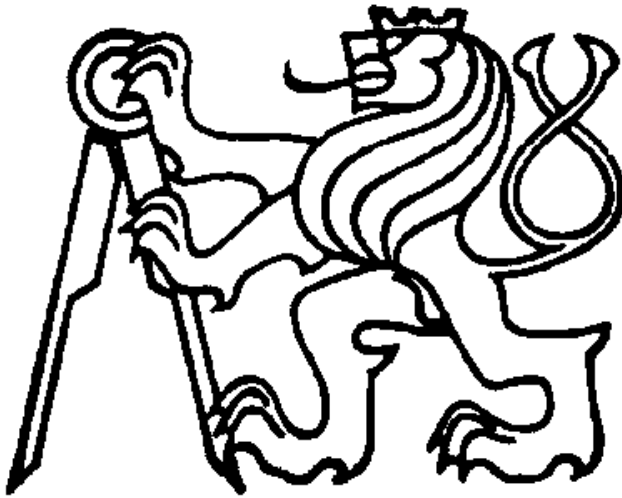# CZECH TECHNICAL UNIVERSITY IN PRAGUE

DOCTORAL THESIS STATEMENT

Czech Technical University in Prague

Faculty of Electrical Engineering

Department of Economics, Management and Humanities

Ing. Pavel Pavlátka

MODERN VALUATION METHODS IN THE ENERGY SECTOR

Ph.D. Programme: Electrical Engineering and Information Technology

Branch of study: Business Management and Economics

Doctoral thesis statement for obtaining the academic title of "Doctor", abbreviated to "Ph.D."

Prague, August 2015

The doctoral thesis was produced in *combined* manner

Ph.D. study at the department of Economics, Management and Humanities of the Faculty of Electrical Engineering of the CTU in Prague

Candidate: Ing. Pavel Pavlátka
Department of Economics, Management and Humanities
Faculty of Electrical Engineering of the CTU in Prague
Zikova 4, 166 27 Prague 6

Supervisor: Prof.Ing. Oldřich Starý, CsC.
Department of Economics, Management and Humanities
Faculty of Electrical Engineering of the CTU in Prague
Zikova 4, 166 27 Prague 6

Opponents:

The doctoral thesis statement was distributed on:

The defence of the doctoral thesis will be held on …………….. **at**...………
…**a.m./p.m. before the Board for the Defence of the Doctoral Thesis in the branch of study Business Management and Economics in the meeting room No.** …………… **of the Faculty of Electrical Engineering of the CTU in Prague.**

Those interested may get acquainted with the doctoral thesis concerned at the Dean Office of the Faculty of Electrical Engineering of the CTU in Prague, at the Department for Science and Research, Technická 2, Praha 6.

Chairman of the Board for the Defence of the
Doctoral Thesis
in the branch of study *(to be specified)*
Faculty of Electrical Engineering of the CTU
in Prague   Technická 2, 166 27 Prague
6.

1. CURRENT SITUATION OF THE STUDIED PROBLEM

The large investments in power generation assets motivate many players to realise proper power plant valuations. The energy sector has seen many changes in the past decade, mainly in the sectors of renewable resources, regulatory framework and energy markets development. The considerable impact could be also attributed to implementing smart metering and possible future changes to the design of the spot and balancing market. Because of this market development, commonly used valuation methods should take into account all of these impacts. Current valuation methods are generally oriented to the standard discounted cash-flow approach or are based on the real options approach. Both mentioned approaches have drawbacks and limitations regarding incorporating flexibility value, the technical aspects of power plants and the hourly structure of electricity prices that presents structural changes in merit order and electricity market. The most utilised current method of power plant valuation works with discounted cash flow that considers the long-term contracts forward curve and subsequently predicts electricity prices on the revenue side of business plans. Clearly this forward curve does not include the hourly granularity of spot prices, which are important for valuing power plant flexibility apart from the fact that a significant part of the electricity could be sold on a long-term contract basis as a standardised product. We assume that there exists an arbitrage-free condition that results in the neutrality between the hourly price forward curve and year base load contract. We therefore assume that the production optimisation by flexible power plants allows the asset holder to receive additional profit. Public literature [2],[6] that addresses the real options approach mainly considers the stochastic behaviour of electricity fuel prices, including technical specifications, as ramp rates and operational time constants. Nevertheless our approach additionally considers the non-linear heat rate curve that results in non-linear variable costs depending on the electricity output. Current research by Tseng [3],[4] notes correctly that option-based valuation can capture operational flexibilities and financial risks in a single framework. This literature considers the deterministic variable costs and stochastic costs of electricity and fuel. We assume and agree with the literature's presumptions that the above-mentioned approach is effective mainly for cycle gas power plants with very high ramp rates. However, this methodology does not involve optimisation based on a plant's specified ramp rate or non-linear heat rate curve. Moreover, the above-mentioned papers [1],[3] solves valuation in the short term without extension to the hourly granularity for long-term contracts. In our case, the option value that is resolved using the traditional valuation approach that is used in financial options is replaced by hourly price curve simulation and using a deterministic model of production optimisation.

