# CASE STUDIES OF INVESTMENT STRATEGIES IN DISTRIBUTED GENERATION

Bjørn GRINDEN
SINTEF Energy Research – NORWAY
bjorn.grinden@sintef.no

Karl Magnus MARIBU
École des Mines de Paris – FRANCE
kmaribu@gmail.com

Andrei Z. MORCH
SINTEF Energy Research – NORWAY
andrei.z.morch@sintef.no

Stein-Erik FLETEN
Norwegian University of Science and Technology – NORWAY
stein-erik.fleten@iot.ntnu.no

## *ABSTRACT*

*This paper studies how the real options method can be applied to investment analysis of distributed generation (DG) projects, and compares it with the traditional net present value method.*

## INTRODUCTION

Investors who are operating in deregulated energy industries are facing a market with extremely volatile prices and high investment risk. In this situation, using real options analysis for assessing investment projects has many advantages compared to traditional investment analysis. The real options method (RO) takes into account both the value of an option to invest and the value of postponing investment in order to gain more information about future market prices. Generally, this method will give a higher investment trigger price, compared with the net present value method, when there is an opportunity to delay project start-up. The paper describes the RO method in the first section and than exemplifies it using data from a case study on distributed generation (DG) in the second section.

## THE REAL OPTIONS METHOD

In Figure 1, a non-expiring opportunity to invest 125 000 € in a 75 kW windmill is shown, assuming the electricity price (S) follows a multiplicative stochastic process.

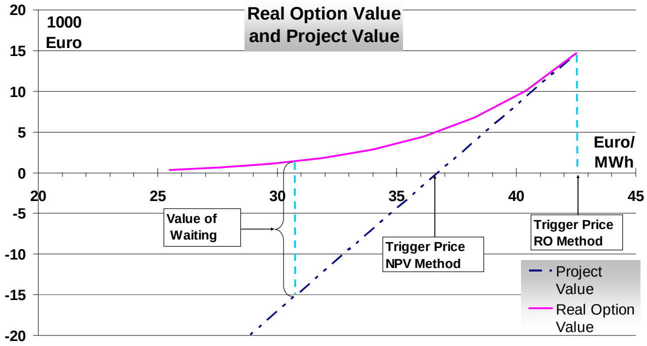

Figure 1. Principles of using the real options method for investment decisions.

The real option value, *F(S)*, is calculated as described in [1] and [2]:

$$F(S) = AS^{\beta} \tag{1}$$

where:

*F(S)* = Value of investment opportunity *before* investing
*S* = Electricity start price adjusted for short-term deviations
*A* = Constant in option value function
$\beta$ = Positive solution to quadratic equation from differential equation (7)

The constant *A* and the optimal investment threshold are calculated from two boundary conditions at the real option trigger price:

$$F(p) = V(p) - I \tag{2}$$

$$\frac{d}{dS}F(p) = \frac{d}{dS}V(p) \tag{3}$$

where:
*V* = Value of power generating unit after investment
*p* = Optimal investment level for power generating unit

Boundary condition (2) says that when you invest, you give up the opportunity to invest but receive the net present value of the plant. Condition (3) says that the triggering investment level must be chosen optimally to maximise the net present value less the opportunity cost *F*. The long-term electricity price is assumed to follow a stochastic process called geometric Brownian motion, where the change in price over a small time interval is written as:

$$dS = \alpha S dt + \sigma S dp \tag{4}$$

$$E[S] = S_0 e^{\alpha t} \tag{5}$$

$$E[\sigma S dp] = 0 \tag{6}$$

where:
$S_0$ = Electricity start price adjusted for short-term deviations at the time of analysis
$\alpha$ = Expected annual risk-adjusted growth in the electricity price
$\sigma$ = Annual volatility in the electricity price
*t* = Time (year)

*p* = Optimal investment electricity price for power generating unit
*E[S]* = Expected value of the price.

A geometric Brownian motion is a continuous-time version of a random walk with drift in relative price changes. A common way to represent this process in discrete time is a binominal motion. A binominal tree is illustrated below in Figure 2. The numbers used in the figure are only used for illustration. From one time step to another, the value can go either up or down, and there is nothing between (betting system).

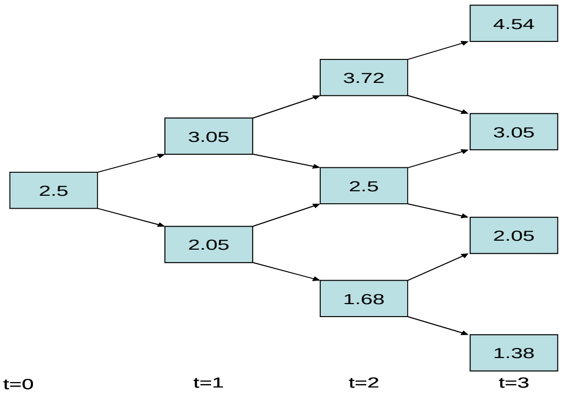

Figure 2. Illustration of binominal motion.

