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Article

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Energy Consumption Optimization in Urban Rail Transport (Case Study: Tehran Subway)

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Abstract: Necessity and importance of energy in state economic, social, and political structure and stability of and terminable fossil resources have been centerpiece of attention to energy issue in last few years. Urban railway, as one of the main pillars of urban economy, has increased the importance of this sector based on mass transit with advantages such as economic savings in fuel consumption, preventing air pollution, reaching environmental standards, and creating social culture and discipline, and it has been followed by continuation and development of rail transport sector in the country. In this research, optimization of energy consumption in urban rail transport has been investigated and some strategies have been presented in this regard. For this purpose, 160 metro experts, who had direct relation with establishment and implementation of energy management system in Tehran Metro Operation Company, were considered as population. By using Morgan table, 113 of them were selected as sample by simple random sampling. To collect data, library ad field studies, interview with related experts, and researcher-made questionnaire containing 22 questions were used. To analyze data, SPSS software, exploratory factor analysis, and Freidman test were used. In order to identify current situation in energy management (based on ISO 50001 standard), general measures Tehran Metro Operation Company in current situation, including contract demands of electricity consumption were detected. However, by using factor analysis, 11 factors were identified and ranked in the field of energy consumption optimization. Appropriate information ranked the highest and encouraging suggested pland ranked the least.

Keywords: optimization, consumption, energy, rail transport, city of Tehran
JEL Classification: E21 ,P36 ,Q43 ,N55

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1- Introduction

Today, energy has a special place among the countries of the world. Awareness of energy consumption is of great importance for many economic and political programs. Given the social and economic sensitivities of energy and the excessive use of fossil resources, countries are pursuing a strategy to reduce energy consumption and production costs, and to increase public welfare and energy efficiency policies. Rail transportation as one of the important parts of the transportation system plays a major role in a country's economic, industrial and social spheres, as well as the fertility of the potential talents of the communities since the passenger and cargo handling methods have been interlinked between the various growth and development factors helping to strengthen the various economic, social and cultural sectors of the country. Some of the benefits of rail transport to other types of transportation include reducing energy consumption, reducing environmental pollutants, environmentally friendly stubbornness and high safety. Comparison of Iran with the countries of the world in terms of macro-energy indicators indicates that currently, the energy intensity of the country is 1.76 tons of crude oil per thousand dollars of Gross Domestic Product (GDP) while the average of this amount in the world is 0.42 and in developed countries is equal to 0.1. This inappropriate situation is in final consumption levels, such as building and housing, transportation and industry sectors. The low cost of energy carriers and not using day-to-day technology in manufacturing, construction, agriculture and transportation factories have led to a very high per capita consumption of energy in the country compared to other developing countries (Mobini Dehkordi et.al, 2009).

Studies in the field of rail transport industry, as the main link between supply and demand of these services, have been dealt with the process of increasing energy consumption or the necessity of reducing energy consumption in the transport sector so far. Therefore, in this research, we are going to present strategies to reduce energy consumption in the railroad transportation industry as a main railroad industry in Tehran. In providing possible solutions, the following points have been given special attention. 1. Reducing energy consumption is not always desirable, and the quality of services should be considered. 2. The proposed solutions should be tested and reviewed operationally (Bakhtiyari et.al, 2009). Therefore, in this study, in addition to considering the stated cases, since Tehran Urban & Suburban Railway Operation Co. is connected to ultra-high voltage network with regional power dispatcher (electric control room) and it provides the required electric power by high pressure stations (63.20 kV) and each of these posts purchases electric power from the regional electricity company with respect to connection loads and development plans and the regional electricity company also plans and assesses the energy supply of all its customers according to the amount of the contract notice; therefore, if the consumption exceeds 100% of the contract, it will be considered as a violation of the contract term, which is normally several times the contractual tariff rate, as a fine for violating the power. For some reasons, Tehran Urban & Suburban Railway Operation Co. has also paid some expenses for power overruns due to some consumers and the structure of low-pressure distribution and traction substations, as well as some unusual conditions in the upstream network or internal distribution system, etc. Thus, this research is aimed at providing energy efficiency optimization solutions in the inland urban transportation industry, and studying the amount of energy saving Rials, especially the correction of conventional electricity consumption. In addition to measuring and monitoring the consumption of high-pressure substations and electricity distribution, measurement of the costs and the amount of its rape has been done.

2- Literature Review

After the oil crisis of the 1970s, much attention was paid to optimizing energy consumption, managing and maintaining it at the international level and since then, research activities have focused more on encouraging countries to use energy efficiently (Takhshid & Matin, 2011). Many of the studies on energy and its optimal use have been focused on energy efficiency indicators, energy measurement and its plans and policies. In the following, some of them are mentioned.

a) Foreign Researches

González-Gil et.al (2015) in order to reduce energy consumption and operating costs in urban rail systems, in addition to multi-level analysis of energy performance of the system, along with accurate assessment of successful saving strategies, developed a comprehensive approach to energy management systems. In this plan, a complete list of key performance indicators was proposed by stakeholders, out of which, 22 indicators were available at to two levels: 10 key indicators of total system performance and existing subsystems and 12 performance indicators of subsystem units were divided. Finally, a framework was developed along with a descriptive method to optimize energy consumption in urban rail systems.

