Brazilian power distribution investment under service price uncertainty: A Real Option analysis

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Abstract: Power distribution companies face great challenges in balancing profit maximization with the regulatory board requests. Modeling uncertainties has been essential to distribution investment risk assessment. For the Brazilian environment, the uncertainties in setting the price of wheeling services, coming from the Electricity Regulatory Agency, add more volatility to the investment return, as well as to other common uncertainties, like interest rates and equipment costs. The proposed investment analysis method encompasses the effects of price-cap regulation in association with the irreversibility, flexibility and uncertainty of a new investment. A Real Options framework is used to valuate investment opportunities under the regulated wheeling charge, providing the optimal investment frontier in terms of price. Examples coming from a real company are used for illustrating the concepts introduced in this paper.

Keywords. Power distribution investment, Electricity Distribution Pricing, Uncertainty modeling, Real Options Theory

1 - Introduction

In the electric-power distribution environment, the major challenge to the regulatory boards is to design an economic regulatory scheme balancing appropriately the return for monopoly concessionaires' investments and operational costs with the promotion of cost-efficiency incentives combined to adequate service quality standards. Furthermore, the final prices of the rendered services must be acceptable to the consumers (Rudnick and Donoso 2000].

These are conflicting goals, since the more the efficiency incentives increase, the less certain the cost recovery and profitability become. But if the uncertainty in outcomes is reduced, by providing guarantees for cost recovery, motivation for cost reduction is affected. This is the core dilemma in regulation (Dismukes and Ostrover 2001).

Incentive regulation schemes, such as the price cap regulation, have been practiced throughout the world in order to encourage the companies' efficiency. In essence, price cap regulation employs caps on service prices which allow the individual companies discretion over all investment and operating decisions. However, until there is a new price review, the firm bears risks associated with varying exogenous input prices and changeable demands. The positive aspect of price cap regulation is the utility incentive to minimize short-term costs. Since short-term prices are established, any cost reductions achieved by the utility is directly translated into increased profit. One problem is that strong incentives for cost reduction can lead to quality degradation, therefore requiring additional controls on quality levels (Cowan 2002; Marangon Lima et al. 2002).

Although price cap regulation has been successful in establishing incentives for cost efficiency, its ability to induce appropriate long-term investment has not been proved yet. The inclusion of the business uncertainties on the price definition is a concern present in many discussions over the best regulatory practices (Pyndick 2005).

The interaction of irreversibility, flexibility and uncertainty makes a significant difference in the valuation of an investment alternative and should be considered in the tariff design process.

Even though public utilities usually have a contractual obligation to serve, i.e., they must provide service to any consumer request in their concession area, these companies have managerial flexibilities over the timing and the extent of those investments (Pyndick 2005). These flexibilities, associated with the decisions made along the investment horizon, represent real options. When exercised in optimized form, they increase the project value obtained through traditional metrics applied in investment appraisal such as the Net Present Value (NPV). Among the options applicable to distribution service are those of investing in a new project, or of expanding the project, in case the results are better than expected, or of contracting it, replacing equipment by another with lower capacity (Marangon Lima et al. 2002). The literature on real options research is extensively covered in Dixit and Pindyck (1994), and Trigeorgis (1996).

Modeling uncertainties and managerial flexibility has been essential to distribution investment risk assessment. For the Brazilian environment, the uncertainties on price settings coming from ANEEL, the Brazilian Electricity Regulatory Agency, add more volatility to the investment return, besides interest rates and other variables associated with the market. So, from the distribution side, the inclusion of the real option value can change the motivation to invest.

When a distribution company (DISCO) makes an investment under uncertainty, it is actually exercising its option to invest but, simultaneously, it is giving up its option to wait to see how uncertainty will be resolved and thus investing in an optimal time. The wait value grows with the uncertainty emphasizing that the option to invest is crucial in a value-based management environment (Pyndick 2005). However, if the DISCOs are forced to invest due to regulation, i.e., the obligation to serve due to concession contracts, they need to face all the future uncertainties which should be valued and passed through the tariff. There is a lot of discussion about the fairness of such approach (Panteghini and Scarpa, 2001, Moretto et al., 2008, C.,Dobbs, 2004, Roques e Savva, 2006, Clark and Easaw, 2007; Nagel and Rammerstorfer 2008, Panteghini and Scarpa, 2008, Camacho and Meneses, 2009) especially at the telecommunication regulation (Salinger 1998; Alleman and Noam 1999; Volgesang 2002; Pyndick 2005; Evans and Guthrie 2006). Anyway, even in this case, the calculation of the real option becomes important to value the associated DISCO risks.

This paper contributes to analyzing the effects of regulatory uncertainty on investment incentives in the presence of irreversibility, flexibility and uncertainty. A real options framework is used to valuate distribution investment opportunities under the Brazilian regulatory environment analyzing the impact of price controls on its level and timing. An investment in a new substation of a Brazilian distribution company is taken as an example. The value of the project considering the power distribution service price uncertainty is taken into account to calculate the impact on the investment value and provide the optimal investment frontier in terms of price.

The remaining of the paper is organized as follows: Section 2 describes the regulatory scenario concerning the electric-power utilities in Brazil. Section 3 presents the investment opportunity model under the distribution service price uncertainty. In Section 4 the introduced concepts are applied to a real case of a Brazilian DISCO company. Section 5 ends with the conclusions.

2 - The Brazilian economic regulation model

The electric-power distribution companies supply electricity to their consumers based on a concession contract made with the Federal Government. Concession contracts set clear rules regarding tariff rates, their updating process, besides quality, continuity and safety of the delivered services. According to the concession contracts, the supply tariffs can be updated through three mechanisms: annual tariff readjustment, periodic tariff review and extraordinary tariff review.

