Power Grid Assets Management
Bruno B. Ribeiro, Instituto Superior Técnico
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Abstract - The Investment in a net asset, in which the objective is not only to improve the system functioning but also to collect the resulting income, must be estimated taking into account inherent uncertainty of the associate variables to the own investment.

Variables like fuel and electricity prices make investment value and its income also subject to uncertainty, and therefore have a stochastic behaviour. Adding the fact that transactions taking place in an energy system, work in a market environment, the uncertainty associated to the all process becomes even higher. The investment analysis, in case of a transport line, passes first by knowing the investment viability, and then the benefits that it can bring to the system. In this work, several possibilities to carry out the investment are tested, with the objective of finding a solution that maximizes the income and at the same time presents better benefits to the system in which it is incorporated. Uncertain is described using some stochastic process such as Markov process, Wiener process or Brownian Motion. Monte Carlo Simulation process is used to obtain trajectories for different possibilities tested. Final objective is to find the solution that maximizes earnings and, at same time, is able to improve system behaviour.

Key words - Transmission Investment, Monte Carlo simulation, Financial Transmission Rights, electricity markets.

I. Introduction

Nowadays, the necessity to invest in expansion and improvement of the electric transmission grid is a reality. This investment has to be made taking into account the actual energy market structure. So, to invest in energy net assets, means to improve and expand the actual transmission grid, contrary to what happened in the past where these investments meant adding new generating resources and the consequent integration on existing grid. The main goal was to decrease the global system costs.

The investment must consider the current energy market properties. Demand/supply rule, wide range of intervenient, and inherent market imperfections are some constrains that when added to the stochastic nature of all the variables involved increases the uncertain present in the investment. Consequently the risk concerned to all process will be higher.

As the more participants there are in the market, the more competition will exist, which will affect all the functioning of the market. With the increase of market competition, electricity price will be subject to more volatility. In addition to this fact, the variation of final electricity price increases the risk associated to the investment which should be made taking into account all the market constrains.

In fact, it is not only necessary but also extremely important to apply financial tools that make it easier to deal with stochastic nature that involves the global energy market functioning. The use of those tools can minimize the risk intrinsic to the own investment.

Expanding and improving the energy transmission grid, becomes a complex optimization problem where time is also source of uncertain. If to estimate the electricity (fuel) price at short medium term is already a hard task, when the period is about ten years it becomes even more difficult to predict the evolution, which adds a lot more of uncertain. It is then necessary to estimate with the tightening possible the evolution of the different variables involved in all process. Another important point is the contribution that the indicators resulting from the system operation may have to better estimate the fuel prices and electricity prices or daily load values. Another important situation is when the lines reach the limits, leading to congested network.

Before taking the decision to invest, it is necessary to quantify the values involved, either the initial investment value, or the future earnings. Moreover the investment in new transmission assets must meet the existent market structures and whenever possible reduce the global system cost, i.e. reduce the cost necessary to satisfy the demand (social welfare).

It is necessary to guarantee that the future revenues could pay the investor so that he can recover his initial investment. In cases where this is not possible, it will be necessary to find another way to pay the investor.

Due to the nature of some of the variables involved, some stochastic process will be used to describe variables as fuel prices, demand evolution or electricity price. The final objective is to obtain the results related to the investment life time. Annual revenues and the global system cost can be compared with the initial investment to let one know about the viability of the investment. The annual revenues will be calculated according to the quantity of energy transmitted by the line in question. The contract establishes financial transmission rights (FTR) at the line. FTR are financial instruments issued by the transmission network operator. The FTR entitle the
holder to be reimbursed for the congestion charges being paid when energy is sent (if it is a producer) from one location to another.