2. AIMS OF THE DOCTORAL THESIS

The aim of this thesis is to investigate the problems of electricity markets and power plant valuation followed by formulating a method for optimising electricity production based on the spot market prices and technical parameters of the unit. For this purpose, the link between optimisation, valuation approaches and business approaches has to be established by a presenting method that aims to combine these concepts. Furthermore, an important aim of the developed concept is to incorporate operational flexibility, production limits and non-linear heat rate curve into optimising power production by considering hourly electricity price structure. Statistical modelling and the hourly price forward curve (HPFC) method are the basis for presenting the spot price structure and the valuation of power assets. This HPFC method is developed in order to enable deriving this forward curve from historical electricity spot price data in order to present the hourly structure changes. Our thesis presents a modified discounted cash-flow DCF method of energy asset valuation using the hourly price forward curve to fully integrate the structural changes in the energy market. Author´s goals for his thesis are as follows:

Description of energy industry and electricity market. For the deep analysis of the electricity market, it is necessary to describe electricity market development in the Czech Republic and the European Union, including the regulatory framework, with its considered impact on conventional power plants values. Moreover, this area of the thesis includes detailed descriptions of standard and financial commodity products and common approaches to hedging the open positions of electricity producers or consumers.

Description of the hourly price forward curve concept. The aim of this part of the thesis was to describe and develop a method of deriving the hourly price forward curve, which represents the spot hourly structure of long-term electricity contracts with the assumption of arbitrage-free neutrality with the long-term contract price. We conducted detailed research on hourly price forward curve problems and took into account similar approaches that are described in more detail in the state of art chapter. This concept and research are further considered in formulating an optimisation method. Structural changes in the electricity market are investigated and evaluated using the HPFC in order to determine its impact on asset value.

Description of valuation methods. For the purpose of the valuation model description, we conducted a deep analysis of the basic concept of the DCF method and the real option valuation method. This area of the thesis also describes the concepts of enterprise valuation. This theoretical background is necessary in order to be able to distinguish between different value concepts and to correctly formulate

our valuation model, which is described in detail in order to incorporate optimisation that includes the value of the source's operational flexibility.

Formulating the optimisation model and identifying the real impact of the method on valuation. The optimisation model was formulated and programmed in Wolfram Mathematica software in order to incorporate the technical aspects of the power assets and hourly structure of electricity prices into the asset valuation. A published chapter with a real case study demonstrates how technical and contractual market development impact power plant value. The main focus is on spot market electricity production optimisation. The case study assumes that the power plant is supporting grid services for TSO and selling residual electricity loads on the market.

Author´s hypothesis.

The author´s hypothesis is that the well-known DCF concept of power plant valuation using average mean value could underestimate the value of conventional power plants, with the possibility of output regulation flexibility.

3. WORKING METHODS

DCF concept with implemented optimisation
We first defined a model income statement of a thermal power plant that was prepared for the purpose of evaluating the business model. The main goal of this concept is to modelling the value of clean dark spread using a modern approach to electricity load valuation using the HPFC curve that is consistent with optimisation that considers the technical specifications of the power plant. The developed methodology separates part of the inputs that are valued by the optimisation algorithm into $EBITDA_{opt}$ (revenue, variable costs and some fixed costs that are independent of production volume) and the remainder of the income statement into $EBITDA_{res}$. For the purpose of the cash-flow calculation methodology, assume that:
$$EBITDA_{tot} = EBITDA_{opt} + EBITDA_{res} \qquad (1)$$
Inputs for the optimisation model that will result in $EBITDA_{opt}$ are as follows:

1. Total power and heat sales - the case study considers only GSS services and power production as a stand-alone without taking into account any residual heat produced or state subsidies.
2. Fuel costs - Fuel costs are incorporated into the optimisation algorithm by implementing the heat rate function.

3. Other fuel-related costs (limestone, fuel transport, cost of ash-off take) are solved by a linear function related to the amount of burned fuel in tones(GJ)
4. CO2 costs - linear function, CO2 factor related to fuel type (coal, lignite, gas)

The considered valuation method must be enriched by the operational flexibility value of the power plant in order to adjust production decisions to electricity price movements and the hourly structure of the electricity curve. The firm valuation method will incorporate only cash-flow variables from operations and CAPEX, which are clear from equation 2.

$$FCFF_{t,OPT} = CF_{op} + CF_{inv} \tag{2}$$

For the purpose of the developed model, valuation is CF_{op} set by equation 3 and 4.

$$CF_{op} = EBITDA_{opt} + EBITDA_{res}; t \in (0; t_{tradableCAL}) \tag{3}$$

$$CF_{t,op} = EBITDA_{t,PRE}; t > t_{tradableCAL} \tag{4}$$

This well-known method of NPV is described in detail in the thesis; nevertheless, it is necessary to further develop this method by incorporating the "plug-in" of $EBITDAt_{,opt}$ that is involved for the period $t_{tradableCAL}$ of tradable contracts at energy exchange. Another important step in discounted cash flow valuation is determining relevant cash-flow and revenue development for the non-tradable period that is involved in the valuation model as $EBITDA_{t,PRE}$.

