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PROBLEMS OF GENERATING UNITS PLANING IN THE ELECTRICITY MARKET ENVIRONMENT

Prof. dr. sci. Ferdinand Gubina

1. Introduction

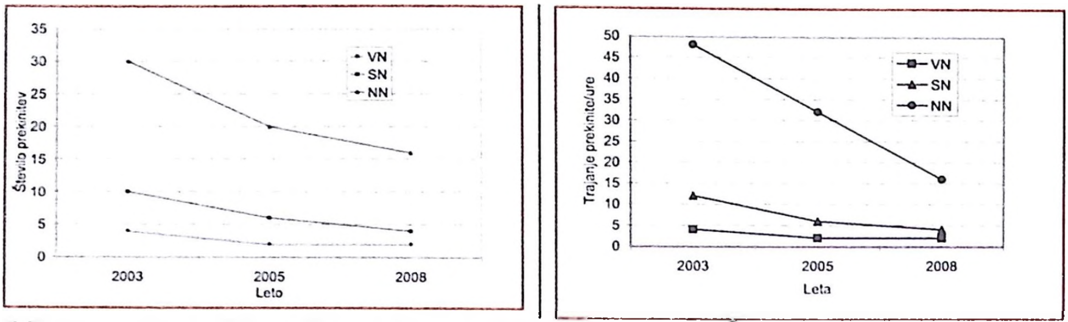
Power system expansion planning has experienced a drawback in the era of electricity market introduction to electric energy industry. Deregulation has brought about horizontal industry organization structure organizationally decoupling generation from the network in order to eliminate the natural monopolistic mode of operation. Independent system operator (ISO) absorbed that monopolistic characteristic and, additionally, ISO took the responsibility to oversee the needs for development of generation and transmission to ensure satisfaction of the users' needs and security of power system operation. On the other side, regulation of quality of delivered energy and other decisions concerning adequacy of system have been entrusted to a regulator independent from the government. That arrangement was bound to fail with respect to the power system expansion planning since both of these actors lacked the executive power to enforce expansion of energy production units as well as network expansion with growing consumption.
Vertically organized power companies split and converted into horizontal organizations containing generation companies (GENCO), transmission companies (TRANSCO), distribution companies (DISCO), and nonprofit ISO's. To increase competitiveness of GENCO-s in the market, these companies merged gradually to large entities and occasionally abused their market power. Although entering of independent power producers to the electricity market was expected that did not happen apparently due to high investment cost, high investment costs, and long construction times of new generating units, and price uncertainty after that period.
Existing energy market models exhibited even more flaws causing severe perturbations in power system operation including the increased number partial and total black-outs. The power networks operated closer to their limits, but expansion was not following due to lack of investments and long times to obtain new right of ways. Decreasing quality of electricity supply made it inevitable that the governments had to intervene in the power system markets to ensure required electricity quality for their industry and domestic customers.

Prof. dr. sci. Ferdinand Gubina
University of Ljubljana, Slovenija

Following deregulation, privatization of power generating sector quickly entered the scene and, in some cases, created additional problems. A lot of attention of power and other energy companies were drawn to the possibility to buy generation and distribution companies with exception of transmission networks. New generating companies formed buying out smaller enterprises, especially in the economically weaker countries. The monopoly problems and national resentment made governments to interfere in the process. Privatization is therefore still a hot issue due to its application to the basic country's infrastructure supplying electricity to the industry and domestic consumers.
Restructuring of the electricity supply industry has changed the previous paradigm of generation expansion planning based on the least cost and central decision process. Different market participants operate the power system segments and optimize their own profit based on the relatively short-term economic analysis horizon. They tend to evaluate their own expansion strategies in the same scheme. The long-term generation expansion planning is therefore characterized by structural change and strategic behaviors of market participants.

