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AN INVESTIGATION OF INSTALLATION AND OPERATIONAL DIFFICULTIES IN LIGNITE COAL POWER PLANTS AND ENVIRONMENTAL IMPACTS

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Abstract- Today, the total installation capacity of the coal and lignite fired thermal power plants in Turkey is approximately 17.538 MW, which belongs 22.32 percent of the total energy production capacity. Turkish economy has grown rapidly in last decades and obviously electricity generation has played a strategic role in this growth. Recent developments in the technology paved the way to increase in the efficiency of thermal power plants, but still additional studies and further improvements are needed to achieve the required production continuity. In this article, on the basis of Afsin-Elbistan Thermal Power Plant, the difficulties experienced during the electricity generation stage in lignite coal-fired thermal power plants in Turkey are examined and suggestions are proposed together with discussing environmental impacts.

Keywords: Thermal Power Plant, Lignite Coal, Cost Analysis, Energy Requirement, Environmental Impact.

I. INTRODUCTION

Today, electricity is an indispensable part of our everyday life and has an undisputed priority. Development of technology and increase in the population have increased the need of additional energy in Turkey as well as in the world, which necessitates using existing available energy sources more efficiently and looking for new alternative energy sources. Turkey is a member of the OECD but the energy requirement is more than the average value of the other OECD countries. The increase of Turkish installed electrical power between 1970 and 2016 is illustrated in Figure 1 and the world energy outlook is shown in Figure 2.

In view of the fact that thermal power plants which are able to operate with low calorie lignite are installed in the region and electricity can be generated in high order, it is necessary to examine the difficulties related to electricity generation in the thermal power plants and to solve the difficulties experienced. Effective use of the energy resources can only be achieved by knowing the current potential and by providing a proper distribution. Turkey, as it can be seen in Table 1, has adopted a mix of renewable and non-renewable energy sources such as thermal, natural gas, hydropower, wind, solar, geothermal and biomass to meet rising energy requirement.

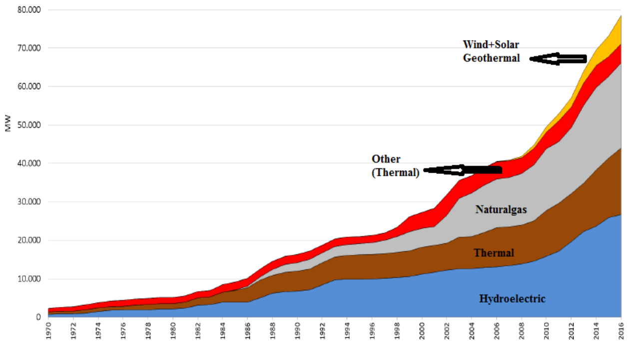

Figure 1. The increase of Turkish installed electrical power between 1970 and 2016 [1]

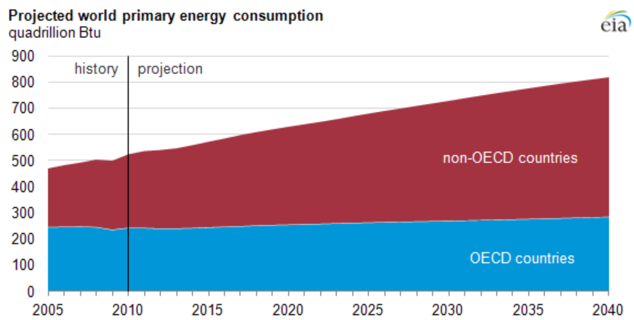

Figure 2. International energy outlook 2013 [9]

According to the official website of the Ministry of Energy and Natural Resources, electricity production in Turkey was 261.7 billion kWh and gross electric energy consumption was 265.7 billion kWh in 2015. In 2016, electricity generation was 274.7 billion kWh and gross electricity consumption was 278.3 billion kWh [3]. It is evident that the electric energy generation has been less than consumption and this energy gap has been met by imported electricity [3]. Although the hydroelectric power plants have a large share in the installed electricity power in Turkey, their share in the electricity production rate was 24.7% in 2016 as they were not suitable for production during the year because they are in operation in certain suitable months and seasons.

