energy consumption reduction and optimization was accomplished through using mathematics and thermodynamics equations. Beside the energy savings and costs reduction, they have led to an increase in competitive market and a reduction in green gasses diffusion and also a healthy environment [8].

In another research titled “energy consumption optimization in freezers” energy consumption has been reduced through using an experimental method and by eliminating coolers and tropical examination. The results indicate that by using a cooler in hot walls of the refrigerator, reducing cooling pipes, compressor recharge alterations and adjusting the cooling capacity of compressors and electro-motors, a reduction in freezers’ energy consumption is accomplished [9].

Using “programming with mixed integers” and also LP and time restrictions methods presented ways to decrease energy consumption useful fortransit transport system. Results indicated that a relative distance is considered as a maximum deviation from the optimum energy consumption [10].

So far, various tools and methods have been utilized in conducted investigations in order to decrease electrical energy consumption. Experts’ opinions are used in order to identify solutions and criteria and also weighting the criteria.

In order to clarify research literature and the purposes of current research, a comparison is carried out between the mentioned researches in Table 1.

Table1. Comparing past investigations

Row	Researcher	Titles	Method and tools	Location	Conclusion
1	Monika Dutta (2010)	An outlook into energy consumption in large scale industries in India	Markal modeling	India	Utilization of accepted energies such as iron ore, coal, electricity, steam and oil.
2	Tili (2013)	energy conservation in cement industry	Energy audit	Thailand	Substitution of renewable energies
3	SARMITA (2013)	Optimized parameters in order to minimize energy consumption in cement industry	Taguchi method	Mexico	Patterns control, cutting depth and pace, machinery process control in aluminum industry
4	Wang (2013)	Saving in transport energy consumption	Descriptive	China	Establishment of technology in energy saving, creating railroad and water transportation, development of transportation paths.
5	Jaravan	Analysis of energy intensity change in industry	Logarithmic analysis of average indices	Thailand	Variables of Change in structure in industry and energy intensity lead in energy optimization development and energy intensity reduction
6	Atmaca and Yamratas (2014)	Analysis of electrical engines and Reducing energy consumption in cement industry	Numerical calculations and excel software	India	With variables of heat losses, special energy and energy calculationsand with the conclusion of furnaces' inner temperature hanging, adjusting the inner temperature of furnaces and thickness of firebricks.
7	Zhao (2014)	Comparing energy consumption and energy optimization	Experimental studies	China and Japan	Strong relationship between energy intensity reduction and development in energy optimization
8	Alves (2014)	Optimization of Energy Consumption in Cold Chambers in the Dairy Industry	Simulation, mathematical method, thermodynamic equations	Portugal	Energy saving results in reduction of greenhouse gasses diffusion in order to contribute to a healthy environment
9	Ghadiri (2014)	Optimization of energy consumption in freezers	Experimental method	Iran	Using a cooling system, reducing the diameter of the cooling pipes, compressor and electric motor setting
10	Mrad (2014)	Energy consumption optimization for a transit transport system	IP programming with complex numbers		Energy consumption reduction leads to a decrease in transportation

2. Methodology

Current research is conducted in order to rank the solutions and indices of electrical energy consumption reduction in cement industry. The used approach consists of 5 fundamental steps; the explanation of the steps is as below:

- Solutions and indices of electrical energy consumption reduction are collected and investigated.
- According to research subject, some information regarding the identified weight of indices is required which can be used to rank the identified solutions.
- Ranking the solutions using TOPSIS method. In order to use this technique, the solutions and indices identified in the previous steps will be defined as primary solutions and indices.

In order to achieve the research goals, research method is investigation of goals, and study type is descriptive and survey-based. Searching for identifying and ranking solutions and indices in reducing electrical energy consumption began and they were identified based on subject, scope and investigation regions. The population of cement experts was selected through questionnaires and experts' investigation. In Table 2 information analysis method, research steps and data collection and analysis tool are explained.