2. Electricity supply requirements

In spite of deregulation and privatization, the basic requirements of electricity supply remained practically the same except for ever increasing quality requirements due to more stringent needs of industry operations. The electricity market does not deal with these problems although it has been initially expected that it will solve all such problems. The growth of electricity demand endangers the balance of supply and consumption, which has to be met at each and every instant. Unfortunately, electric energy can not be stored efficiently to be used in case of temporary production shortage. Therefore, frequency control has to be maintained independently from the energy market by ensuring a solvent power reserve market. Similar appears the need for maintaining the adequate voltage profile across the network and sufficient reactive power reserves, which have to be sufficient and spatially distributed.
Along with others, these tasks remained unchanged from the previous vertically organized system for the ISO to deal with. Moreover, new ones originated from the market control problems as for instance from power balance demonstrated as a difference between contracts and actual use of electricity, measurement and billing, observation of environmental limits, and from an increased need for security check of power flow in the network for potentially critical states detection etc. Their detection requires extensive calculations for each market trading time interval since the networks have been pushed to operate close to stability and security limits.



(NN-low voltage, SN medium voltage and VN high voltage, Število prekinitev= Interruption mumber, Trajanje prkinitev=interruption duration/hours)

Fig. 1. Planned CAIFI and CAIDI for the Slovenian power network

The quality standards represent limitations on operation and additional requirements to expansion planning of production units as well as to the transmission and distribution network expansion and are increasing steadily. For instance, the required adequacy risk indices like loss of load probability (LOLP<10h/a) and energy non served (ENS<0,3%) are pushed down by industry. Similarly, the indices denoting quality of delivered energy on the distribution side, like customer average interruption frequency index f_{CI} (CAIFI) and customer average interruption duration index T_I (CAIDI) are targeted to reach lower values, as shown in example in Fig. 1 for Slovenia.
The black-outs resulting usually in huge economy losses are becoming of primary concern of the power system operation security. They result in lowering the system adequacy due to lack of investments in transmission networks and of nonsystematic planning of generation units. A rush in building the extensive wind parks with a large share in power production and with their volatility of power production became a problem of power system control. Better control centers and more complex means of power system control are sought along with careful expansion planning of new generation units and transmission lines.

3. Effects of electricity markets and privatization process

3.1. Public versus private ownership in the energy sector

Electricity market models used throughout the power industry suffer from various defects resulting in shortage of production and transmission capacities in the long range. The market gives insight into the future energy needs only for a day in advance, while in developed and functioning power exchanges, the forward markets can predict prices for up to six years ahead, a bare minimum in the planning horizon. The generation companies were preoccupied with windfall of profits following the surplus of generation from the regulated era, exploiting the existing infrastructure for financial gain. It took governmental bodies more than a decade and generation shortage situation with spiking energy prices to notice the generation shortage phenomenon and realize the need for action.

For that reason, the idea of *capacity markets* emerged. Their main problem is nature of the power system expansion. It is easy to build simple and cheap gas units what happened, for instance, in the USA after the first power shortages plagued the electricity industry. The operating costs including fuel made them soon unattractive and they were for sale as soon as there were cheaper conventional generating units became available.

Unfortunately, a large time span is needed to implement an expansion plan and to build cost effective generation units. From a country's as well as from a large production company's standpoint, several criteria have to be followed including diversification of fuels to keep the security of power supply satisfied, observation of the environment constraints, and risk management. Large lag times in conventional generation units in construction ranging from five to over ten years plus planned pay back time combined with very high costs of construction, increase the financial risk of the investment in generation projects, which is a high burden even for larger power companies. That is why new smaller independent power producers have refrained from entering the electricity markets.

Moreover, the role of governments was overlooked when designing the electricity markets since the regulator and ISO jointly lack the executive power to enforce generation unit's expansion. Electricity markets operate on a country's given transmission and distribution network infrastructure, transport infrastructure of rail, rivers and on a given energy natural resources. At the end of the day, the government has to ensure that the infrastructure is there for functioning of electricity market at all times regardless of the players in the market. The vital infrastructure in country's economy is therefore of basic importance for well being of a country's economy and population.

Privatization is a code word in many countries when discussing the electricity markets. In many smaller countries it is advertised that energy systems should be privatized immediately after opening the market. It is necessary to emphasize, that the notion that private companies are more effective in electricity markets than the government owned ones is simply not always true since there exist large very successful power companies which are government owned. The company's success in the market depends largely on a good management team and on minimum political interference in its management.