Table 1. Distribution of electricity generation in Turkey by sources in 2016 and today's installed electricity power [6]

Power Plant (MW)	Distribution of average electricity generation by sources in Turkey in 2016	Installed electrical power (May 2017)	Ratio (~ %)
Hydro Electric	24.7%	26.817 MW	34.12
Natural Gas	32.1%	24.256 MW	30.86
Thermal	33.9%	17.538 MW	22.32
Multi Fuel		1.641 MW	2.09
Nuclear	-	-	-
Wind	57%	6.023 MW	7.66
Geo Thermal	1.8%	851 MW	1.08
Solar	1.8%	651 MW	0.88
Biogas, Biomass, Waste Heat and Pyrolytic Oil		444 MW	0.57
Total Power	100%	78.530 MW	100

Along with this, it is a serious handicap for Turkey economy to meet almost about 50% of electricity production from natural gas stations, which is totally provided by import. The total power of the thermal power plants is 17.538 MW and 10.0125 MW of this power is generated with local coal resources.

The total production capacity of the licensed production plants, pre-licensed plants, planned coal and lignite thermal power plants is 15.866 MW, and almost 5.6055 MW of this power is intended to be generated with local coal-lignite resources. Considering that all of these thermal power plants operate at full capacity after production, 15,617.678 MW of 33.400 MW power will be met by national resources. Along with the existing installed power, in the next 6-13 years (2023-2030), if the existing natural gas plants operate fully together with 3 nuclear power plants which are expected to be completed in this period, it is estimated that Turkey is going to have an electricity production capacity of 120-130 GW with production of hydroelectric, thermal, wind, geothermal and solar power plants included.

This article is focused on difficulties and problems on power generation in thermal power plants and especially in Afsin-Elbistan B power plant, which has 4 units with 1440 MW capacity in total (each unit has 1 boiler, 1 steam turbine, 1 cooling tower and auxiliary systems) and the challenges faced, and the positive effects of the installation of these plants are examined. The lignite (low calorie coal) reserve in Turkey is approximately 3.2% of the total lignite reserves in the world; which is among countries that are not rich in terms of oil, natural gas and coal resources. Most of this lignite contains a high percent ash and moisture but the thermal value is low; therefore, this lignite is specially preferred in thermal power plants rather than the heating purposes in the buildings.

The lignite deposits in Turkey are spread over almost all regions and the thermal values of these reserves range between 1000-5000 kcal/kg. The average calorific value of the lignite in the Afsin-Elbistan region, which is about 46% of the country lignite reserves (about 1.5% of the world's lignite reserves) is below 2000 kcal/kg and two power plant exist at present which has a total of 2795 MW power. The main difficulties encountered in Afsin-Elbistan B thermal power plant, which works with low calorific lignite coal, from the installation phase to the electricity generation stage are discussed in the following.

II. ELECTRICITY PRODUCTION CHALLENGES

A. Fuel Usability

About 46% of Turkey's lignite reserves, in other words about 1.5% of the world's lignite reserves are in the Afsin-Elbistan region. The calories of this lignite are constantly variable as well as being low in calories [3]. Continuous change of the calorie value of the fuel causes difficulties such as combustion imbalance, boiler burner release, difficulties in ash delivery, and imbalanced electrical power generated in the steam turbine during the operational phases in two thermal plants located here. The high moisture content of the lignite in this region necessitates a moisture separation process and a coal drying process, resulting in an increase in the investment cost. Due to the mentioned problem, it is difficult to invest by the private sector and public authority. Furthermore, lignite in this region requires the use of liquid fuel and natural gas together with solid fuel in order to be able to realize the calorific value due to low calorie value.

B. Problems of Coal Blocks

Afsin-Elbistan A Thermal Power Plant, which was started to production in 1984 in this region, has a capacity of 1355 MW and the coal requirement is met from Afsin-Elbistan Lignite Establishment. Lignite sources of Afsin-Elbistan B Thermal Power Plant with a power of 1440 MW was met by the Afsin-Elbistan Lignite Establishment in need of coal during the commissioning and provisional acceptance works. With the dawning of the Collar sector starting from August 2009, coal has been supplied form this sector.