Variable cost function implemented in the model

Selected drivers of the variable cost function of production electricity are costs for coal, other fuel-related costs and CO2 emission allowance costs. As was mentioned earlier, the model considers that there is an option to consume a specified volume of coal because of final electricity production; that is, the model works with fixed marginal costs for coal with no option premium or take-or-pay contract condition.

Furthermore, the model incorporates the efficiency curve of the electricity production considered as a downward-slopping efficiency curve with peak at 95% of the maximal installed capacity depending on power output. Equation 5 that relates the variable costs that are incorporated into the model is as follows:

$$f_C(P) = VC_{P\min} \times \left(1 + q_{var} \times \left(\frac{P - P_{ef}}{P_{max}} \right)^2 \right)$$

(5)

Variable $VC_{P\min}$ represents the minimal variable costs of function, where this variable is equal to the previously mentioned marginal variable costs $MVC(P)$. Variable P_{ef} is the output of the unit with highest production efficiency (it is supposed that this value will be at 95% of maximal output). Variable q_{var} represents the slope curve coefficient. The variable costs function of the considered coal unit with the above-mentioned assumptions is below in figure
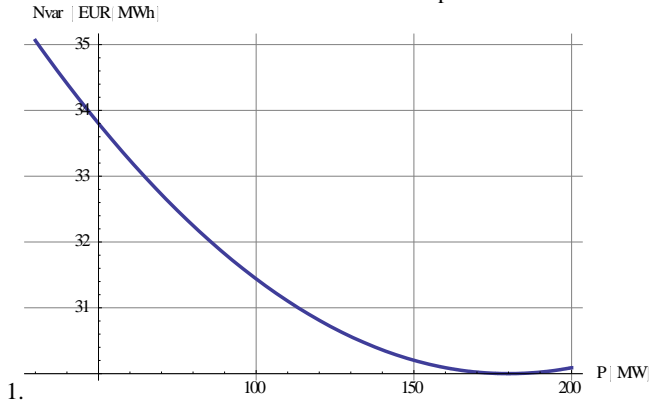

1.

Figure 1: Variable costs function

Optimisation method

The conjugate gradient methods are unconstrained optimisation algorithms that are characterised by strong local and global convergence properties. The basis for a non-linear conjugate gradient method is to effectively apply the linear conjugate gradient method but replace the residual with the gradient. A model quadratic function is never explicitly formed, so it is always combined with a line search method.

The first conjugate gradient method was proposed by Fletcher and Reeves [6] as follows. Given a step direction p_k, use the line search to find α_k such that $x_{k+1} = x_k + \alpha_k \cdot p_k$. Then compute equations 6 and 7.

$$\beta_{k+1} = \frac{\nabla f(x_{k+1}) \cdot \nabla f(x_{k+1})}{\nabla f(x_k) \cdot \nabla f(x_k)} \tag{6}$$

$$p_{k+1} = \beta_{k+1} \cdot p_k - \nabla f(x_{k+1}) \tag{7}$$

The above-mentioned method was applied in the case of finding the maximum possible profit from the output optimization. To ensure maximal speed and feasibility of the method, it is necessary to incorporate a penalization function. This penalization method leads to shorter computation time to evaluate the algorithm and also to run algorithm without Boolean if conditions replaced by the continuous smooth tangent functions. The algorithm works with the assumption that states and transition between them are not discrete but continual. Due to regulatory framework and technical parameters defined in the thesis, consider that power output during the business hour is defined by the integral of the load curve. Therefore, the algorithm works with three transition possibilities resulting in different computation of energy produced during transition state. Figure 2 illustrates the schema of transition state.
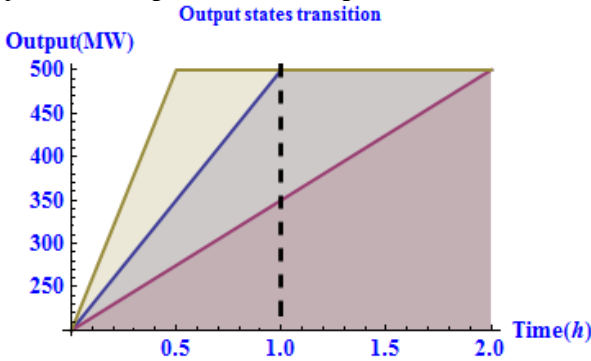

Figure 2: Output states transition

Finally, the common cost function results from the above-mentioned variable cost function defined by equation 5.The integral of the variable cost spent to produce power in a defined period with a specific heat rate is defined by the following equation 8.

$$VC = (P_{end} - RaT \cdot P_{end}) \cdot f_C(P_{end}) +$$
$$\int_0^{RaT} \frac{\left((RaT \cdot P_{start} + (P_{end} - P_{start})) \cdot t \cdot f_C\left(P_{end} + \frac{P_{end} - P_{start}}{RaT} \cdot t \right) \right)}{RaT} dt \qquad (8)$$

The key aspect of the presented method, as described above, is in the optimisation of fuel utilisation and profit maximisation. This method could be applied to any number of energy resources and commodities. From a more general point of view, the method is applicable to the smart grid concept as well. The methodology is applied to a power plant operation case study. The evaluation algorithm was programmed in Wolfram Mathematica software.