Xia et al. (2015), in a research study, investigated and simulated urban power supply system, taking into account functions such as economic efficiency and voltage compensation, to explain energy management strategy with a combination of genetic algorithm and the simulation platform for urban power supply of rail system.

b) Iranian Researches

In a paper titled “application of EDLC capacitors in dynamic brake dynamics of electric trains”, Jalehpour and Jafarinsab (2010) stated that due to the expansion of the application of dynamic brake in the rail industry, for optimal use of energy and returning thermal energy to the electrical supply network, the need to pay attention to the category energy storage systems is of great importance in the event of lack of energy absorption in the power network. However, high cost as well as the complexity of the electric energy backflow of the dynamic brake in the DC network compared to the AC increases the importance of the dynamic energy storage electrical energy system.

Zinelzade et al. (2012), in an article titled "optimal capacitoring in harmonic contaminated distribution networks by clustering artificial bumblebee algorithm,” concluded that casualties in distribution networks accounted for the largest share of casualties in a power system. The use of capacitor banks to compensate for reactive power in the area will reduce losses. In this paper, the positioning and compensation of the capacitor was carried out by using innovative honeybee optimization method.

Poush Pars and Rezazadeh Nochedehi (2014) in an article titled "optimizing the train brake recovery for maximum efficiency in electric high-speed rail systems,” proposed an optimized train timetable to fully utilize the train retrieval energy. However, a simple metro system was simulated and the genetic algorithm was used as an optimization method. Finally, the results of the optimized cases were compared with the usual ones to show the effect of the proposed method.

Alizadeh et.al, (2014) also stated in an article that electric trains receive the highest energy consumption in accelerating mode from the network. When several trains begin to accelerate simultaneously, the power of the subscription reaches its maximum.

Javadi et al. (2014) in an article reviewed the traditional energy management systems of the metro network to use the powertrain generated by the traction engine, in addition to investigate the necessity of providing a new model for the use of motor energy of the traction.

In this research, modeling by using new data mining techniques, Bana Derakhshan & Tolouei Ashlaghi (2015) identified the main elements that affect the energy efficiency of buildings in Tehran municipality district 7.

3- Theoretical Framwork

Energy is a subset of the economic and social system that has a major impact on the economic development process. The energy economy has a major role in production and service sectors and it creates widespread economic, political and other interactions due to job creation and increased revenues from trade in energy. In energy systems, interactions between different sectors are considered and the effective factors are regarded as parametric.

The increasing expansion of metropolitan populations and issues such as visual and environmental anomalies, traffic and air pollution have led urban management to adopt effective solutions such as sustainable development to address these problems (Keyhaniyan, et.al, 2012).

In developing countries, due to insufficiency and lack of investment in infrastructure, there is a greater need for investment in the transport sector along with economic development. According to the Law on Public Transportation Development and Fuel Management, approved by the Islamic Consultative Assembly on December 9, 2007, public transportation should be developed. In particular, Article 1 of this law obliges the government to take steps towards the development of inland and suburban transportation with an emphasis on the improvement and development of the rail network, because the rail transport industry has the highest efficiency in terms of energy consumption and entails the least damage to the environment. In other words, the railway industry is the most adaptable environmentally-friendly way of moving, known as the Green Transportation Industry.

Urban Railway, as one of the major modes of passenger transportation, along with benefits such as: economic savings in fuel consumption, preventing air pollution, close to environmental standards (due to rising fuel prices in the future and emphasis on environmental preservation), has increased the importance of this sector for the feasibility of carrying out secure inland trips with the highest possible technology and creating culture and social order (Tehran City Statistics, 2011). There has also been a continuation and development of the rail transportation sector in the country. Mass transportation, known in various cities as underground railroads or subway, is a rail transport system that is used exclusively through the power received from a third rail or overhead cable and with stations with long platforms. Metro trains, unlike ordinary trains, have no separate locomotives, and trains consist of identical wagons driven by electric motors. Due to features such as: relatively long distance between stations, short stop times and routes that other transport modes do not affect, with a maximum and average speed of 90 and 27-40 km/h, it has the possibility of moving up to 80,000 people per hour in the path. This system is the most cost-effective public transportation method, but it has the maximum passenger carrying capacity.