The plant has stable operated at full capacity in this period (17-18 months), as a result of two earthquakes dated 6 and 10 February 2011, this sector was locked and since then the plant's coal demand has been met from Afsin-Elbistan Lignite Enterprises again. As, the lignite obtained from Afsin-Elbistan region cannot be well blended, high quality veins cannot be detected and lignite calorific value cannot be increased so that the design calorie of 1150 kcal/kg ± 15% be achieved most often these plants fail to operate at full capacity and efficiency [2].

C. Protection-Maintenance, Fault Management and Equipment Impairment

Thermal power plants are complex structures that require serious protection and great care. As thermal power plants have many technological components and units for automation, control and protection, these components and units are operated by PLC and DCS, which have high cost. They also increase both installation and operating costs. Also, if the amount of the instrument used is high the possibility of further malfunction will be encountered.

Failure of the qualified workforce to operate, maintenance and maintenance instructions may lead to more faults in the plants, which results working with lower capacity, and even loss of power plants, which causes lower energy output to fall even further (thermal plant efficiencies 30% to 43%).Most of the technological equipment used for lignite extracting and producing electricity are imported products for Turkey and obtained from abroad. The use of existing materials in power plants for many years necessitates replacement of these materials, but if these materials are not backed up, the material is often supplied from abroad, which makes the country dependent to other countries in terms of technological materials.

The problem with thermal power plants are mainly form key components such as primarily boilers, turbines and generators, ash dispenser, flue gas treatment system. Two actions must be taken to prevent shortages of equipment. The first of these actions is to install domestic R-D centers for mechanical, electrical and electronic products that can be used in power production plants and lignite plants. Secondly, it is necessary to select the robust materials that for power plants to be installed for many years and to leave enough spare material for long years. In both cases, the equipment supply must be managed effectively during all the supplement period.

D. State Policy

In Turkey, coal power plants which can work with imported coal from time to time are built by private sector firms. As a general government policy, dozens of thermal power plants have been installed in order to benefit from the coal-lignite calorific value of electricity coal sector. In the region, coal reserves are kept idle to a significant extent for the purpose of electricity generation. At the beginning of the year 2000, the total producible reserve of Afsin-Elbistan Lignite Region was estimated to be 2.776 Billion Tons and it was estimated that new power plants could be built in the region at maximum 4.200 MW of power and this could result an installed power potential of about 7.000 MW. However, investigations in recent years have shown that the total lignite reserve in this region is about 5 Billion Tons. Under this condition, it is necessary to increase the target for electric power considering the whole detected lignite and to increase the potential electric power target to 7,000 MW and to increase the installed power potential of 10,000 MW.

E. Provision of Land Acquisition

If the power plant is located too far from the coal mines, transport costs will increase and thus the operating cost of the plant increases. B thermal power plant in the region is located at a distance of 8-10 km from the hearth where the lignite is extracted, and the coal demand of this plant is transported by the bands. In addition, the presence of the bands carried by the cargo outside the plant site poses difficulties in terms of the safety and operation. A dislocation in the bands interrupts the transport of the carcass to the plant site in the event of slipping or tearing. Therefore, coal needs of this plant should be provided from a closer field. This situation must be handled in the first stage in order to expropriate new land, to allocate a amount of budget and to realize some bureaucratic and legal processes, in terms of continuity of the production of the plant.

F. Process Water

One of the most important environmental impacts of thermal power plants concerns cooling water and process water. In the case of thermal power plants, water needs are usually provided from sources such as rivers and lakes, so it is necessary to build them in close proximity to such sources. Thermal power plants require greater cooling water and process water. In the boiler of each working unit of the plant, there is a serious amount of purified water between 364 tons/hour and 379 tons/hour. According to the design values, approximately 2000 lt per MW water at steam mode is throwing out from cooling towers to the atmosphere.

The temperature of this water is 30-35 degrees Celsius. So the power plant requires continuous pure water. This is achieved by removing water from the Ceyhan River, which is close to the plant. However, the supply of water from both the A Thermal power plant, the Sugar Factory at region, and the B Thermal Power Plant cause serious reductions in the river water flow, especially during the October-January interim period. Therefore, it prevents the full capacity operation of two power plants in the mentioned period. This necessitates the need to address the water needs of the B Thermal Power Plant and to conduct research with a focus on new water resources.

