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Valuing a Flexible Regulatory Framework for Transmission Expansion Investments

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***Abstract*—Regulatory frameworks for inducing efficient and well-timed investments in electric transmission systems is currently an issue of considerable interest for researchers, policymakers and transmission investors. The traditional approaches have encountered several problems in managing the huge uncertainties involved in the transmission expansion problem, preventing investors expanding from the system in an optimal manner. For dealing appropriately with uncertainty within the transmission expansion problem it seems necessary to introduce some kind of strategic flexibility in order to make contingent decisions. In this article, a new investment approach that properly assesses a merchant transmission investment with the option of becoming regulated in case of an unfavorable unfolding of the uncertain future conditions (switching option) is proposed. In a numerical example, the economic value of the flexibility provided by the proposed approach is compared against the option value of deferring investments in the traditional merchant approach.**

***Index Terms*—Merchant Transmission Investment, Monte Carlo Method, Real Options, Regulated Transmission Investment, Strategic Flexibility, Switching Option, Uncertainty**

I. INTRODUCTION

The liberalization of the power markets has created new challenges for the electric transmission business related to the investment in the network infrastructure and its financial and risk management. The restructuring of the power industry has generally resulted in insufficient investment activity in the transmission system [1]. Therefore, networks are not well adapted to the emerging power flow patterns of electricity markets. Consequently, transmission lines are increasingly congested and the reliability levels are continually deteriorating. Thus, the investment in transmission networks has become a subject of major concern in the electricity industry despite the regulatory efforts for encouraging timely and adequate investments in the transmission grid.

Investments in the transmission system might be structured according to two different approaches. A regulated approach refers to a system which does not include any incentive mechanism specifically set to face the long-run transmission investment problem. Under the regulated scheme, investments are initiatives proposed by a centralized agency, e.g. the system operator or a regulatory agency, responsible for the transmission expansion planning. The expansion planning usually seeks to maximize the social welfare of the electricity market. In practice, investments are backed by a rate-of-return regulation. A second mechanism is the merchant approach, which would allow private companies to invest in the transmission system, subject to certain constraints. They would be rewarded by allocating transmission rights to investors. In this framework, the investments are valued by the private investor. Then they are carried out under the risk investors. A mixture of both mechanisms is feasible and is considered as the third approach in this paper [2]-[3].

On the other hand, in the context of the restructured electric power industry, transmission investments can be assimilated to a risk management problem rather than a market or competition problem [4].

Basically, risk management techniques consist in assessing a transmission investment plan that under an unfavourable event either let the planner make adjustments in an easy and economic way (flexibility) or satisfactorily withstand such circumstances without changes (robustness) [5].

Strategic flexibility is a risk management technique that is increasingly gaining research attention [5], [6] as it allows properly managing major uncertainties, which are unresolved at the time of making investment decisions. However, expressing the value of flexibility in economic terms is not a trivial task and requires sophisticated valuing tools [5]. The Real Option Valuation method has proved to be a well-founded framework to assess the economic value of strategic flexibility. The real options approach is an innovative method that allows tangible asset valuation in uncertainty condition and flexibility in the decision taking.

In this paper, a mixed approach, where a private company invests under a merchant structure with the option to switch to regulated revenues in case of unfavorable evolution of the future market conditions is proposed. This option is subjected to a certain expiration time. The strategic flexibility of having the chance to adopt a regulated environment has an important value and should be fairly valuated.

This article aims at assessing the flexibility value of the mixed investment mechanism by means of the Real Options in order to reveal the incentive to invest offered by the proposed approach.

II. TRANSMISSION EXPANSION APPROACHES

Under the liberalized market structure, transmission investments are commonly classified as merchant or regulated [2]-[3].

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On one hand, regulated investments are normally executed by Transmission System Companies (TRANSCO), which are typically rewarded with a rate-of-return regulation fixed by the system regulator. The rate of return should be cautiously selected and dynamically adjusted in order to prevent the TRANSCO from earning excessively high or low profits, since an erroneous revenue level might induce over- or underinvestment. Furthermore, this mechanism does not generate incentives in order to improve the system efficiency and additionally needs a set of rules for the allocation of the investment cost among the market agents (i.e. network users).

On the other hand, the merchant transmission investments are carried out by private investors, where opportunities of arbitraging energy among geographical locations provide an incentive for building new transmission lines. Under this approach, the investor bears the whole risk of the transmission investment related to the uncertainty affecting the development of the power market in the long-run, e.g. spatial pattern of the load growth, location of the new generation capacity, long-term fuel costs, future network topology, etc.