With the objective to ensure the concession's economic and financial stability, tariff revisions are performed for each individual distributor every four years in average. This timeframe is previously defined in the concession contract and expressed in budgetary time periods (for instance, August to July fiscal years).

The tariff revision is performed through two steps, calculation of the review index and assessment of the *X*-factor.

In the tariff revision process, the agency initially analyzes and adjusts the DISCO annual required revenue (*RR*), which consists of two parts (ANEEL 2009).

$$RR = RA + RB \tag{1}$$

RA refers to the non-manageable costs by distributors, consisting of sector charges, transmission costs and power purchase for the regulated consumers. These costs are directed passed through the tariffs. This part of the revenue is not the subject of this paper because it does not affect the return of the company.

RB represents the distribution service revenue, and it consists of the profitability over the utilities' invested capital, depreciation and their manageable costs: expenses with operations and maintenance. This part of the revenue represents the pure activity, i.e., the "wire" business.

The review index (*RevI*) is given by:

$$RevI = \frac{RR - AI}{VR} \tag{2}$$

Where *RR* is the annual distribution required revenue, *AI* is the annual additional income not linked to the concession purpose, and *VR* is the verified revenue, obtained applying the current tariffs to the forecasted demand required by the distributor to supply it for the base year (the 12 months after the date of revision).

The *X*-factor, which represents the economic efficiency and productivity goals for the subsequent tariff period, is applied in the annual tariff readjustments during the time span between the revisions. The *X*-factor is assessed through a Discounted Cash flow (DCF) with the objective to valuate the company's future incomes and costs given a specified load growth and the forecasted investments in network expansion.

The annual tariff readjustment is foreseen in the electric energy distribution concession contracts to maintain the financial equilibrium achieved by the tariff revision. The controllable costs incurred during the reference period are relayed to the consumer. Then the adjustment of the controllable costs to inflation is done by correcting RB for the variation of an inflation index (usually the IGPM in Brazil) observed in the 12 previous months to the date of the adjustment. The resulting value is then reduced by the X-factor. The adjustment index ($AdjI$) is obtained dividing the total revenue by the previous 12 months verified revenue (VR).

$$AdjI = \frac{RA + RB(IGPM - X)}{VR} \qquad (3)$$

The average distribution service price $P(t)$ at year t of the distribution wheeled service is calculated dividing the distribution revenue (RB) by the annual wheeled energy $E(t)$.

$$P(t) = \frac{RB(t)}{E(t)} \qquad (4)$$

3 - Investment opportunity model

Given the distribution regulatory environment, next it is shown how the Real Options Theory (ROT) can be used in the decision making process.

A. Project Present Value without managerial flexibility

Consider a distribution expansion investment project with lifetime T. The incremental project net cash flow $\pi(t)$ at some future time $t \leq T$ can be estimated according to

$$\pi(t) = (1 - IR)[8760 LF(1 - DL)D(t)P(t) - I(C + Depr)] + Depr \cdot I \qquad (5)$$

where:

IR is the income tax rate;

LF is the project load factor;

DL are project annual distribution technical losses;

$D(t)$ is the incremental demand supplied from the presence of the new investment;

I is the present value of the investment cost;

C is the annual OPEX, defined as a percentage of the investment value; and,

$Depr$ is the linear depreciation rate.

The average distribution service price $P(t)$ evolves over time with an α_P rate, thus its future expected value given a current P_0 is given by

$$P(t) = P_0 e^{\alpha_P t} \qquad (6)$$

The present value of the project is obtained by using the traditional DCF method without considering any managerial flexibility. The project value (V) is the continuous expected present value of the asset operation after T years, being expressed as

$$V = \int_0^T \pi(t) e^{-\mu t} dt \qquad (7)$$

where μ is the project's WACC.

Applying the equations 5, 6 and 7, the expected project value after T years of operation can be written as

$$V = \int_0^T \left\{ (1-IR)\cdot 8760 \cdot LF(1-DL)\cdot D(t) P_0 e^{\alpha_P t} + I\left[IR \cdot Depr - C(1-IR)\right] \right\} e^{-\mu t} dt \quad (8)$$

The added system demand that will be supplied by the project is a linear function that grows at a constant rate α_D until attaining the asset power demand capacity limit $\overline{D}$ at $\overline{T}$. Beyond $\overline{T}$, the supplied power demand is constant and equal to $\overline{D}$. Therefore, for the analysis asset investment:

$$D(t) = \begin{cases} \alpha_D t + D_0 & \text{for} \quad 0 \le t \le \overline{T} \\ \overline{D} \text{ for } \overline{T} < t \le T & \text{where} \quad \overline{T} = \dfrac{\overline{D} - D_0}{\alpha_D} \end{cases} \quad (9)$$

Substitution of equation 9 into equation 8 gives

$$V = M_1 P_0 + M \quad (10)$$

where

$$M_1 = \frac{(1-IR)}{(\mu - \alpha_P)} 8760 LF(1-DL) \left\{ \frac{\alpha_D}{(\mu - \alpha_P)} \left[1 - e^{-(\mu - \alpha_P)\overline{T}} \left(1 + (\mu - \alpha_P)\overline{T} \right) \right] \right. \quad (11)$$

$$M_2 = \frac{I\left[IR \cdot Depr - C(1-IR)\right]}{\mu} \left(1 - e^{-\mu T}\right) \quad (12)$$

The net present value (NPV) of the project is assessed by

$$NPV = V - I \quad (13)$$

Therefore, the distribution company objective is to maximize the expected net present value, with the constant discount rate μ.

B. Project volatility

The inclusion of volatility analysis allows utilities to anticipate strategies against undesired variations of the project uncertainty. The approach adopted in this paper to estimate the volatility of the distribution projects as a function of the expected distribution price considers that the future value of the project cash flow evolves over time according to a geometric Brownian motion (GBM) (Dixit and Pindyck 1994).

$$dV = \alpha_V V dt + \sigma_V V d \quad (14)$$

α_V is the drift rate and σ_V is the project volatility, defined as the standard deviation of the return rate of the project's present value (*dV/V*).

For the sake of simplicity, only the average distribution price *P(t)* is considered as the input random variable, which also evolves over time according to a GBM.

$$dP = \alpha_P P dt + \sigma_P P dz \quad (15)$$

α_P is the drift rate; σ_P is the volatility which remains constant over time; and, dz is the standard Wiener process, defined as $dz = \varepsilon_t \sqrt{dt}$. ε_t is a serially uncorrelated and normally distributed random variable $\varepsilon \approx N(0,1)$, and $N(0,1)$ is the standard normal distribution.

As the project payoffs depend on the average distribution price, the project value *V(P,t)* can be obtained as a function of this variable. The following partial differential equation is obtained by using Ito's Lemma.

$$dV = V'_P \, dP + V_t' dt + \frac{1}{2} V''_{PP} (dP)^2 \quad (16)$$

From equation 15

$$dV = \left(\frac{1}{2} \sigma_P{}^2 P^2 V''_{PP} + \alpha_P P V'_P + V_t' \right) dt + \sigma_P P V'_P \, dz \quad (17)$$

The project's volatility and its drift rate are obtained by inspection, comparing the equations 14 and 17 (Lima and Suslick 2006).

$$\alpha_V = \frac{1}{V} \left(\frac{1}{2} \sigma_P{}^2 P^2 V''_{PP} + \alpha_P P V'_P + V_t' \right) \quad (18)$$

$$\sigma_V = \frac{P}{V} V'_P \, \sigma_P \quad (19)$$

When the project starts at year *t* into the future, its current value is assessed by

$$V(t) = M_1 P(t) + M_2 \quad (20)$$

Combining the equations 6, 19 and 20 for *t* =0 the project volatility is

$$\sigma_V = \frac{P_0}{V} M_1 \sigma_P = \left(1 - \frac{M_2}{V} \right) \sigma_P \quad (21)$$

The project drift is obtained from equations 6, 18 and 20.

$$\alpha_V = 2 \frac{P_0}{V} M_1 \alpha_P = 2 \frac{\sigma_V}{\sigma_P} \alpha_P \quad (22)$$

Therefore, the GBM parameters of the project value are greater than the corresponding distribution price ones.

According to the Capital Asset Pricing Model (CAPM), the project required rate of return (α_V) is proportional to the asset risk, measured in terms of its correlation with the whole market portfolio (Sharpe 1964). Under uncertainty conditions α_V can be equal to its certainty equivalent, the risk-free rate of return (r), plus a risk premium of the project expressed by $\lambda_V \sigma_V$ (Martzoukos and Teplitz-Sembitzky 1992).

$$\alpha_V = r + \lambda_V \sigma_V \tag{23}$$

Assuming the risk-neutral model proposed by Hull (2007), the distribution price trend is

$$dP = (\alpha_P - \lambda \sigma_P) P dt + \sigma_P P dz \tag{24}$$

This equation, obtained substituting the equations 18 and 19 into equation 23, is similar to equation 15, with a modified drift rate of $(\alpha_P - \lambda \sigma_P)$ instead of α_P (Brandão and Saraiva 2007).

Let λ be the market price of risk for the distribution price. This parameter can be estimated by

$$\lambda = \frac{\rho_{P,m}}{\sigma_m} (\mu_m - r) \tag{25}$$

where $\rho_{P,m}$ is the correlation between the returns on the asset chosen to represent the distribution price and a whole market index returns. μ_m is the expected return of a market index, and σ_m is the volatility of the whole market index.

Given that the distribution price represents all the project uncertainty of the project, then

$$\rho_{V,m} = \rho_{P,m} \tag{26}$$

$$\lambda_V = \lambda \tag{27}$$

The volatility of the distribution price, $P(t)$, can be assessed from historical series of $E(t)$, and $RB(t)$, by using equation 4. The GBM can be represented by the stochastic evolution of $P(t)$, based on an Ito process.

$$d \ln P = \left(\alpha - \frac{\sigma_P^2}{2} \right) dt + \sigma_P dz \tag{28}$$

The discrete time equation for the GBM stochastic process allows the assessment of $p(t)$ current value as a function of its $p(t\text{-}1)$ $p(t-1)$ previous value, as shown in equation 29.

$$d[\ln(p(t))] = \ln(p(t)) - \ln(p(t-1)) = \alpha dt + \sigma_P \sqrt{dt} \varepsilon_t \tag{29}$$

The distribution service price volatility parameter (σ_P) is the standard deviation and α is the average value of the $\ln(p(t)/p(t-1))$ series. Thus, the modified drift rate in a risk-neutral environment is

$$\alpha_P = (\alpha - \lambda \sigma_P) - \frac{\sigma_P^2}{2} \tag{30}$$

C. Real Options Assessment

A distribution company with an opportunity to invest in capacity expansion is holding an option analogous to a financial American call option. The DISCO would have the right, but not the obligation, to build an asset at a given investment in some future time. However, at a certain moment this right may transform into an obligation to satisfy the rising demand. By making the irreversible investment, the company exercises its option to invest but, simultaneously, it gives up its option to wait to see how the project uncertainties evolve and, therefore, its opportunity to invest at an optimal time.

As the project value depends on the average distribution service price, the DISCO stochastic optimal control problem is to maximize the NPV of the project considering the option to invest (*F*), which expires in τ years, subject to equation 14, deriving the time instant τ^* when the project reaches an optimal value V^* (Dixit and Pindyck 1994):

$$F(V,\tau) = \sup_{\tau^* \in [0,\tau]} E\left[e^{-r\tau^*}\{V(t) - I\}\right] \quad (31)$$

For project values below the *V** threshold, the DISCO will prefer to hold the option to invest; otherwise, i.e., for $V \geq V^*$, there will be immediate investment. This option value is given by the following partial differential equation (Dixit and Pindyck 1994):

$$\frac{1}{2}\sigma_V{}^2 V^2 F''_{VV}(V,t) + \alpha_V V F'_V(V,t) - rF(V,t) + F'_t(V,t) = 0 \quad (32)$$

Equation 32 is subject to the following boundary conditions (McDonald and Siegel 1986, Dixit and Pindyck 1994; Dias et al. 2004), which reflect the initial conditions and terminal payoff characteristics:

$$F(0,t) = 0 \quad (33)$$

$$F(V,\tau) = \max[NPV(V,\tau);0] = \max[V(P,\tau) - I;0] \quad (34)$$

$$F(V^*,t) = NPV(V^*,t) = V^* - I \quad \text{for} \quad t < \tau \quad (35)$$

$$F'_V(V^*,t) = NPV'_V = 1 \quad \text{for} \quad t < \tau \quad (36)$$

Equation 33 means that when V=0 the option to invest is also zero since nobody will pay an investment cost to undertake a zero present value project.

Equation 34 is the option expiration condition, i.e., at τ the option is to invest, earning the NPV value, or to not invest, earning a zero option value.

Equation 35 is the value-matching condition, where the option is exercised at the optimal time (τ *) and it is equal to the optimum project value with critical price P^* minus the payment of the investment value (I), in the case the threshold exists for a given $t<\tau$.

Equation 36 is the smooth-pasting condition that sets the continuity of the option value derivative at the optimal value to invest (V^*). At this point, $F(V^*,t)$ is tangential to NPV (V^* - I). When the investment is constant the smooth condition is given by equation 36 (Dixit and Pindyck 1994).

The solution of equation 32 and its boundary conditions is complex and requires numerical solution. In this paper, it is used the early exercise boundary closed form proposed by Bjerksund and Stensland (2002). The assessment sequence is given by equations 37-48.

$$B_\infty = \left(\frac{\beta}{\beta - 1}\right) I \quad (38)$$

$$B_0 = \max\left(I; \left(\frac{r}{r - \alpha_V}\right) I\right) \quad (39)$$

$$h(\tau) = -\left(\alpha_V \tau + 2\sigma_V \sqrt{\tau}\right)\left[\frac{I^2}{B_0(B_\infty - B_0)}\right] \quad (40)$$

$$V^* = B_0 + (B_\infty - B_0)\left(1 - e^{h(\tau)}\right) \quad (41)$$

$$\beta = \left(\frac{1}{2} - \frac{\alpha_V}{\sigma_V{}^2}\right) + \sqrt{\left(\frac{\alpha_V}{\sigma_V{}^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma_V{}^2}} \quad (37)$$

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$$h(\tau) = -\left(\alpha_V \tau + 2\sigma_V \sqrt{\tau}\right)\left[\frac{I^2}{B_0(B_\infty - B_0)}\right] \quad (40)$$

When $V \geq V^*$, the investment must be immediately undertaken. Thus

$$F(V, \tau) = NPV = V - I \quad (42)$$

When $V < V^*$, it is better to wait until the optimum threshold.

$$A = \frac{(V^* - I)}{(V^*)^\beta} \quad (43)$$

$$\begin{aligned} F(V, \tau) = {} & AV^\beta - A\varphi(V, \tau, \beta, V^*, V^*) + \varphi(V, \tau, 1, V^*, V^*) - \varphi(V, \tau, 1, I, V^*) \\ & - I\varphi(V, \tau, 0, V^*, V^*) + I\varphi(V, \tau, 0, I, V^*) \end{aligned} \quad (44)$$

The function φ is given by

$$\varphi(V, \tau, \gamma, Y, V^*) = e^{\chi\tau} V^\gamma \left[N(d1) - \left(\frac{V^*}{V}\right)^\kappa N\left(d1 - \frac{2\ln(V^*/V)}{\sigma\sqrt{\tau}}\right)\right] \quad (45)$$

where

$$\chi = \left[-r + \gamma\alpha_V + \frac{1}{2}\gamma(\gamma - 1)\sigma_V^2\right] \quad (46)$$

$$d1 = -\left(\frac{\ln\left(\frac{V}{Y}\right) + \left(\alpha_V + (\gamma - 1/2)\sigma_V^2\right)\tau}{\sigma_V\sqrt{\tau}}\right) \quad (47)$$

$$\kappa = \frac{2\alpha_V}{\sigma_V^2} + (2\gamma - 1) \tag{48}$$

The DCF traditional decision rule is: invest when *NPV*>0, that is, when *V*>*I*, as illustrated in Figure 1.

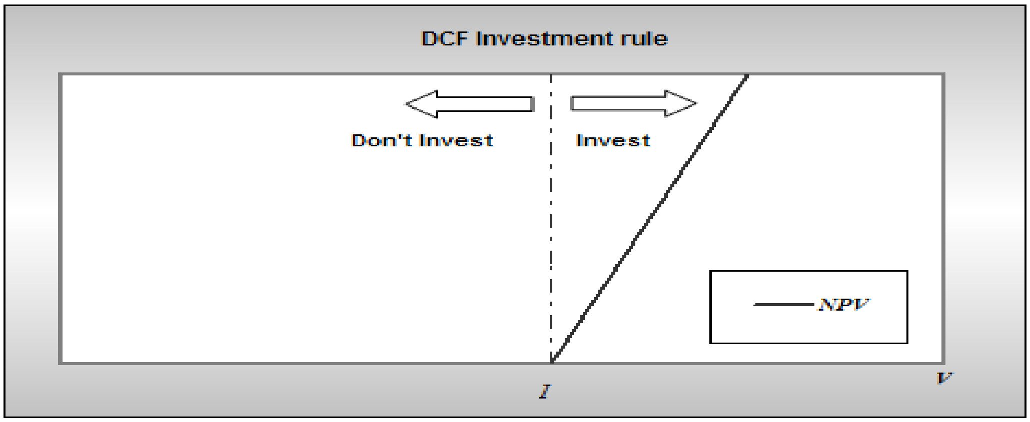

Figure1: Traditional Investment Rule.

With the ROT approach, the decision rule is stated according to the *V** threshold. Thus, as shown in Figure 2, if $V \geq V^*$, the DISCO must invest immediately, otherwise it is better to wait and see if investing in the future is worthwhile.

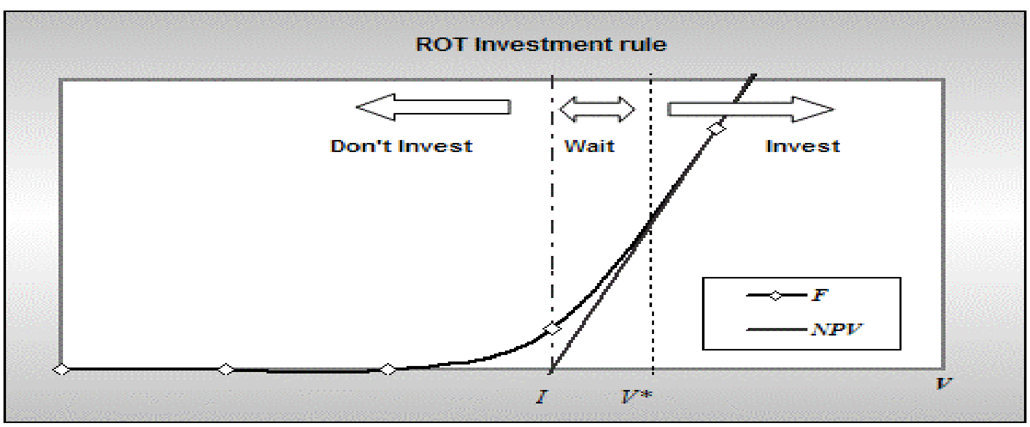

Figure2: Project optimal investment rule in a real options framework.

The value added by the investment option, or real option premium (*RO*), is expressed by

$$RO = F - NPV \tag{49}$$

The investment rule also can be expressed in terms of *P* as illustrated in Figure 3.

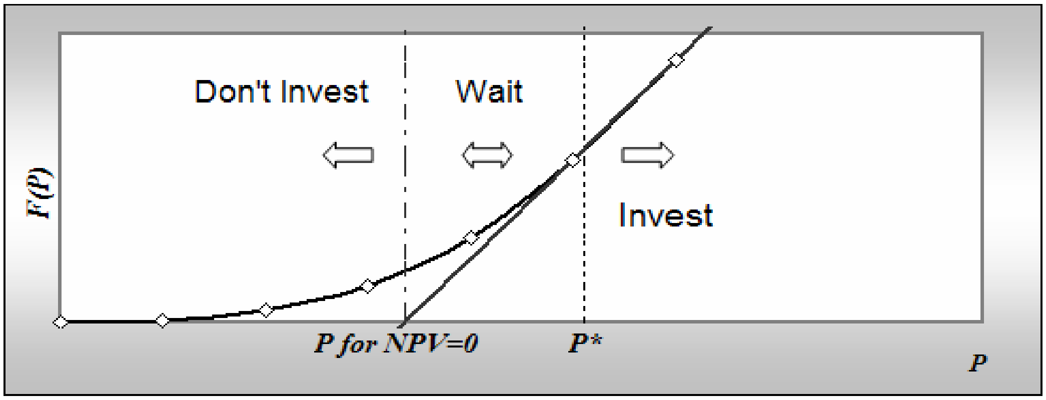

Figure 3: *P* Optimal investment rule in a real options framework.

Thus, the minimum distribution price for which the investment becomes viable ($P_{NPV=0}$), or break-even price, occurs when:

$$V\left(P_{NPV=0}\right) = I \tag{50}$$

The equation for $P_{NPV=0}$ was developed from equation 21.

$$P_{NPV-0} = \frac{I - M_2}{M_1} \tag{51}$$

Thus, according to this rule, the DISCO would invest when $P \geq P_{NPV=0}$.

By using equation 21 the optimal value to invest *P** can be expressed as a function of *V**.

$$P^* = \frac{V^* - M_2}{M_1} \tag{52}$$

Therefore, in presence of uncertainty and flexibility the optimal price value exceeds the traditional optimal price to invest by a percentage markup or premium that reflects the value of waiting for new information (McDonald and Siegel 1986; Dixit, A., Pindyck, R., Sødal, S. 1999; Pindyck 2005).

$$P_{MU}(\%) = \frac{P^* - P_{NPV=0}}{P_{NPV=0}} = \frac{P^*}{P_{NPV=0}} - 1 \tag{53}$$

In the regulatory context, the distribution companies do not have many alternatives in terms of investments. They are usually required to serve at certain quality levels due to their concession contracts. However, if the investment is not directly related to supplying new load, the company can analyze if it is better to postpone it, which may imply in fines related to quality performance. If this is not possible, the distribution service price should include the risk of the mandatory investment.

4 - Case Study

In this section, the proposed real options framework is applied to valuate the investment opportunity to build a new substation at the concession area of EDP ESCELSA, a Brazilian distribution company.

The ten years planning studies alternative considered for the expansion in the region comprises the immediate expansion of the existent distribution substation, including the replacement of a transformer and the construction of two new bays, followed by the construction a new substation 138/11.4 kV and six new bays in the year 3. It also considers the construction of another substation in the year 6, with the installation of its first 138/11.4 kV - 41.5 MVA transformer and four bays of 15 kV.

The study case only will valuate the investment of the year 3. Thus, the DISCO has a three-year period during which it may invest R$ 12 million to build a new 138/11.4 kV substation. This investment comprises a transformer of 30 MVA, a 138 kV transmission line with 4.5 km and six bays of 15 kV.

In this section, the Brazilian currency is used (R$) and its equivalence in US$ is shown in the tables.

The first step of the real options approach is to assess the expected present value of the project operational cash flow, which is calculated by using the data shown in Table 1 and the equations 10, 11, and 12. The project expected value is R$ 14.037 million. The project's NPV is R$ 2.037 million, indicating the financial viability for an immediate investment. However, an analysis of the project uncertainties should be carried out. The investment should be added in order to give more information about the project future.

Table 1: Base Case

Symbol	Parameter *	Value
I	SE Investment (R$ Million)	12
T	Project economical lifetime (Years)	35
Depr	Linear depreciation rate	2.86%
IR	Income tax rate	34%
μ	Project WACC	13.02%
r_D	ANEEL distribution risk-free rate	5.32%
R	Continuous risk-free rate $= \ln(1 + r_D)$	5.18%
C	OPEX (% of Investment)	2%
D	Substation power capacity limit (MVA)	30
PF	Project Power Factor	0.93
$\overline{D}$	Project power demand capacity (MW)= $D \cdot PF$	23.28
D_0	Project initial demand	1.25
α_d	Demand growth rate	2.05
$\overline{T}$	Time until demand capacity limit (Years)	10.76

LF	Project Load Factor	0.52
DL	Annual Distribution Technical Losses	8%
P_0	Average distribution service price (R$/MWh)	48.12
$\rho_{p,m}$	Correlation between IEE index and Ibovespa returns from Jan,2000 to Nov,2009	0.77
μ_m	Ibovespa annual average return	8%
σ_m	Ibovespa return volatility	28.1%

* U$1 = R$2.31

The evolution of the distribution service price and revenue is presented in Figure 4. The DISCO annual average distribution service price $P(t)$ was obtained through the equation 4. EDP ESCELSA review cycle has three years and the fiscal year begins in August [13].

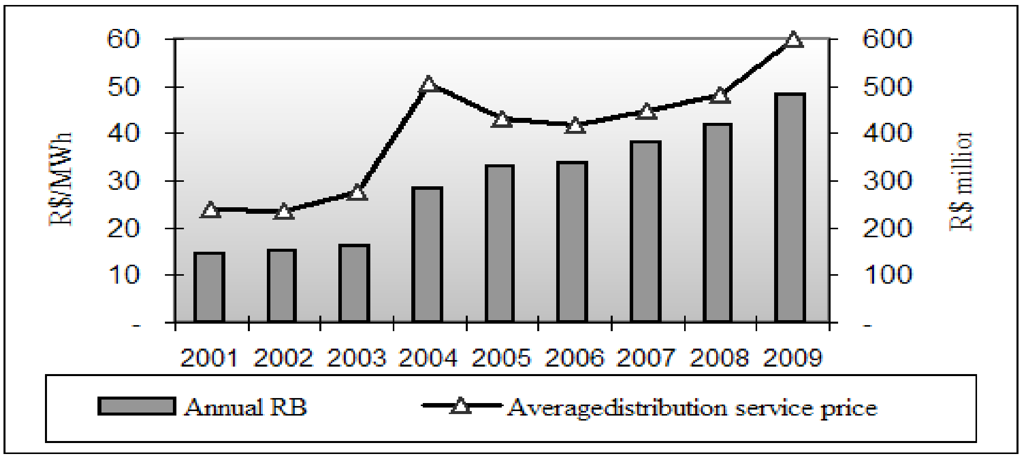

Figure 4: Distribution revenue *RB* and Average distribution service price evolution.

The ANEEL tariff update process methodology was consolidated on the last two tariff review cycles. The last two DISCO tariff reviews occurred in 2004 and 2007, but the final results were published only in 2005 and 2009, respectively, and the intermediary results compensation was done through *RB* annual values, distorting the price cap revenue characteristic behavior. The evolution of the revenue should follow a behavior similar to the period of 2004-2006 where the 2004 revised revenue was decreased due to the *X*-Factor application in 2005 and 2006.

The GBM parameters for the project α_V and σ_V were evaluated from equations 22 and 21.

The distribution revenues (*RB*) were adjusted to August, 2009 by the IGP-M index (Brazilian inflation index) as shown in Table 2. Annual distribution revenue has seven months with the *RB* of the last year and five months with the current year *RB*. The value of the volatility σ_P was calculated by finding the standard deviation from the $\ln\left(p(t)/\,p(t-1)\right)$ time series from 2005 to 2009. α_P was assessed by using the equations 25 and 30. In the assessment of the project market price of risk (λ), which results in 0.078, the Brazilian electrical energy index (IEE) was chosen to replicate the distribution service price. The whole market considered was Ibovespa (São Paulo Stock Exchange Index). Both IEE and Ibovespa return series were deflated by IGP-DI, the most widely used Brazilian inflation indicator.

Table 2: GBM Parameters for the Service Price Uncertainty

Year	Real *RB* * (R$ million)	Annual Revenue (R$ million)	*E* ** MWh	*P* R$/ MWh
2001	189.04	145.75	6.111.549	23.85
2002	114.30	150.46	6.364.928	23.64
2003	259.14	163.21	5.900.329	27.66
2004	361.90	284.26	5.625.917	50.53
2005	326.05	328.81	7.639.000	43.04
2006	402.83	337.70	8.059.687	41.90
2007	401.64	380.71	8.488.300	44.85
2008	497.05	416.29	8.651.906	48.12
2009	524.91	480.91	8.021.491	59.95
	GBM Parameters		α_P	1.35%
			σ_P	0.1401

* Ref 08/2009 $1=R$1.85
** IAN Report from Securities and Exchange Commission of Brazil (CVM):
http://energiasdobrasil.infoinvest.com.br , www.cvm.gov.br

The results for the investment option are showed in Table 3.

Table 3: The Option to Invest Results

Symbol	Description	Value
M_1		298,333.40
M_2		-317,892.81
V	(R$ million)	14.037
I	(R$ million)	12
τ	Real option expiration date (Years)	3
α_V	Project drift	2.765%
σ_V	Project volatility	0.1433
r	Annual risk-free rate	5.18%
NPV	Project Net Present Value (R$ million)	2.037
F	Project NPV considering the option to invest (R$ million)	3.037
RO	Real option premium = *F-NPV* (R$ million)	1.000
V^*	Optimal project value to invest (R$ million)	28.381
P^*	Optimal service price (R$/MWh)	96.20
$P_{NPV=0}$	Break-even service price (R$/MWh)	41.29
P_{MU}	Markup on traditional optimal price	133%

Figure 5 confirms that the option value creates an additional financial threshold that the project must exceed in order to justify immediate investment. The optimal project value to invest under uncertainty (V^*) of R$ 28.281 million obtained from equation 41 is 102% higher than the project present value of R$ 14.037 million. So, the optimal strategy is to wait and use the future information set on the investment decision making.

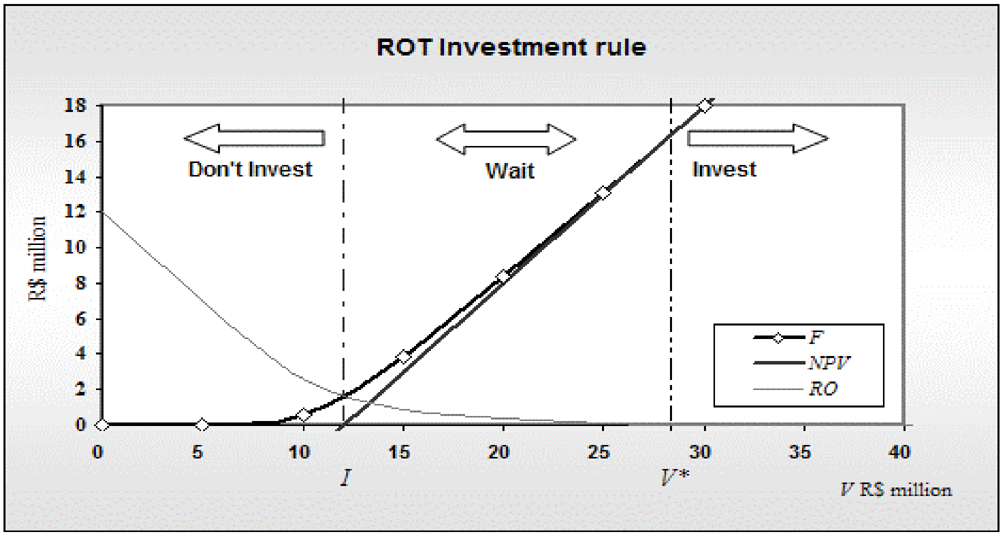

Figure 5: Real Option optimal investment rule for the Case Study

The results of the sensitivity analysis of V^* to the option lifetime τ presented at Figure 6 demonstrate that the investment option duration aggregates value to the project. V^* is strongly influenced by the time interval that the company has the flexibility of waiting to invest. Furthermore, the trigger V^* is more sensible to τ than the payoff due to the option value (F). At $\tau = 0$ the results of the real options approach are the same of the traditional approach, that is, $V^* = I =$ R$ 12 million and $F = NPV =$ R$ 2.037 million.

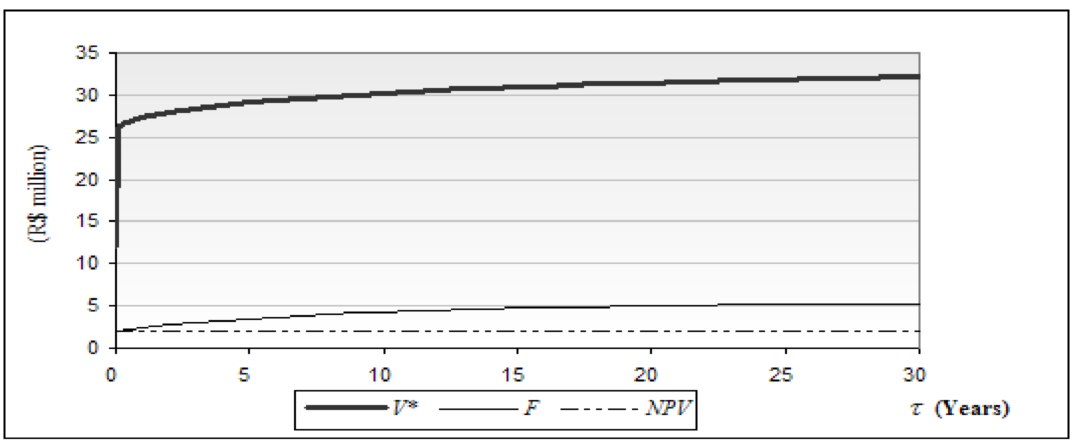

Figure 6: Sensitivity analysis of V^* f the investment option lifetime.

Figure 7 illustrates the real option optimal investment criteria in terms of service price. The minimum price for a viable investment applying the NPV metric, i.e., the price for a zero NPV, is 41.29 R$/MWh, and it was assessed by using equation 51. The optimal price to invest under uncertainty (P^*) was calculated by using equation 52 and results in 96.20 R$/MWh. The markup on the traditional optimal price, obtained from equation 53, is 133%. Since P_0=48.12 R$/MWh is less than P^*, there is a financial benefit in delaying the investment decision.

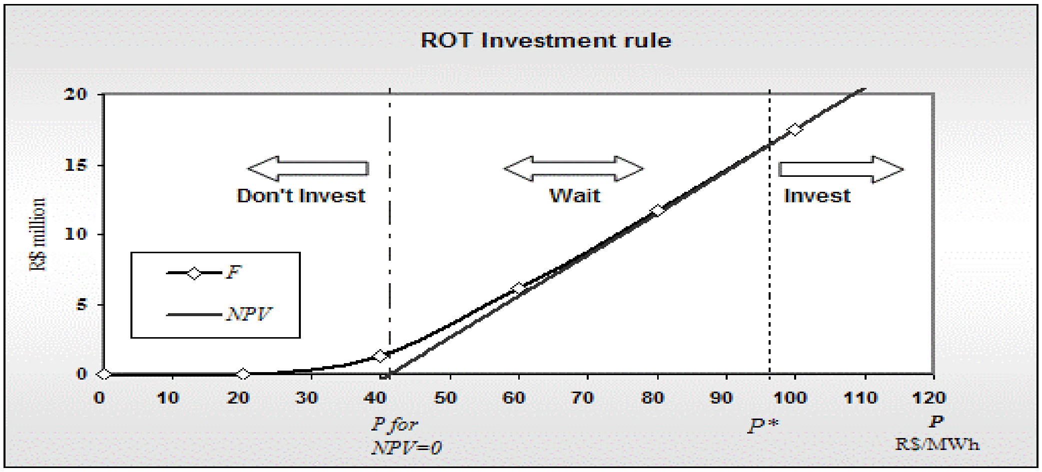

Figure 7: Real Option optimal investment criteria in terms of the service price.

When a utility decides not to invest immediately expecting more profitable returns by investing later, it doesn't imply that it will commit itself to the investment. The DISCO can reconsider its decision based on future information.

Figure 8 shows four possible paths of the distribution service price and the optimal exercise boundary for the investment option. The trigger P^* is the critical price that optimizes the immediate investment in the project. Thus, the option should be exercised when the distribution service price crosses the threshold line, such as occurs with paths 0, 1 and 2. The darker region of the graphic is the investment real option exercise region, and the wait region comprises the values of $P(t)$ under the threshold curve. At t= τ=3 years, if the investment option was not exercised, the NPV metric is applied and the investment is undertaken when $P(t) \geq P_{NPV=0}$.

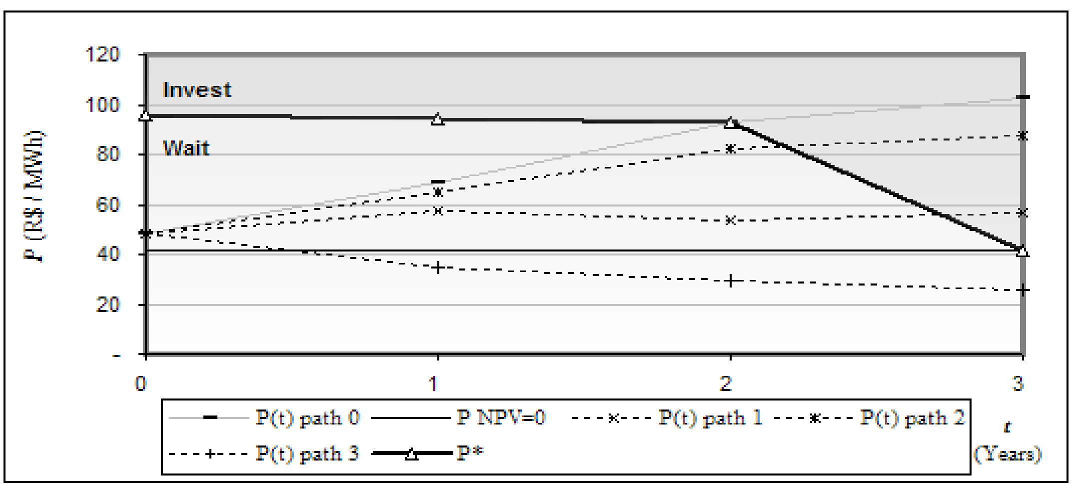

Figure 8: Optimal exercise boundary for the investment option.

5 - Conclusions

The incorporation of the project uncertainties and flexibilities through a Real Options framework improves the distribution investment analysis process. This way, it is possible to efficiently evaluate investments and providing more security for the investors.

The real options analysis introduces a new paradigm on the asset valuation, modifying the traditional investment rule. The most widespread result from real options theory is that irreversibility and time flexibility can lead investors to wait until uncertainty is resolved before committing themselves to an investment decision.

Even in the case where the DISCO has the obligation to supply and to invest, the Real Option can provide the value of the investment risk in terms of money. The regulatory board can use this to pass-through these costs to the consumers.

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