AN INNOVATIVE APPROACH FOR THE OPTIMUM PORTFOLIO RISK CONTROL INSTEAD OF RISK EVALUATION

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ABSTRACT

This paper presents an innovative and realistic approach for the Optimum Energy Contract Portfolio problem. The proposed approach minimizes the expected value of costs plus exposures and/or penalties for the possible future load/price scenarios, while obeying all market, consumer and company's rules and requirements. Instead of using classical Risk Analysis models, this work presents a novel model, able to really control risks. The model is implemented into a friendly and efficient framework: solution of a realistic case study (corresponding to roughly one-ten thousand equations) is achieved in a few minutes in an ordinary notebook.

INTRODUCTION

Energy trading in most young markets [1,2] is a challenge. Uncertainties are tremendous – from resources availability to consumer's demand, not to forget future price levels and regulatory constraints. Each new regulatory model produces an abrupt change in market conditions and responses, and past history becomes obsolete, unable to represent present or future scenarios. The absence of a reliable history makes it risky (if not impossible) to use traditional tools to solve the Energy Trading under Uncertainty problem – from classical Markowitz approaches to statistical/neural models, which may produce solutions biased to the recent past, but not to the real future.

Moreover, goals and requirements are more ambitious. Surrounded by a "sea of uncertainties", the agent does not want a mere minimization of the expected values. It is important not only to calculate risks but to ***control*** *risks.* This requirement leads again to a new challenge, since available tools may calculate risks associated to a given decision, but are unable to calculate the best set of decisions given a desired risk level.

Objective

New challenges require new solutions – and lead to innovations. This work describes a new tool able to find the best solution for a given risk level. The mathematical model corresponds to a decision-under uncertainties model (the best decision for the set of possible future scenarios). Market rules correspond to linear constraints, while risk targets are written as non-linear integer constraints. Real-options concepts were intensively used to provide all possible flexibility – all possible mitigations, within allowable limits – are used to reduce risks and costs.

The computational program was designed specifically to meet all efficiency and usability needs. Easy of use and quick response were top-targets: agents are able to build the best model for their needs and run a complete Portfolio model within a few seconds.

THE PORTFOLIO PROBLEM FORMULATION

This work will focus on the Distributor Company (buyer) portfolio. The extension to the Generator (seller) or Trader (buyer/seller) is easy and straightforward.

Objective Function

Our aim will be therefore the contract mix that minimizes total buying costs plus the expected value of deficit costs along each time interval

$$Min \; c_{A_i} A_i + \sum_s p_s \left(cdef_{s,t} * Def_{s,t} \right) \qquad (1)$$

where
c_{Ai} are the costs associated to the contracts *Ai;*
p_s is the probability associated to scenario *s;*
cdef is the deficit cost (penalty)
$Def_{s,t}$ is the deficit associated to scenario s at instant *t*

Basic Constraints

Problem constraints correspond to load balance for each time interval and each load scenario

$$\sum_i A_i + Def_{s,t} = Load_{s,t} \qquad (2)$$

Where $Load_{s,t}$ is the load associated to instant *t*, scenario *s*

Contract limits are stated as

$$\underline{A_{i,t}} \le A_{i,t} \le \overline{A_{i,t}} \qquad (3)$$

where $\underline{A_{i,t}}$ e $\overline{A_{i,t}}$ are the upper and lower limits associated to type of contract *i* at instant *t.*

Risk Analysis x Risk Control

A classical portfolio optimization model will minimize costs; risks are consequences of the achieved solution. It is possible to perform a risk analysis of the optimal solution – for instance, calculate the probability of deficit or its expected value. A deeper look, possibly based on Value-at-Risk (3,4) concepts, would offer the complete picture of the risk assessment associated to a given solution. However, none of those evaluations would offer the real aim of the agent: risk control.