Huge geographical arbitrage opportunities often appear due to the existence of extraordinary revenues related to system areas showing poor reliability levels. Even though revenues under deficit conditions can be very significant, this situation does not occur frequently and is very difficult to predict for the investment horizon. Despite the economic desirability, investments in transmission infrastructure are usually postponed or not executed because of the risk-aversion of investors.

In this context, this article proposes a mixed regulated-merchant approach in which the System Regulator entitles the private merchant investor, for a certain time, to switch to regulatory framework. This allows the investor to capture the extraordinary revenue opportunities which appear mainly in deficit energy scenarios with the option to cut possible losses by switching to regulated revenues. Hence, the investor has an important source of strategic flexibility that encourages the immediate execution of the investment instead of deferring the investment decision [7].

This new approach then originates an important incentive for private investments in the transmission system due to the flexibility embedded, which must be correctly valued. In order to conduct this, the next section presents the approach to valuation of flexible investments under uncertainty.

III. VALUING INVESTMENT FLEXIBILITY UNDER UNCERTAINTY

Traditionally, the problem of assessing the investment project worth has been addressed with the Discounted Cash Flow (DCF) method. This method expresses the expected present value of cash flows that the project generates throughout its life time.

Under this method, different criteria exist about to take the decision of going ahead with the investment project or discarding it. The Net Present Value (NPV) criterion is the best-known and most-implemented. The NPV has a good performance when the project variables are not subjected to uncertainty and the project does not offer any type of strategic flexibility in the management.

In the NPV calculation, the expected future cash flow is discounted at the estimated cost of capital. However, fixing the appropriate discount rate can be difficult due to the fact that the project under consideration has not correlation to any traded asset. For representing high risk, the discount rate is frequently increased, accordingly reducing the NPV of the project. Therefore, a higher perceived risk reduces the likelihood of executing the project [8].

Moreover, when the future cash flows are affected by substantial uncertainty, the classical appraisal methodology recommends making a sensitivity analysis. This allows studies under different type of possible scenarios, or to find a probability distribution of the project NPV through simulation techniques such as Monte Carlo method [9].

Although, this facilitates the decision making, this does not solve the shortcomings of NPV, mainly because it not considers the management flexibility over the project lifetime.

In real-life, company managers do not have a passive role. They are continuously trying to adjust to the dynamics of the market. In other words, the managers have flexibility for decision-making throughout the life time of the project. This property highlights important difference between the traditional appraisal method of projects and the reality in actual settings.

Most recently, the investment appraisal paradigm has had an important change. It has been proved that under irreversibility, even for investment projects showing positive NPV, the optimal strategy could be postpone the investment in order to be reconsidered later [9].

Indeed, maintaining the investment opportunity open is valuable, since the information which arrives in the future, though never complete, allows for a better decision-making.

The new appraisal approach is called Real Options. This approach gives an important value to the flexibility of management and its capacity to detect opportunities and act according to the unfolding information.

The most important advantage of real option method is that emphasized the asymmetry inherent between profit and loss in the project structure. Real Option method expands the traditional concept of NPV by including the value of the flexibility in the project. Thus, the expanded term are called Flexible Net Present Value [8].

$$\textit{Flexible NPV} = \textit{Static NPV} + \textit{Flexibility Value}$$

The flexibility value is the key concept in the real options method. This flexibility may entitles the investor to various actions at different stages of the projects, like the options to postpone, expand, contract or even abandon the investment. This ability to adjust to fluctuating market conditions has an intrinsic value. Since this value is positive, its presence adds value to the project and has to be considered when project implementation is being decided [8].

It is import to emphasize that this value cannot be quantified in the framework of the classic NPV method [9].

A. *Real Options Analysis.*

The real options approach emerges from the idea of applying financial option valuation theory - to real assets or capital investment projects.

The financial options are based on contracts. In contrast, the real options are inherent features of strategic investments and must be identified and specified [10].

The real option method copes with the investment problem and uncertainty in a particular way. It provides the opportunity to make a decision according to how events unfold. At the decision time, if events have developed favorably, the investor will make certain decision, but if events unfold unfavorably, the decision will be different. This means that the option payoffs are nonlinear, due to these are modified with the nonlinear investor decisions. In contrast to traditional method, payoffs are linear because no matter what happens the decision is fixed (noncontingent) [11].

Hence, the real options create value when significant uncertainties and volatile cash flows exist. Moreover, the option value increases with its maturity. As in financial options, the real options holder is protected from losses while his profits are not limited.

