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Electric Power Restructuring in Iran: Achievements and Challenges

Although the power market in Iran is not fully constructed, several key steps have been taken to meet privatization and restructuring objectives. The addition of a power exchange sector has placed the power market on par with that in other countries. Operational concerns that still need to be addressed include technical and non-technical losses, enhancing new investment, and providing incentives for introducing energy efficiency and promoting green power generation.

Kaveh Aflaki Khosroshahi, Shahram Jadid and Mohammad Shahidehpour

I. Overview

Restructuring and privatization of assets, when managed properly in conformance with sound socio-economic principles pertaining to specific cultures across the globe, could lead to better services, technological improvements, improved reliability, and the reduction in customer costs. Electricity restructuring started in the U.K. and advanced to the United States, Scandinavian and other European countries, Asia, Australia, and Latin American countries. Iran's ministry of energy initiated steps about 10 years ago for the restructuring of its electric power industry, which was believed to be of great interest to electric power generators and consumers. The country's expanding energy infrastructure continues to shift toward the privatization and establishment of

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a reasonable competition in its electric power sector [1].

Shahidehpour and Alomoush extensively discussed the electricity restructuring in the U.S., Canada, Australia, England and Wales, and Nordpool [2]. Rudrick and Zollezzi reviewed the history of restructuring in Latin America [3]. Javerzac [4] and Jaucher [5] analyzed restructuring in Europe. Srivastava and Shahidehpour studied restructuring in India [6]. Eyban and Shahidehpour reviewed the issue in France [7]. Bekiarov and Shahidehpour reported on the results of restructuring in Bulgaria [8]. Tor and Shahidehpour reported on the impacts of power restructuring in Turkey [9,10]. The preliminary experience has shown that the establishment of an electricity market is going to be specific to government, culture, economy, and electricity operation and practices in participating nations.

Iran is located in the heart of the Middle East. It is the 18th largest country, with an area that is roughly 1,648,000 km^2 (about 636,300 square miles). Its area is equal to that of the United Kingdom, France, Spain, and Germany combined, and slightly smaller than that of the state of Alaska. It borders on Azerbaijan (432 km/268 miles), Armenia (35 km/22 miles) and Turkey (499 km/310 miles) in the northwest; Turkmenistan (992 km/616 miles) in the northeast; Pakistan (909 km/565 miles) and Afghanistan (936 km/582 miles) in the east; Iraq (1,458 km/906 miles) in the west; and finally the waters of the Persian Gulf and the Gulf of Oman in the south. Iran is divided into 30 provinces. The capital city of Tehran, with a population of about 8 million, is the largest city and houses about 11 percent of Iran's population. The other major Iranian cities are Mashhad, Isfahan, Shiraz, and Tabriz. Iran's annual population growth rate is 6.7 percent [11,12].

II. The Power Sector in Iran

A. History

Table 1 presents a short review of Iran's electric power generation since the beginning and the evolution of its electric power industry over recent years [14,15,19].

B. Generating facilities

Iran's installed generation capacity by the end of 2007, detailed in **Figure 1**, was 48,085.4 MW. Iran's Ministry of Energy and its subsidiaries owned 89.35 percent of the total generating plants, while large industries together with private sectors owned the remaining 10.65 percent. In 2004, Iran inaugurated its first wind-powered and geothermal plants and its first solar thermal plant will be online in 2009. Demographic trends within the last decade have resulted in an 8.5 percent per year increase in Iran's electric power demand. The government's stated goal is to increase the installed capacity to 130,000 MW by 2020 [13,14].

C. Electricity grid and interconnection

The electric power transmission network of Iran consists of a 39,023 km circuit of high-voltage transmission lines (400 and 230 kV); 55,842 km circuit of sub-transmission lines (132, 66 and 63 kV); and 317,694 km-circuit of medium-voltage lines (33 and 20 kV and 400 V) and low-voltage lines [13]. **Figure 2** demonstrates the 400 and 230 kV network of Iran in 2005 in which 13,498 km circuit of existing high-voltage transmission lines consists of