Declared goals of privatization are to increase efficiency of company operations in the market, which eliminates less successful companies. The governments sell some entities to private investors to reduce the public debt. Some governments want to reduce their responsibility at managing and interfering in these entities. Dispersing the ownership and ownership of employees may be another goal of privatization. Another form of partial privatization is a concession for exploitation, and Build - Operate - Transfer system.

Shadow side of privatization may emerge in the following: exploitation of market power, weak interest of private sector for production of goods and services with small profit prospects, reduction of workforce, and attempts to squeeze money from public funding.

The most important appears that the private ownership leads to actions which are contrary to interests of the public. Private companies are interested to optimally use the infrastructure to make profit and in that sense to spend minimum for its maintenance and expansion. If they possess the infrastructure it can happen that they exploit it to its economical limit and then abandon it like an obsolete plant. That should not happen under any circumstance to the energy supply infrastructure. In case it happens, though, the government must intervene and reinvest at least the money obtained at the sale of that particular infrastructure, losing money in long term in that kind of operation. That has happened and has been experienced outside of the area of energy systems, as for instance in the public transport systems, too.

3.2. Role of existing generating units infrastructure in expansion plans

Generating power companies entered the electricity marked with certain portfolio of power plants. They shortly experienced their advantages and deficiencies in biding in the market. It is natural that they tried to improve the portfolio by refurbishing and upgrading their units or closing them down permanently and by acquisition of new ones. Some power plants were obsolete or did not meet the environmental criteria, which required additional funding to meet them. If these plants had to operate they were classified as a stranded investment. Those plants could be helped by giving them an opportunity to sell their energy at a higher price. The difference in price was forwarded into the power system operation costs together with the costs of power system control. That help was extended to them for a certain period to remunerate the capital loss.

In Slovenia, the experience with the 120 MW Trbovlje thermal power plant (TPP) was characteristic. Its burnt coal from a neighboring mine with a high content of sulfur and a very high chimney was built (360 m) along with the sulfur scrubbing plant. It had to be listed as a stranded investment. Since it had chronically mechanical troubles with the turbine it was earlier decided to build a new power plant. However, the public turned against it and the plan had to be scrapped. After some years, the situation in the marked changed along with the shift in the public opinion and a new power plant is planned with a considerably increased power to 350 MW burning with low sulfur content imported coal or its mixture with domestic coal.

Companies with generating units in bad condition have to make the decision to sell them out, close them down or to refurbish them. Their decision is based on the plant condition and the projected prices in the electricity market. Usually, it is better to refurbish a plant since the electricity prices are ever raising due to lack of new investments. However, the obsolete plant with main components in a bad shape is bound to be shut down. Those with low efficiency grade could be used for a shorter time as peaking units or as a replacement reserve capacity.

Similarly, the power plants using renewable energy sources (RES) have to be predominantly subsidized. Their product has been classified as "green" energy and, in turn, offered in the market to the consumers. There are several system of support of RES in place in the EU, including feed-in tariffs, tradable green certificates coupled with quotas, tendering, and subsidies that are currently used to support implementation of new RES technologies.

Among the most aggravating problem in generation planning is to find a new site for a coal or nuclear power plant due to the local population protest (Not In My Back Yard - NIMBY syndrome). It may be met in case of refurbishment of hydro power plants (HPP), too. In Slovenia, such a case is the Moste storage HPP, which needs urgently to be refurbished and upgraded since its machine house is subject to sliding the plant has low efficiency due to inadequate intake pipe parameters and since the storage was contaminated by toxic byproducts of a nearby steel plant. The process was practically blocked by public opinion mainly due to bad communications with the public and due to particular local interests.

A problem is the potential HHP-s on the Soča River. In reason is that the Soča River is an environmental pearl. Its upper part is a nature protected region. However, utilization of its tributaries is explored for potential HPP-s.

Another problem is the HPP-s on the Idrijca River, where a large Trebuša storage HPP of 200 MW could be built. Although the site has been reserved for that project for decades, it with time became unacceptable due a too high dam and its public rejection. An alternative was offered with two HPP-s and total of 150 MW installed capacity, but was practically stranded by public opinion so far. In turn, unacceptable run of river small HPP-s have been offered by environmentalists as a counter-project.