B. Valuation of Real Options.

Different methods were developed to value financial options but their applications in the real options setting are conditioned to the particular characteristics of each problem. In practice, the underlying assumptions of traditional option valuation methods do not hold when assessing capital investment projects.. There are three general solutions methods:

- *Stochastic differential equations.* This method solves a partial differential equation (PDE). It mathematically expresses the dynamics of the option value specific conditions. The analytic solution of the PDE provides the option value as a direct function of the inputs. The Black-Scholes equation is the best known analytic formulation [13].
- *Stochastic dynamic programming.* As is exposed in [10], dynamic programming is a very useful approach for dynamic optimization problems under uncertainties. It decomposes a whole decision sequence into two components: the immediate decision and a valuation function that encapsulates the consequences of all subsequent decisions, starting with the position that results from the immediate decision.
  The more popular method is the binomial lattice, introduced it by Cox, Ross and Rubinstein [14].
- *Simulation models.* In this case the model takes a thousand possible paths of the underlying asset evolution into account from current date to the moment of decision. The commonly used method is Monte Carlo simulation. At the end of each path, the strategic optimal investment is obtained, and the income of the project is calculated. Finally, the option value is calculated as the present value of the mean of the income [15].

C. Binomial Lattice Models

The present work implements the binomial lattice method for valuing the real options [14]. The reason for selecting this method is that it allows the appraisal of a wide variety of options, is easy to implement and to explain. In addition, it presents the appearance of discounted cash flow analysis. Therefore, uncertainties and the consequence of contingent decisions are described in natural form. Moreover, the method provides a graphical solution of the decision making problem.

The binomial lattice model consists of four steps: 1- Define the underlying asset, 2 - Construction of event lattice for the underlying asset, 3-Assessment of the option value at terminal node, 4- Construction of the decision lattice, and working backward, valuation of option at its internal nodes. Finally, the option value is achieved at the first node.

Commonly, the classic NPV are defined as an underlying asset, *S*, which is calculated by the traditional DCF method. Next, the volatility of the logarithmic return, σ_{LogR}, is estimated by Monte Carlo simulation, and for this purpose, the construction of the event lattice is required.

In the second step, underlying asset values are generated at each of the nodes of binomial lattice, see Fig. 1. This is characterized by '*n*' intervals of time from t=0 to the time where the option expires.

To define the evolution of the underlying asset, it is necessary to calculate the coefficients of upward movement, *u*, and downward movement, *d*. These coefficients are strongly related to the volatility, σ_{LogR}, and the underlying asset value and option maturity, *T*.

If it is considered that the underlying asset follows a Geometric Brownian Motion (GBM), the equation that describes the coefficients *u* y *d* are:

$$u = e^{\sigma_{LogR}\sqrt{T}}\,;\, d = e^{-\sigma_{LogR}\sqrt{T}} \tag{1}$$

where σ_{LogR} is the volatility of the GBM. In this case, it is the volatility of logarithmic returns of the underlying asset. Having the underlying lattice, the next step is valuing the option in the terminal nodes. At the maturity, the investment is considered as a now-or-never investment. Thus in the terminal nodes the decision criterion is the same as the NPV approach.

The next step determines the value option in the intermediate nodes. In these nodes, the option value is calculated using the risk neutral assumption. Under this assumption, the option value is equal to the expected present value of its future payoffs. In each node, the expected value is calculated from the option values of the later two nodes weighted by their respective probabilities, *p* to an upward move of the underlying, and (*1-p*) to a down move. The expected value is then discounted at the risk-free rate, *r*. It is important to remark that the probability *p* is a non-objective probability. This is called risk-neutral probability. [16]

A huge advantage of this method is that it is not necessary to pay any attention to investor attitude for bearing the involved risk. In this case, risk in not considered.

Thus, the option value is found for each node, starting at the penultimate time step, and working backward to the first node of the lattice. Therefore, the option value (*C*) at an intermediate node is calculated applying (2).

$$C = \frac{(p_u C_u + (1-p_u).C_d)}{(1+r)^T} \tag{2}$$

Where p_u is the risk-neutral probability as follows:

$$p_u = \frac{(1+r)^T - d}{u-d} \tag{3}$$

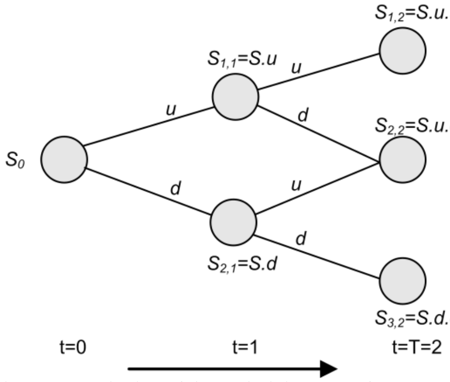

Fig. 1. Event lattice of the underlying asset for two steps

This method could be easily extended to a multi-step binomial lattice. For the sake of clearness, an example valuation of deferral options (call option) in two step lattice is depicted in Fig 2, where *X* represents the exercise option value or the investment cost.