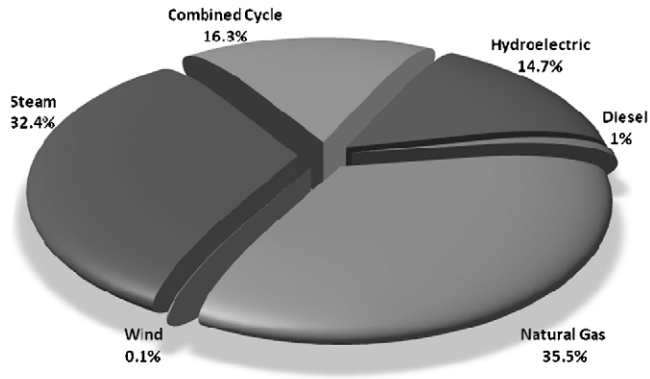

Fig. 1: Iran's Total Installed Generation Capacity as of Year-End 2007

Table 1: The History of the Electric Power Industry in Iran.

Years	Event and Policies	Technical Features	Administrative Features
1885	The first dynamo in Iran came into service. The 3 kW machine was used for electric lighting of the royal court in Tehran. This occurred 14 years after the invention of Z.T. Gramme machine and 3 years after the inauguration of the first commercial electrical lighting institution by Thomas Edison in New York.		
1903	A 12 hp generator was installed for electric lighting of Imam Reza's shrine in Mashhad by the private sector.		
1903–1906	The first license for establishing commercial electric lighting was granted, inaugurating the first power plant in 1906.	Low-voltage distribution	Private business. Electricity was used for lighting only during evening hours.
1906–1940	The private sector became active in the electricity business. Electricity supply facilities were installed by private sections. Municipalities developed their supervision on electricity issues.	Isolated generating plants and short networks confined to low-voltage distribution. Non-uniformly accepted standards for voltage and frequency.	Electricity was considered as a luxury product and was only used for lighting. Small number of customers throughout the country.
1940–1960	Municipalities became active in installing and operating electric utilities. After World War II, the government was actively involved in electrification.	Extension of electrical networks to voltages higher than distribution levels. Installation of larger power plants throughout the country.	Supply of electricity with subsidized prices. Round-the-clock supply of electricity to consumers.
1960–1985	Establishing the Ministry of Energy and regional power companies. Establishment of Iran Power Generation and Transmission Company (TAVANIR). Banning the private sector from investing in electricity business.	Installation of very large power plants. Development of 400 and 230 kV power transmission networks. High-quality power supply (constant voltage and frequency). Development of power equipment manufacturing.	Highly subsidized prices in all sections. Development of ascending electricity tariffs.
1985–2008	Decentralization of electricity sector. Development of relevant manufacturing and contracting in the electric power industry.	Completion of national grid. Coverage of all potential electricity consumers. Installation of a large number of combined-cycle and hydroelectric power plants.	Movement toward financial self-reliance in electricity sectors. Endeavors for persuading investment by private sectors. Possible reduction in electricity prices.

400 kV and the other 25,525 km circuit is of 230 kV [14].

D. Electricity consumption

In 2007, Iran's electricity consumption exceeded 190 TWh and is expected to grow by 7.6 percent to 205 TWh in 2008. The 2007 load consumption categories in Iran are depicted in **Figure 3**, which shows that the highest consumption occurred in the residential and industrial sectors. **Figures 4 and 5** demonstrate that the Iran's peak demand in summer 2007 occurred in July at about 9:00 p.m., coming to 34,894 MW (versus installed generation capacity of 47,296 MW). It is reported that the peak demand in Iran will increase by 8 percent to 40,189 MW in 2008 and grow by 9 percent to