As a conclusion, the potential power plans should be carefully prepared beforehand by early information properly and gradually presented to the population. It should be showing strengths and weaknesses of the project.

Some prospects for remuneration should be given to the local population solving their local and personal problems, too. The compensation negotiations should encompass all segments of the population, which is normally not interested in power plants, power system needs or power company's plans. Actually, the idea has to be successfully "sold" to the public.

4. Power system planning under uncertainty

Integrated resource planning has dominated in electric power industry before the era of deregulation. Scenarios of resources were compared with respect to the present value of costs taking into account numerous constraints of technical, power system, social and of environmental nature. The WASP program, for instance, utilized probabilistic estimation of system production costs, non served energy cost, and reliability indices. It assessed optimal dispatch policy satisfying exogenous constraints on environmental emissions, fuel availability and electricity generation by some plants, searching for optimum of alternative system expansion policies on the costs basis. The approach yielded the best solution for a company or the whole country with integrated power system.

4.1. Scenarios and parameters

The essential part of generation planning is preparation of credible scenarios of generating units. Although there are usually several production companies, the generation and network planning are of national economy interest, too. The scenarios have to observe the national resources and security of imports of primary energy to ensure diversity of fuels and to exploit available sites. A good insight into the possible generation mix is needed. Conventional generation encompasses fossil fuels (lignite, hard coal, gas, and oil), hydro power with storage hydro and run-of-river hydro, pumped-storage, the nuclear power, renewable generation (other than hydro), wind, photovoltaic, geothermal, biomass, biogas, waste, etc.

The basis for a good generation expansion planning is a long range prediction of load growth. The best approach gives a long range scenario approach separate for industrial segment consumption growth assessed by experts for each of the segment and than observed a whole. The total load growth is usually in the range of (1-3) %/a, lower value for mature economies and upper values for the growing ones.

Fuel	LOW €/GJ	HIGH €/GJ
Gas	4.31	5.54
Coal	1.59	1.65
Peat	2.64	3.12

Tab. 1. Fuel cost scenarios

The future fuel and electricity prices are important to forecast although it is a formidable task due to their daily and long range volatility. The values given in Table 2 nay be used, but they have to be projected changing in the planning time span since the economy of different countries may influence them by having different growth rates.

Another problem may be the question of CO_2 emissions. Sequestration of CO_2 has not found a satisfactory solution yet. The values of the CO_2 emissions can be evaluated in the scope of the EU Emisison Trading Scheme (EU ETS). Although they have been exhibiting a considerable volatility in their first trading phase (2004-2007), in the EU ETS second phase (2008-2012) the national quotas have been much more stringent as to permit CO_2 coupon prices only above the 25 €/tCO_2 mark. Still, these costs are mainly expected to be transferred to the electricity prices.

Similarly, the production costs of different generating units have a wide range as shown in Fig. 2. The cost of nuclear units is the lowest and significantly influences the environment constraints regarding the CO2 emissions. The biogas has different structure, but its technology price still needs some sort of support mechanism to be competitive.

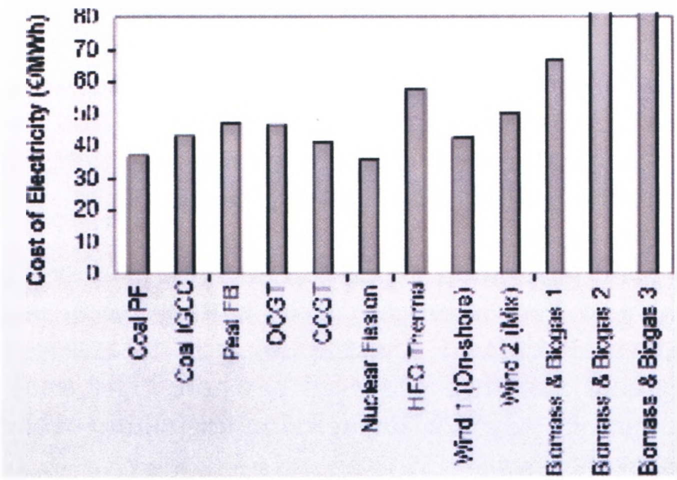


Fig.2 Generation costs

Capital costs of different units are important for composing the scenarios. Table 2 illustrates a set of parameters for different generating units. An important factor is availability of power production of the generating units since it influences the position of a unit within the load diagram. The efficiency of units varies and construction times may vary, too.