4. RESULTS

We describe and utilise the net present value concept enhanced by optimisation to fulfil the research goals and confirm the hypotheses of this work. We applied a systematic approach and developed a methodology for an hourly price forward curve and optimisation algorithm that was then incorporated into the DCF methodology, and all results were then verified by the author´s testing of the hypothesis. The HPFC optimisation model using the numerical conjugate gradient optimisation that was implemented in Wolfram Mathematica 9.0 considered the technical and economical parameters that were described in detail in the thesis in order to calculate the operating power plant's free cash flow and discounted profit.

The optimisation of energy production was tested with the above-mentioned technical and economic data for the period of one week. The result is presented in Figures 3. The one-week optimisation profile clearly indicates the impact of the price on the power plant output based on the profitability of the specific hours.
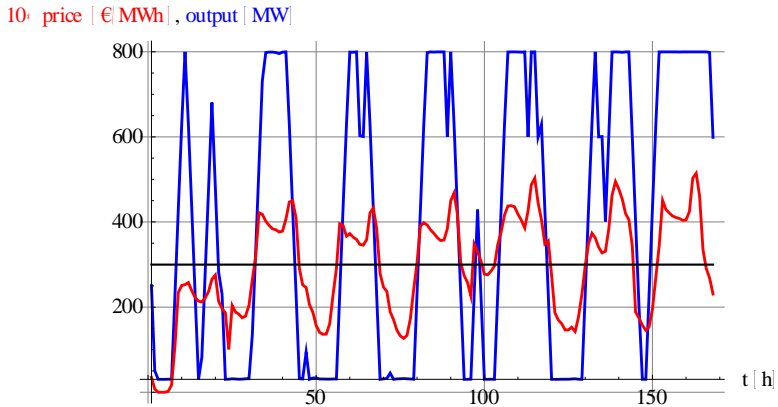
Figure 3: **One-week optimisation profile**

The free cash flow calculation of the optimised block is clear in figure 4. The net present value of the optimised unit is demonstrably higher than in the case of the standard DCF method. The optimised profit from the Mathematica model is indexed by the effective production rate, which adjusts the full capacity production optimisation to the real effective working hours assumption. The firm value is calculated, and the firm's first three years of free cash flow result primarily from the Mathematica optimisation; price prediction is also considered. The reason for such a great discrepancy is that optimised production does not include possible loss from the hours with spot prices that are lower than variable costs.

This result confirms that the valuation method that incorporates production optimisation embodies additional value for the operational flexibility of the source.

Free cash flow calculation		2015	2016	2017	2018
Mathematica optimization					
Revenues total		143 553 354	140 442 564	137 538 229	138 675 857
Revenues from the sales of electricity		135 301 434	132 355 682	129 613 085	130 909 216
		8 440 950	8 440 950	8 440 950	
Revenues from ancillary services		8 251 920	8 086 882	7 925 144	7 766 641
Operating costs		**-141 215 399**	**-139 184 614**	**-137 176 300**	**-137 403 690**
Coal consumption		-97 564 500	-92 496 214	-90 449 838	-91 345 381
CO2 costs		-29 321 384	-29 321 384	-29 321 384	-29 614 598
Other fuel related costs		-6 829 515	-6 829 515	-6 829 515	-6 829 515
Personal costs		-2 500 000	-2 537 500	-2 575 563	-2 614 196
Other fixed costs		-5 000 000	-5 000 000	-5 000 000	-5 000 000
Provisions for general overhauls	(cash deposited)	0	-3 000 000	-3 000 000	-2 000 000
Income tax		-1 594 645	-986 163	-948 201	-89 712
Change in working capital		0	0	0	0
Cash flow from investments - General overhauls		0	3 000 000	3 000 000	2 000 000
Free cash flow		7 598 225	5 004 169	4 842 330	1 182 456
Discount factor		0,909	0,826	0,751	0,683
Discounted Cash Flow		6 907 477	4 135 677	3 638 115	807 633
Valuation assumption WACC	10%				
Net Present Value 20y	27 248 194,30 €	1	2	3	4
NPV 2013-2015	14 681 268,09 €				

