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Multi-criteria evaluation and priority analysis for localization equipment in a thermal power plant using the AHP (analytic hierarchy process)

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ABSTRACT

Ensuring the safety of its energy supply is one of the main issues for newly industrialized/developing countries when utilizing domestic sources for electricity generation. Turkey depends heavily on imported gas to generate electricity, and the ratio of natural gas power generation to total electricity production is nearly 50%. Coal-fired thermal power plants using domestic resources are considered a good option to decrease the large amount of imported natural gas, and to supply a secure energy demand. However, electricity generation from coal-fired power plants using local lignite reserves is not adequate to maintain a secure energy mix and provide sustainable development, as Turkey does not have indigenous energy sector technology. Therefore, technology transfer and its localization are crucial for newly industrialized/developing countries such as Turkey. The aim of this study is to use the analytic hierarchy process to determine a priority analysis in relation to localization equipment for a thermal power plant. Parameters involved, such as readiness of both infrastructure and human resources, manpower as skilled labor, market potential for equipment developed by transferred technology, and competition in global/internal market, are related to localization in thermal power plant technologies, and are considered in relation to the country's technological capability, design ability, possession of materials/equipment, and ability to erect a plant. Results of analysis show that the boiler is the most important piece of equipment in this respect, and that heaters and fans are ranked after the boiler with respect to local conditions.

1. Introduction

According to the OECD (Organization for Economic Cooperation and Development), Turkey has one of the fastest growing economies [1] (due to its very young population and rapidly growing economy), and as such the country is demanding an increased energy supply [1]. Turkey's economy is now ranked 17th largest in the world and is the 6th largest in Europe; the country is considered to be the economic hub in its geographical area [2,3]. Second to China, Turkey has the highest rapid energy demand and usage growth, but in relation to past policies, it is highly dependent on external resources of energy [4]. According to the average value taken from the TEIAS (Turkish Electricity Transmission Corporation) report, Turkey's electricity demand has increased by up to 7.4% per year in the last few years [5], and in accordance with the latest Turkish Electrical Energy 10 Years Generation Projection (2012–2021) report published by TEIAS, the total electricity demand is expected to reach 425 TWh by 2021, with a 6.7% compound annual growth rate in the low demand scenario [6]. In the next ten years, the current level of energy demand is expected to be roughly doubled. However, in relation to this increased demand for electricity, there is a requirement for the construction of new PP (power plants).

It is considered that the Turkish government needs to reduce the country's dependence on imported natural gas and coal by diversifying its energy mix using domestic lignite [7]. Turkey's domestic fossil fuel energy source is mainly comprised of lignite reserves [8]. In addition to the positive economic effects, the growing utilization of such resources could make a significant contribution to Turkey's energy sector and energy mix with respect to electricity generation. Since 2000, the government has attempted to develop a policy that encourages locating additional domestic lignite reserves by using a

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suitable model of public–private partnership, with the aim of decreasing the rate of imported natural gas for electricity generation. At present, however, the high demand for electricity is mostly met by combined-cycle, natural-gas-fired PPs, contributing approximately 44% of the energy supply in 2013 and 48% in 2014, according to records in reports published by EUAS (Electricity Generation Company of Turkey) [9].

In spite of its poor quality, lignite reserves are spread across the whole country throughout more than 40 regions. According to the latest data from TKI (the state owned Turkish Coal Enterprises), the amount of these resources exceeds 13 Gt (11.8 Gt of lignite and 1.3 Gt of hard coal) [10], and of this amount, 45% was added to Turkey's lignite reserve after considerable exploration progress in the last few years. The installed coal-fired (local coal-lignite and imported hard coal) thermal PP capacity for electricity generation is 14.03 GWe (20.4% ratio to total capacity). In the future, it will be important to use this huge reserve of domestic lignite [12].

However, there are several difficulties relating to the use of Turkey's lignite with respect to combustion in boilers at thermal PPs. The main problem is that a high moisture level and ash rate leads to a lower calorific value. Most of the coal fired thermal PPs in Turkey were built with PC (pulverized coal) combustion technology in the 1980s and 1990s, before the maturation of CFB (circulating fluidized bed) combustion technology. Therefore, domestic lignite was never considered suitable for CFB combustion and utilized in such PC fired coal fired thermal PPs. Such problems relating to the combustion of domestic lignite in PC fired boilers have caused decreasing availability and power capacity factor, which has led to a rise in operational costs.