Plant Type	Notional Size of Installation (MW)	Plant Life (Years)	Build Time (Years)	Average Efficiency (%)	Capital Cost (€/MW)	Op & Main (€/MW p.a.)	CO_2 Emissions (Tons Co_2/MWh)	Availability (%)	Resource Limited (MW)
Coal PF	1000 (3 x 333)	30	4	37	1,479,200	34,800	0.92	84	-
Coal IGCC	800 (2 x 400)	25	5	48	1,761,321	69,000	0.71	84	-
Peat FB	150	25	4	37	1,223,807	55,200	1.15	87	1000
OCGT	110	20	1	43	518,411	35,000	0.47	92	-
CCGT	390	20	2	56	537,500	50,000	0.36	88	-
Nuclear Fission	1000 (2 x 500)	30	5	-	1,999,758	59,500	0.00	88	-
Wind 1 (On-Shore)	30 (15 x 2)	20	2	-	981,475	34,800	0.00	-	1200
Wind 2 (Mix)	30 (15 x 2)	20	2	-	1,028,775	54,250	0.00	-	2600
Biomass & Biogas 1	10	20	2	-	2,418,750	80,000	0.00	78	70
Biomass & Biogas 2	10	20	2	-	3,386,250	90,000	0.00	78	50
Biomass & Biogas 3	10	20	2	-	4,353,750	90,000	0.00	78	500

Tab.2 Plant parameters and utilization

The minimal construction time figure is given for a nuclear power plant, but its implementation time in practice may be even doubled due to various obstacles like its acceptance in public. The CO_2 emissions are unit dependent and so is the plant life. The costs of construction, operation, and maintenance vary with different power plants and technologies.

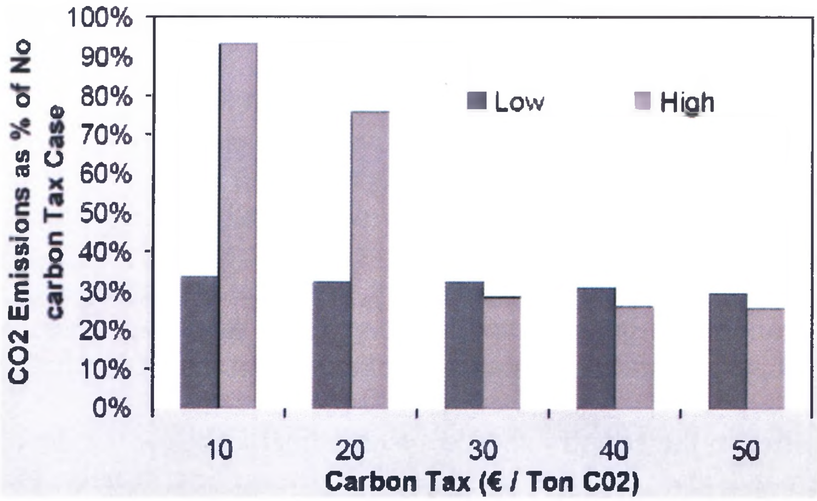


Fig. 3 Effect of Carbon tax

Due to volatility of these parameters, a sensitivity analysis should be performed to get a credible range of scenarios in the optimization process. Fig. 3 shows the influence setting of various CO_2 emission tax on emission itself and Fig. 4 demonstrates the effect of nuclear plant entrance on the CO_2 emissions.
When choosing a scenario, it is important to note that while natural gas based system may result in high volatility in fuel prices, wind generation and biomass may offer limited help to supply consumption. The coal technologies are still important for a supply scenario composition. The green glass house effect revived the nuclear option as a solid part of scenarios contributing to CO_2 reduction significantly. Effect of a nuclear plant in the scenario is demonstrated in Fig.4 regarding the CO_2 emissions.