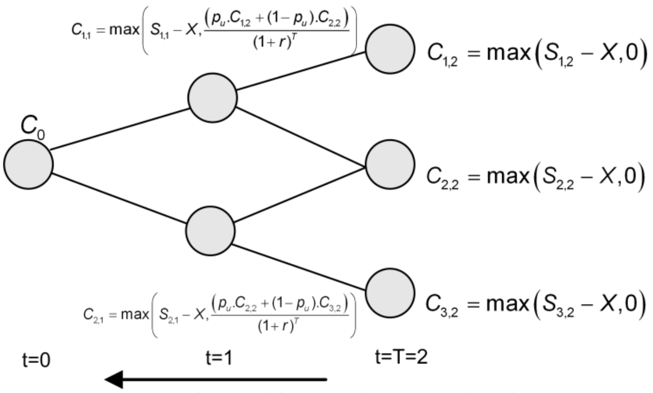

Fig. 2. Two steps binomial lattice, call option with expire time *t=T*

IV. VALUING FLEXIBLE TRANSMISSION INVESTMENTS UNDER A MIXED MERCHANT-REGULATED FRAMEWORK

This section exposes a methodology for valuing the investment performance of pure merchant transmission and mixed merchant-regulated investments under uncertainties. This model seeks to derive the investment signals that each approach offers for making an optimal investment decision.

Both investment structures are applied to a stochastic model which replicates the uncertain behavior of the electricity market. Uncertain variables such as: spatial load growth, evolving generation costs, availability of system components are taken into account in the model through adequate stochastic processes.

Firstly, it must set up the electrical parameters of the system and the stochastic parameter of uncertain variables. Moreover, it is necessary to define the financial data such as discount rates, option maturities of each investment approach and the regulated rate-of-return for the mixed proposal.

The investment performance is obtained through the Monte Carlo simulation method for determining the probability density functions of the project revenues. Afterwards, these revenues are evaluated according to the Real Options Method in order to evaluate the strategic flexibility embedded in the investments, i.e. the postponement option in the merchant investment and the option to become regulated in the mixed Merchant-Regulated investment.

This appraisal approach is an adequate way to determine the incentive that generates this novel regulatory framework for transmission investments. It is also a powerful analysis tool for the regulator in order to determine the efficient rate-of- return necessary to trigger an immediate investment keeping open the switching option instead of deferring the transmission expansion.

The proposed methodology is schematically shown in Fig. 3.

V. VALUING FLEXIBILITY IN AN INTERCONNECTION LINE. NUMERICAL EXAMPLE

Following, a detailed numerical example built on an actual setting is presented. The importance of considering the value of flexibility within the proposed investment framework is demonstrated.

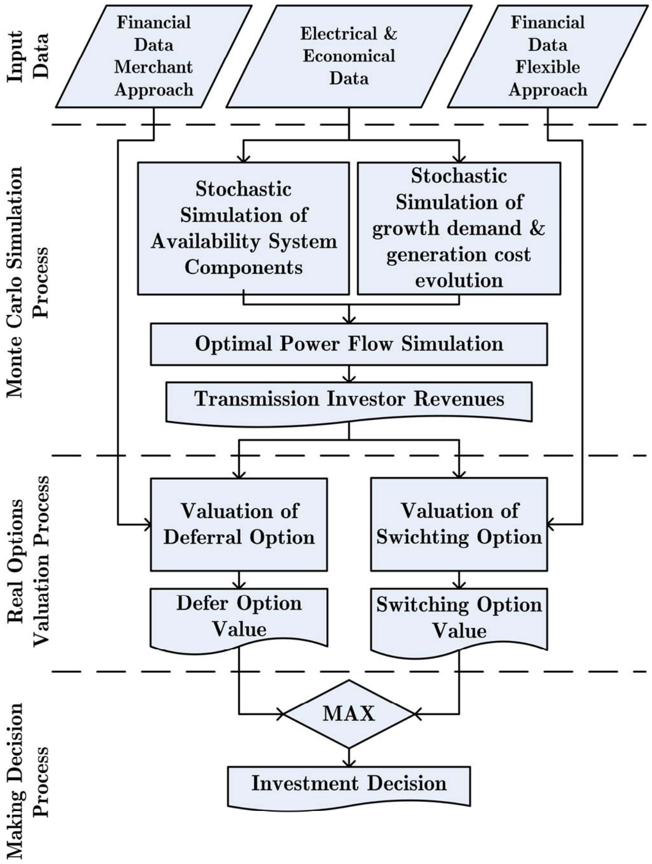

Fig. 3. Proposed Assessment Methodology Scheme.

An investment in an interconnection transmission line of 1000 MW and 250 km between two isolated systems is considered (Fig. 4).