A. Paper structure

This paper is organized in five sections. Section II introduces the uncertain and the methods used to deal with. Some stochastic processes used to describe the uncertain are also introduced, such as Wiener process, Markov process or Brownian motion. The Monte Carlo simulation process and its usage in mean-reversion process are described. Section III gives a definition of the different market structures and their functioning. Also in section III, is done the analysis of investment and the way proposed to pay the investor. Is described the FTR contract, and how it fits in the functioning of the energy market. Finally, the simulations results for each one of the tested cases are presented, and the relative annuity value and respective system cost are compared. In section IV, a different way to pay the investor based on the decrease of system cost is given. Section V shows the comparative analysis of the study cases with the desired results. In addition, the conclusions related to all work are presented.

II. Describing uncertainty, stochastic nature of energy market

The energy market has particular constrains that give it high degree of uncertainty. These facts added to the stochastic nature of market functioning, make the objective to modulate the market workout, a complex optimization problem. First of all, it is necessary to find the best way to describe the uncertainty. In addition and as it is a liberalized market, demand/supply rules will establish final prices. Also important is the high volatility of fuel prices. So, even modulating all variables, uncertainty will be a characteristic always present.

It is thus important to start by modulating fuel prices due its importance to determine the final electricity price. So, fuel prices are described by mean reversion process given by:

\[ \frac{ds}{s} = \lambda(\Omega - x)dt + \sigma dz \]

where \( z \) variable is described by Wiener process, and \( x = \ln(s) \). Using Itô’s Lemma [6]:

\[ dx = \lambda(\Omega - x)dt + \sigma dz \]

with

\[ \Omega = \Theta - \frac{\sigma^2}{2\lambda} \]

A known process is thus obtained, with mean and variance also known and given by:

\[ E[x(t)] = x(t_0)e^{-\lambda(t-t_0)} + \Omega[1 - e^{-\lambda(t-t_0)}] \]

\[ Var[x(t)] = \frac{\sigma^2}{2\lambda}[1 - e^{-2\lambda(t-t_0)}] \]

(3)

It is possible to write a discrete-time of this process as it follows:

\[ x_k = x_{k-1}e^{-\lambda\delta t} + \Omega(1 - e^{-\lambda\delta t}) + \epsilon_k \]

(4)

With \( \epsilon_k \) given by follow distribution,

\[ \epsilon \sim N(0, \frac{\sigma^2}{2\lambda}(1 - e^{-2\lambda\delta t})) \]

(5)

Where \( \delta t \) represents the time period and \( \epsilon \) a random variable described by a normal distribution. It is possible now, based on mean reversion process used on fuel and electricity prices, to use the Monte Carlo process to obtain final trajectories for both prices. Figure 1 show the trajectories obtained for electricity price when used mean reversion process is used.

![Figure 1 – Trajectories for electricity price with reversion](image)

Even being from the fuel prices and it own volatility that comes most part of uncertain, cannot be disregarded the evolution of load and installed capacity, above all if is considered a large time period of investment.

It is possible to describe the relative growth of load and installed capacity, by a Wiener process as in fuel prices case.

\[ ds = \mu\delta t + \sigma\delta z \]

(6)
Where $\mu$ and $\sigma$ represent the growth drift and volatility, respectively. This process can be simulated through a discrete-time process:

$$s_k = s_{k-1} + \mu \delta t + \epsilon$$

$$\epsilon \sim N(0, \sigma^2 \delta t)$$  \hspace{1cm} (7)

It is only considered the growth of existing generation and load, i.e. the load and installed capacity growth is considered at same places where there already exists.

### III. Transmission line investment

The final price at which electricity is exchanged depends on many factors just as the cost production depends directly on the fuel prices. Consequently, any oscillation on these prices will be reflected immediately on the price of electricity. On the other hand the market-like workout makes the selling price variations depend on the highest or lowest level of demand at the moment and on the existence of overloaded lines. In other words, it depends on the highest or lowest demand at a given moment.