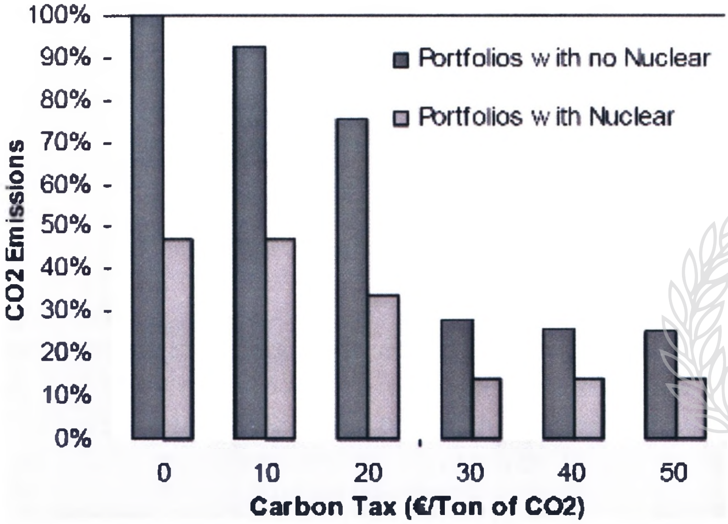


Fig. 4. Effect of nuclear plant on CO2 emissions

Generation companies are facing difficulties, which are significantly impactting their investment planning. Among them are relatively long lead times in generation construction, environmental constraints, lack of suitable locations, inadequate national energy plans, which may grossly underestimate the future energy needs or do not foster sufficient investments in expected national generation mix diversification. Generally, the market participants do not get adequate economic signals from the long term markets, which add to the uncertainties in generation expansion planning of an individual generation company.
The authorities in the country should systematically follow the development of energy demand and mitigate market failures, giving timely incentives to ensure the security of supply and expansion plans implementation. Monitoring

of generation adequacy has been a significant issue for not only the public authorities but also for the market participants.

4.2. Expansion planning models and methods

Generation expansion planning is a complex process which has to take into account the power system operation and maintenance costs, credible development scenarios, estimated energy consumption growth and several limitations, as for instance the environmental limits including emissions and their costs, technical parameters of various generating units, site limitations regarding the inflow of fuel etc. The process has to follow the estimates of reliability of supply as shown in Fig. 5. Both aspects of supply are important, generation adequacy and network adequacy along with security of the network operation.

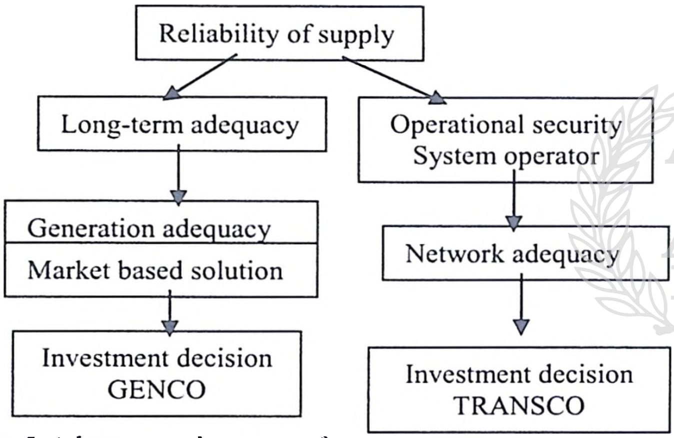


Fig.5 Adequacy planning of a power system

The deregulation and market environment introduced an important new element of risk associated with decisions of the competition in the market and with needed generation adequacy planning. In a competitive auction market for long-term electricity contract, the bidding results critically influence the determination of generator loading priority list, and the expected investment payoff, both of uncertain nature. Moreover, the investor (GENCO) can not obtain full set of information on other competitor's decisions. A Monte Carlo simulation could be used to achieve the profit probability distribution of the GENCO's investment.

For risk management, roles and responsibilities should be clearly defined amongst stakeholders, including regulators, system operators, government and commercial market players. Regulatory uncertainty for investors is created due to a lack of decisions in these areas. Clear and credible long-term policy

decision gives the power to the government to reduce a significant cost caused by this uncertainty.
A risk assessment tool called Conditional value at risk (CVaR) Fig. 6 can be applied to manage the risk of the generation expansion project where the sum of capital investments, operation and maintenance costs of a unit, energy and operational constraints are a basis of generation expansion planning. It is a coherent risk measure based on the standard deviation of normal planning parameters distribution. It gives the investors an intuitive criterion for making an investment decision. Due to its complexity, the model requires solving large-scale programs.