G. Environmental Considerations and Waste Management

As in all thermal power plants operating with coal, combustion products such as Ca-Si, slag/ash and toxic and carcinogenic gases such as COx, NOx, SOx are also formed in Afsin-Elbistan B Thermal Power Plant. Burned fuel residues must be treated with caution, and these gases must be treated with extreme caution. This means that the plant has a Flue Gas Decontamination (FGD) system to prevent the release of flammable gas into the atmosphere, which means that an extra 15-20 MW of electricity is used internally. Moreover, because of the different design characteristics of the charcoal used in the design phase, it makes difficult to use the existing FGD system with coal (coal from the AEL field).

In addition, it has serious difficulties in meeting the standards of occupational health and safety in this plant. All staff in such plants are always in risk of exposure of pollutants (ash-coal dust, radioactive substances, electromagnetic effects, high voltage, noise, etc.) and also other factors that may cause health related hazards.

H. Finance

Recently, a large number of studies based on the costanalysishavebeencarriedoutbymanyresearchersforvariouspowerplants [11-14]. Depending on the production capacity of the plant, the amount of investment varies proportionally. Generally, the greatest part of the power plant costs is the initial investment cost, which is discussed next.

Initial Investment Cost:

The initial investment cost is the sum of the costs of machinery, equipment, buildings, land, etc., in order to prepare the plant for energy production before commencing operation. They are expenditures made for basic elements. The greatest part of the energy plant costs is the initial investment costs. This is the cost to be paid for a unit of power.

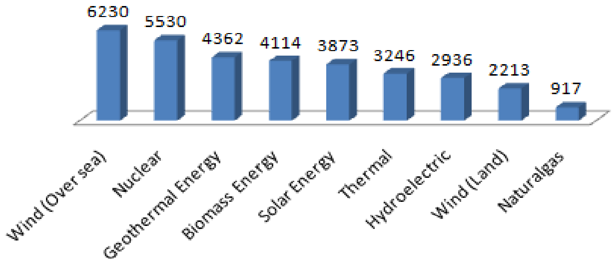

Figure 3. Initial investment costs ($/kW) [7]

Operation and Maintenance Cost:

Operation and maintenance costs are the expenditures that must be made for generation of energy from the plant after the power plant installation. Operating costs are categorized as fixed operating costs and variable operating costs.

1. *Fixed operating costs* are costs such as employee salaries and premiums, plant general and administrative expenses, power plant support equipment costs, scheduled maintenance costs. In addition, the fixed operating cost is the cost which is given to for unit power from the plant during the year.

2. *Variable operating costs* are the costs caused by fuels, energy, water, chemicals, catalysts, gases, lubricants, consumable materials and resources and waste used in the plant. This can be expressed as the cost which is paid for unit energy.

As can be seen from Figures 2 and 3, the initial investment cost is $3246/kW, the fixed operating cost is $37.8/kW-year and the variable operating cost is $4.47/MWh for coal-fired thermal power plants.

In addition, the equipment used in thermal power plants operating with lignite loses its function over the time, which necessitates the supplement of spare materials; and the spare equipment supplied increases the cost of operation in general.

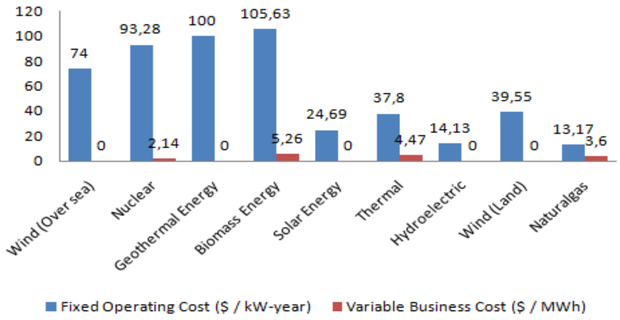

Figure 4. Fixed and variable business costs ($/kW-year) [7]

III. ADVANTAGES OF LIGNITE COAL POWER PLANTS

Approximately 3.2% of the world total lignite and sub bituminous coal reserves are placed in Turkey [3]. The percentagedistirbution of the lignite according to the calorie value is illustrated in Table 2.