#### A. Market Models

The necessity to create rules that regulate the activity of the energy market leads to the creation of working models of that market. Therefore there are many possibilities which these models can follow to describe how the energy market works. On the one hand, it is defined a model on which the exchanges are directly done between generation(sell) and demand(buy) and on which the network is only used as a mean for energy transportation, having only two distinct players, generation and demand. This is bilateral model. On other hand there is the possibility to have generation and demand on a global auction system, where each point of the network will be subject to demand/supply rules and existent constrains. So, marginal values that correspond to energy cost in each point of network the LMP – Locational Marginal Prices will be defined. This value is also known as nodal price and represents the cost to produce one more energy unit at any point of the network. The model described is named pool-based model.

It is therefore of utmost importance, that the information about LMP can be used efficiently, so that the decisions on investment can be worthwhile since these depend on greater or lesser success in investment.

#### B. Investment Analysis

Therefore is important to own a transmission grid that can be able at the limit to meet the demand necessities. At beginning of the investment, it is essential to analyse and evaluate the most potential places to maximize the investor revenue and at same time reduce the system cost. These two points are the main indicators of investment success. As well as the point focus before, the line is expected line to solve some capacity limits of related transmission grid.

The case study is about a transaction market where the facility is the electric energy and where load and generation are intertwined by a transmission network where the new line will be integrated. Hour is defined as the smallest time unit. Market is described as a set of sellers and buyers. At each point of the network only one single seller and one single buyer are considered. At generic node $n$, for the selling entity is defined marginal cost as $p^s_{n,t}(p^s_{n,t})$, where $p^s_{n,t}$ is the power sold by a generator at node $n$ at hour $t$. Equally, for buying entity is defined marginal bid as $p^b_{n,t}(p^b_{n,t})$, where $p^b_{n,t}$ is the power bought by a demand unit at node $n$ in hour $t$. Assuming that generators(demand) and offer(bid) energy are at marginal cost, then the offer and bid expressions respectively become cost and benefit functions.

The process that determines the successful offers/bids of all intervenients is stated as Transmission Scheduling Problem (TSP). The objective of the TSP is to maximize the social welfare, subject to network constrains. Social welfare can be described as the difference between demands benefit and generators costs functions. So as that difference becomes higher, the benefit achieved becomes larger.

Quadratic expressions are used for costs and benefits functions. Respectively, for each seller and buyer the functions are given by:

for a generic seller : $S_i$

$$C^s_i(p^s_i) = a^s_i p^s_i + 0.5 b^s_i (p^s_i)^2, i = ..., M^s$$  \hspace{1cm} (8)

and for a generic buyer $B_j$:

$$B^b_j(p^b_j) = a^b_j p^b_j - 0.5 b^b_j (p^b_j)^2, j = ..., M^b$$  \hspace{1cm} (9)

Where $p$ is the energy in MWH offered by the seller or requested by the buyer entity. $M^s$ and $M^b$ are respectively the total number of sellers and buyers present at entire network, respectively.

The coefficients $a^s_i$ and $b^s_i$ ($a^b_i$ and $b^b_i$), represent the linear function parameters for seller $S_i$ (buyer $B_j$).
So for $S_i$ seller function:

$$\sigma^{S_i}(p^{S_i}) = a^{S_i} + b^{S_i}p^{S_i}, i = 1, \ldots, M^S$$

$$\nu^{B_j}(p^{B_j}) = a^{B_j} - b^{B_j}p^{B_j}, j = 1, \ldots, M^B$$

(10)

And TSP can be described by:

$$\begin{align*}
\max_{p^b_{n,t}} S = \sum_{t \in T} \sum_{n=0}^{N} [B^b_{n,t}(p^b_{n,t}) - C^b_{n,t}(p^b_{n,t})] \\
\text{s.t.} \quad g_{n,t}(p^b_{0,t}, p^b_{1,t}, \ldots, p^b_{n,t}, p^g_{0,t}, p^g_{1,t}, \ldots, p^g_{t}) = 0 \\
\quad \mu_{n,t}, \forall n \neq n, \forall t \\
\quad h_{l,t}(p^b_{0,t}, p^b_{1,t}, \ldots, p^b_{n,t}, p^b_{n,t}, p^l_{0,t}, p^l_{1,t}, \ldots, p^l_{t}) \leq f_{l,\max} \\
\quad \lambda_{l,t}, \forall \text{linha} l, \forall t
\end{align*}$$