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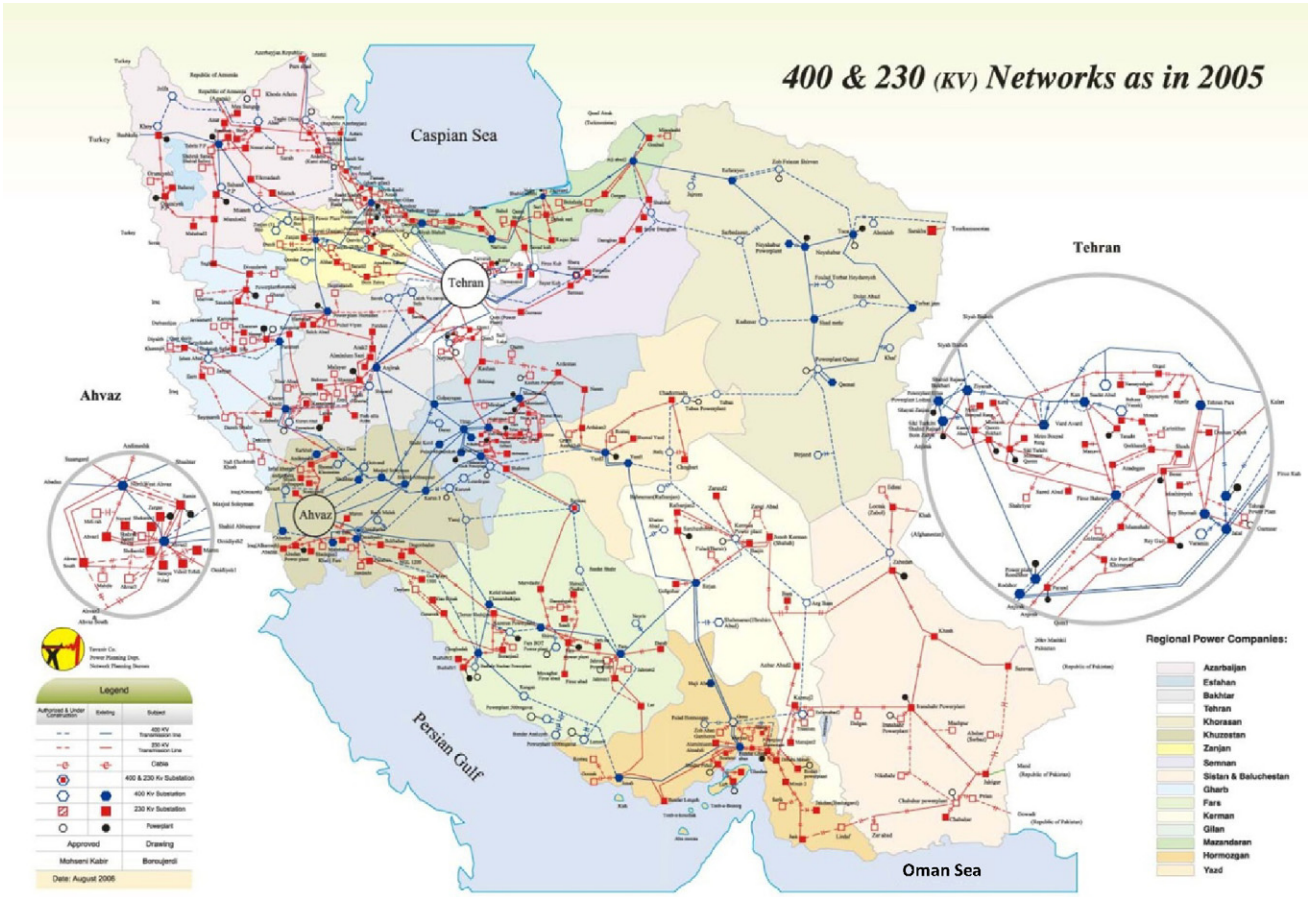

Fig. 2: 400 and 230 kV Networks in Iran

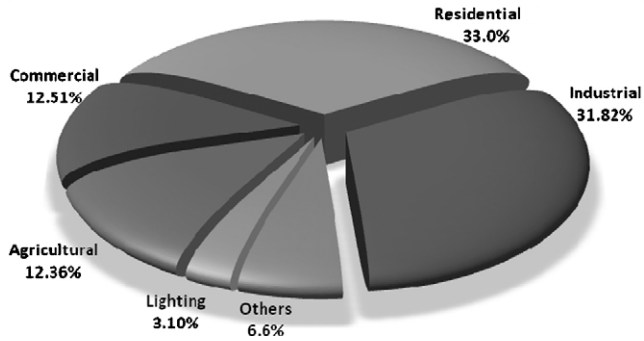

Fig. 3: 2007 Categories of Electricity Consumption in Iran

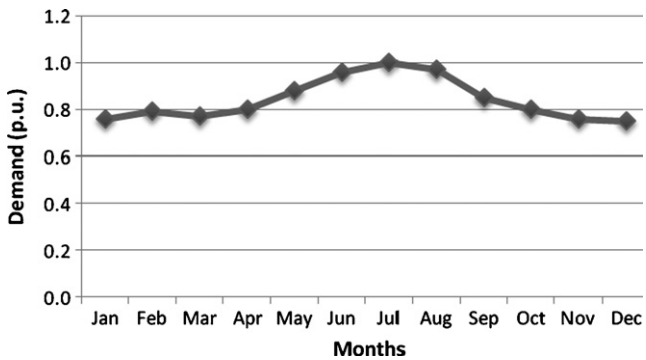

Fig. 4: 2007 Monthly Peak Load Pattern in Iran [13]