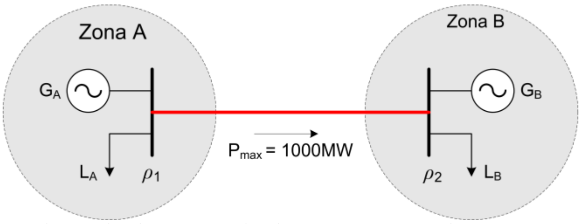

Fig. 4. Line interconnection between Zone A and Zone B

This investment can be committed under two mutually exclusive revenue frameworks, merchant or flexible merchant-regulated approach.

Under the merchant approach, the investor revenues will be nodal price difference between both zones per MW transmitted by the line. The investor has the option to postpone the line construction for two years (deferral option).

On the other hand, if the investor adopts the flexible merchant-regulated revenue framework, he has the obligation to execute the investment immediately. Initially, under this approach the investment revenues are the same as the merchant approach, but in case of an unfavourable evolution of market conditions, the investor has the choice to switch to a regulated approach where is rewarded with a rate-of-return regulation fixed by the System Regulator. Similarly to the defer option; the switching option remains open for two years.

A. Input Data

The annualized investment cost in the transmission line (Ω_c) is considered proportional to capacity (T_c) and length (l_c):

$$\Omega_c(T_c) = k_c l_c T_c \tag{4}$$

where, the annualized marginal investment cost of per unit length (k_c) is assumed equal to 50 \$ / (MW·km·year).

The amortization period of the investment is considered 15 years, so that the initial outlay of the interconnection line construction is 187.5 M\$.

Annual financial costs are equal to 13% for the merchant structure and 12% for the merchant-regulated structure. The financial cost is lower in the second structure due to the lower downside risk [2].

As stated before, deferral and switching options have maturity equal to two years. Moreover, the regulated rate-of-return for the switching option is 7%. Thus, the present value at exercise time of the regulated revenues is equal to 200.63 M\$.

Both generators have a maximum power of 5000 MW and represent the aggregated supply system of each zone. The aggregate supply curve for each zone is assumed to have a quadratic behaviour. The Value of Lost Load (VOLL) is fixed at 500 \$/MWh. The load duration curves at the initial time are shown in Fig. 5.

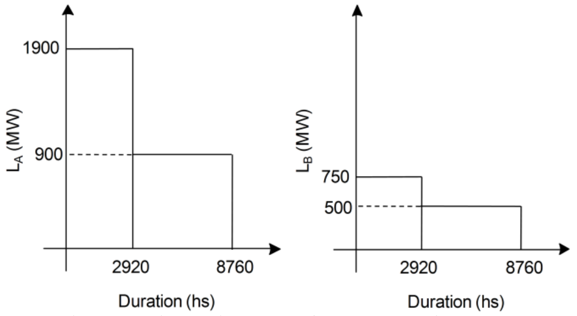

Fig. 5. Load Duration Curve for Zone A and Zone B

B. Monte Carlo Simulation Process

Spatial load growth, generation cost evolution and availability of system components are taken into account in the evaluation as uncertain variables and must be modeled by adequate stochastic process.

The demand growth rate is assumed to follow a Brownian Motion (BM), where the expected growth rate is 5% for the peak load period with a standard deviation of 0.4% and 2% for the low load period with a standard deviation of 0.3%.

This article considers a thermal generation system using fossil fuels as primary energy source. The evolution of the fuel prices follows a mean-reversion stochastic process according to (5).

$$p_{t-1}^F - p_t^F = \alpha\left(\overline{p^F} - p_t^F\right) + \sigma_{p^F}\varepsilon_t \tag{5}$$

where, α is the reversion velocity (0.64), σ_{p^F} is the fuel price volatility and $\varepsilon_t \sim N(0,1)$.

Commonly, generation cost is linked with the fuel prices through the input-output function of the generating unit ($H(q_t)$ [MBtu/h]), according to the following expression [15]:

$$C\left(q_t, p_t^F\right) = \left(a_0 + a_1 q_t + a_2 q_t^2\right).p_t^F \equiv H\left(q_t\right) p_t^F \tag{6}$$

where $C\left(q\ (t), p_F(t)\right)$ is the generation cost at a production level of $q\ (t)$ [MW] and a fuel price of $p_F\ (t)$.

The parameters involved in (4) and (5) can be found in Table I.

TABLE I.
GENERATION COST PARAMETERS

Generator	a_2	a_1	p^F [\$/BTU]	σ_{p^F}
G_A	0.009	12	4.596	0.57
G_B	0.012	25	4.596	0.57

The system component availability is modeled by a conventional two-state process, which can be seen in Fig. 6. In this figure, **O** represents the operation state and **F** the failure state, λ is the failure rate and μ is the repair rate.