(11)

Where $B^b_{n,t}(p^b_{n,t})$ is the benefit a demand unit for consuming power $p^b_{n,t}$ in hour $t$, $C^b_{n,t}(p^b_{n,t})$ is the cost of generator that produces power $p^b_{n,t}$ in hour $t$, $g_{n,t}$ is the equation that describes the real power flow balance at node $n$ in hour $t$ and $h_{l,t}$ is the real power flow expression at line $l$ in hour $t$.

Considering the expression given by:

$$B^b_{n,t}(p^b_{n,t}) - C^b_{n,t}(p^b_{n,t})$$

(12)

or by a more general expression $\beta^b_{n,t}(p^b_{n,t}) - \beta^b_{n,t}(p^b_{n,t})$. DC power flow comes:

$$p^b_{n,t} - p^b_{n-1,t} = \sum_{n \neq m} B_{nm} \cdot (\delta_{n,t} - \delta_{m,t}), \forall n \neq m, \forall t = 1, \ldots, T$$

(13)

where $B_{nm}$ represents the susceptance of the line that connects node $n$ and $m$, $X_{nm} = -\frac{1}{B_{nm}}$ is the reactance of same line and $(\delta_{n,t} - \delta_{m,t})$ is the difference between the angles of node $n$ and $m$ in hour $t$. In expression (11), $h_{l,t}()$ can also be described by $F_{n,m,t} = |B_{nm} \cdot (\delta_{n,t} - \delta_{m,t})| \leq F_{l,\max}$, where $F_{n,m,t}$ is the active power flow at the line that connects node $n$ and $m$.

Solving TSP expression (12) can be determined by the quantity sold and bought by market players. Moreover, the coefficients $\mu_{n,t}$ and $\lambda_{l,t}$ define the nodal price for each node - locational marginal price (LMP), at node $n$ in hour $t$ and the marginal value of a change at line limit at line $l$ in hour $t$, respectively.

At current work, the demand is assumed as inelastic with respect to price and no losses are considered.

Although the LMP represent hourly values, the time to consider in power systems investments is normally in order of tens of years. Also, at current study, are considered annual changes in considered variables. To the investor is useful to consider the different possibilities that investment can take, i.e. have multiply trajectories for LMP evolution, and consequently for electricity price. This information is important to transmit to the investor information about the investment development. Due to the stochastic nature of all process and the uncertain associated, the information about LMP will be stricter, as more can be the number of trajectories obtained.

The objective is that the investor can be paid in function of power transmitted by the line where the investment was made. The financial transmission rights (FTR) grant to the investor the right to be paid for the energy transmitted. FTR are issued by transmission network operator and work as a guarantee for the investor that he will be remunerated according to the line power flow, being the line in congestion situation or not. This situation means the increase of marginal value $\lambda_{l,t}$, and consequently the raise of money earned.

At current study case the FTR value is obtained from:

$$FTR = \max \{\Delta LMP \cdot P_{transmitida}, 0\}$$

(14)

This guarantees the investor never to earn negative values, i.e. when $\Delta LMP$ takes negative value, investor is not paid. This happens when the power flow occurs in opposite to pre established way.

So the more energy is transmitted, the higher will be the income wages earnings. In despite of this, there can be paradox situations. Being the objective place the investment where the power flow can be higher, it can happen that after installing the new line on a overloaded zone (maximum energy transmitted, line operating at physical limit), the line solves the overloaded situation and the potential earnings decreases. In these cases, it is important to know about the possible decreasing of the system cost which could compensate the earnings reduce that results from FTR contract.