43,762 MW in 2009. However, water shortages in hydroelectric dams and forced outages of less efficient generating units have impacted the reliability of power supply in Iran [13,14].

E. Supply–demand balance

It is clear that there is a need for a rapid build-up of new generating plants in order to supply the growing electricity load in Iran. The government encourages independent and private investments on generating plants especially for wind energy and other renewable plants. The available reserve capacity in Iran is relatively low, reported at about 7 percent [13].

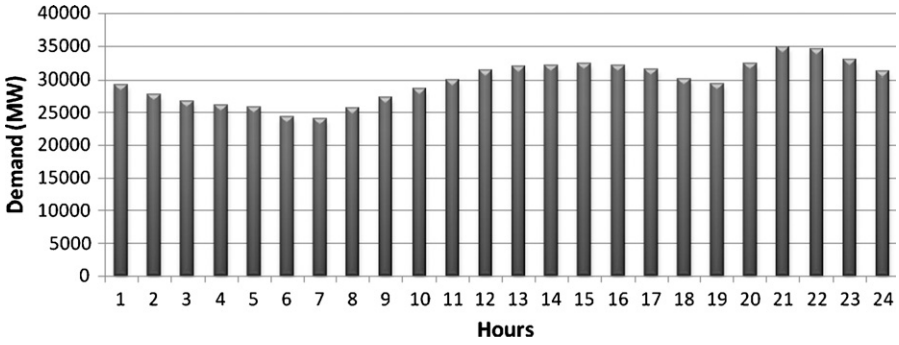

Fig. 5: Daily Load Curve during a Peak Summer Day

The main reasons for low operating reserves are higher rates of increase in electricity demand during summer months, lack of sufficient resources such as water for hydro power generation, and higher rates of forced outages of available thermal power generating capacity to keep pace with demand increases. Therefore, all efforts are exerted to increase the investment in all sorts of new generating capacity and enhance the availability of existing power plants by implementing a more comprehensive and optimal planned outages of equipment and services. The application of load management at various levels of consumption and the introduction of energy efficiency have slightly eased the supply–demand imbalance in Iran.

III. Iran's Power Exchange Contracts with Its Neighbors

Iran was ranked 17th among electricity-generating countries in 2005 according to the statistics provided by EIA [20]. **Table 2** shows Iran's electricity indices among the 40 top electricity-generating countries.

Although the backbone of Iran's grid is based on 400 and 230 kV transmission lines, a high-voltage 765 kV line which links Iran with Russia, an HVDC line which links with Turkey, and an underwater line which links with United Arab Emirates are further under consideration. Recently, Iran has established electric power contracts for enhancing its interconnection at various levels with Armenia, Azerbaijan, Turkey, Turkmenistan, Afghanistan, Pakistan, and Iraq.

Figure 6 shows the interconnections between Iran and its neighboring countries. **Table 3** demonstrates the existing and under-construction