Energy audit is the basis of the codified approach for decision making in the field of energy management, and it attempts to balance the total input energy and its consumption, and to calculate all energy streams in the set of facilities, to identify and to use energy according to discrete functions. With an in-depth visual inspection, energy saving opportunities can be widely identified in different sectors and the requirements for detailed analysis can be estimated. Initial energy audit is a relatively quick way to determine the energy consumption of an organization, estimating the potential for savings, identifying more convenient areas for energy savings, identifying saving strategies, or quickly improving (especially low or no cost). Considering the fact that most of the equipment in operation of stations, lines and terminals are most electric, energy management is of great importance in highway metro. At present, Tehran Metro has been operating with about 162 km of lines currently in operation, 100 active stations, 94 train rails in Tehran and the suburbs, 5 train stop terminals and more than 4 administrative buildings located in different parts of Tehran. The subway of Tehran consists of mobile equipment and fixed equipment, including electric power supply network, telecommunication and signaling network, and control and command center for repair shops, ventilation, elevators and escalators. Tehran Metro Power Grid is also transmitted to high voltage substations and sub-distributive substations at 230 and 63 kV voltage levels by regional power company using ground or air transmission lines through 230 kV high voltage substations. At these levels, the voltage from high and high voltage substations is 20 kV cable lines from the outlet side of the special and upstream subway stations, which feeds the substation and the distribution and in order to provide the power required for the trains at the voltage level, the relevant posts for Provision of required power, electrical and mechanical installations of stations and the route of power lines of electric trains, including all types of rail rails or overhead grids. In order to fulfill mentioned requirements, energy affairs should be managed efficiently and highly effective. Planning is the key element in energy management. Planning is an important step in decision-making that converts the idea of energy savings into executive projects according to organizational constraints and it causes all energy saving measures be seen in a coherent and consistent manner, taking into account other activities of the organization. The requirements for the management of energy management are legal, technological, environmental and economic ones (Keyhaniyan et.al, 2012). The largest portion of the energy loss in traction is related to train brake. Also in stations, air ventilation airbags, escalators, elevators and more are considered as major uses. Based on bills issued by the Electricity Organization of the province of Tehran, regarding, monthly from July 2014 to July 1394 for a period of one year the total amount of consumed energy in this area, indicates that the energy consumption varies in Tehran Urban & Suburban Railway Operation Co. based on the weather conditions of different seasons. In the summer, due to the active operation of the cooling system of the stations, the amount of consumption in the subway reaches its peak, but in autumn, fan is shut down with the coolness of the air, and the consumption is at its lowest level in this season, then, the consumption gradually increases over the winter due to the use of heating appliances. Importantly, the decrease in consumption in warm seasons is compared with last year, which indicates the company's attention to energy efficiency improvement. As current policies continue, consumption will decrease despite the development of lines and stations. Therefore, taking into account all aspects, the more consumption is closer to the base line; the results will be noticeably significant in the company's electricity costs. Considering the basis for energy consumption, the average monthly energy consumption is 31541384 kWh, which can greatly benefit economic optimization in high season and close to the mean line (Tehran Metro Annual Report, 2014).

4- Research Method

This research is applied in terms of purpose and is descriptive-survey in terms of method. The present study was conducted with a general review of the state of energy management in the metro complex and interview with the experts of this industry about the potential for energy savings, as well as the changing contractual remnants and the establishment of an energy management system. Therefore, a series of indicators in the form of ISO 50001 and the variables proposed in the Energy Management Matrix were extracted. In order to provide solutions to improve the status quo based on the ISO 50001 standard, library studies, technical documentation reviews, energy management, and safety management and quality engineering have been used. Then with the experts of this industry, an individual interview was conducted and finally, through a group interview with them, a final compilation was made of library studies and individual interviews that led to identifying factors. Approximately 160 metro experts who directly linked with the establishment and implementation of an energy management system at Tehran Urban & Suburban Railway Operation Co. were considered as the statistical population. According to the Morgan table, 113 people were selected by simple random sampling. The questionnaires were distributed among them in order to study the status and to understand the implementation and establishment of energy management system in Tehran Urban & Suburban Railway Operation Co. Based on library studies and interviews, a researcher-made questionnaire was compiled of 22 questions with 6 dimensions of investment, marketing, information systems, motivation, organization, and energy policy and 22 indicators. In this study, the reliability of the instrument was determined by using Cronbach's alpha coefficient. After analyzing the reliability of the data, the Cronbach's alpha coefficient for 22 identified indicators was calculated 0.913, which is very appropriate for the reliability of the questionnaire.

One way to determine the status of any organization in terms of energy is to determine the organization's position in the energy management matrix. The rows of this matrix (from 0 to 4) represent the complexity and evolution of the organization with respect to effective energy management and its columns in relation to key management issues.

In order to determine the main influential factors with exploratory factor analysis, the indicators that have the highest factor load were identified. Friedman test was used to rank the indexes related to the dimensions of the research, which is as follows: SPSS output consists of two tables; in the first table, the statistical data and statistics of chi-square and in the second table, the average rank of each variable are presented. The higher the average ranks, the more important it is. According to the SPSS output, the significant number (sig) is less than the standard significance level ($\alpha = 5\%$). Therefore, there is a significant difference between the existing statuses of 10 indicators related to energy management. Moreover, statistical analyses of power bills including active and reactive power, energy, residual and consumed electricity costs were investigated. Finally, using a combination of indices and energy consumption analysis, practical solutions to manage energy resources consumption were explained in Tehran Urban & Suburban Railway Operation Co.

5- Research Findings

Intra-city rail transport network (Metro) is one of the largest transportation networks and electric power consumer of Tehran's metropolitan, and energy consumption management of this vast network has a significant impact on the growth of the urban economy based on resistance economy. Typically, the power grid of Tehran Urban & Suburban Railway Operation Company, at the level of the over-voltage network, is related to the regional power supply dispatcher and the electrical required power is provided by the high-voltage substations (63.20 kV), such as: Amir Kabir, Bonyadrang, Azadi , South, Qeytariyeh, Abbasabad, Qurkhaneh (Imam Khomeini) and Tehranpars. Each of these posts purchases the amount of power and electrical energy as the contract term (maximum electricity consumed on a contractual basis in each period) from the regional electricity company, with regard to connection loads and development plans. On the other hand, the regional electricity company also plans and estimates the supply of electricity to all its customers, according to the amount of contract. The electricity company considers 90 percent of the contract as the base line and considers the consumption calculation of each consumer as follows:

- If the amount of consumption is less than 90% of the contract notice, this amount is considered as the amount of consumption.
- If the consumption rate is between 90% and 100% of the contract, it takes into account the actual consumption of the consumer.
- If the consumption rate is more than 100%, it takes into account the amount of the exceeding the contract demand, which is usually several times the contract tariff rate, as a penalty for the violation of power.