Table 2. Percentage distribution of lignite with respect to calorie values

Percentage of Lignite Reserves in Turkey (%)	CalorieValue (kcal/kg)
3.4	> 4000
5.1	3000–4000
23.5	2000–3000
68	< 2000

As it can be seen from Table 2 generally the calorie value of lignite is low and not suitable for domestic heating. However, it is well suited for the thermal power plants for generation of electricity. In thermal power plants operating with low calorie lignite it is necessary to enrich the calorific value of the coal in order to increase the combustion efficiency. In such plants, one of the units used in the boiler unit is the electrostatic precipitator system. In the power plants where the vapor precipitator system is used, the coal is grinded in the mills and then the coal is separated in the separator located over the mill.

Approximately 1/2 of the drying gas/vapour mixturetogether with about 2/3 of the pulverized coal obtained from the seperator is directly injected into the furnacethrough the main burners. The remaining 1/2 of the flue gas/vapour mixture, together with the residuary 1/3 of pulverized coal is conducted through the vapour ductto the following electrostatic vapour precipitator. The electrostatic precipitator is succeeded by a booster fansucking the vapour off and discharging them into the common vapour duct.Also the temperature after mill is regulated by means of recirculated cold gas and vapour [15].

Pulverized coal is drawn into the electrostatic precipitator tanks by the oscillation of the mill and the suction of the fan motors. The damp coal is trapped by the plates in the Electrostatic Precipitator. The coal dust in the dry state is shaken by the motors running in horizontal and vertical positions connected to the palms at certain intervals.

After the dry coal dust is separated from the electrostatic vapour precipitator, the roead of the coal dust is like this in oreder;the electrostatic vapour precipitator will be conveyed through a rotary feeder, a distributor and vapour falling ducts into the venturi nozzles and from there with hot air to the vapour burners. The caol firing system is shown in Figure 5.

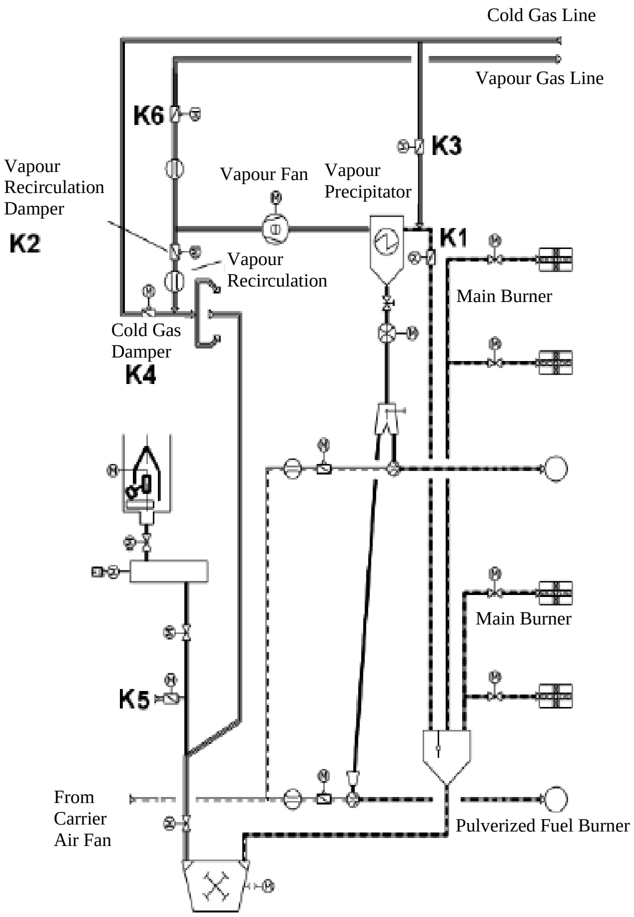

Figure 5. Coal firing system of Afsin-Elbistan B Thermal Power Plant [15]

Since the mill receives a mixture of hot gas recirculated from the upper part of the furnace, cold gas recirculated from the flue gas ducts downstream of the ID fans and vapour gas recirculated from downstream of the vapour fan. The burners designed for burning the coal dust separated by the vapour precipitator will serve for about 30% of the respective total firing rate and represent an ideal continuous support of the fire [15].