Figure 4: Firm value of optimised production

As it is clear in the previous figure, optimisation has very considerable impact on the power plant's value. Moreover, Figure 5 presents the important relationship of ramp rate and average energy asset profit in €/MWh. Based on this visualisation, it is obvious that increasing the unit's ramp rate has considerable and positive impact on energy asset value.
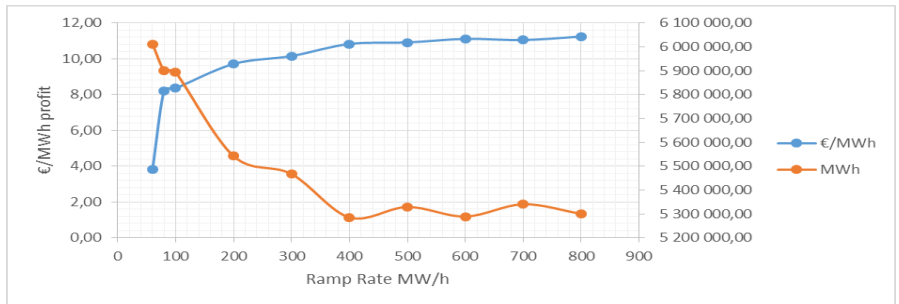

Figure 5: Ramp rate vs. profit and production

The optimisation algorithm was also utilised to calculate production profitability related to the different electricity spot price structures in 2005 and 2013. Implementing and constructing the HPFC curve were based on our developed method. As is clear from Table 1, the result of the optimisation that used the 2005 structure gives a higher asset value than that in the 2013 structure, mainly because the 2005 peak load hours showed a more stable pattern.

Table 1: Different HPFC structure impacts

Ramp Rate +/- [MW/h]	RR in % of Pmax	Profit €/MWh	€ Profit	MWh	HPFC structure
100	13%	10,96	50 680 300,00	4 624 307,77	2013
100	13%	11,97	55 339 500,00	4 624 307,77	2005

5. CONCLUSION

Our method appears to be exploitable for energy asset valuation. The developed and presented method identifies the additional value of operational power plant flexibility with verified results. The optimisation method was utilised to perform calculations with limited technical restrictions because of the required feasibility of the gradient optimisation algorithm and the demanding computational time for the yearly spot structured curves. Contemporary development of energy markets requires valuation and optimisation tools that are enhanced by technical flexibility and other specific aspects of energy assets. As it is clear from the presented research on energy market specifics and the production optimisations that were conducted on different hourly price forward curve structures considering different years structure between 2005 and 2013, energy market quote structural changes were likely attributable to the massive implementation of renewable resources. These structural changes, in light of the developed optimisation algorithm, have considerable impact on energy asset value and everyday operation. Moreover, the operational flexibility of energy assets is the important driver of value. Nevertheless, it is necessary to also consider other technical aspects of such a cycling power plant with the impact of decreasing its lifetime and effective production time. Each aspect and driver of the asset value was considered from the systematic viewpoint, but nevertheless, some of the above-mentioned technical limitations were omitted in order to simplify the optimisation algorithm. Computational time of the algorithm considering all technical aspects could be very long, and incorporating discrete functions into optimisation algorithm will seemingly complicate this process.

We assume that future low-carbon energy power systems and smart grids will favour resources that have low marginal costs and provide system flexibility, including the ability to cycle on and off to follow rapid changes in spot and balancing market.

Description of the energy industry and the electricity market

The actual situation focused primarily on renewable energy resource implementation and smart-grid integration. These innovative trends are rapidly changing energy markets and each energy asset valuation must consider this development. From the spot price market behaviour, it is clear that there is a gradual change in daily and seasonal price patterns, likely because of the increased production from renewable resources. The most important difference for energy asset valuation is the difference between the base load and peak load hours and electricity spot price volatility.

Description of the hourly price forward curve concept

We utilised systematic research on the hourly price curve concept in order to develop a simplified method of hourly structure indexation without incorporating weather or other stochastic variables. The presented method is based on the market price of calendar year electricity contract indexation with respect to the historical structure of spot prices. This method allowed the optimisation model to valuate production flexibility based on the clean dark spread profit during a particular hour of the year. The reliability of the HPFC curve was tested by calculating the day-to-day differences in order to confirm the hypothesis.

Description of the appraisal methods

We gave detailed descriptions of the main aspects of enterprise appraisal with emphasis on the discounted cash-flow (DCF) method. Based on the research, it is very important to consider all relevant drivers that have considerable impact on asset value. Generally, it is very important to choose a value computation method that enables incorporating all specifications of the considered asset. For the purpose of this thesis, it was assumed that the main specifications in the case of energy asset valuation are linked to the stochastic behaviour of electricity prices and the technical aspects of power plants that differ in flexibility values. As was already mentioned, net present value as it is commonly used could considerably underestimate the asset value, but with the real option method, it is more complicated to incorporate the technical specifications of power plants, especially with the implemented non-linear heat rate curve and output optimisation.

In order to meet all requirements of valuing the operational flexibility of energy assets, a DCF concept was developed and enriched by energy production optimisation

Formulating the optimisation model and identifying the real impact of the methodology on valuation

We described all input technical and economic data that were necessary for the valuation and optimisation models. The numerical conjugate gradient optimisation model considered only the influence of minimal and maximal output with ramp rate and evaluated the non-linear variable cost function on every level of output to maximise the possible power plant profit. The model was tested in two separate ways in order to confirm the hypotheses.