Table2. Research steps and tools

Step	Goal	Data type needed	Collection tool	Data analysis
1	Studying and collecting solutions and indices of reducing electrical energy consumption	Solutions and indices in the field of electrical energy	Research literature revision and questionnaire	Content analysis
2	Indices' weight	Weight of indices	paired comparisons questionnaire	Data hierarchical method (AHP)
3	Ranking solutions	Decision making matrix	Questionnaire and TOPSIS method and Excel software	Experts

In the first step of this study, library method was used in order to investigate the research literature; including mainly books, papers, Latin and Farsi resources on the internet, databases,data and library resources and besides a researcher-made questionnaire among experts. In the second step, indices' weight was calculated through AHPmethod by using paired comparisons questionnaire. In the Third step, TOPSIS technique and indices' weight were used to rank the solutions.

3. Case Study

This research was implemented in Isfahan Sepahan Cement Firm as a cement manufacturing industry and the solutions and indices of reducing electrical energy consumption were examined. Current research's validity and reliability were examined. After gathering the questionnaires, structure reliability was confirmed by confirmatory factor analysis. Besides, Cronbach's alpha coefficient average was calculated as 0.92 which is, more than 70 percent and therefore questionnaires are reliable. In the steps of this research, firstly, 20 solutions and 5 indices were

collected in Table 3. Then, a questionnaire was made by cement and energy auditing experts and afterwards, the questionnaire was distributed among 15 experts. In order to ensure the selected 20 solutions and 5 indices presented in Table 4, another questionnaire was designed and was distributed among 50 experts. In the second step in order to obtain the weight of the 5 identified indices in Table 5, paired comparisons questionnaire was distributed among 15 experts and at the end, 100 designed questionnaires were distributed among experts in order to rank the solutions and establish the decision making matrix. After analyzing and using time range for changing questionnaire's digits, TOPSIS method was used to rank the solutions. The ranked solutions are shown in Table 6. Results of current research have identified and ranked the solutions and indices that in case they are used in cement industry, they will enable this industry to consume much less electrical energy.

4. Results and Discussion

Necessity of reducing the consumption of electrical energy in industries, due to global environmental and social crises and causing decrease in energy resources has made managers to consider the electrical energy consumption reduction more than ever. This energy consumption reduction in cement industry is achieved when important and influencing solutions and indices on different aspects of electrical energy reduction are identified and ranked and afterwards, political policies are considered and actions are conducted based on them.

The framework and method for identifying and ranking solutions and indices in current research include steps that can be applied in all organizations and firms in order to decrease electrical energy consumption.

Step 1: Data Collection

After investigating and studying previous researches regarding the solutions and indices of decreasing electrical energy consumption, 20 solutions and 5 indices are collected and shown in Table 3 and 4.

Table3. Existing solutions

1	Investigating different energy fees	13	Maintenance
2	Decreasing production line stoppages	14	Production plan improvement in order to increase production rate
3	Increasing the efficiency of electro motors	15	Channeling for compressed air compressors in order to get the air out of compressor house
4	Decreasing the amount of false air leakage to system	16	Decreasing the amount of compressed air leakage
5	Adjusting proportioning of mill feed in the desired limits	17	Using speed control drives on grate cooler fans
6	Continuous control of material grinding charge	18	Using elevator instead of airlift
7	Continuous control of cement grinding charge	19	Using PREGRINDER
8	Using materials that help shaving in cement grinding	20	Using oxygen injection technology in Cement kilns and reducing the flow of combustion gases
9	Using high efficiency separator		
10	Substituting rolling grinders for ball grinders		
11	Using silicones with low pressure drop		
12	Recycling the heat from compressed air compressors		

Table4. Existing indices of consumption decrease

1	implementation time of electrical energy consumption reduction solutions
2	implementation time of electrical energy consumption reduction solutions
3	Required infrastructures to implement solutions
4	Experts needed
5	Dependency on other countries in order to supply required parts

Step2: Indices' Weight Calculation

Indices' weight is measured by hierarchical method through questionnaires and making paired comparisons matrix among experts as presented in Table 7.