For developing countries, localization of the electricity generation sector is important to secure the supply of electricity generation and to maintain sustainable economic growth. It is indicated that Turkey needs to invest about 250 billion USD into the energy sector by 2030. Specifically, nearly 60% of imports (equal to an amount of 150 billion USD) will consist of machinery and equipment used in PPs [11]. It would thus be beneficial if Turkey transferred and/or developed related technologies in the PP sector in order to decrease such imports of machinery and equipment.

A thermal PP uses mainly 10 groups of main technologies (including approximately 50 sub-technologies/systems and main equipment). However, making an evaluation and priority analysis for the localization of equipment used in PPs is not simple, as a number of criteria need to be explored to cover every aspect of the national conditions and priorities. In this respect, multicriteria analysis is mandatory for use in the evaluation of prioritization of PP's main equipment. The AHP (analytic hierarchy process) is one of the most widely used methods in this respect, and the associated methodology is not only valuable but also simple. The AHP makes an analysis tool available for making a multicriteria decision by selecting performances of alternatives against selected criteria, with the aim of evaluating the overall system as an indicator of the situation. It provides a rating (originally a measurement scale of 1–9) and ordering in a hierarchical tree, as a measurement of alternative solutions in relation to the specified criteria and sub-criteria. The AHP also enables determination of the weights of the criteria on which the entire structural analysis is based. In addition, the AHP simplifies problems by using a hierarchy structure that includes criteria and sub-criteria, and makes a pairwise comparison against criteria to evaluate and determine the performance of alternatives. The method also includes a consistency check of the pairwise comparison in an evaluation of a matrix to ensure that correct decisions are being made.

The AHP method was introduced by Saaty [13] for decision analysis. The principles and philosophy of the method are given in Ref. [14], the critical points and highlights of the theory are explained in Ref. [15], and some improvements are discussed in Ref. [16]. The approach has been applied widely to several different areas [17] such as social, the manufacturing sector, politics, engineering, education, industry, government, and others sectors such as sports, management, and the power generation sector. Areas of application within the energy sector are as follows: as a failure mode effect analysis of thermal PPs [18], for energy evaluation [19], for ranking energy production technologies [20], for determining a critical analysis of equipment used in PPs [21], and for evaluating power plant efficiency [22]. Chatzimouratidis and Pilavachi published a series of studies for determining the impact of PPs. In one study, ten types of existing PPs (including fossil fuel, nuclear, and renewable energy-based PPs) were evaluated with regard to their overall impact on the living standard of local communities [23]. Another study conducted a sensitivity analysis by considering a number of factors relating to PPs (for example, technological, economic, and sustainability evaluation of PPs) [24]. A further study evaluated ten types of PPs to determine their impact on living standards [25], and a subsequent study made a technological, economic, and sustainability evaluation of PPs using this method [26].

The AHP method was also used for failure mode analysis in thermal PPs in consideration of critical maintenance [18]. In addition, the energy consumption of a thermal PP was evaluated using the AHP method [19]. To determine a secure power mix, the AHP method was also used to select a power generation method in consideration of financial, technological, environmental, and social/economic/political criteria [20]. Furthermore, an analysis of critical PP equipment was identified in view of the environmental impact, customer inconvenience, and maintenance cost [21], and an investigation of operating efficiencies of a set of electric PPs was also conducted [22]. The AHP has been used to make an appropriate selection of a method of technology transfer [27,28]. However, no study yet exists in literature that evaluates and prioritizes the localization of power plant equipment via the transfer of technology.

This study presents an evaluation and priority analysis of 11 main pieces of equipment used in PPs for localization in the energy sector by covering different sets of weights of the criteria, including five criteria and four sub-criteria. The aim is to determine a priority order of equipment used in PPs in relation to localization. As the development, or transfer, of the technology involved in a piece of equipment or within a system requires considerable engineering effort and time, it is considered that evaluation and determination of the priorities should be made as an initial step.

2. The importance of technology transfer in developing countries

2.1. Technology transfer

Development of technology is crucial for developing countries, in order to increase international competitiveness and supply sustainable economic growth. The sourcing of technology from developed countries has increased globally in the last decade, as it is initially much cheaper, easier, and faster to transfer technology from developed countries than to develop it. Such technology is transferred under contracts including tangible ones such as patents, designs, and rights of production, and intangible elements such as “trade secrets” or “know-how.” Transferred technologies provide competitive advantages for companies, as they enable the development and localization of such technology to ultimately produce new products. However, such technologies need to be adapted according to the country's local conditions, and to be absorbed within companies and developed for future