The steady state probabilities of operation and failure are obtained from these rates according to [17]:

$$\Pr(\text{O}) = \frac{\mu}{\mu+\lambda};\ \Pr(\text{F}) = \frac{\lambda}{\mu+\lambda} \tag{7}$$

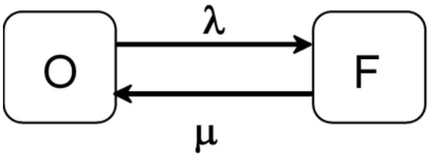

Fig. 6. Two-state reliability model of electric system component

Transition between states in this model is defined by the random Time To Failure (TTF) and Time To Failure (TTR) which are distributed according to exponential distributions with constant parameters equal to μ and λ respectively. These times are simulated in a chronological way through random and independent samples.

$$\text{TTF} = -\frac{1}{\lambda}(\text{U}[0,1]);\ \text{TTR} = -\frac{1}{\mu}(\text{U}[0,1]) \tag{8}$$

where U [0,1] are independent random numbers uniformly distributed in the interval [0,1]. Table II summarizes the reliability parameters of each system component.

TABLE II
RELIABILITY PARAMETERS OF THE SYSTEM COMPONENTS

Component	λ	μ
G_A	0.0001	0.0495
G_B	0.0001	0.0495
Line	0.0005	0.0495

A number of 20000 Monte Carlo realizations [18] are computed in order to obtain the expected present value (PV) of the cumulated revenues and their corresponding volatility under each investment approach. Fig. 7 shows the histogram of these stochastic simulations.

The expected Present Value (PV) and Net Present Value (NPV) for the merchant transmission investment and the mixed approach are exposed in Table III. Moreover, the logarithmic return volatilities (σ_{LogR}) of each approach are also shown in the same table.

C. Real Option Valuation Process

The Real Option Valuation method is applied to assess the option value of deferring the transmission investment under the merchant approach and the option of switching the investment return to a regulated regime.

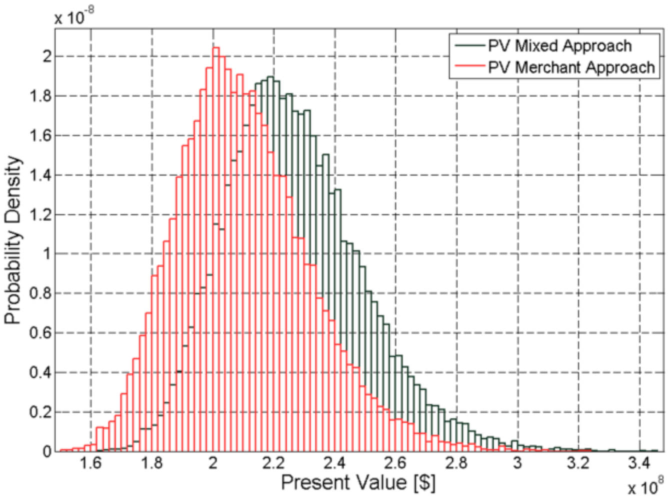

Fig. 6. Investment performance stochastic simulation results

TABLE III
EXPECTED PV & NPV AND LOGARITHMIC RETURN

Approach	PV [M$]	NPV [M$]	σ_{LogR}
Merchant	210.05	22,55	10.06%
Merchant-Regulated	226.44	38.94	9.76%

The strategic flexibility (deferral and switching options) is evaluated by the binomial lattice method as outlined in Section III. The risk-free return on investments is assumed 4.5%. Table IV summarizes the binomial parameters calculated applying (1) and (3).

TABLE IV
BINOMIAL LATTICE PARAMETERS

Approach	*u*	*d*	*p*	*1-p*
Merchant	1.106	0.904	0.6983	0.3017
Merchant-Regulated	1.103	0.907	0.7057	0.2943

Fig. 7 and 8 show the binomial lattice of the underlying asset for each approach considered. Based on this evolution along the option maturities, the strategic flexibility valuation is carried out.

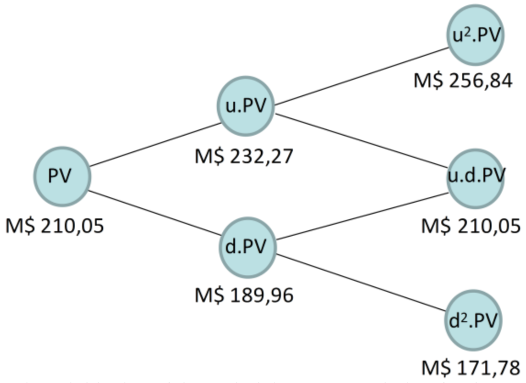

Fig. 8. Binomial lattice of the underlying asset evolution for the merchant approach

The intrinsic value of the option to defer is equal to the net present value -in each binomial lattice node- of the underlying asset, i.e. subtracting the investment cost from the underlying asset value. The binomial lattice of the intrinsic option value can be seen in Fig. 9.