Tehran Urban & Suburban Railway Operation Company also pays costs as a violation of power for some reasons, such as the structure of low-pressure distribution and traction substations, and sometimes with the emergence of abnormal conditions in the upstream network or internal distribution system. Therefore, in the following, we study the costs of high-pressure substations during the period from the first to the seventh (from 2011 to 2013) as a pilot. Tables 1 to 4, by year and period, represent the amount of contractual notice, the amount of power consumption and fines for exceeding demand (RLS), and in the last column is the total penalty year.

Table1. The costs of exceeding the contract demand (Rial fine, 2011)

High power pressure power station	Contract standing (KW)	Annual power consumption per kilowatt (KW)	The costs of exceeding the contract demand (Rial fine, 2011)												
			Period												Total annual fine (Rials)
			1	2	3	4	5	6	7	8	9	10	11	12	
Amir kabir	4000	3607	0	0	0	0	0	0	0	0	0	0	0	0	0
Bonyadrang	14000	16193	0	7668908	47048867	121155562	108100456	30396705	580624	0	0	0	0	0	314951122
Azadi	9000	12342	57057352	73295654	196011009	188236177	228031130	194652711	235467427	137442804	71027852	59576158	58585501	64350386	1563734161
Abbasabad	9000	18089	96040169	526101309	609082229	280174395	439501272	377927381	417092278	295114074	233904812	176873531	229682776	208841911	3890336137
South	5000	5164	0	0	7563405	0	0	0	0	0	0	0	0	0	7563405
Qeytariyeh	4000	3325	0	0	0	0	0	0	0	0	0	0	0	0	0
Ghoorkhaneh (Imam Khomeyni)	14000	22235	0	363651077	594916567	239334787	88003099	45379321	0	0	0	0	0	0	1331284851
Tehranpars	6900	10375	132350897	137649864	246390997	188822810	266028734	247442424	172576101	136837433	149534964	113344018	116305997	91255223	1998539462

Reference: (Researchers' findings)

Table2. The cost of exceeding contractual standing (annual Rial fine, 2012)

High power pressure power station	Contract standing (KW)	Annual power consumption per kilowatt (KW)	The cost of exceeding contractual standing (annual Rial fine)												
			Period												Total annual fine (Rials)
			1	2	3	4	5	6	7	8	9	10	11	12	
Amir kabir	4000	9780	0	253233787	0	0	14852611	10859801	9920223	168259	0	0	0	0	289034681
Bonyadrang	14000	14620	0	0	0	13083357	14767008	30128787	0	0	0	0	0	25954634	83933786
Azadi	9000	11978	119927199	47074069	132898118	207862393	147405663	83886061	180350570	139791601	167567300	104868560	217180762	24131509	1572943805
Abbasabad	9000	19597	203309093	379335707	352227768	816090015	252311792	471698579	418737014	632232023	337109072	641704539	638937261	500038610	5643731473
South	6000	5236	0	0	10133356	0	0	0	0	0	0	0	0	0	10133356
Qeytariyeh	4000	4421	0	0	0	8457315	18467408	0	0	0	0	0	0	0	26924723
Ghoorkhaneh (Imam Khomeyni)	14000	21221	0	0	513071626	474268410	575594038	583976866	327021186	273202053	0	0	0	0	2747134179
Tehranpars	6900	10161	127116735	181099988	192551925	240823794	303692062	225261903	176798190	119080450	91467753	56567584	10357571	659698323	2384516278

Reference: (Researchers' findings)

Table3. The cost of exceeding contractual standing (annual Rial fine, 2013)

High power pressure power station	Contract Remainder (KW)	Annual power consumption per kilowatt (KW)	The cost of exceeding contractual standing (annual Rial fine)												
			Period												Total annual fines (Rials)
			1	2	3	4	5	6	7	8	9	10	11	12	
Amir kabir	5000	5150	0	0	0	0	0	0	0	0	0	0	0	9313221	9313221
Bonyadrang	14000	15450	0	27855620	29512123	60437251	74774015	17853066	61861574	50533014	58812566	52220524	69510174	26160813	529530740
Azadi	11000	11520	5728722	0	11021170	10185282	10150847	6235298	6786232	22597232	18618198	231146603	23322617	22998091	368790292
Abbasabad	11000	18620	462811638	327718224	560611737	491230029	449609322	215823731	350019628	232316311	639731206	540119352	239725021	513724717	5023440916
South	6000	4810	0	0	0	0	0	0	0	0	0	0	0	0	0
Qeytariyeh	4000	5306	0	0	0	65968697	0	0	0	0	0	0	0	0	65968697
Ghoorkhaneh (Imam Khomeyni)	14000	22460	0	0	361130075	7184722	391691180	530890677	562578305	265173322	0	0	0	0	2118648281
Tehranpars	8000	8900	16666953	17079170	2652256	0	0	4459239	0	0	0	0	29291307	35985734	106134659

Reference: (Researchers' findings)

Table4. The cost of exceeding contractual standing (annual Rial fine, 2013)