Author´s hypothesis

Our research on the global hypothesis that the well-known DCF concept of power plant valuation using average mean value underestimates the value of conventional power plants with the possibility of output regulation flexibility is based on the synthesis of the research linked to sub-hypotheses that solved two coexisting drivers that were separately tested. Other factors could affect the global hypothesis, but we selected the two above-mentioned hypotheses as key elements of the research. The hypothesis was confirmed by deduction from the results that were calculated with the valuation model, which was based on quantitative research.

As it is clear from the thesis goals that were achieved, the impact of net present value optimisation based on the hourly price forward curve is visible and considerable for appraising energy assets. As it was presented in this thesis, the difference between standard NPV calculation and optimisation calculation for a specified period was considerable. Our hypothesis that the well-known DCF concept of power plant valuation could underestimate the value of conventional power plants with the possibility of output regulation flexibility is confirmed by numerical results. Furthermore, the positive relationship between ramp rate and unit value that was presented in our work confirmed the hypothesis as well. One reason for the energy asset value underestimation is the absence of hourly structured long-term electricity contracts that project the hourly price structure of electricity to the value of the energy asset. This is confirmed by the numerical results in thesis. It is clear that the structure of the HPFC has an impact on the optimised power plant production and therefore on asset value as well.

The case study confirmed the assumption that implementing RES slightly modified the curve's structure and led to higher volatility in the spot prices during peak-load hours. The statistical test and histogram in chapter 4 of thesis support the idea that year electricity forward price structured with hourly granularity based on real historical data by the indexation method is consistent and reliable for valuing any structured electricity load. The HPFC computation was tested by day-to-day differences, and the result was that 80% of the data sample showed differences lower than 15%. The computation of HPFC based on the developed methodology followed by comparison with real data showed that this method is reliable. The results for the Mathematica algorithm presented in chapter 6.6 for optimising electricity production by incorporating key technical drivers of power asset confirm that energy assets with higher flexibility parameters have higher value and vice versa.

List of literature used in the thesis statement

[1] Chung-hsiao wang and k. Jo. Min, Electric Power Plant Valuation Based on Day-Ahead Spark Spreads, Louisville Gas & Electric Company and Kentucky Utilities Company, Lousville, Kentucky, The Engineering Economist, 58>157-178,(2013)

[2] Shi-Jie Deng, Blake Johnson, Aram Sogomonian, Exotic electricity options and the valuation of electricity generation and transmission assets. Elsevier 2001

[3] Chung-Li Tseng, Graydon Barz, Short-term generation asset valuation: A real options approach. Operations Research Vol.50, No. 2, March-April 2002, pp. 297-210

[4] Tseng, C.L. And Lin, K.Y. (2007) A Framework using two-factor price lattices for generation asset valuation. Operations Research, 50, 297-310

[5] Tseng. C.-L. and Zhu.W. (2010) Optimal self-scheduling and bidding strategy of a thermal unit subject to ramp constraints and price uncertainty, IET Generation, Transmission and Distribution Vol.4,Iss.2, pp. 125-137

[6] Dennis, J. E. and R. B.: Schnabel. Numerical Methods for Unconstrained Optimization. SIAM, 1996 (Original edition 1983)

List of candidate's works relating to the doctoral thesis

Publications in peer-review journals

[1] Pavlátka, P.: Option Derivatives in Electricity Hedging. Acta Polytechnica.2010,vol. 50, no 4,p. 65-69. ISSN 1210-2709.

[2] Adamec,M.-Pavlátka,P.-Starý, O.: Costs and Benefits of Smart Grids and Accumulation in Czech Distribution System. In Proceedings of 2011 International Conference on Smart Grid and Clean Energy Technologies. Singapore: International Association of Computer Science & Information Technology Press, 2011, p.42-46. ISBN 978-981-07-0154-3. Share of the author Pavel Pavlátka is 45%.

[3] Adamec, M. – Pavlátka, P. – Kloubec, M. – Starý, O.: Impacts of Smart Grid concept on Energy Industry. Technology and Investments. 2013,.ISSN 2150-4059. Share of the author Pavel Pavlátka is 20%.

Publications excerpted in WOS

[4] Adamec, M. – Pavlátka,P. – Starý,O.: Costs and Benefits of Smart Grids and Accumulation in Czech Distribution System. Energy Procedia[online].2011, vol.12,p-67-75.   Internet: http://sciencedirect.com/science/article/pii/S1876610211018376. ISSN 1876-6102. Share of the author Pavel Pavlátka is 45%.

Others

[5] Pavlátka,P.: Power Option derivatives in Electricity Hedging. In POSTER 2010 – 14th International Student Conference on Electrical Engineering. Prague: Czech Technical University, 2010, ISBN 978-80-01-05242-6.