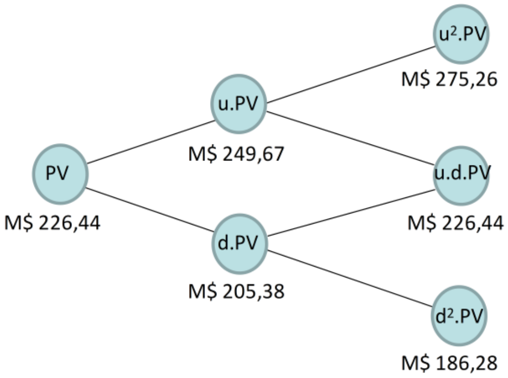

Fig. 7. Binomial lattice of the underlying asset evolution for the flexible merchant-regulated approach

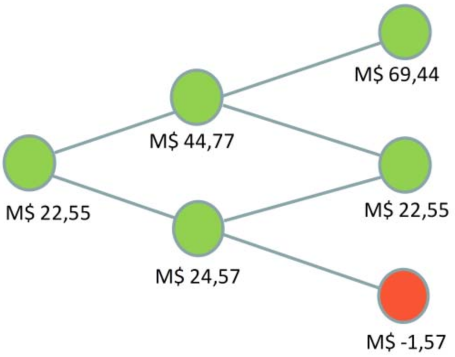

Fig. 9. Binomial lattice of the intrinsic option value for merchant approach

The deferral option value is founded working backward - according to (2) - from underlying asset and intrinsic option value lattices. This process is exposed in Fig. 10.

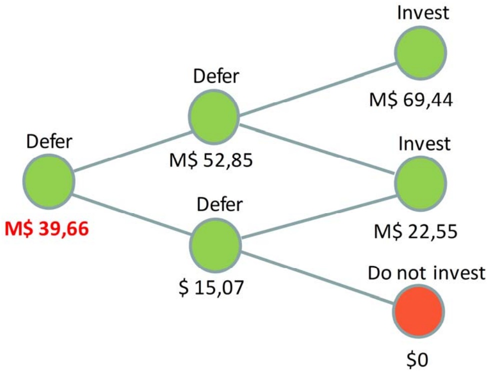

Fig. 10. Valuation of Option to Defer for mixed merchant approach.

For sake of simplicity, under the flexible framework the intrinsic value of the switching value in any state of the binomial lattice is equal to the present value of the regulated revenue.

In any state of the binomial lattice at the maturity of the switching option, the investor exercise this option only when the present value of the regulated revenue is higher than the underlying asset value.

Thus, the switching option value is found working backwards - applying the framework analyzed in Section III - from the underlying asset binomial lattice and the exercise option criterion exposed in the paragraph above. The binomial lattice used for calculating the switching option value and its optimal exercise timing is illustrated in Fig. 11.

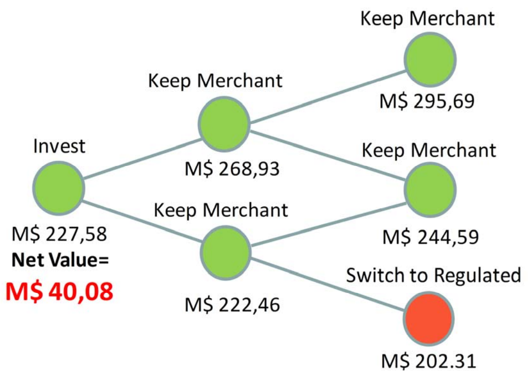

Fig. 11. Valuation of Switching Option for flexible regulatory approach

D. *Making Decision Process*

Under the merchant approach, as is shown in Fig. 9, the investment has a positive net present value at initial time. However, if the investor has the entitlement to defer the investment, the optimal investment policy is to postpone the exercise of that option until its maturity. In this case, the investor executes the project only if the uncertainties unfold favorably, Fig. 10.

Due to the large uncertainties that affect the transmission merchant investment, deferral option normally has a significant value. Consequently, this kind of investment is often not executed. Therefore, flexibility added by the option to defer in general does not incentive immediate private investments.

On the other hand, the flexibility added by the switching option under the flexible regulatory framework increases the net present value of the project (see Fig. 11). As this framework does not offer the postponement option, the investment is executed immediately.

It is important to note that investor only exercises the switching options after two downward consecutive steps. Therefore, the proposed approach provides incentives for the private investment through a flexible framework and it is likely that the switching option does not be exercised.