High power pressure power station	Contract Remainder (KW)	Annual power consumption per kilowatt (KW)	The cost of exceeding contractual standing (annual Rial fine)												
			Period												Total annual fines (Rials)
			1	2	3	4	5	6	7	8	9	10	11	12	
Amir kabir	6000	6560	47884783	0	97109011	18078885	41626578	32126578	51610836						288436671
Bonyadrang	14000	17070	71433513	63072168	23317713	283272975	26736810	26736810	0						494569989
Azadi	11000	11110	0	0	6495614	5499784	0	0	0						11995398
Abbasabad	11000	15800	262413599	268297853	626244383	587941811	579996491	252796256	403810549						2981500942
South	6000	4680	0	0	0	0	0	0	0						0
Qeytariyeh	4000	3640	0	0	0	0	0	0	0						0
Ghoorkhaneh (Imam Khomeyni)	14000	22620	230913717	184015215	411197761	466925204	110134144	732217883	92331569						2227735493
Tehranpars	8000	7870	0	0	0	0	0	0	0						0

Reference: (Researchers' findings)

Table 5 represents the annual total Rial fines and in the last column, the aggregate fines of Rials are exceeded by power have been represented, separated by high-pressure posts from the first period until the seventh (2011-2014) briefly.

Table5. Total fines for exceeding of the power of the first period until the seventh (2011-2014)

High power pressure power station	The cost of exceeding contractual standing (Rial fine)				
	2011	2012	2013	2014	Total fines for exceeding from the power
	0	289100681	9313221	290458640	588872524
Amir kabir	314951122	83924786	551751740	468022179	1418679827
Bonyadrang	1563724161	1592945906	160990309	11995398	3329665774
Azadi	2890336127	5648141496	5443641216	3254500943	17236619782
Abbasabad	7563405	10133356	0	0	17696761
South	0	26924722	65968697	0	92893419
Qeytariyeh	1331284851	2747334179	2384648301	2229735493	8693002824
Ghoorkhaneh (Imam Khomeyni)	1998529462	2375616297	106134859	0	4480280618
Tehranpars					

Reference: (Researchers' findings)

As you can see, Abbasabad power station has the highest amount of monetary penalties due to the abuse of power over the intended period; 17,236,619,790 Rials. In addition, Qurkhaneh power stations, Tehran Pars, Azadi and Bonyadrang have also been worthy of Rial fines. Amir Kabir power station has been almost in normal conditions compared to the five posts mentioned above, due to the increase in contract notice from 4,000 to 6,000 kilowatt per annum from 2012 to 2014. Moreover, Qaytrieh and southern power stations are located in almost normal conditions of use (according to the contract notice and type of cargo). Table 6 represents the amount of the domestic and proposed contract based on kilowatts for Azadi, Qurkhaneh, Abbasabad, Tehranpares, and Bonyadrang power stations.

Table6. Proposed contract standing

High power pressure power station	Current contract standing (KW)	Proposed contract standing
Azadi	11000	13000
Qoorkhaneh (Imam Khomeyni)	14000	20000
Abbasabad	11000	17000
Tehranpars	8000	9000
Bonyadrang	14000	17000

Reference: (Researchers' findings)

How to calculate Rial increase of contract notice is such that the Regional Electricity Company has used two different methods to calculate Rial price over time. In other words, since 2004 to October 2013 with a formula and from that date until spring 2014, with increasing the coefficients of the previous formula, the Rial price has calculated the increase of the contract price by another way. Therefore, in this study, the calculations were carried out in two periods since 2004 to October 2013 and October 2013 to spring 2014.

Subsequently, the proposed contract standing has been considered in these two periods. For example, spring 2013 from the first period and, spring of 2014 from the second period were considered as the sample time for the calculation; the results are given in Table 7.

Table7. The amount of increase contract notice of high-pressure power stations (Rials)

High power pressure power station	The current contract demand (kw)	The proposed contract demand (kw)	Rial price increase of contract remaining conformed to the expiry calculation (Spring 2013)	Rials increase of the amount of contract standing according to the current calculation (new) (spring 2014)
Azadi	11000	13000	259660000	4047456000
Qoorkhaneh (Imam Khomeini)	14000	20000	9652980000	15444768000
Abbas Abad	11000	17000	8414580000	13463328000
Tehran pars	8000	9000	102403000	1638448000
Bonyadrang	14000	17000	4516890000	7227024000

Reference: (Researchers' findings)

Rial price increase of contract standing for five high-pressure power stations that exceeded the power and fined were given. Comparing columns 4 and 5 of table 7, the difference between increases of Rial price of contractual demands can be seen in two calculation methods until 2013/10/07 (previously calculated method) and calculation from 2013//10/70/ (newly calculated method). For example, in view of the successive Rial penalties for violating the Abbas Abad power station in consecutive years, if we increased the contract from 11,000 to 17,000 kilowatts in the spring of 2013, 5,048,748,000 Rials would be saved. In order to save on and avoid breaking contract, solutions such as deploying new energy-saving technology, modifying or revising the design and engineering the train path, optimal use of the slope, the use of surplus energy return methods into the network, and the use of equipment, and to use low energy consumption in the development of future lines are recommended. Table 8 shows the values of power consumption bills of Bonyadrang power station, which supplies the electrical energy required for the Tehran Metro Line 5. In addition, in this table, the amount of active and reactive power consumption is given.