C. Monte Carlo Simulations

The results of the investment can be predicted by Monte Carlo simulations. In respect to load evolution, even considering it stochastic variation, it’s possible to establish historical values that can be used to characterize a daily profile. So it becomes extremely important to interpret the daily operating values of the electrical system, to be able to estimate with higher exactness the load levels, allowing building historic data for load. Figure 2 – Load daily profile simulations represents the daily load diagram.
trajectories. Load evolution is modulated by a Wiener process like described in section II.

In this model some factors, which could also have influence at some results are not considered. Weather conditions or possible market strategies are not modulated in current work.

The fuel prices and its continuous deregulation are a significant source of uncertain for the investment. This fact assumes special importance due to the high dependence that fuel prices changes have in the estimate of electricity final price. Thus, it is necessary to hold as many trajectories as possible, allowing to have sufficient information to evaluate the investment. Figure 3 shows the trajectories obtained for the fuel prices.

The natural trend leads to the increase of load values. This fact guides to the necessity to have more installed capacity many times using renewable energies increasingly a solution for energetic problems. The increase of load values may cause more overloaded lines situations, and consequently the increase of marginal prices at which energy is traded leading to the higher benefits for line operator and at same time for the investor. Therefore, new investment opportunities may appear what attach further importance to a correct analysis of the investment.

Regarding the system cost, it is important to know the value for base case without the new line being installed. This is essential to let one compare the final value, obtained after new line investment results. Although the main goal is to let the investor recover the invested cash, the decreasing of system cost is also a very important point.

The study is based on 30 Bus (30 Bus - Power Flow Test Cases [2]). Figure 5 and Figure 6 presents the system cost and mean/standard deviation trajectories respectively.
Both figures are related to base case, without any new line considered. The diagram of existing network is presented in Figure 7.

The objective is, considering the existing network, to study and analyse different solutions for the investment. Choose the place to install the new line, be aware of the necessity to install a transformer in case where different voltage level points are connected by the line. Final point is to compare the final results, choosing those who get more pay.

It is important to place the line near a high power flow point of the network because the FTR value depends directly on the energy transmitted by the line, so the more power flows, the more cash is earned. Another important point is to choose a place where there is a low cost generation unit that could maximize the benefits. Must also be considered the length of the line, as the longer the line is, the higher will be the associated cost.

In figures the energy values are presented in MWh and costs in €/MWh. The uncertain associated with load is 2.5%, and required rate of return is 10%. Time period considered is 10 years.

As already approached, the investment is based on a construction of a new line between two network nodes, involving or not distinct voltage levels. The investor is proposed to be paid by a FTR contract on the line. The value is calculated by expression (14).

Assuming the generic case of a new line between node A and B, the FTR value depends on the difference between the locational market prices (LMP_B - LMP_A). Are also considered the power flow between A and B and the respective price spreads what able to define the way established on the contract. Positive price spreads means the chosen way is correct while negative price spreads means the necessity to change the power flow way selected.

The cash flows are considered during the time period of the investment. The respective free cash flows are obtained by subtracting taxes and adding the amortization from the cash flows (10 years). Considering the required rate of return of 10%, is obtained the present value of the project (NPV), which must be nearest the investment value to able the investment to be recovered. In cases where NPV is under the investment value, the investment will probably not be recovered.

Adding to NPV reference, the annual cash flows obtained from investment are also a good comparative point to evaluate the success of the investment. So the objective is that the annual cash flows can equal the investment cost annuities (with a 10% interest rate), so that the invested cash can be recovered.

D. Results

The case chosen is about installing a new line between node 1 and 15 of the given network, adding to a necessary transformer due to different voltage level in the nodes concerned. Figure 8 illustrates the changes on the network. A transmission line is represented by dashed line. It is important to compare the results obtained with and without the new line. The line joins node 1 at 132 kV to node 15 at 33kV. So investment needs to include a transformer.