For instance, a low deficit cost or a low scenario probability could lead to the risk of deficits associated to the optimal solution – which could be optimum from the mathematical point of view, but unacceptable for a conservative, risk-averse agent. This paper proposes a more realistic approach, able to correctly model agent's objectives and aims. Taking a Boolean variable (0-1) which represents the existence or not of a deficit in scenario s, instant *t*,

$$Idef_{s,t} = \begin{cases} 0, & no\ deficit\ allowed\ in\ s,t \\ 1, & deficit\ allowed\ in\ s,t \end{cases} \quad (4)$$

it is possible to establish a limit on the maximum tolerated risk for each time instant

$$\sum_{s} p_s \ Idef_{s,t} \le \overline{\varepsilon\, def_t} \quad (5)$$

$\overline{\varepsilon\, def_t}$ is the maximum accepted deficit risk for instant *t.*

The agent is now able to effectively *control* the risks of a decision, limiting the level of accepted risk for each time instant. It is possible, for instance, to assign a low (maybe null) risk for the first years and accept a higher risk for a more distant future – where uncertainties are higher and precision is poor.

The Role of Flexibility

Energy purchases are made on a "here-and-now" basis – that is, generally several months or years ahead the beginning of the delivery period. Risk mitigations mechanisms operate on a "wait-and-see" basis, and may be decided when the scenarios are better defined – so consequences may be better evaluated. Some of the mechanisms for risk mitigations include contract renegotiations or exchanges between companies, generally regulated (and limited) by market authorities.

This work includes the risk mitigation actions throughout a Real Options approach (5), where scenario-dependent variables offer all possible flexibility to the portfolio problem. The agent may, for instance, purchase a specific amount of energy able to cover any exposure – taking into account the possible contract reduction if the load growth proves to be lower than previously expected. The overall model is able to optimize contracts (scenario independent) and risk mitigation variables (scenario dependent), synthesizing the joint optimal solution.

A REAL DISTRIBUTOR PORTFOLIO

The described approach will be applied to a brazilian distributor – AES-Eletropaulo, responsible for roughly 40% of the total brazilian load. The complete set of constraints is extensive and could not possibly be fully modeled within this paper limits. We will therefore focus on the main market rules and derive the associated model. Further restrictions may be easily included, as the implementation is general and able to accommodate any sort of constraints (linear, non-linear, integer, etc.).

Main Market Rules

Market rules require distribution companies to purchase contracts from generators through a public auction process. In principle, there is a pass-through mechanism to consumer's tariffs, as long as:

- Load must be fully met – deficits are subject to severe penalties and derived costs, such as energy purchased in the spot market, cannot be transferred to the tariffs.
- The maximum amount of costs allowed for pass-through is limited to purchases that sum up to 103% of total load

Contract Limits

Public auctions offer 15 to 30-year contracts negotiated three and five years prior to delivery (A-3 and A-5); existing energy, comprising 5 to 15-year contracts must be negotiated an year before delivery (A-1). Rules were designed to favor long-term commitments, so, in order to achieve full pass-through, the distributor must meet some requirements:

- there is no maximum limit for long-term (A-5) contracts
- medium-term contracts (A-3) are limited to 2% of the longer-term volumes (A-5). Fail to do so implies in limited pass-through to tariffs
- short-term contracts (A-1) are limited to 1% of total company load.

Risk Mitigation

The main mechanisms for risk mitigations are:

- free exchanges between companies, whenever there is a need to balance the contractual position, either for long or short positions
- contract reductions, due to (1) compensation for the exit of potentially free consumers from the Regulated Market, (2) reduction, at the distribution companies' discretion, of up to 4% per year of the annual contracted amount, as a compensation of market deviations from the estimated projections.

The Optimal Portfolio Model for a Distribution Company must therefore minimize the total purchase costs (in order to achieve the lower possible consumer's tariff) plus the expected value of deficits and excess purchases (above 103% of the total load)

Final Model

Objective Function

The objective of the Optimum Portfolio Problem for this distributor may therefore be written as

$$Min\ c_{A_i} A_i + \sum_s p_s \left(cdef_{s,t} * Def_{s,t} + cexc_{s,t} * Exc_{s,t} \right) \quad (6)$$

where

c_{Ai} are the costs associated to the contracts *Ai (A-1, A-3, A-5,* adjustments, etc.);

p_s is the probability associated to scenario *s*;

$cdef_{s,t}$ is the deficit cost(penalty) in scenario *s*, instant *t*

$cexc_{s,t}$ is the cost of penalty associated to the excess (above 103%) of total load in scenario *s*, instant *t*