Table8. Consumption of Bonyadrand power station in the first 9 months of the year 2015

Consumption of Bonyadrand power station in the first 8 months of the year 2015			
Period	Active power consumption (GWH)	reactive power consumption (GVARH)	Volt Amp Hours (GVAH)
1	4.519	3.921	5. 982942587
2	4.728	3.938	6. 153196568
3	4.795	3.59	5. 990003087
4	5.0979	3.664	6. 278015644
5	5.364	3.927	6. 647843635
6	4.759	3.803	6. 091870813
7	4.456	3.765	5. 83362317
8	4.23	3.547	5. 52033535
9	4.553	3.534	5. 763589593
SUM	4.5019	33.689	54. 23430856

Reference: (Researchers' findings)

According to Table 8, about 37% of energy consumption in line 5 of Tehran Metro is of reactive power type, which is stored or leaked in heat transfer or leakage flux in the induction reactance of overhead network and traction load. The presence of reactive power in the network is necessary for initial loading, and also by the nature of the electric charge, but its high consumption rate is unacceptable and it consumes a significant part of the capacity of the power systems which may, in the long run, reduce the life of the equipment and increase the cost of depreciation and maintenance activities of the equipment. It should be noted that the high reactive power supply through the overhead system increases the network flow and decreases the voltage range, which also increases the losses in the traction systems. On the other hand, optimization of automation of line 5 power distribution systems (SCADA) for remote control, the amount of consumption, and consumption readings, prepares the ground for management of the network residual value, and the possibility of optimizing switching processes in the overhead power supply network. Ensuring operations in Line 5 power distribution systems relies on data communication systems of telecommunication and data channels, which should enhance the performance of telecommunication systems in this segment and improve automation of energy control operations. There are several ways to improve network efficiency and reduce losses caused by electrical energy distribution systems. Moreover, excessive consumption of reactive power causes voltage drop and voltage fluctuations in the overhead network. Since high drop in overvoltage triggers the traction circuits of the trains, performing any compensating action plays a special role in preventing the collapse of the overvoltage and disturbing the performance of the traction system. To improve static stability in order to maintain network equilibrium under normal operating conditions of the system or in case of disturbances caused by small signal changes, the following may be useful: increasing the voltage level of the overhead network in a nominal value by using multiple switching or transponder options, adding new lines to transmission system of 230 kV or adding a new overhead distribution power station at the end of the line development, reducing line reactance series with a bundle of lines and feeders 25+ and -25 kV distribution system and correction and compensation systems.

According to the presented materials, in this research, a total of 6 main indicators and 22 sub-indicators were selected by industry experts (table 9). According to software output, the highest frequency of respondents was age group between 26 and 35 with frequency of 80, work experience was under 5 years with frequency of 65, an organizational level, a staff with a frequency of 69, and a level of education, a bachelor's degree with frequency of 55 have been allocated to themselves (table 10). Factor analysis has been used to identify the main components effective on the variables. The first step of factor analysis includes evaluating the relevance of the data for factor analysis; the second step includes the extraction of the factor and the third one is the items affecting the components. The two main issues in the factor analysis of the data are considered. The first is the statistical sample, the larger the sample size, the results can be more generalized. The second one depends on the strength of the mutual correlations between the indicators. The

Bartlett test and the Kieser-Mir-Olekin (KMO) proximity index have been used to help assess the data functionality (table12).

Table9. Energy Management Factors (Matrices)

Energy Management					
Dimensions	**Index**		**Number**	**Mean**	**S.D.**
Investment	Q1	Macro management investment	112	2.5	0.89
	Q2	Investing in economical savings	112	2.7	1.02
	Q3	Standard work environment	112	2.38	0.92
	Q4	Investing in employee training	112	2.23	0.72
Awareness	Q5	Proper culture creation	112	2.63	0.73
	Q6	Proper information	112	2.8	0.83
	Q7	Proper notification	112	2.6	0.77
	Q8	Information exchange with other cities	112	2.3	0.77
Information systems	Q9	Preservation of production documents	112	3	0.98
	Q10	Database of statistics and reports	112	2.78	0.95
	Q11	Technical reports and consumption metrics	112	2.83	0.89
	Q12	Availability of information	112	2.75	0.98
Motivation	Q13	Employee trust	112	2.6	0.9
	Q14	Commitment of Senior Managers	112	2.7	0.98
	Q15	Encouraging suggestions	112	2.2	0.92
	Q16	Access to job information	112	2.6	0.1
Organizing	Q17	Determining planning counselors	112	3	1
	Q18	Custodians' specified description of services	112	3	0.95
	Q19	Buying equipment with low energy consumption	112	2.5	0.83
Energy policy-making	Q20	Specific strategy	112	2.5	0.87
	Q21	Informing employees to policies	112	2.6	0.93
	Q22	Senior management participation in policy making	112	2.6	0.99

Reference: (Researchers' findings)

Table10. Demographics of respondents

Row	Alternative	Credit range	Frequency	Percentage frequency	Row	Alternative	Credit range	Frequency	Percentage frequency
1	**Age**	<25	9	8	**3**	**Organizational level**	Employee	69	61.1
		35-26	80	71.3			Expert	36	33.1
		45-35	33	19.6			Managerial level	7	6.3
2	**Work experience**	5>	65	59	**4**	**Education**	Under B.A.	8	7.1
		10-5	19	17			B.A.	55	29.1
		15-10	17	15.2			M.Sc.	38	33.9
		20-15	11	9.8			Ph.D.	1	0.9

Reference: (Researchers' findings)

Table11. The average impact of indicators on performance improvement

Variable	Investment	Marketing	Information system	Motivation	Organizing	Energy policy maknig
Number of indicators	4	4	4	4	3	3
Mean	2.5	2.6	3	2.6	2.83	2.56

Reference: (Researchers' findings)

Table12. KMO and Bartlett tests

KMO sampling index	0.800
Bartlett Test	466.104
Degrees of freedom	55
Sig	0.000

Reference: (Researchers' findings)

In this study, based on the output of the software, Bartlett test, Sig = 0.00 and the coefficient of KMO = 0.8, which is suitable for factor analysis, was calculated based on the output correlation matrix between the indices (Table 13).