Table5. Indices' weight

Row	Indices' weight	W_i
1	(0/9837,0/2284,0/0028)	W_1
2	(0/9258,0/02539,0/0025)	W_2
3	(0/0026,0/0334,0/7960)	W_3
4	(0/0025,0/016,0/8505)	W_4
5	(0/6226,0/0555,0/003)	W_5

Step 3: Ranking Solutions

In this step, the 23 identified solutions for decreasing electrical energy consumption are ranked based on the 5 indices identified in the previous steps. Based on these steps of TOPSIS method presented in the first step, decision matrix is made. For this purpose, the amounts for each of the 23 identified options or solutions are determined. In step 2, B decision matrix is compared. Step 3, determines the weighted decision matrix. The fourth step, finds the ideal and anti-ideal options. The fifth step, calculates the distance between the ideal and anti-ideal solutions. In sixth step, similarity index is calculated and eventually, in the last step, the options or the solutions of Table 8 are ranked.

Table6. Solutions prioritization

Row	Ranking solutions for energy consumption reduction	Ranking
1	Recycling the heat of hot exhaust gases and generating electricity	0/824960678
2	Substituting rolling grinders for ball grinders	0/824561825
3	Using elevator instead of airlift	0/823561415
4	Using PREGRINDER	0/793735082
5	Using silicones with low pressure drop	0/748197245
6	Using high efficiency separator	0/712102662
7	Using speed control drives on grate cooler fans	0/694697343
8	Using oxygen injection technology in Cement kilns and reducing the flow of combustion gases	0/681340646
9	Decreasing the amount of compressed air leakage	0/494137746
10	Maintenance	0/438498648
11	Production plan improvement in order to increase production rate	0/438498648
12	Channeling for compressed air compressors in order to get the air out of compressor house	0/438498648
13	Using materials that help shaving in cement grinding	0/319578266
14	Continuous control of cement grinding charge	0/319570672
15	reducing stoppages of production lines	0/251135374
16	Improving the performance of electro motors and related systems	0/251135374
17	Decreasing the amount of false air leakage to system	0/251135374
18	Adjusting proportioning of mill feed in the desired limits	0/251135374
19	Continuous control of material grinding charge	0/251135374
20	Investigating different energy fees affecting reduction of electrical energy consumption.	0/180720815

5. Conclusion

Given that this research has been conductedwithin a certain time frame,the results of the analysis of its findings cannot be used definitively and permanently. Therefore, the suggestions presented are based on the results of the research period and the statistical sample.

• In order to review and identify energy reduction methods and also the indexes periodically in Sepahan Cement Company, it is recommended that managers use the proposed method for specific periods of six months or one year and evaluate the results and utilize them in order to execute appropriate enforcement actions accordingly.

• Considering the priorities and ranking of solutions in Sepahan Cement Company, according to the indicators, Sepahan Cement Companies managers can examine the impact of these solutions on reducing electrical energy consumption and reducing costs and use as important and effective solutions in their management.

• Managers can investigate the existing problems and inadequacies in electrical energy consumption reduction by holding meetings with experts, after evaluating these indices and solutions.In current research, the result of ranking the most significant solutions and rankings indicates that “Recycling the heat of hot exhaust gases and generating electricity” got the highest rank and “Investigating different energy fees affecting reduction of electrical energy consumption” acquired the lowest rank.

•It is recommended that researchers investigate more solutions and indices in cement factories in their future studies. In addition, it is recommended to use other multifold decision-makingapproaches and compare their results with current papers. In case the recommended method is used in other cement factories and their results are compared with current research, the recommended method validation will increase. Finally, conducting current research in other periods can pave the way for analyzing the reliabilityof current research in the course of time.

6. Reference

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