[6] Pavlátka,P.: Power Plant Valuation and Investment Decision. In POSTER 2011 – 15th International Student Conference on Electrical Engineering. Prague: Czech Technical University, 2011, ISBN 978-80-01-05242-6.

[7] Pavlátka, P-Starý, O.: Valuation of Option premiums in the Electricity Market, In the Future of Energy: Global Challenges, Diverse Solutions. Cleveland: IAEE, 2010, ISSN 1559-792X. Share of the author Pavel Pavlátka is 80%.

[8] Adamec, M.-Pavlátka,P.-Starý, O: Real Options as an Instrument for Electricity Smart Technologies Evaluation. In Energy Economy, Policies and Supply Security: Surviving the Global Economic Crisis. Cleveland: IAEE, 2010, p.431 -432. ISSN 1559-792X. Share of the author Pavel Pavlátka is 60%.

[9] Pavlátka,P. – Starý,O.: Real Options as an Instrument for Operational Flexibilities Valuation of Energy Assets. In Power Engineering 2011. Bratislava: Slovak University of Technology in Bratislava, 2011, p.85-86. ISBN 978-80-89402-40-3. Share of the author Pavel Pavlátka is 60%.

[10] Adamec,M.-Pavlátka,P.-Vinkler,K.:Strategic Changes in Power Industry: Smart Grids and its Impact to Electricity Trading. Pro-Energy.2011, roč.5,č.3, s.30-33. ISSN 1802-4599.(in Czech). Share of the author Pavel Pavlátka is 33%.

[11] Adamec, M.-Pavlátka,P.-Vinkler,K.: Strategic Changes in Power Industry: Smart Grids and Its Impact to Electricity Trading. Energia [online].2011, Internet: http://www.energia.sk/analyza/elektricka-energia/inteligentne-siete-a-ich-vplyv-na-obchodovanie-s-elektrickou-energiou/4692/. (in Slovak) Share of the author Pavel Pavlátka is 33%.

[12] Adamec,M. – Kloubec,M. –Pavlátka,P.: RES-E Support Principles Benchmark. In POSTER 2013 – 17th International Student Conference on Electrical Engineering. Prague: Czech Technical University, 2013, ISBN 978-80-01-05242-6. Share of the author Pavel Pavlátka is 35%.

[13] Adamec,M.-Pavlátka,P.: Cost Benefit Analysis of Smart Grids. In Smart Art. Praha: FEL ČVUT, 2012. Share of the author Pavel Pavlátka is 10%.

[14] Adamec,M.-Bemš,J.-Králík,T.-Pavlátka,P.-Sokol,R-et al.: New Aspects Influencing Electric Energy Generation and Trade III.[Výzkumná zpráva]. Prague: CTU, Faculty of Electrical Engineering, Elektra, 2012.9999.104s.(in Czech) Share of the author Pavel Pavlátka is 10%.

[15] Adamec,M.-Bemš,J.- Pavlátka,P.-Sokol,R- Starý,O.-et al.: New Aspects Influencing Electric Energy Generation and Trade II.[Výzkumná zpráva]. Prague: CTU, Faculty of Electrical Engineering, Elektra, 2011.9999.79s.(in Czech) Share of the author Pavel Pavlátka is 17%.

[16] Adamec,M.-Pavlátka,P.-Karajica,M.- Starý,O.-Vastl,J.: New Aspects Influencing Electric Energy Generation and Trade [Výzkumná zpráva]. Prague:

CTU, Faculty of Electrical Engineering, Elektra, 2010.9999.92s.(in Czech) Share of the author Pavel Pavlátka is 20%.

List of other´s candidate´s work

[17] Adamec, M.-Pavlátka, P.-Starý, O.: Costs and Benefits of Smart Grids on Liberalized Markets. Journal of Electronic Science and Technology.2012,vol.10,no.1,p.22-28. ISSN 1674-862X. Share of the author Pavel Pavlátka is 30%.

[18] Pavlátka, P.: Market Coupling and Price Coordination between Power Exchanges. In Energy, Policies and Technologies for Sustainable Economies. Cleveland: IAEE, 2009, vol.1,p.305-306. ISSN 1559-792X.

[19] Pavlátka,P.: Market Coupling. In POSTER 2009 – 13th International Student Conference on Electrical Engineering. Prague: Czech Technical University, 2009, ISBN 978-80-01-05242-6.

[20] Adamec,M. – Pavlátka,P. – Indráková,M.: Transformation of the Commercial Flows into Physical Flows of Electricity. In Energy, Policies and Technologies for Sustainable Economies. Cleveland: IAEE, 2009, vol.1,p.226-227. ISSN 1559-792X.

[21] Adamec,M. – Pavlátka,P. – Indráková,M, - Starý,O.-Vastl,J.: Market Coupling Principles in Electricity Market.[Výzkumná zpráva]. Prague: CTU, Faculty of Electrical Engineering, Elektra, 2008.9999.31s. (in Czech).