By using Bellman's principle of optimality[1] and some rearrangements[2], the following differential equation for the value of investment opportunity *F*, as a function of the electricity start price can be obtained:

$$\frac{1}{2}\sigma^2 S^2 \frac{d^2}{dt^2}F(S) + \alpha S \frac{d}{dt}F(S) - rF(S) = 0 \qquad (7)$$

where:
$r$ = Risk-free nominal interest rate
and all other constants and variables are defined above, under equations (1) to (6).

Equation (1) is a solution to eq. (7), and $\beta$ is the positive solution to the equation resulting from substituting equation (1) into (7).

Electricity generated from the distributed generation unit may both be used to displace expected load (previously imported from the grid) and exported back to the grid. The price for imported electricity (expenditure) is typically spot price plus a supplier mark-up, grid tariffs and taxes. The price for exported electricity (revenue) is typically the spot price minus a supplier mark-up etc. Hence, it is more profitable to replace imported electricity than to export electricity, if this is an option like in embedded generation. Export may be profitable if the operating costs are lower than the wholesale price. In the further analysis, seasonal variations of generation, demand and prices also have to be taken into account.

The net present value of the investment is the sum of all expected benefits less investment cost and operational costs in the project life time. Details for calculating NPV are not shown here.

The real options method gives a trigger price (eq. (2)) of 42.5 €/MWh for the wind turbine in Figure 1, while the net present value method, which says to invest when net present value becomes positive, gives a trigger price of 36.8 €/MWh. At a price of 31 €/MWh the value of waiting is 15 000 €. At the NPV trigger price, the value of waiting is still more than 5 000 €. The value of waiting is defined as the real option value (i.e. the value of the investment opportunity) less the net present value (project value). In the next section, it is shown how this method can be applied to distributed generation units with a predefined production capacity.

## A CASE STUDY OF DISTRIBUTED GENERATION

As a part of the research project "Embedded generation[3] " a case study of 14 distributed and embedded generation projects in Norway was carried out [4]. The study concentrated on small and medium sized generating units. Most of the projects were already commissioned and were in regular operation at the time of the study. All projects, except two standalone liquid petroleum gas (LPG) units, are connected to the distribution grid. Also most of the projects are so-called autoproducers, i.e. have a possibility to use a significant share of the production for their own needs and thus avoid distribution costs.

The case study included a survey and interviews, which collected technical and financial data from the projects. Since not all the necessary data were available, several assumptions had to be made, e.g. on yearly production, own consumption and the value of own work, materials and machines. One hydro plant and two standalone LPG, have been omitted from the analysis due to lack of data or because they have been decommissioned after the study. Based on an analysis of the remaining 11 projects, the

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[1] The Bellman equation expresses the value function in relation with an observation of itself and the reward
[2] Among those; Ito's lemma to find the differential of a stochastic function

[3] The project was funded by the Norwegian Research Council, Statkraft, Entro Energi, EffektPartner, and several other energy companies

Table 1: Main Results from Case Study of Distributed Generation in Norway (Sorted in Order of Increasing Trigger Prices)

| No. | Technology | Production [MWh] | | Own consumption [%] | NPV [1000 €] | NPV Trigger price [€/MWh] | Real Option Trigger price [€/MWh] | Net Value of Waiting [1000 €] |
|---|---|---|---|---|---|---|---|---|
| | | El. | Heat | | | | | |
| 1 | Hydro | 16 500 | | 0 | 3 625 | 11 | 14 | 0 |
| 2 | Nat. gas | 15 330 | 14 770 | 100 | 2 321 | 19 | 22 | 0 |
| 3 | Hydro | 14 500 | | 0 | 1 405 | 22 | 26 | 0 |
| 4 | Hydro | 486 | | 100 | 50 | 21 | 27 | 0 |
| 5 | Wind | 160 | | 44 | 18 | 23 | 27 | 0 |
| 6 | Hydro | 20 000 | | 0 | 1 033 | 27 | 31 | 0 |
| 7 | Hydro | 700 | | 100 | 33 | 26 | 32 | 0.1 |
| 8 | Nat. gas | 154 | 319 | 100 | -6 | 34 | 40 | 17 |
| 9 | Wind | 172 | | 79 | -14 | 37 | 43 | 15 |
| 10 | Hydro | 300 | | 33 | -32 | 40 | 46 | 33 |
| 11 | Nat. gas | 2 100 | 3 090 | 100 | -450 | 48 | 56 | 636 |

economics of investments are compared using real options and traditional investment analysis. Technologies analyzed are hydro power, wind power and combined heat and power (CHP) fuelled by natural gas.

Forward prices on Nord Pool, the Nordic electricity exchange, are used for estimating the risk-adjusted value of future electricity generation in the analysis. Spot prices may also be used as shown in [3]. Table 1 shows the results for the small and medium size distributing generation units in the study. NPV and the value of waiting in the table are calculated at a market price of 31 €/MWh. Distribution tariffs are mostly following the minimum requirements derived from the central network regulations and tariffs for generation. In the real option calculations it is assumed that the investment can be postponed indefinitely.

The analysis shows that distributed generation may be profitable from an end-user perspective, even in a market with relatively low power prices. 50% of the small and 80% of the medium size units are profitable using the NPV method at 31 €/MWh, and the trigger prices calculated from the real options method are lower than this price. Cases 1 to 6 are profitable at a power price of 31 €/MWh using both the NPV and the real options method. Case 7 is profitable at 31 €/MWh using the NPV method, but not using the real options method. The remaining units have a trigger price from 34 to 48 €/MWh based on the NPV method. Using the real options method, the trigger prices are 40 to 56 €/MWh respectively. The net value of waiting is from 15 000 to 636 000 € for those remaining units. The cases 8 to 11 are not profitable, neither using the NPV or the real options method. The two CHP systems (case 8 and 11) were built as demo installations, and the wind power (case 9) was based on an idealistic motivation rather than economic profit. There has been a significant growth in the market price since the case studies were performed (2003-2004), and most of the remaining projects would be profitable today.

## DISCUSSION

The real options method can also be used for optimizing capacity and timing simultaneously as shown in [2] and [5]. A generalization of the methodology described above can be applied, by introducing $F_j(S)$ in equations (1) to (7) where $j$ is power generating unit considered for investment under uncertainty. Different units (i.e. capacities) have different NPV functions, and different capacities may be profitable in different price intervals. For DG units based on renewable energy resources, it is also necessary to take into account availability and variability of the resources as shown in [5] and [6]. Especially for small hydro generation this is important.

The case study shown in Table 1 only takes into account revenue from sale of energy and avoided costs by using a significant share of the production for own needs. Ancillary services, CENS, backup, reserves and emergency supply may provide extra benefits. For renewable technologies, availability has to be taken into account when considering such ancillary services. Distributed generation technologies based on fuels may be better suited for such use [11].

In [8] it is also shown how investments in CHP units can be used for price hedging. A new DG project may not only increase expected profit in an electricity portfolio, but can also change its risk characteristics. Using Monte Carlo simulation of electricity and natural gas prices it is shown that thermal DG can provide a natural hedge for an electricity and natural gas consumer.

A large development of distributing generation may be a difficult challenge to the existing centralized generation and distribution system. One challenge is that all participating actors must have a long-term benefit from DG. If one or more participants have bigger expenses than revenues, the business idea has a very small probability to survive in the long run.

For this analysis, a tool for business modelling developed by Vrije Universiteit Amsterdam has been applied to DG, in the EU project “Business Models in a World Characterized by Distributed Generation (BUSMOD)” [9]. This project was organized under the “Energy Environment and Sustainable Development Programme (EESD)”. The software is called $e^3$value [10], and is designed to give an overview over actors involved in a business scenario, and the exchange of services and payments between the actors. Using such a tool it is also possible to reveal any hidden costs. Based on a simple NPV calculation it is easy to see which actors who do not have a positive benefit, and which changes that are needed to obtain a positive NPV for all partners.

Business scenarios that are sustainable can be picked out for a more detailed analysis, e.g. using the real options method and resource analysis.

## CONCLUSIONS

The real options method is not a replacement, but a supplement to the net present value method. The real options method gives a better decision on when to perform an investment, especially under uncertain conditions like the market price of electricity. By using the real options method, it is also possible to value information or flexibility, such as the possibility to postpone an investment to gain more information about the development of electricity prices. It is also important to be aware that the real options method describes the value of the investment opportunity before investing. After the investment, the value of the project is calculated by the NPV method.

In the cases studied, the difference is that the real options method gives a higher trigger price than the NPV method. Using the real options method, the trigger price to execute an investment, is when the value of the resource (or option) is equal to the net present value. On the other hand, the traditional NPV method trigger price is when the net present value equals zero.

The real options method may be used by investors operating in a competitive and uncertain environment. The real options method is typically applied on large investment projects but can easily be applied also to small distributed generation projects as in the presented case studies. The real options method has advantages from a business point of view.

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