$Def_{s,t}$ is the deficit associated to scenario *s*, instant *t*

$Excs_{s,t}$ is the excess above 103% of energy required associated to scenario *s*, instant *t*

Portfolio Constraints

Portfolio Constraints may be listed as

- Energy balance (includes eventual deficits, excesses or reductions):

$$\sum_i A_i - \mathrm{Re}d_{s,t} + Def_{s,t} - Excp_{s,t} - Exc_{s,t} = Load_{s,t} \quad (7)$$

where

$Load_{s,t}$ is the load associated to instant *t* and scenario *s*

$Def_{s,t}$ is the deficit associated to instant *t,* scenario *s*

$Excp_{s,t}$ is the excess above 100% of load associated to instant *t*, scenario *s,* whose costs may still be passed-through tariffs

$Exc_{s,t}$ is the excess above 103% of load associated to instant *t*, scenario *s,* whose costs cannot be passed-through tariffs

$Red_{s,t}$ is the contract reduction associated to scenario *s* and instant *t*

- Limits of the energy auction products (A-1, A-3, A-5, Adjustments etc.) are straightforward and will not be detailed due to paper size limits. Base contracts will be decided beforehand, and their limits depend solely on type and time instant

$$\underline{A_{i,t}} \le A_{i,t} \le \overline{A_{i,t}} \quad (8)$$

- Adjustment contracts and reductions will be decided upon scenario occurrence, and corresponding limits depend on time instant and scenario

$$\underline{A_{i,s,t}} \le A_{i,s,t} \le \overline{A_{i,s,t}} \quad (9)$$

$$\underline{\mathrm{Re}d_{s,t}} \le \mathrm{Re}d_{s,t} \le \overline{\mathrm{Re}d_{s,t}} \quad (10)$$

It is interesting to observe that use of reductions and adjustments as scenario/time variables follow, as previously mentioned, the Real-Options concept (5), taking advantage of all possible flexibility in order to achieve the best solution.

Risk Management Constraints

Limits associated to the maximum risk of over or under contract position:

$$\sum_s p_s\ Iexc_{s,t} \le \overline{\varepsilon\, exc_t} \quad (11)$$

$$\sum_s p_s\ Idef_{s,t} \le \overline{\varepsilon\, def_t} \quad (12)$$

where

$Iexc_{s,t}$ is the boolean variable which represents the possible existence (1) or not (0) of excess of energy above the limit allowed for pass through tariff (103% of total load) in scenario *s* and instant *t*;

$Idef_{s,t}$ is the boolean variable which represents the possible existence (1) or not (0) of lack of energy (deficit) in scenario *s* and instant *t*;

$\overline{\varepsilon\, exc_t}$ is the maximum accepted risk of excess above the limit allowed for pass through tariff in instant t;

$\overline{\varepsilon\, def_t}$ is the maximum accepted risk of deficit in instant t;

Computational Implementation

The resulting non-linear, integer programming problem is efficiently implemented in an EXCEL spreadsheet and solved by an integrated commercial optimizer (WHAT'S BEST/ LINDO). Although relatively large (a typical portfolio corresponds to 1000 constraints, 2000 variables), solution is achieved in one-two minutes.

CASE STUDY : SOME RESULTS

Main Hipothesis

This case study presents the evaluation of the optimum contract portfolio for Eletropaulo for 2006-2015, considering all possible contracts and risk mitigations. Uncertainties are modeled by a three-scenario approach, corresponding to extreme (low and high) load scenarios. Prices were forecasted by an external model. Company's policies require no exposure – that is, null risk of deficit.

Load Scenarios

Figure 1 illustrates the company's load growth. Green region corresponds to transmission/distribution losses (to be included in the total load, for purchase purposes). White and dark blue curves correspond to lower and higher extreme load and price scenarios. It is possible to observe that uncertainty is very high (actually, much higher than the 103% allowance).

