Stochastic assessment of investment efficiency in a power system

Sreten Davidov, Miloš Pantos*

University of Ljubljana, Faculty of Electrical Engineering, Tržaška 25, SI-1000, Ljubljana, Slovenia

ABSTRACT

The assessment of investment efficiency plays a critical role in investment prioritization in the context of electrical network expansion planning. Hence, this paper proposes new criteria for the cost-efficiency investment applied in the investment ranking process in electrical network planning, based on the assessment of the new investment candidates impact on active-power losses, bus voltages and line loadings in the network. These three general criteria are chosen due to their strong economic influence when the active-power losses and line loadings are considered and due to their significant impact on quality of supply allowed for the voltage profile. Electrical network reliability of supply is not addressed, since, this criterion has already been extensively applied in other solutions regarding investment efficiency assessment. The proposed ranking procedure involves a stochastic approach applying the Monte Carlo method in the scenario preparation. The number of scenarios is further reduced by the K-MEANS procedure in order to speed up the investment efficiency assessment. The proposed ranking procedure is tested using the standard New England test system. The results show that based on the newly involved assessment criteria indices, system operators will obtain a prioritized list of investments that will prevent excessive and economically wasteful spending.

1. Introduction

Assessment of the investment efficiency in a power system can be a complex and thought-provoking issue for the system operators (SO), that merits a closer look. Some SOs apply simple and traditional assessment procedures (contingency analysis, power-flows, etc.) in including the new investment candidates in the electrical network, whereas others SOs oppose these simple procedures and support probabilistic approaches for cost-efficient investment and improved SOs performance in a performance-based regulation (SOs perceive awards, thus, profitable gains). This latter position is certainly the stronger of the two, as a consequence of the random nature of the electrical network components and should be examined in detail.

Up until now, the literature has recognized a variety of electrical network planning methods. Investment assessment is vital component of the electrical network planning, since it helps the SOs to easy-decide the expansion or reinforcement investment. In Ref. [1], a traditional electrical network expansion planning procedure is presented, elaborating the impact assessment, power system operation simulation and financial analysis as the main ground steps in an integrated energy utility’s traditional planning practice. Also, a comparison is made underlining the substantial differences between electrical network expansion planning procedures in two regulation environments. It is ascertained that the reliability assessment is gaining points in the assessment of investment efficiency. In Ref. [2], it is pointed out that deregulation of the power system has introduced new objectives and requirements for the electrical network expansion planning problem. Authors have used a multi-objective optimization framework as static electrical network expansion planning methodology. Three terms are included in the objective function: investment cost, reliability and congestion cost. To obtain the final optimal expansion decision fuzzy decision making is applied. In Ref. [3], reinforcement and expansion of the electrical network is proposed as a way to mitigate the impact of increasingly plausible deliberate outages. The network planner selects the new lines to be built accounting not only for economic issues, as traditionally done, but also for the vulnerability of the transmission network against a set of credible intentional outages. The resulting vulnerability- and economic-constrained electrical network expansion planning problem is formulated as mixed-integer linear program. In the paper, the objective function comprises two terms. The first term represents...
the vulnerability of the transmission network against intentional attacks and the second term accounts for the investment cost by employing a binary variable. The complex mathematical formulation is formulated as mixed-integer linear programming problem. Furthermore, deregulation of the electric power industry has employed new uncertainties for the electricity market participants and has made the electrical network planning more difficult. In Ref. [4], a novel electrical network expansion planning approach is proposed to meet the electricity market uncertainties by employing a statistical approach and identifying several possible future scenarios. In the proposed approach, the electrical network expansion planning is formulated as mixed integer nonlinear programming problem, including the expected energy not supplied and the adoption cost of the electrical network expansion plan. In Ref. [5], a mixed-integer linear programming formulation for the long-term electrical network expansion planning problem in a competitive pool-based electricity market is presented. In the paper, market functioning is modeled while defining a number of scenarios based on the future demand of the power system. Also, the investment and operating costs, transmission losses, generator losses and demand bids are considered in the optimization procedure. Another part of the electrical network expansion planning process is the retirement decision making. In Ref. [6], the probabilistic generation expansion and retirement planning problem is formulated as an optimization problem. It includes the retirement decision of aged generating units in the expansion process, which might be beneficial, since old units can work with increased costs and decreased efficiencies. The objective function is set to minimize the expected total cost consisting of the investment required for the commissioning new units, operation and maintenance costs, retirement salvage costs and system risk costs. The objective is subjected by the generating unit and the system physical and operational constraints. In Ref. [7], a new approach has been developed, based on the probabilistic failure density of the electrical system components, for the life assessment of the electrical components and decision-making support. What criteria should guide electrical network expansion planning is a crucial issue, since the least-cost expansion planning is no longer viable. In Ref. [8], a new framework is presented for multi-objective electrical network expansion planning. It is based on a multiple criteria decision making whose fundamental elements are network reliability and electricity market. In Ref. [9], a new method is introduced for choosing the best electrical network expansion plan considering a probabilistic reliability criterion based on the uncertainties of transmission system elements. In Ref. [10], a multi-criteria formulation for multiyear dynamic transmission expansion planning problems is presented. The investment and operation costs and the energy not supplied are considered in the establishment of the decision criteria. Still, as stressed in Ref. [11], there is an enhancement necessity to improve the traditional electrical network expansion planning by applying probabilistic approaches. Therefore, to the traditional single contingency security criteria N–1, multicomponent outages must be considered, since the random nature of the power system components have a great effect on power system performance. The occurrence probability of outages must be simulated, uncertainties in network topologies, probabilistic power-flows and stability assessments. Other reasons to include probabilistic approaches in the electrical network expansion planning can be found in Refs. [12] and [13].