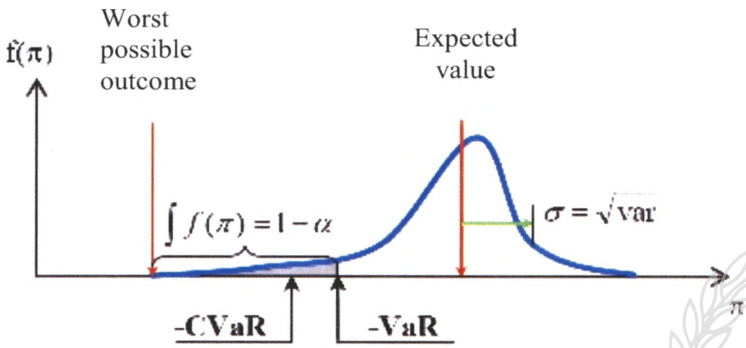


Fig. 6 VaR and CVaR scheme

Using the uncertainties of bids for long-term contracts in the electricity market, the probability distribution of the surplus on bid price over marginal cost are obtained and the distribution of expected generated energy for a given period can be achieved to calculate the profit of a generation company.
A more advanced program of capacity adequacy planning of a power system includes two dimensions in reliability of supply. One is the long-term generation and transmission adequacy, which is concerned with the sufficient and timely investment at proper site with the right technology. The other is the security of system operation in the short-term, which should ensure the continuity and the quality of supply in operation.
The generating companies (GENCO-s) as independent entities in the competitive market environment (agents) could plan for their own generation investment separately. In the process of simulation, they as agents are learning how to behave in the market environment. The decisions are based on the profits of investment which are conditioned by the company's exposure to risk. Reliability index used in this analysis is expected non served energy as this index integrates duration and magnitude of load loss.

The procedure may use a complex-adaptive systems approach to represent agent learning and adaptation as in Electricity Market Complex Adaptive System package (EMCAS) [9]. It deals with the following tasks:

- Utility function characterization of agent objectives,
- Heuristic optimization for unit commitment,
- Demand response functions to reflect the consumer reaction,
- Transmission power flow analysis,
- Complex-adaptive systems approach to represent agent learning and adaptation.

With its simulation capacity and based on appropriate scenarios and model data, the program enables the following:

- Combines engineering techniques with quantitative market analysis where DC load flow is used to simulate the actual operation of the physical system configuration since AC power flow uses to much time;
- The market participants and agents to make individual decisions to maximize own utility profit using multiple objectives including risk exposure where they learn and adapt to results of previous runs;
- Simulation of markets operations with changing rules while analyzing the behavior of both individual agents and the system under different market configurations.
- Studying a market in transient conditions due to agent interactions and analysis of states with no equilibrium and the origins of system problems.
- The studies of power system expansion planning have to compare different scenarios. The results of cost comparison give results like those in Fig. 6. As seen from the figure, the comparison is made in the form of prices depending on their standard deviation. The decisions depend on the accepted company's of degree of price risk exposure.

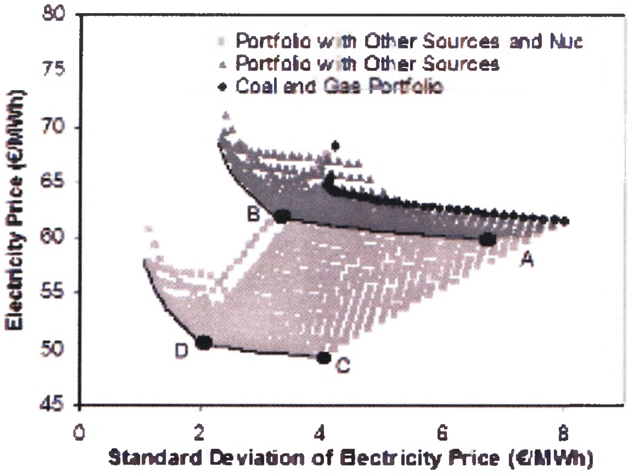


Fig. 6 Comparison of different portfolio scenarios

Profit-driven companies tend often to sacrifice the system security for commercial objectives, therefore coordination and cooperation between the market players and interconnections is needed and, therefore, simulated in the program. To rebuild the responsibility chain of competing companies for reliability and security in power system operation to ensure the balanced and consistent expansion development becomes a complicated task.