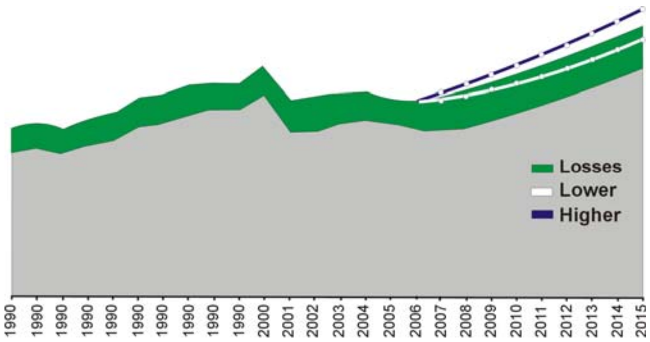

Figure 1. Company Load Growth

Contract purchases are made before scenarios occur – and are therefore subjected to risks. It is interesting to observe that the extremely low load scenario leads to overcontracting (orange point sequence, above the 103% green limit); conversely, the extremely high load scenario leads to undercontracting (gray point sequence, below the 100% red limit). The optimization model, under the Real-option concept, intensively uses all available risk mitigation variables, ensuring that there will always be a way to bring the total purchases to the pass-through zone (100-103% of the load). In other words, the optimum portfolio minimizes purchase costs (and therefore consumer's tariffs), and eliminates all risks of deficits or excesses.

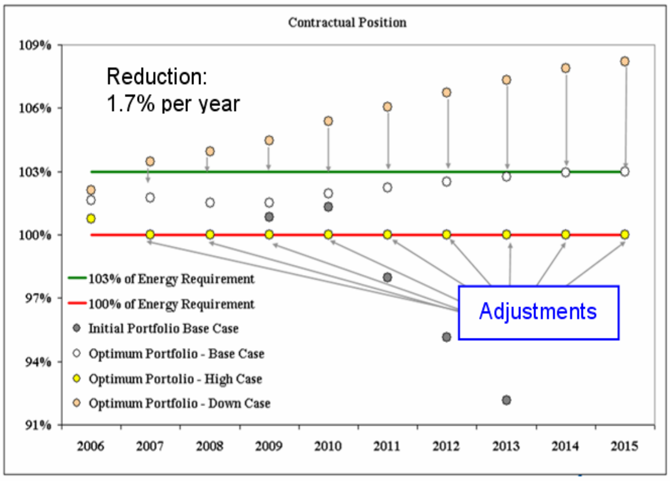

Figure 2. Optimization Results

Value at Risk

Table I provides results from the optimization model, presenting the Expected Value and Expected Value at 95% for the initial contract position and the optimum portfolio solution. As expected, the optimal solution offers a significant reduction in the Value-at-Risk for all years of the trading horizon.

TABLE I. RESULTS FROM THE OPTIMIZATION MODEL (VALUES IN R$ MM)

	INITIAL CONDITION			OPTIMUM PORTFOLIO OUTPUT		
	Expected Value	VaR at 95%	Expected Value a 95%	Expected Value	VaR at 95%	Expected Value a 95%
2006	0,00	0,00	0,00	0,00	0,00	0,00
2007	3,03	29,07	32,09	1,51	13,33	14,84
2008	27,81	83,12	110,93	9,27	24,92	34,19
2009	60,51	166,22	226,74	15,13	37,29	52,42
2010	109,96	325,53	435,49	21,99	58,55	80,54
2011	166,18	510,59	676,77	27,70	76,61	104,31
2012	283,62	640,13	923,75	40,52	81,52	122,04
2013	440,70	772,36	1213,06	55,09	85,14	140,22
2014	585,76	918,29	1504,05	65,08	89,46	154,54
2015	1352,09	3450,94	4803,03	135,21	308,96	444,16

CONCLUSIONS

This paper presented a novel model for the Optimum Portfolio of Energy Contracts able to effectively control risks. The resulting model is able to combine all market constraints and company's policies and targets, producing a customized solution, oriented to the agent's aims and requirements.

The resulting model corresponds to a mixed-integer nonlinear, stochastic programming problem, efficiently implemented into an Excel Spreadsheet, and solved by a specialized optimizing program within a relatively low computational effort: a mere couple of minutes in a standard notebook.

The case study focuses in Risks – both analysis and control. It may be seen that the model is able to combine standard outputs (as the Value at Risk), while achieving a previously impossible goal: guaranteeing a desired risk-level at any instant of the horizon of study.

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