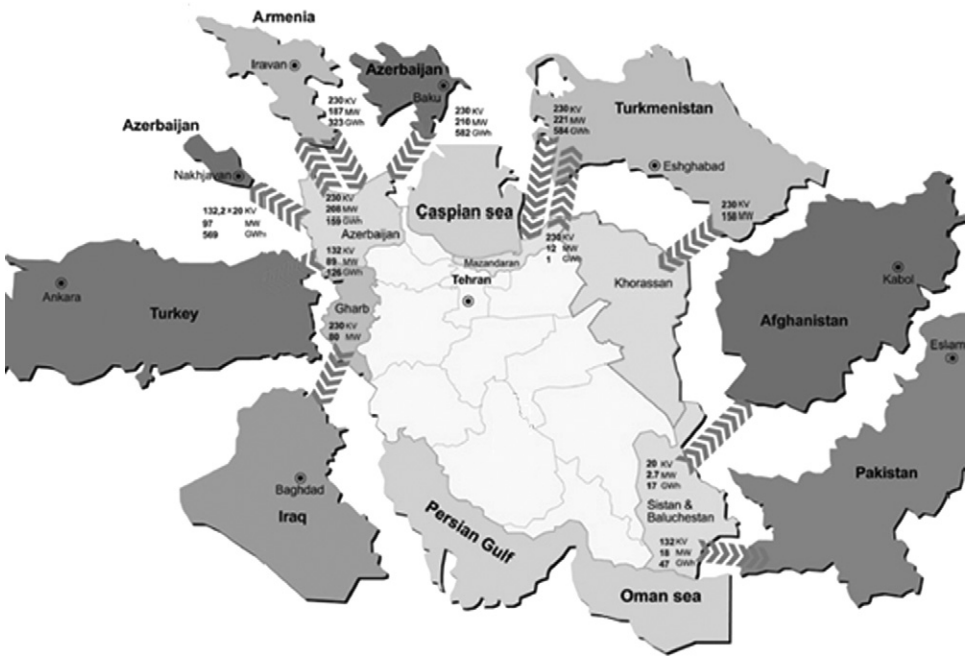

Fig. 6: Interconnections of the Iranian Grid with Neighboring States [14]

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Table 2: Ranking of 40 Top Countries with Respect to Various Indices in 2005.

No.	Country	Population	Installed Capacity	Net Electricity Generation	Net Electricity Consumption	Electricity Exports	Electricity Imports	Capacity per Capita	Net Generation per Capita	Consumption per Capita	Operation Index
1	United States	3	1	1	1	8	3	4	4	5	25
2	China	1	2	2	2	14	19	35	35	35	7
3	Japan	8	3	3	3	31	40	8	9	10	28
4	Russia	7	4	4	4	6	16	14	17	20	27
5	India	2	5	5	7	30	26	38	38	39	14
6	Germany	11	6	7	5	2	1	15	15	14	13
7	Canada	25	7	6	6	3	8	3	2	2	10
8	France	16	8	8	8	1	17	10	8	13	11
9	Brazil	5	9	9	9	29	4	33	32	31	22
10	United Kingdom	17	10	10	11	21	13	19	19	18	17
11	Italy	18	11	12	12	25	2	18	22	21	34
12	Spain	22	12	13	13	13	15	11	16	16	30
13	South Korea	19	13	11	10	32	39	20	12	12	1
14	Ukraine	20	14	18	19	15	27	21	26	26	39
15	Mexico	9	15	16	17	24	29	32	33	34	24
16	Australia	31	16	14	14	33	38	6	6	6	16
17	Iran	14	17	19	20	22	25	30	28	30	32
18	South Africa	21	18	15	15	12	14	25	21	22	2
19	Taiwan	29	19	17	16	34	37	12	7	7	4
20	Turkey	13	20	21	22	23	28	31	31	32	26
21	Sweden	36	21	22	21	7	10	2	3	4	20
22	Saudi Arabia	26	22	20	18	35	36	22	18	19	6
23	Poland	24	23	23	23	10	20	28	25	25	12
24	Argentina	23	24	28	28	19	18	29	29	28	35
25	Norway	40	25	24	25	11	23	1	1	1	9
26	Thailand	15	26	25	24	28	22	34	34	33	15
27	Malaysia	28	27	32	32	36	35	24	27	24	37
28	Indonesia	4	28	26	27	37	34	40	40	38	8
29	Venezuela	27	29	29	33	38	33	27	24	27	21
30	Netherlands	32	30	30	26	17	6	17	20	15	23
31	Romania	30	31	38	39	18	24	26	30	29	40
32	Pakistan	6	32	31	34	39	32	39	39	40	19
33	Egypt	12	33	27	29	26	30	36	36	36	5
34	Switzerland	38	34	39	37	4	5	7	13	9	38
35	Kazakhstan	33	35	36	38	20	21	23	23	23	33
36	Finland	39	36	35	31	27	9	5	5	3	29
37	Czech Republic	35	37	34	36	5	12	13	11	17	18
38	Philippines	10	38	40	40	40	31	37	37	37	36
39	Austria	37	39	37	35	9	7	9	14	11	31
40	Belgium	34	40	33	30	16	11	16	10	8	3

Table 3: Interconnections between Iran and Its Neighbors [14].

