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A comprehensive sequential review study through the generation expansion planning

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ABSTRACT

The generation expansion planning (GEP) problem involves the determination of types, location and construction time of new generation technologies which should be added to the existing system in order to meet the growing demand over a planning horizon. It is a vital issue due to electricity-dependent aspect of everyday life as well as most production and service systems in society. Over the past few decades, the GEP has experienced multifarious changes resulting in emerging a multitude of new models and solving methods. In this context, many studies have been carried out to achieve optimal expansion strategies with respect to the different energy-related issues, such as electricity market, uncertainties, low carbon economy requirements, distributed generation, renewable sources, energy policies, demand-side programs, and so on. In pursuance of finding out further research ideas in the field of GEP and identify less-addressed areas, a need for a comprehensive review of accomplished studies has been felt. By reviewing almost all aspects that have been considered in the GEP as yet, the present paper provides a detailed classification of a large number of done GEP studies. Reviewing results provide useful insights into the future of GEP research activities.

1. Introduction

In the today's modern world, the importance of a reliable power system is ever increasing as nearly as all welfare aspects in societies direct or indirect depends on how to access to electrical energy. Meanwhile, the complexity of power generation and delivery procedure increases while new economical, technical, and environmental issues are being introduced into power systems along with growing demand. The required changes nourish the ongoing discussion on how the power system should be organized to supply various loads reliably, while uninterrupted access to the electricity becomes critically important as a result of economic growth and the development in industries. Hence, the generation expansion planning (GEP) problem has been addressed by the electrical industry community for more than 40 years. Solving the GEP problem allows planners to make a decision on the generation technology types, size, location and construction time, taking constraints into account on different techno-economic issues [1].

Since the advent of electrical power systems, engineers have obtained significant amount of experience from the GEP. Accordingly, a large set of models have been appeared by translating the experiences to the mathematical forms. Regarding these models, it can be seen that the GEP originally is a challenging problem due to its nonlinearity, non-differentiability, high-dimensionality, and to the discrete nature of the variables indicating unit size and allocation. Known as one of the most complicated type of power system planning problems, the GEP problem has been broadly investigated through numerous studies presenting a wide range of objectives ranging from cost minimizing in the monopoly regime to profit maximization in the restructured environment. In this important energy context, beside restructuring, the advent of smart control strategies and new generation technologies based on renewable energy sources (RES) in parallel with anthropogenic climate change issue and enacted energy policies resulted in a great revolution tacking place in generation planning fundamentals, such as objectives, constraints, and analyzing methods. Generally, electricity market and competition, global environmental considerations, uncertainties and reliability, demand-side management programs (DSM), energy policies (in both forms of incentive-based RES support schemes and CO_2 mitigation measures), energy security, distributed generation, generator maintenance scheduling (GMS), Smart Grids, transmission expansion planning (TEP), natural gas systems (NGS), fuel supply cost, short-term thermal cycle operation scheduling, clean coal technologies (CCTs), CO_2 capture storage (CCS), so on, are included subjects or concepts which have recently been

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either changed or appeared in the field of generation expansion planning.

From the above-enumerated subject/concept-point-of-view, a state-of-the-art review of GEP problem is provided in the present paper. Unlike few studies that have already reviewed the GEP in an incomplete framework, here, it is tried to cover the whole aspects completely that have been considered so far in GEP researches done during the last three decades. Among aforementioned studies, references [2–5] classify solving methods applied to the GEP only; researches with the aim of planning the hybrid (both renewable and nonrenewable) generation systems are reviewed in [6]; an overview of initial reliability models in the context of GEP are also presented by [7]. Demand-side management, reliability, uncertainty, and electricity market are included the perspectives considered for reviewing the GEP problem in some parts of recent study [8]. The focus of addressed study in [8], indeed, is more on the TEP problem reviewed from different aspects and views such as modeling, solving methods, reliability, distributed generation, electricity market, uncertainties, line congestion, reactive power planning, DSM and so on. More complete framework for reviewing the TEP, as a non-detachable part of long-term power system planning, is presented in [9] which provides a comprehensive background to find out the further works in this field. Current challenges to TEP and its most recent development with some instances in a European context is reviewed in [10]. By performing a critical review on TEP, this study in fact suggests a taxonomy of modeling decisions and solving methods for this problem, linking them to some of their main representative studies in the literature. In this regard, current status and trends in power transmission; challenges involved in construction, operation and maintenance of these lines and possible solutions for mitigating the challenges; methods applied for carrying out design and optimization studies; and ultimately, methodologies adopted for economic analysis of transmission lines are reviewed in detail in [11]. Uncertainties associated with power systems planning problems with modeling techniques are reviewed in [12] to clarify how most appropriate uncertainty modeling approach should be selected in each area of power systems planning problems. As it can be seen from the literature, reviewing the GEP problem from various aspects has been less noticed till now.