In Afsin-Elbistan B Thermal Power Plant the positive effect of the vapour precipitator can be summarized as; the raw lignite with 1060 kcal/kg is prepared to serve with about 3060 kcal/kg to the vapour burner and about 2420 kcal/kg to the main burners, respectively. As a result of this, the average heat value blowing in the furnace chamber is increased from 1060 to about 2640 kcal/kg [15].

IV. FUTURE PLAN AND PROJECTS RELATED TO COUNTRY ENERGY

Although the power plants to be installed in Afsin-Elbistan Region based on lignite reserves are very economical in terms of electricity generation, investments of 2.800 MW power plants, which constitute only 28% of the power plant potential in the region was completed up to now. Large reserves of coal are left idle in the region, which can be used for electricity generation purposes [4]. In particular, a model that can be organized by the public can be used to optimize the coal reserve in the region [4].

Despite some difficulties, the government makes production plans for the future, especially in the production sector, as well as in different sides of the sector. Some of these plans are aimed to give incentives to the private sector and the generation plants are made through private companies and the plants are realized without any burden on the treasury. Nevertheless, Turkey is trying to provide energy diversity in production by increasing the share of renewable energy resources in production. Grants and interest-free loan support, which is up to 50% by the state in recent years for electricity production with renewable energy sources, makes such investments attractive. On the other hand, in recent years, the government has been working on nuclear energy, which will reduce our dependence on foreign efforts.

V. DISCUSSION AND CONCLUSION

Fossil fuels always play a leading role in the electricity generation worldwide. As in the whole world, coal is used as a primary source of electricity production in Turkey for a long time. Due to the fact that 3.2% of the world's lignite reserves are in Turkey, this lignite can be used to produce electricity with thermal power plants of different powers in almost every region of the country. In order to reduce dependence due to national security concerns, it is imperative to treat with care the thermal power plants located in the country and carry out R-D to improve the efficiency and built new plants accordingly [8]. Through the procurement process, the desert coal area, which is located in the Afsin-Elbistan region and has better quality fuel than the region, needs to be reallocated. When these areas are allocated, these reserves could be utilized in order to feed two power plants for a minimum of 10 years by taking precautions to ensure operational safety. The legal and bureaucratic process must be accelerated and connected to the results so that they can be realized.

In addition to the ever-increasing energy needs of Turkey as a developing country, the rapid use of domestic lignite is one of the sources to produce the energy as an alternative to the existing technologies cause energy supply-demand balance continuity with imported resources. Since natural gas and liquid fuel are inadequate, the lack of these mines is eliminated somehow by importing, which also growths external dependency. Turkey is aiming to maintain the position of the coal in both the energy composition and the electricity generation by starting a new era in coal.

In another word, the government plans to use all available coal resources by 2023 in order to protect the coal production in electricity generation and increase its share in the energy composition at least 30%. However, realizing this needs difficult investments as well as some other difficulties.

It is expected that domestic hard coal production will increase in the future up to 5 million tons (Mt) by 2030, and lignite production is expected to double by 2030 [5]. The power plants to be installed in the region are estimated to be the most advantageous power plants in terms of unit production cost as the per capita employment is considerably lower in terms of investment cost than natural gas and nuclear power plants [4].

In addition, in order to improve the efficiency of lignite in particular, the lignite calorie can be upgraded by various processes and the establishment of the generation plants in accordance with this lignite will ensure the production efficiency. It is considered that this can only be achieved by establishing and operating a proper and effective energy policy by the relevant authorities. When all these plans are being made, the environmental impacts and problems arising from energy generation, transmission and consumption for sustainable development and sustainability of the region and the living environment of the country need to be considered.

In order to evaluate low-calorie lignite in the electricity generation, it is important to construct large capacity power thermal power plants, which offers energy diversity and reduce external dependence. In addition, the establishment of thermal power plants offers employments of thousands of technical personnel as well. Even before the removal of the lignite from the open areas near the thermal power plants operating with domestic coal, the dewatering operations (drilling operations) made on the mine fields can be used to reduce the lignite moisture and can be utilized various fields (drinking, irrigation etc.). Therefore, it is necessary to consider the advantages of such facilities and take into account the benefits mentioned.

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BIOGRAPHIES

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