Table13. Correlation matrix

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22
Q1	1.000																					
Q2	0.756	1.000																				
Q3	0.434	0.370	1.000																			
Q4	0.454	0.470	0.540	1.000																		
Q5	0.433	0.333	0.488	0.575	1.000																	
Q6	.373	0.336	0.404	0.500	0.703	1.000																
Q7	0.389	0.439		0.480	0.390	0.498	1.000															
Q8		0.300						1.000														
Q9	0.331			0.319	0.437	0.362			1.000													
Q10	0.366			0.400	0.491	0.427			0.792	1.000												
Q11									.56287	0.588	1.000											
Q12						0.332			0.410	0.366	0.482	1.000										
Q13							0.417						1.000									
Q14	0.401	0.525		0.399		0.324	0.619						0.654	1.000								
Q15		0.507					0.344						0.512	0.560	1.000							
Q16		0.360		0.362						0.259		0.395		0.320	0.379	1.000						
Q17	0.304	0.341		0.355		0.355	.549		0.417	0.414	0.313		0.339	0.494	0.367	0.343	1.000					
Q18	.0.311	0.423		0.377	0.418	0.417	0.377		0.426	0.483	0.454	0.361		0.432	0.469	0.445	0.686	1.000				
Q19		0.374							0.368	0.414	0.351	.408		0.325	0.404	0.506	0.349	0.481	1.000			
Q20		0.363											0.428	0.399	0.445			0.386	0.388	1.000		
Q21	0.335	0.386	0.420	0.458	0.370	0.314	0.321	0.381	0.305			.372	.322	0.398		0.537		0.378	.502	.487	1.000	
Q22	0.375	0.408		0.393			0.459		0.342	0.302	0.456		0.438	0.556	0.364		0.425	0.380	0.352	0.455	0.549	1.000

Reference: (Researchers' findings)

The coefficients above 0.5, the high correlation, the coefficients between 0.3 and 0.49, the average correlation and the coefficients of 0.01 to 0.29, show a weak correlation. In the above matrix, coefficients above 0.3 have been determined that the indices that have the highest correlation coefficient are identified. As the data output shows, most of the variables are correlated with each other. According to the results obtained from exploratory factor analysis using SPSS software from 22 questions, 11 questions were deleted due to less than 0.5 share and wrong load factor on other unrelated variables, and 11 factors were classified in two dimensions. The two factors also account for about 55.6% of the variance of grades (Table14).

Table14. General variance description

	Total	%of Variance	Cumulative%	Total	%of Variance	Cumulative%	Total
1	4.296	39.052	39.052	4.296	39.052	39.052	3.600
2	1.820	16.584	55.600	1.820	16.548	55.600	3.460
3	0.997	9.062	64.662				
4	0.726	6.602	71.264				
5	0.672	6.107	77.371				
6	0.633	5.758	83.129				
7	0.544	4.948	88.076				
8	0.491	4.460	92.536				
9	0.326	2.967	95.03				
10	0.283	2.574	98.177				
11	0.212	1.923	100.000				

Reference: (Researchers' findings)

Accordingly, it can be concluded that the data are suitable for factor analysis. The transformed matrix of the factor indicates the high correlation between the items (factors) and their low correlation with other factors, which indicates the appropriate divergent validity for the scale. The matrix explains the influential components and items in which the items with a gain of more than 0.5 are selected and the remaining items are removed from the components. The main options in the first component include management investment in consumption optimization, standardization of the work environment, training on optimization of consumption, culture creation, proper information in the field of optimization, and information exchange with other organizations. The second component consists of employee trust in the programs, senior management commitment, encouraging plans, developing clear strategies, and senior management involvement in policymaking, which can be considered as factors influencing energy efficiency (Tables 15&16). Friedman test was used to rank the indicators related to the dimensions of the research. The SPSS output consists of two tables (Tables 17 and 18).

Table15. Identification of factors with the most factor load

First component		Second component	
Q1	Management Investment in Optimization of Consumption	Q13	Employees trust in the programs
Q3	Standardization of workplace	Q14	Senior management commitment
Q4	Learning to optimize consumption	Q15	Encouraging plans
Q5	Creating culture of consumption optimization	Q20	Developing clear strategies
Q6	Appropriate information on optimization	Q22	Senior Management Participation in Policy Making
Q8	Information exchange with other organizations		

Reference: (Researchers' findings)

Table16.Matrix of components

			Structure Matrix	
			Component	
			1	2
First component	Creating culture of consumption optimization	Q5	**0.847**	0.197
	Learning to optimize consumption	Q4	**0.808**	0.305
	Appropriate information on optimization	Q6	**0.775**	0.284
	Standardization of workplace	Q3	**0.727**	0.308
	Management investment in Optimization of Consumption	Q1	**0.673**	0.417
	Information exchange with other organizations	Q8	**0.362**	0.309
Second component	Senior management commitment	Q14	0.439	**0.820**
	Employees trust in the programs	Q13	0.298	**0.790**
	Encouraging plans	Q15	0.214	**0.769**
	Senior Management Participation in Policy Making	Q22	0.385	**0.720**
	Developing clear strategies	Q20	0.207	**0.705**

Reference: (Researchers' findings)

Table 17 presents statistical data and χ^2.

