AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
ELECTRICAL POWER AND MACHINES DEPARTMENT

Integrated Resource Planning in the Egyptian Electricity System

Submitted by:

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A thesis submitted to the faculty of Engineering at Ain-Shams University in Partial Fulfilment of the requirements for the Degree of Master of Science

In

Electrical Power and Machines Engineering

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Statement

This thesis is submitted to Faculty of Engineering, Ain Shams University in partial fulfilment of the requirement for the degree of Master of Science in Electrical Power and Machines Engineering.

The work included in this thesis was carried out by the author, at the Electrical Power and Machines Department, Faculty of Engineering, Ain Shams University.

No Part of this thesis has been submitted for a degree or qualification at any other universities.

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Abstract

In this thesis, swarm based optimization techniques are utilized to develop an accurate and computationally efficient mathematical model using MatLab programming tool to solve the IRP planning for a power system. These include two swarm intelligence techniques; Particle Swarm Optimization (PSO) and Fire Fly Optimization (FFO). The developed IRP model is verified against published results for the future plans of the Indian electricity system.

The developed IRP optimization mathematical model is used to investigate IRP planning of the Egyptian power system. Since there are committed plans of the power system in Egypt till 2019/2020, the study base year is taken to be 2019/2020. The IRP planning tool is applied to explore the development of the system over the next 20 years up to 2039/2040.

Two base cases regarding the objective functions are considered. These are; the minimum total cost per MWh of electrical energy demand and minimum average heat rate (fossil fuel consumption) of electrical energy demand. Other system constraints are considered. Furthermore, technical, financial and cost databases considering the most reliable data have developed to be utilized as input to the model. Also, a variant for the minimum cost scenario is to consider using FFO as an optimization technique instead of PSO, which has been used as a base technique in this thesis. Parametric study has been carried out for the impact of some important parameters on the model results. Finally, an IRP analysis is carried out for the impact of DSM and CO_2 costing as well as both.

The impact of IRP planning on the existing pool has been analyzed. Furthermore, the structure of the generation pool at different milestone years as well as by the end of the planning horizon in 2039/2040, has been assessed and analyzed. This analysis took into consideration seven indicators. These include; Share of non carbon based energy generation, Share of installed capacities of different renewable energy technologies, Average heat rate, Average specific CO_2 emissions, Levelized energy cost per MWh, Herfindahl-Hirschmann Index for supply diversification and the Total investments needs over the planning period.

Based on the output results it has been found that regardless the scenario, a total capacity of 13.2 GW should be phased-out permanently of the existing power pool, as they will not be needed along the planning period of 20 years. These may be due to their low efficiency or unsuitable capacity. This means that an asset management program is needed to optimize the utilization of these assets. This program should include technical and commercial dimensions.

Also it has been found that, the share of the renewable energy for all scenarios will be around 34%-43% depending on the scenario. The higher limit is for minimum heat rate, while the lower limit is for the minimum cost using FFO scheme. This ratio will increase as other non hydrocarbon sources, such as nuclear sources are considered. This necessitates having higher share of simple cycle gas turbine in the system to provide the necessary capacity credit to this share of intermittent renewable sources. Yet, the system is designed in a way that reliance on these simple cycle gas turbine units for energy generation is minimum. Moreover, all scenarios show minor reliance on coal as source of supply. Using IRP optimization algorithm shows a general tendency of all scenarios towards progressive improvement in HHI, meaning better diversification of the supply sources

Considering different planning scenarios, it has been found that, in case of minimum heat rate objective function, the highest share of renewable energy as well as non carbon based sources can be achieved. Also, it will ensure the highest diversification of energy supply sources, yet it will not achieve the lowest energy cost to consumers. Furthermore, higher GDP rate with minimum cost objective function has the second highest share of renewable energy as well as low average heat rate almost similar to that minimum heat rate scenario, which represent multiple benefits to the economy. However, the latter will lead to higher investments needs. Yet, this should not be looked as a burden, on the contrary this represents an investment opportunity.

It is important to mention that, in case if the system operator diverts from the planned mode targeting minimum reliance on the simple cycle gas turbines as source for energy supply, due to operational circumstances, this will have minor negative impact on the average heat rate, yet it will have positive impact on levelized energy prices and total investments needs, compared with the base scenario.

The lowest energy cost can be achieved when DSM is applied. Also, the lowest investment needs can be achieved when a combined scenario of DSM and CO_2 costing is applied.

This thesis provides an effective decision support tool, which can help decision makers to achieve better results for ensuring; security of supply, optimum utilization of resources, fair cost to consumers and minimum impact on the environment.

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