The next figures present the results for system cost and for annual cash flows obtained from FTR contract. The results were obtained with 200 trajectories for each case.

The reference value for a 10 years investment is about 0,11 M€/year, from a total investment value of 1M€ with (10% interest rate). If during the period of the investment, annual cash flows values never pass the reference value, the investment will probably not be recovered.

In this case the cash flows obtained do not meet the reference value of 0,11M€/year, so probably investment will not have success due to insufficient earnings from FTR contract. On the other hand, as is showed in Figure 9 and Figure 10, system cost is under the value for base case, although FTR annual values are significantly lower when compared with
the 1,1M€ reference value of total investment Figure 11.

So, from the perspective of social welfare, the project improves the system cost behaviour, when compared with initial value (Figure 6 - Base case and Figure 10 – line between node 1 and 15).

Figure 8 – Changed network topology (line 1~15)

Figure 9 shows the system cost trajectories during the 10 years period. System cost mean and standard deviation are showed in Figure 10. Comparing both system cost figures, initial case and with line 1~15, there is a reduction on system cost. This fact can compensate for the lack of annual cash flows as is discussed in the following section.

Figure 9 – Changed topology system cost

Figure 10 – Changed topology system cost: mean and standard deviation

For this investment the NPV obtained is about 0.49€. This value is significantly below the investment value, which means the investment will probably not be recovered.

Figure 11 – Annual cash flows

IV. Different possibilities to pay the investor

A. Merchandise Surplus

In cases where the investor can’t be paid in order to cover the initial investment, there is a need to find alternative ways to pay the investor. Then, the solution may pass by being paid not only for FTR contract but also in function of a possible reduce of system cost, particularly using merchandise surplus.

This solution may benefit the particular situations where overloaded lines situations drop considerably after installing the new line and consequently the earnings from FTR contract are affected. I.e. reducing overloaded lines situations means reducing marginal prices which affects directly the FTR revenues. Although the decline of system cost being one of the main goals of the investment, improving the social welfare, with the possibility of insufficient earnings
from FTR contract, it may become an important economic goal to meet.

The chance of being paid indirectly by system cost decrease, may be one of the possible solutions to adopt. Reducing system cost, means lower energy price by generation units. It will be at this point that investor could get some extra earnings adding to FTR revenues.

Always considering marginal values, is defined producer surplus $S^p_i$ as the difference between the profit obtained on selling energy $R_i$ and the costs supported to produce the same quantity of energy $C_i$. Both values are related to a generic producer. So $S^p_i$ is given by:

$$S^p_i = R_i - C_i$$ (15)

Consequently for a generic consumer (network operator) $i$ is defined the consumer surplus $S^d_i$ as the difference between the benefits $B_i$ obtained from energy use, and the payments $T_i$ dispensed acquiring the same energy. $S^d_i$ is given by:

$$S^d_i = B_i - T_i$$ (16)

If all system is considered instead of a unique generation or consumer unit, can be defined the global system values for the producer and consumer surplus, $S^p$ e $S^d$ as being the sum of all individual $S^p_i$ and $S^d_i$. The social surplus can also be defined:

$$S^s = \sum_{i \in D} B_i - \sum_{i \in G} C_i$$ (17)

On the other hand defining $S^d$ and $S^g$ as demand and consumer surplus, social surplus can also be defined as:

$$S^s = S^d + S^g$$ (18)

On an unconstrained market only the participant’s limits are considered. Those limits will establish the market clearing price ($\rho^M$), that corresponds to the point where the producer and consumer prices curves get intercepted. This fact is illustrated on Figure 12.

In case of unconstrained market, all participants will be subjected to same $\rho^M$ value, both consumer and producer will be paid on that price. I.e. the market clearing prices, related to producer and consumer will be in this case the same, and consequently equal to $\rho^M$.

$$\rho^d_i = \rho^p_i = \rho^M$$ (19)

Considering now a situation where unconstrained solution is not valid, the new constrains will change directly the transactions prices. Consequently there isn’t only one market clearing price anymore. So the last expression is no longer valid. In the case of having an overloaded line, the market clearing prices in nearest nodes will consequently be distinct for each one. One of the results of this fact (different $\rho^M_i$ for each intervenient) is the reduce of $S^s$, resulting on the difference of $\rho^M_i$.