The present paper, as a comprehensive state-of-the-art review, is therefore intended to provide a comparative sequential framework for subjects and novelties carried out to determine optimal expansion strategies so far. Consequently, a wide range of articles addressing the GEP problem are hierarchically reviewed with regard to the events, agreements, regulations, and relatively recent developments in power industries. To achieve this aim, first, the subjects that have resulted in transformation of the GEP problem during last three decades are prioritized. Regarding these subjects, a wide range of GEP studies are reviewed; then, to better illustrate the changing process of viewpoints on the GEP and better appreciating the fields that have less been discussed till now, the reviewed studies are classified in several tables in accordance with the time interval (decade) in which the studies have been published. Thus, the paper has the final goal of providing the reader with a comprehensive review of the GEP and its previous and current circumstances, together with comments that have the goal of serving as a guide to choice directions for future research works as well as suitable modeling and solving methodologies.

The rest of this paper is organized as follows:

- Section 2 describes the general hierarchy of GEP studies transformation factors. In this section, in fact, what factors could basically affect GEP strategies and models during recent decades are discussed.
- Section 3 reviews a wide range of GEP investigations in detail from various perspectives with respect to the classified factors from Section 2.
- Section 4 presents a discussion on less-investigated areas of the GEP problem and most-applied methodologies and models.
- Section 5, finally, provides conclusions derived by the present study.

2. GEP transformation factors hierarchy

The proposed hierarchy to review the most important transformation factors of the GEP studies is generally illustrated in Fig. 1 with respect to their rate's effectiveness.

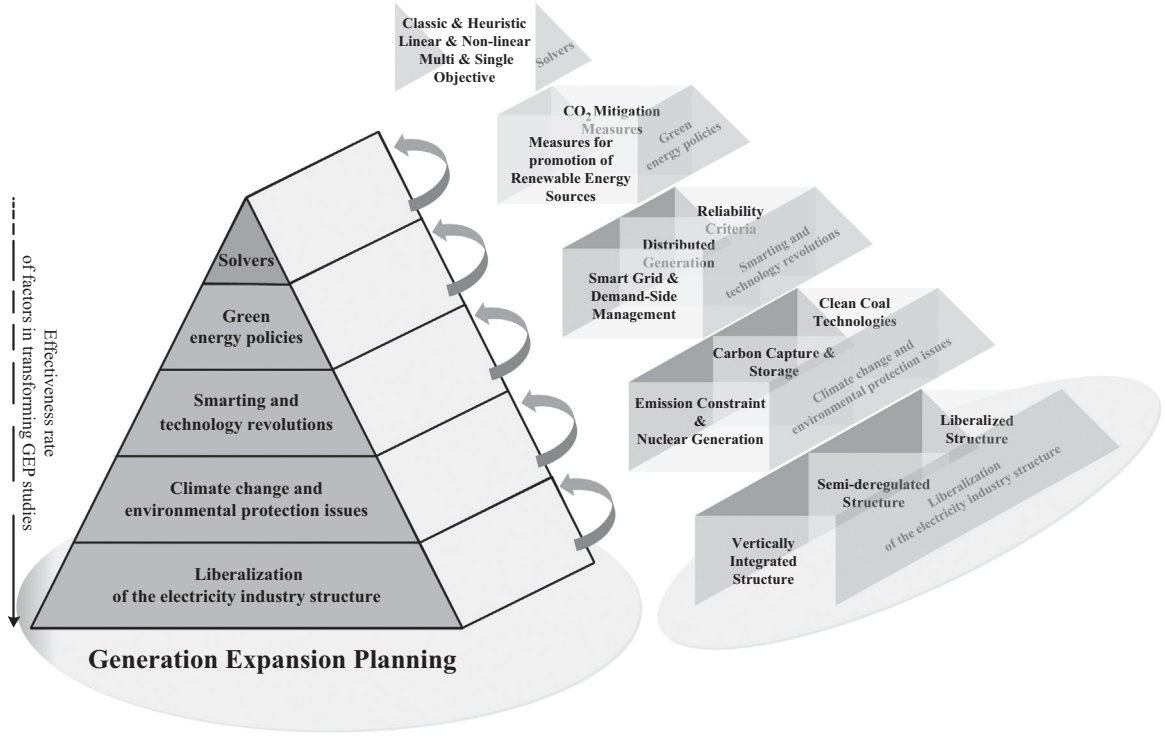

Fig. 1. The hierarchy of considered perspectives to review GEP studies.