EFFICIENT ELECTRICITY PRODUCTION PORTFOLIOS TAKING INTO ACCOUNT PHYSICAL BOUNDARIES

Florian Kienzle, Power Systems Laboratory ETH Zurich, Switzerland, +41 44 632 8925, kienzle@eeh.ee.ethz.ch
Gaudenz Koeppel, Power Systems Laboratory ETH Zurich, Switzerland, +41 62 286 7863, koeppel@eeh.ee.ethz.ch
Pascal Stricker, Power Systems Laboratory ETH Zurich, Switzerland, stpascal@ee.ethz.ch
Göran Andersson, Power Systems Laboratory ETH Zurich, Switzerland, +41 44 632 0816, andersson@eeh.ee.ethz.ch

Overview

Over the last three decades, the world electricity consumption has increased with an average annual rate of 3.7%, while growth in total primary energy supply was only 2.1%. In most industrialized countries the demand for electric energy is increasing and substantial energy shortfalls are expected within the next twenty years if no measures will be taken in the near future. In Switzerland, for instance, the domestic electricity consumption exceeded the domestic electricity supply for the first time ever in the year 2005. There are three solutions to compensate these shortfalls: increase power imports, considerably enhance energy efficiency and/or increase domestic production. As most European countries face similar situations, import strategies are not likely to be economical solutions and efficiency gains are often compensated by increasing demand for electricity. In the third case, investment strategies resulting in a financially and technically optimal production portfolio must be formulated. One approach to do this is the application of the mean-variance portfolio theory to power generation assets. This provides information about the risk-return structure of a chosen electricity generation mix.

Production portfolio selection, however, is subject to boundary conditions of different nature. Investors give special emphasis to financial aspects, whereas at the same time technical as well as legal limitations must be taken into account. These different aspects may sometimes contradict each other. Though it might, for instance, be rewarding in financial terms to hold a one-asset portfolio exclusively composed of wind power plants, the power supplier might not be able from a legal point of view to guarantee continuous power delivery to its consumers due to the limited availability of production from wind power plants. Other types of portfolios may not respect the Kyoto protocol and its regulations on CO_2 emissions. Although in liberalized electricity markets priority will be given to financial aspects, portfolio construction will thus be limited by legal and physical boundaries. Mean-variance portfolio theory, however, lacks a direct relation to physical quantities; it neither indicates the required installed capacities nor incorporates availability of supply.

In this paper, the production assets of BKW, a major Swiss utility, are modeled as mean-variance portfolio and methods to incorporate availability of supply and to identify required capacities are introduced, discussed and applied.

The paper is structured as follows. Section 2 gives an overview of the methods used for the analysis. Section 3 presents the results of the study of BKW's current portfolio and examines possible future scenarios. Section 4 concludes the paper.

Methods

Mean-variance portfolio theory is applied to BKW's electricity generation assets.
The analysis based on relative changes in electricity production costs is extended and compared to an analysis based on actual average production costs per MWh.
By means of a method using the capacity factor concept, the installed capacity per technology required to satisfy the projected annual electricity demand is determined.

Results

Firstly, the current BKW portfolio is analyzed. An analysis, where return is defined as relative change in production costs, is extended and compared to an analysis based on actual average production costs per MWh. The results indicate that the current BKW portfolio is close to the efficient frontier and to the minimum variance portfolio. Furthermore, it is shown that the analysis based on relative cost changes is compatible with the analysis based on actual production costs due to the strong correlation between actual unit costs and their change rate.

Secondly, possible future scenarios for the BKW portfolio are assessed. The results illustrate how adding gas and coal power plants would impact the risk-return structure of the current BKW portfolio. It is shown that gas and coal power plants are viable options for BKW to extend its production capacity. The share of the corresponding installed capacities, however, should stay on a relatively small level. Otherwise, the generation portfolio would become inefficient.

Thirdly, the number of power plants required to realize the minimum variance portfolio for the case of the five considered technologies (nuclear, run-of-river, pumped-storage, gas, and coal) is determined using the capacity factor concept. This is done for two cases – on the one hand for the electricity consumption of the year 2000 in the BKW service area, and on the other hand for the projected consumption in the year 2035.

Conclusions

Mean-variance portfolio theory has been applied to the portfolio of a major Swiss utility. The efficient frontier for the current generation mix has been derived and it has been shown that the current BKW portfolio is close to the minimum variance portfolio. In addition, the efficiency of possible future generation mixes has been analyzed considering different scenarios. Furthermore, the mean-variance portfolio theory has been extended with two analyses to illustrate the physical meaning of a resulting portfolio. On the one hand, a third dimension has been introduced to show the actual average production costs per MWh. On the other hand, the projected total annual production is divided into the respective number of installed capacity per technology by using the capacity factor concept. This second analysis identifies how many units of which technology need to be built in order to obtain the defined portfolio. The suggested method has proven expedient and gives useful insights concerning future investment plans. It helps to identify required installed capacities based on calculated portfolio allocations and provides valuable support for investment decision makers.

References

H. M. Markowitz. Portfolio Selection. Journal of Finance, 7(1):77–91, 1952.

W. F. Sharpe. Capital Market Prices: A Theory of Market Equilibrium under Conditions of Risk. Journal of Finance, 19:425–442, 1964.

S. Awerbuch and M. Berger. Applying Portfolio Theory to EU Electricity Planning and Policy-Making. IEA/EET Working Paper, 2003.

B. Krey and P. Zweifel. Efficient Electricity Portfolios for Switzerland and the United States. Working Paper No. 0602, 2006.

IEA. 30 Key Energy Trends in the IEA and Worldwide. 2005.

NEA and IEA. Projected Costs of Generating Electricity. 2005.

Swiss Federal Office of Energy. The Energy Perspectives 2035 – Volume 1 (Synthesis), 2007.