Another fact resulting from constrained market is that the difference between market clearing prices will lead to appear of merchandise surplus and a lost quantity represented in Figure 13 as dead-weight loss.

As already referred the $S^s$ value will decrease and is now given by:

$$S^s = S^D + S^G + \left( \sum_{i \in D} \rho^d_i \cdot q_i^d - \sum_{i \in D} \rho^p_i \cdot q_i^p \right)$$ (20)

Starting from the equation used for unconstrained market, the difference to present case is the $S^M$, that will be added to first expression:

$$S^s = S^D + S^G + S^M$$ (21)

Then $S^M$ can be given by $\sum_{i \in D} \rho^d_i \cdot q_i^d - \sum_{i \in D} \rho^p_i \cdot q_i^p$.

The constrains that may exist at market could lead to a positive or negative value of $S^M$. Positive case
means network operator gets benefits, negative value means that operator have to support that difference.

Is not the reducing of $S^M$ that means reducing of $S^\xi$, because it is only a part of it. Figure 12 shows $S^M$, resulting from the difference between the market clearing prices from generation and demand respectively.

Other side the merchandise surplus can be described by:

$$S^M = \sum l \lambda d_l \cdot p_{d_l} - \lambda g_l \cdot p_{g_l}$$

So in the case approached in this work, line between node 1 and 15, the value obtained for $S^M$ for the 10 years period is about 0.42 M€/Year. This margin can be used by line operator to able the investor to be paid for the system cost behaviour. This can compensate the investor for low values obtained from FTR contract.

In this case the total FTR contract earnings are even minors than in one line investment - Figure 15. Adding this fact to a higher value investment, two lines instead of one (value near 1.5M€), make it a not profitable solution, although the system cost is lesser then in base case.

NPV obtained for this case of investment is about 0.29M€, what confirms that the annual cash flows won’t compensate the all investment value. However as in the first proposal for investment, using the system cost reducing may be a solution. This case system cost reducing is about 10% of initial cost - Figure 17

So the investor could in this case be paid using the $S^M$ added to FTR contract earnings.
V. Conclusions

Investing in the improvement of the energy power systems involves a high number of interveniens and variables that must be considered. There are too many tasks to meet to assure a minimum of certainty at the analysis of an investment. So it’s important to be able to deal with the own market properties, as well to predict the different possibilities that may arise during the investment time period.

The high number of variables present in analysis of investment carries a large margin of uncertain. To modulate this variables some stochastic processes has been used and its representation was made using the Monte Carlo simulations. For each process, 200 were trajectories were simulated.

Fuel prices and load level were some of the variables modulated due to its importance to obtain the final electricity price. Annual cash flows and FTR annuities were also simulated using Monte Carlo process, which allows us to comparing the results and knowing about the possibilities of a successful investment. One point observed was the high electricity price dependence on fuel prices.

The model used was tested on 30 bus network (Power Flow Test Cases [2]), and involves the investment on a line and a transformer (necessary due to different voltage level between the nodes to connect). The study was made based on a FTR contract, which gives to the investor the financial transmission rights at the new line. Different locations for the line were analysed and the most profitable solution has been chosen. Other possibilities have been tested, such as installing two lines, or only one line without a transformer involved (shorter line connecting same voltage level nodes). The results based on FTR contract earnings were not sufficient to pay the investment, so the possibility to be paid in function of system cost reduction was tested.

In all tested situations, system cost decrease was a reality. This means not only economic benefits but also social welfare improvement. Merchandise Surplus gives the investor the right to be paid simultaneously by FTR contract and system cost decreasing.

VI. References