Response

Paper [2] two times cited on WoS

RÉSUMÉ

Autor se ve své práci zabývá problematikou systematického přístupu k oceňování energetických aktiv. Během svého výzkumu autor aplikoval postup systematické analýzy problematiky oceňování energetických aktiv. Porovnávány byly zásadní rozdíly v přístupu dvou stěžejních metod – výnosové metody založené na metodě diskontovaných volných hotovostních toků a dále metody využívající reálné opce pro stanovení opčního prémia. Analýza zásadních rozdílů a předpokladů pro využití těchto metod vedly autora k myšlence úpravy konceptu výnosové metody rozšířením o optimalizační model, jež nahrazuje podstatu reálných opcí a opční prémium tímto započítává do volných peněžních toků. Podstatnou a nezbytnou součástí takového ocenění je promítnutí zásadních proměnných a jejich strukturálních změn do hodnoty aktiva. Důležité vlivy ovlivňující hodnotu těchto aktiv jsou popsány za účelem jejich aplikace v případové studii a důraz je kladen především na cenu elektřiny, respektive na hodinovou strukturu ceny elektrické energie. Právě trh s elektřinou v posledních letech vykazuje strukturální změny zejména v důsledku masivní implementace obnovitelných zdrojů. Tento vliv se promítá zejména do hodinových cen elektrické energie, kdy pracujeme s předpokladem, že flexibilní energetický zdroj ve výrazné míře využívá i této varianty prodeje elektrické energie. Z těchto důvodů lze uvažovat hypotézu, že změna struktury hodinových cen elektrické energie ovlivňuje hodnotu energetického aktiva. Autor za tímto účelem vytvořil metodu pro stanovení hodinových cen elektrické energie z ceny ročního kontraktu na základě historických hodinových cen elektrické energie. Za účelem stanovení hodnoty flexibilního zdroje byla v softwaru Wolfram Mathematica naprogramována numerická optimalizační metoda na bázi nelineární gradientní metody.

Autor si vytyčil několik cílů, kterých v průběhu systematického výzkumu docílil. Zároveň byla ověřena hypotéza, že klasická výnosová metoda založená na metodě diskontovaných hotovostních toků v případě energetických aktiv vede k podhodnocení jejich současné hodnoty v důsledku opomenutí započtení provozní flexibility energetického zdroje. Zejména v případě konvenčních energetických aktiv může být tento dopad významný z pohledu celkové hodnoty aktiva. Test byl proveden na bázi vyhodnocení volných peněžních toků pro akcionáře a věřitele za současného diskontování těchto toků diskontní mírou na bázi průměrných nákladů kapitálu WACC.

Výše popsaná fakta znamenají zásadní změnu pro přístup k oceňování energetických aktiv, zejména tedy konvenčních zdrojů s možností výrobní flexibility. Z pohledu dalšího možného výzkumu této oblasti je nutné brát i v úvahu negativní dopady zvýšené variability výkonu zdroje a jejich započtení do ocenění.

SUMMARY

The author of this thesis applied a systematic approach to analyse energy assets valuation. During the process two fundamental appraisal methods were compared – an income approach based on the discounted free cash-flow and a real option method as well. Analysis of the fundamental differences and assumptions for the utilization of these methods was conducted by the author to consider the idea that the net present value method could be modified by the extension of the optimization model, which substituted for the concept of the real option approach and further incorporated an option premium into free cash-flow.

A substantial and essential part of such an appraisal is incorporating the impact of fundamental variables and their structural changes into the asset value. Important factors impacting the asset value have been described in order of their implementation in the case study with an emphasis on the price of electricity, especially based on the hourly spot price of the electricity. There have been changes to the market for electricity as a consequence of implementation of renewable resources business. This factor is projected primarily to the structure of electricity spot prices; where we work with the assumption that flexible energy assets utilize the spot market in order to increase revenues. Based on this assumption it is possible to consider a hypothesis that changes in structure of the electricity spot prices can affect the value of the energy asset. The author developed a method for the computation of an hourly price forward curve that included hourly granularity in order to meet this hypothesis. The computation of such a figure was based on a yearly electricity contract indexation in accordance with the historical spot prices structure. In order to evaluate the flexibility of energy assets, the author programmed a numerical conjugate gradient optimization using Wolfram Mathematica.

The author achieved several goals of the thesis with this systematic research. In addition to the hourly price forward curve computation, the hypothesis that the classical income approach, based on the discounted cash-flow of the energy assets, leads to its value underestimation as a consequence of omitting the operational flexibility value, was confirmed. In the case of conventional energy assets this impact could be considerable. A test of this hypothesis was performed on the free cash flow for the firm basis with an incorporating discount rate based upon the weighted average of the cost of capital (WACC).

The above mentioned facts represent considerable changes in the energy asset valuation approach, especially in regards to conventional energy assets with operational flexibility. There are many future research opportunities from this data, including the option to consider any negative aspect of an increased output variability of energy assets and consider its incorporation into the asset value.