Above all, the existing planning procedures have been recently upgraded with an assessment of investment efficiency for prioritization and easier decision making. In Ref. [14], a method is presented for ranking and postponing investments in the electrical network planning part. A probabilistic economic criterion which takes into consideration the cost of expected undelivered energy is used to derive a profitability index, a postponement index and combined technical-economical-probabilistic planning criteria to allow the ranking and postponement of technical justified but economically unjustified investments. This ranking method is especially useful when insufficient investment funds are available for construction. In Ref. [15], another ranking methodology for the investments in electric distribution grid is presented. As noted, this ranking criteria was involved to harmonize the quality of service criteria required by the regulatory authorities. In the paper, the presented ranking methodology seeks to identify the group of projects, which presents the highest return on a given amount of available capital. The ranking is performed based on the technical and economic performance of the planned investment. In Ref. [16], a new method for reliability investment decisions when a reward/penalty scheme is applied to the regulation of SOs is presented. New investment planning criterion for SOs subjected to performance based regulation (PBR) is identified and mathematically formulated as new investment efficiency index (IEI), which yields the relation between the improvement of system reliability due to the investment in the electric system and total investment costs. To determine the improvement of system reliability due to the investment in the electric network, the method uses the Monte Carlo simulation technique for the modeling of the stochastic nature of outages in electric networks, along with a linear program, which enables load flow calculation under a fault state that provides information about power deficits in the electric system.

For this paper, the core research has already been approved and shown in Ref. [16], however, in this paper the research developed in Ref. [16] is improved by elaborating a ranking procedure of proposed investment candidates based on their operational effect and investment cost, similar to the reliability investment decision method presented in Ref. [16]. The investment cost includes calculation of the actualized investment cost and the operational effect includes examination of the proposed investment candidate effect on active-power losses, voltage profile and lines loadings. The ranking procedure is developed to enhance the transition from cost-based to performance-based regulation by employing new cost-efficient investment planning ranking criteria. Finally, this paper makes six contributions, noted as following:

- **New cost-efficiency investment index named LEI**, which yields the relation between the decrease of the active-power losses due to the investment in the electrical network and total investment costs. The active-power losses are accounted, since investment candidates that reduce the active-power losses in the power network lead to reduced costs for purchasing ancillary services for compensating the active-power losses, since these costs have to be covered by the SOs and charged to end-users,
- **New cost-efficiency investment index named VEL**, which yields the relation between the improvement of the voltage profile due to the investment in the electrical network and total investment costs. Bus voltages have a significant impact on the voltage profile of the power network, i.e. on quality of supply, which must be constantly improved or at least maintained at acceptable levels as defined by regulations; otherwise, final consumers may demand restitution, which is additional cost for the SOs,
- **New cost-efficiency investment index named PEL**, which yields the relation between the line loadings mitigation due to the investment in the electrical power network and total investment costs. Lines overloading may cause shortage of transmission capacity. Selection of investment candidates that will not additionally burden the electrical power network and that would increase the reliability of the power network must be
دریافت فوری متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات