

Electric-Gas Co-optimization in the Optimal Generation Expansion Plan Determination of a Multi-Country System

1. Overview

The main objective of the Generation Expansion Plan (GEP) is to guarantee an appropriate balance between electricity supply and demand, i.e. to determine the optimal set of generation projects that should be constructed to meet the demand requirements along a horizon (mid and long term). The optimality of the expansion plan means minimizing a cost function considering: (i) investment (capital) and operation (fuel, O&M, etc.) costs of generation plants and (ii) penalties for energy not supplied, also called deficit costs.

In addition, the generation expansion planning task must meet both economic and environmental criteria, within a framework of national energy policies. A key issue of the GEP methodology is how to deal with the uncertainties inherent to the planning process: the most common uncertainties considered being load growth and generation availability, especially in renewable based systems.

The GEP task becomes even more complex when decisions regarding integration with other sectors interfere in the decision-making process – such as considering the joint optimization of multiple countries or the possibility of expanding the gas supply network in tandem with the electricity network. In these cases, because the decision to build a new gas-fired thermal power plant will depend on the gas availability and delivery, an integrated gas-electricity model is needed to represent the flows associated with the gas production, transportation and consumption. Therefore, the integrated co-optimization allows the model to calculate trade-offs between gas investment and operating costs against other alternatives.

Taken the aforementioned facts into account, it can easily be seen that GEP problems are huge and complex tasks, especially when integrated co-optimization of multiple sectors and countries is involved.

2. Methodology

In order to solve the integrated problem, the GEP task is formulated as an optimization problem and can be solved by a decomposition scheme based on a two-stage approach, as described below:

- **First-stage problem** (the investment sub-problem): formulated as a mixed integer programming (MIP) problem where the objective is to propose alternatives for the expansion plan;
- **Second-stage problem** (the operation sub-problem): the objective of the second stage is to evaluate the performance of the expansion alternatives proposed in the first-stage, producing the results that will be used in the first stage to improve the expansion solution. The second stage is solved by a probabilistic dispatch simulation tool.

In summary, the generation expansion planning task is performed through a computational tool which determines the least-cost expansion plan for an electric-gas system and is integrated with a dispatch simulation tool which represents the physical details of production from hydro, thermal and non-conventional renewable plants, besides the gas network. The system selected for optimization can be a region of a country, the entire country, or a set of interconnected countries; and the candidate projects may be hydro, thermal and renewable plants, gas pipelines, gas production nodes, and electric transmission lines (within countries or connecting different countries).

The least-cost GEP is achieved by optimizing the trade-off between investment costs to build new projects and the expected value of operative costs obtained from the stochastic hydrothermal dispatch model, which allows a detailed representation of the electric-gas system's operation under uncertainty.

3. Expected Results

Taking the aforementioned expansion planning model into account, this paper aims at performing case studies based on a multi-country system. Its application will be evaluated in an adapted Central American System, which is composed of six countries: Panama, Costa Rica, Nicaragua, Honduras, El Salvador and Guatemala.

Firstly, the expansion plan will be calculated in an isolated manner, without considering opportunities for cross-country synergies or the possibility of developing an integrated gas network. Afterwards, an integrated optimization program will be solved and the impact of exploiting these additional options will be evaluated on the expansion plan from each country and for the entire region as a whole. Because this second model allows electricity and gas interconnections between systems to be considered as additional candidate projects, it can be interpreted as a benefit for Central American countries of participating in the Regional Electricity Market (MER).

Furthermore, seeing that one key objective of this paper is to analyze different expansion plans under uncertainty, sensitivity studies will be carried out to evaluate the impact of different macroeconomic assumptions (higher load growth and/or different fuel price projections).

4. Conclusions

This paper aims to present (i) a brief characterization of the adapted Central American System, (ii) the methodology used to select the best expansion plan for a given scenario, and (iii) the expansion plan analysis with respect to the corresponding assumptions. The expansion plans will be compared regarding: (i) expansion technologies selected, (ii) environmental impact, and (iii) operational and economic performance. In conclusion, since electric-gas co-optimization and the energy integration between countries are topics of great interest for the energy policy in some Latin American countries, appointments will be made about the benefits of the methodology proposed in this paper and its application for Latin America.