Country	Number of Tie-lines	Interconnection voltage level/s	Capacity (MW)
Armenia	2	230 kV	300
Armenia	1	400 kV	300 – 600
Afghanistan	2	132/20 kV	40
Azerbaijan	3 +	230/132/20/11kV	250
Azerbaijan	1	400 kV	Under study
Iraq	2+	132/63	150
Iraq	Up to 9	400/230/132	900
Pakistan	1 +	132/20 kV	40
Pakistan	1	230 kV	120
Russia	NA	Under negotiation	To be negotiated
Tajikistan	(via Afghanistan)	400 kV	1000
Turkmenistan	3	230 kV	300
Turkmenistan	1	400 kV	300 + 500
Turkey	2	154 kV	70
Turkey	1	400 kV	250 – 650

Existing ☐ Under ☐

interconnections between Iran and its neighbors [14,18].

IV. Electricity Restructuring in Iran

A. Privatization

The establishment of Iran's electricity market seemed to be inevitable since it is expected that the competitive environment will make the electric power sector more attractive to independent investors and lead to the development of efficient and active power sector. The main part of electricity restructuring in Iran pertained to the privatization articles which allow for private investment in new power plants [16]. Another part of electricity restructuring in Iran is its implementation. The electricity sector of Iran has unbundled the vertically integrated utility to four sectors including generation, transmission, distribution, and retail trading, as shown in **Figure 7**. First, the financial separation and transparency are implemented by separate accounting in each sector. Second, each sector is an independent establishment. Third, competition is applied to the competitive generation sector of the industry [17]. The transmission and distribution sectors are still public and managed by the Iran Grid Management Company (IGMC), as discussed next.

B. Grid management

Iran Grid Management Company was formed in 2004 as the first independent system operator (ISO) and the governmental regulatory board in Iran [17]. The main task of IGMC

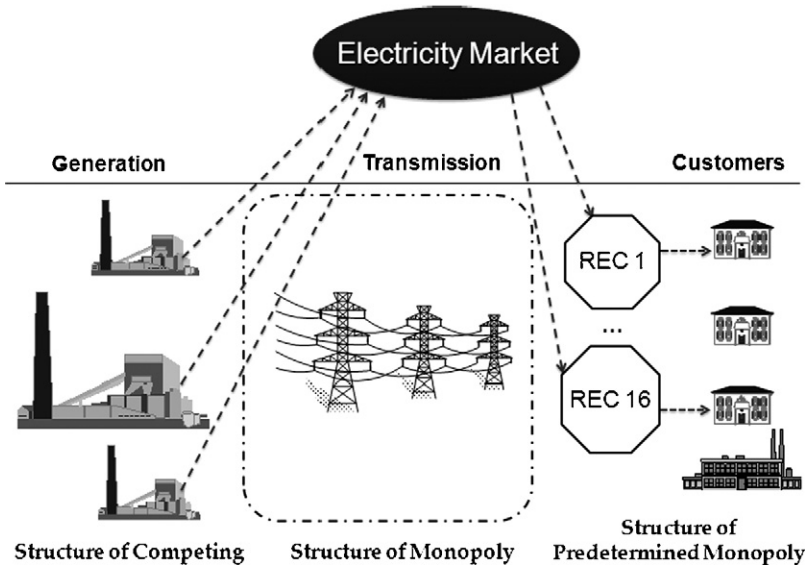

Fig. 7: Restructuring in the Power Sector in Iran

was to supervise the electricity market and keep it competitive. TVANIR is a holding company with 16 regional electric companies (RECs), 42 distribution companies, 27 generation management companies, an Electric Power Research and Development Company (called MATN), Iran Power Plant Project Management Company (MAPNA), Iran Organization for New Energies (SANA), Iran Organization for Energy Productivity (SABA), and Iran Power Plant Repairs Company. As TAVANIR's subsidiary companies, these other entities are responsible for the operation and the security of electric power industry and will carry out their duties by planning, operation, coordination, and supervision of electric power in Iran. RECs are responsible for generation, transmission, distribution, and sales of reliable electric power. MATN is responsible for the research, design, and development of power generating plants in the national grid, carried out through local or foreign contracts [18].