Considering both options (deferral and switching) as mutually exclusive, the optimal decision for the investor is to adopt the flexible regulatory framework, immediately executing the interconnection investment as the switching option remaining open. This decision is based on the fact that the switching value is higher than the value of the deferral option.

The impact of the flexible regulatory approach on the investment incentive is highly correlated with the rate-of-return offered by the System Regulator. Therefore, it is important to adequately fix this rate in order to provide a incentive for the private investment, and at the same time, avoid an early triggering of the switching option.

A sensitive analysis is performed with the aim of shedding light on the behavior of the switching option in function of the rate-of-return. From this analysis, the minimum that originate an immediately private investment execution is 4.21%.

From this least rate (LR), two decision regions can be identified. For rates lower than LR, the optimal investment strategy is to adopt the merchant approach, postponing the investment according to Fig. 10. Finally, for rates higher than LR, the optimal framework is the flexible regulatory approach, where the investor executes the project and seizes the flexibility added by the switching option. In Fig. 12 the sensitive analysis is graphically illustrated.

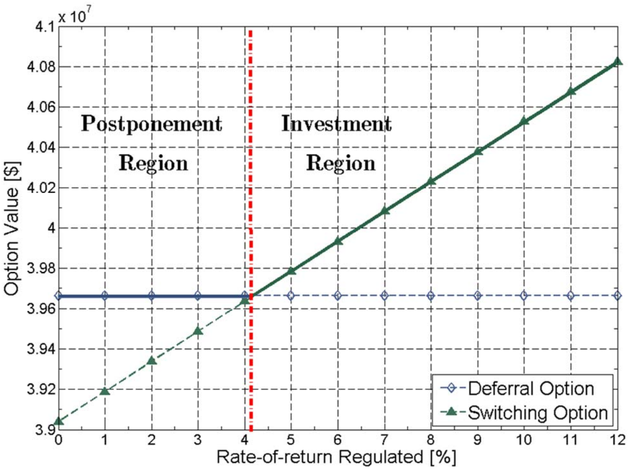

Fig. 12. Sensitive Analysis of Option values in function of rate-of-return

Thus, the exposed valuation model can be used as a useful System Regulator tool for establishing a rate-of-return level, which adequately incentive private investment.

This rate can be even lower than a pure regulated rate, due to the fact that the investor under the flexible approach has the opportunity of seizing extraordinary revenues during its operation as merchant.

These extraordinary revenues are usually associated to scenarios with energy deficit, which originate peaks in the nodal prices difference. Commonly, these scenarios appear when system components are unavailable.

Therefore, it is important take into account as an uncertain variable the system component availability.

Figure 13 shows the component availability impact on the underlying asset value under flexible approach. Bearing in mind that the investment cost is equal to 187.5 M$, from the figure below, can be concluded that -if the extraordinary revenues are not considered - the net present value at the initial time is negative.

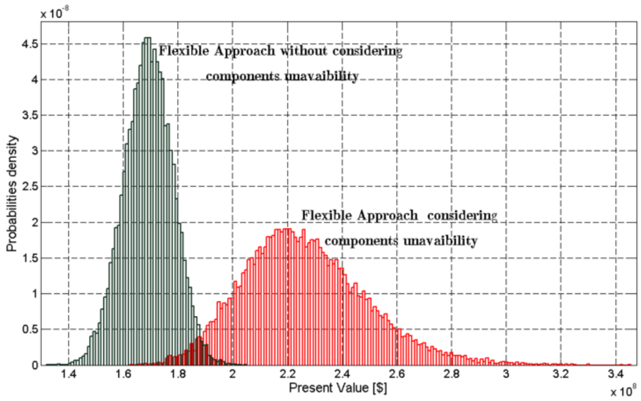

Fig. 12. Impact of component availability on the probability density of investment revenues under merchant approach.

In this case, the investor could exercise the switching option early or postpone the investment adopting the merchant approach. These decisions are sub-optimal according to the previous analysis. Therefore, the investor should consider the unavailability component as an uncertain variable in the investment assessment, in order to make optimal decisions.

VI. CONCLUSION

This article proposes a novel flexible regulatory framework for private transmission investment within the expansion transmission under uncertainties. The uncertainties, related to electric power systems, have been successfully modeled for replicating the power market behavior.

The flexible regulatory framework seems to be a good alternative to incentive the transmission investment from private investors.

The Real Options Valuation method has been applied in order to assess the strategic flexibility of the proposed mechanism, which favours the immediate commitment instead of the postponement option.

The proposed methodology looks promising for developing a regulatory framework that determine the adequate return level in order to provide an incentive for the private investment in transmission infrastructure.

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