Table 18 presents the average rank of each variable and the higher the average rank, the more important it is.

Table 17. The average of ranks in Friedman test to examine the factors related to energy management

Index		Average rankings
Q1	Management Investment in Optimization of Consumption	5.89
Q3	Standardization of workplace	5.49
Q4	Learning to optimize consumption	5.60
Q5	Creating culture of consumption optimization	6.20
Q6	Appropriate information on optimization	7.07
Q8	Information exchange with other organizations	5.29
Q13	Employees trust in the programs	6.23
Q14	Senior management commitment	6.52
Q15	Encouraging plans	4.93
Q20	Developing clear strategies	6.04
Q22	Senior management participation in policy making	6.52

Reference: (Researchers' findings)

Table 18 - Statistical indicators to examine the factors related to energy management

Statistical indicators	Calculated values
Number	112
X^2	55.558
Degree of freedom	10
Sig	0.000

Reference: (Researchers' findings)

According to the SPSS output, the significant number (sig) is less than the standard significance level (α = 5%); therefore, there is a significant difference between the existing status of the 10 indicators related to energy management.

6- Conclusion and Discussion

In this research, the status of the organization in terms of energy consumption was studied. The amount of Rial fines exceeded the power of high-pressure power stations, as well as the Rials price increase of the contract notice of the mentioned posts, were investigated and calculated. With the estimation of the optimum contract and purchasing it, in addition to increasing the amount of Rial fine for exceeding the power to the optimum amount, the purchased stamp was considered as a capital for Tehran Urban and Suburban Railway Operation Company. However, if with development of fleets and utilization stations simultaneously, are power supplies energy consumption also to be started and loaded (63.52 kV sub-distribution substations or linear ones) will also be launched and downloaded, the distribution of load and the distribution of load between sub-distributions are balanced and the possibility of exceeding power in the network's peak load will be reduced. Furthermore, in some cases, excessive consumption and overrun of feeder in metro electricity grid have been due to shutting down upstream networks of regional electricity, which was deployed by Tehran's power distribution dispatcher. It is possible to reduce the extinction of the metro's major and sensitive uses and to improve the reliability of the electrification. The studied variables included investment, marketing, information systems, motivation, organization, and energy policy. Factor analysis was used to identify the main components affecting each of the variables. Friedman test was used to rank the indices related to the dimensions of the research. The appropriate information index in the field of optimization of consumption was in the highest, and encouraging the proposed plans was in the lowest rank. The results of the field observations also indicate that the company has made appropriate measures in the field of information dissemination by publishing specialized journals and sending various messages in the field of optimizing consumption to employees. Finally, in order to identify the impact of each of the indices, analysis of variance was performed based on Chi-square test, which resulted in significance. This shows the different impact of each index on the test. Given the constraints on consumer resources, including energy in the country, it is essential to consider energy optimization as a serious matter. In order to optimize energy consumption in the company and to improve the status quo, the following solutions are suggested:

1. Attention to productivity in optimal use of energy
2. Serious attention to the issue of education and culture in modifying consumption pattern
3. Applying modern architectural techniques to maximize sunlight
4. Teaching proper practices, especially strategies for reducing energy consumption to train drivers
5. The use of surplus energy returns to the network
6. Attention to the energy loss in the transmission path
7. The use of renewable energy in open spaces, especially in stations and terminals

In addition, due to the extensive activities of the company and the cost of consuming energy, it is possible to study in this field, among which the following can be mentioned:

1. Investigating the role of modern technologies in energy consumption management at Tehran Urban & Suburban Railway Operation Company
2. Explaining ways to modify train paths to reduce energy consumption
3. Identifying and introducing new architectural approaches in using sunlight
4. The role of Information Technology (IT) in optimizing metro energy consumption
5. Pathology and supply of energy consumption in Tehran Urban & Suburban Railway Operation Company from technical and management perspective
6. Protecting the network in terms of maintaining the stability and continuity of the electrical system and preventing the breakdown and failure of electricity as the most important parameters of the safety assurance and reliability of the network of interconnecting inland electric rail system
7. Improving and fixing defects caused by wear and tear of the retaining devices and equipment of the overhead network as well as replacement of the contact wire of the overhead network at the wear points
8. Identification and conducting necessary studies related to electrical systems in line with strategies for optimizing electrical energy consumption by reducing

reactive power and improving the voltage profile of the grid distribution network

9. Installation and implementation of modern recuperative systems of reactive power in accordance with dynamic load behavior of traction with the possibility of return on investment in the medium and long term

10. The use of static compensators to support the voltage at power stations

11. Application of capacitors with parallel connection in capacitor banks or reactive power compensator

12. Increasing the voltage and stabilizing it at the end points of the line to reduce electric energy dissipation

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