C. Electricity market

The infrastructure of the Iran electricity market along with its players is demonstrated in **Figure 8**. This figure indicates that the electricity market in Iran is a purchasing agency. The main components of the electricity market are as follows: (1) The market is a mandatory power pool. (2) It is a day-ahead market.

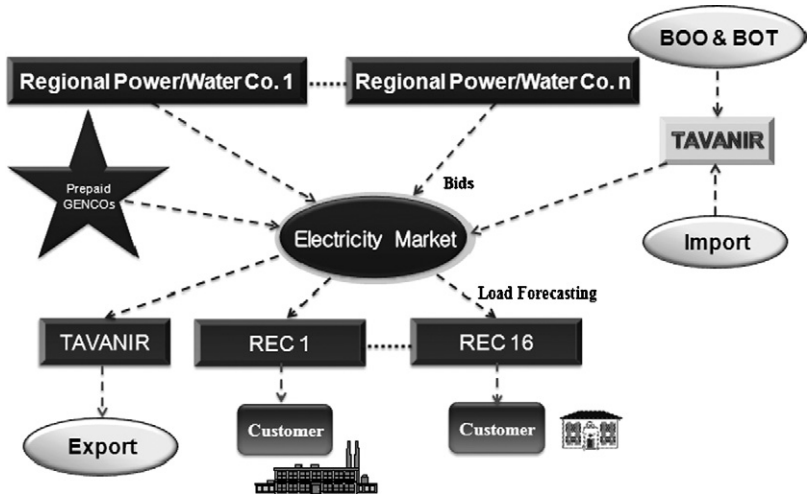

Fig. 8: Electricity Market in Iran [17]

(3) The model of auctions is straight ahead. (4) The method of payment is pay-as-bid. (5) The price of energy is determined through a market clearing price (MCP). In this market, the pool manager (i.e., IGMC) is responsible for scheduling of short-term and long-term generation by unit commitment and providing the results to Gencos. For the time being, the exchange information is managed by the pool manager. However, bilateral contracts and direct access are allowed in this market between RECs and consumers. The contract information, except prices, must be submitted to the ISO. The ISO pays hourly fixed charges to Gencos for providing ancillary services [16,17].

D. Pricing and payments

The price of energy in Iran's power market is calculated through the market clearing price from a submitted bid curve and the payment method is pay-as-bid. The primary reason for this choice is that the possibility of market power is perceived to be less than that in a uniform pricing market. The market regulatory board pays Gencos annually at the end of the financial year for ancillary services. The main advantages of this payment method are that it increases the investment security, prevents price spikes, and avoids unnecessary stress in the market [17]. The overall cost of electricity is divided into variable and fixed costs. Fixed costs are payable through power prices and variable costs are payable through energy prices [18]. RECs collect customer payments and pay the transmission costs to IGMC annually at the end of each fiscal year. **Figure 9** depicts the average price of electricity for different tariffs [14].

E. Technical and non-technical losses

Technical and non-technical losses in transmission and regional distribution grids vary about 15–25 percent. Although

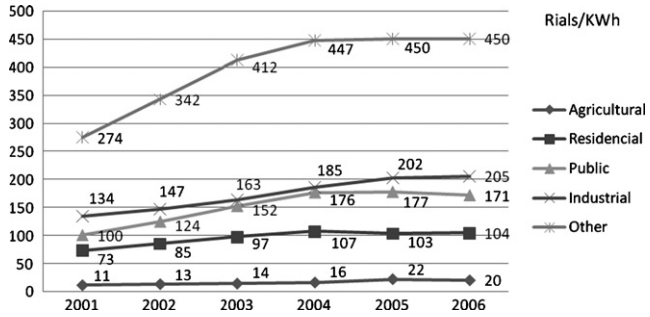

Fig. 9: Average Sale Price for Electric Power Tariffs

some of the reported measures are technical, theft is reported to be an issue in many rural areas of the country. The total loss reported in 2007 was around 22.4 percent of the generated electricity, of which 4.4 percent were transmission and sub-transmission losses and 18 percent were distribution losses and theft [14]. The majority of the technical losses can easily be managed by applying new investment, especially by the private sector, to augment transmission and distributing lines and transformers.

F. Environmental issues and green generation

Greenhouse gas emissions, particularly CO_2 and acid gases such as SO_2 and NO_x, suspended particles, industrial wastewater contaminated with heavy metals, and other contaminants are issues which have to be dealt with in the electric power industry. The electric power industry in Iran is striving to extend its monitoring activities to maintain national and international regulations. The market rules in Iran encourage green generation (especially renewable energy) by offering incentives through long-term contracts or pool purchases even if the proposed bids are not among the winners in the daily market auction. Recently, Iran has been generating 50 MW of wind power in two key areas of the country. A geothermal generator with a nominal capacity of 100 MW will be online by 2009 in the northwest. The use of solar generators in the Iran's power sector is under study and 18 MW of such generation will be online by the end of 2009 [18].

G. The financial status of Iran's power industry

Considering the ever-increasing trend of electricity consumption in Iran, there is a great need for the additional investment in generation, transmission, and distribution.

Figure 10 shows the estimated investment in 2008–2009 [14].

The electric power industry in Iran at present is facing a major challenge, since the electricity tariff is not sufficient to meet the required investment cost as well as the capital needed for the development of the electric power industry. To overcome this financial limitation, the electric power industry in Iran is taking all possible measures including the participation of non-governmental investors under BOO or BOT schemes for investing in electric power generation. During 2005–2006, the injection of 15,000 billion Rials (1 US$ = 9,200 Iranian Rials) by the government into the electric power industry bypassed the financial disaster, without providing a basic solution for supplying needed additional power generation in Iran. It is perceived that the lack of credible investment in the electric power industry can lead to an incapable industry and an economic slowdown in the long term [14]. In order to solve the existing problems with the electric power

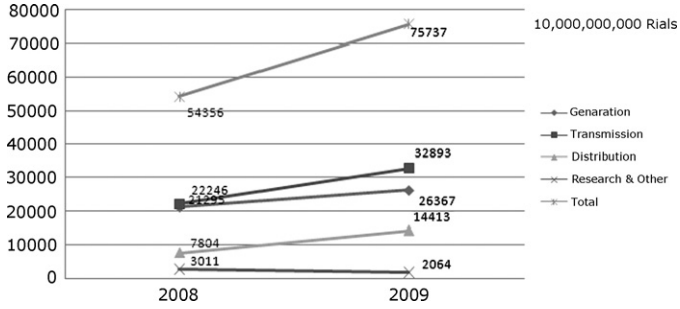

Fig. 10: Estimated Investment (in U.S. Dollars) in Iran's Electric Power Industry during 2008–09

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industry in Iran, enhance the Iran's economic development, and provide a satisfactory service to electricity customers, the country should speed up its restructuring process and introduce additional incentives for encouraging substantial investments by the private sector in the power industry in Iran. There is definitely a high and certain demand growth rate in the Iran's electricity consumption which should ensure the long-term viability for such investments. TAVANIR, as the main government entity responsible for the expansion of the electricity sector in Iran, is charged with mitigating potential investment risks in the country's electricity market [16].

V. Conclusions

This article has presented a brief analysis of the existing electric power sector and restructuring in Iran. Although the power market in Iran is not fully constructed, a number of key steps have already been taken in fulfilling the privatization and restructuring objectives. By adding a power exchange sector, the power market operation in Iran is on par with existing sectors in other countries. Other operational concerns that need to be attended to include technical and non-technical losses; enhancing investment in new facilities and the replacement of old and inefficient generating plants, and transmission and distribution assets; long-term and optimal management of fuel, water, and maintenance scheduling in the electricity sector, providing additional incentives for introducing energy efficiency and promoting green power generation in various parts of the country, and enhancement of electricity tariffs in Iran. It is obvious that the unbundling of the electricity sector and the establishment of trading opportunities in the electricity market will create reasonable opportunities for private investments and participation in the installation and the operation of new power plants. It is imperative for the power market to create synergies with other markets like natural gas and emissions in order to profit from the possible arbitrage of various commodities. The provision of such alternatives in Iran should consider perceived risks for both short-term and long-term planning and operation of the electricity infrastructure and the economic viability of delivering better and more reliable services to customers in Iran.■

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