5. Social benefit and environment degradation

Expansion planning and its implementation bring about growth of social welfare and, inevitably, some adverse effects to the environment. Firstly, it increases the social benefit by improving the quality of delivered electrical energy to the consumers, especially to the industry which fosters new generation capacity in the field of RES. If a satisfactory level of prices is reached they enable development of new products and services. Centralized point of power system expansion planning may contribute to the best way for risk management in some areas on behalf of welfare of society.
Construction of new power plants brings improvement to social welfare and to the environment by employment of additional workers and by support of the community needs by a new power entity. An investment cycle of series of new power plants may significantly improve the gross national product due to wide range of activities spurred by the expansion plan implementation. In the deregulated market, it introduces new players, which may lead to stabilization of prices and to their lower volatility.
Electricity is of vital importance for industry and society, its application to industrial processes is inevitable and is ever growing. In case of surplus of power after successful investment cycle in a country, electricity may be exported occasionally or under long term contracts, usually with good economic results. The reason for that lies in the fact that it is difficult to obtain new sites for generation units. That is well demonstrated in the French case with their long term exports of electricity.
An important task has to be addresses in the field of efficient energy use. That produces **NegaWats** (Negative Watts), ie. reduction in MW of planned power due to better utilization of energy in transport, industry and in households. Moreover, its potential is in saving a lot of investment costs and, correspondingly, it contributes to nature conservation.
Secondly, the environment should be protected to certain extent against excessive usage. In Slovenia, the Natura 2000 covers the vital parts of territory that should be protected for some reasons to pass on the heritage to our grandchildren.

That is why the adverse effects to surroundings have to be considered by utmost care with the aim to minimize them to the highest degree. Since it is hard to obtain new construction site in Slovenia, the public has to become convinced in need of implementation of the selected and approved scenario. For that purpose, a lot of complimentary studies of environment before and its potential changes after the building of a new generating unit have to be performed. Nature degradation should be carefully assessed. The conesquences of potential dislocation of population, flooding of fertile soil, loss or indigenous flora, waste deposition, risk of soil and air poisoning have to be carefully analyzed and evaluated before and after implementation of the planned projects. Countermeasures have to be devised and all technical possibilities employed to minimize the side effects.

Local population is an important factor in that process. Remuneration scheme has to be modeled for disadvantages for environment changes that the population is potentially exposed to after implementation of a generation expansion plan. It has to be assessed, explained, and clearly laid out to the public. A possible individual treatment should be foreseen, too. Of course, the process must be carefully handled and a sufficient time for that has to be foreseen.

6. Conclusions

After restructuring of the electricity supply industry, the power systems are operated by several market participants. That has changed expansion planning from the least cost and central decision process to a risk management process where these companies seek their own profit based on the risk management and economic analysis. The long-term generation expansion planning is therefore characterized by structural change and strategic behavior of market participants.

Considering the process of expansion planning in the market environment and in the privatization aspect, the following conclusions may be drawn:

- Analysis of economy strategic development, load prediction, diversification prospects, quality of delivered energy, strategies and risk exposure of companies have to be carefully prepared for scenarios and assessed for the expansion planning decisions;
- The governments should constantly monitor the adequacy of generation and transmission network along wit quality of delivered energy by distribution companies in order to perpetuate the needed expansion activities in the market at the right time since the implementation requires long time and a lot of investment capital.
- Wide spread general notion that private companies are more effective in electricity markets than the government owned ones is simply not true

since there exist large very successful power companies which are government owned;

- The adverse effects to surroundings have to be considered by utmost care with the aim to minimize them to the highest degree. The expansion plans have to be well documented and supported with series of public hearings including involvement of civil society organizations.

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