Defining advanced wind energy tariffs systems to specific locations and applications: lessons from the French tariff system and examples

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ABSTRACT: Advanced tariff systems for wind power such as in Germany and in France are designed to open large wind power markets and to lower the cost of this development. The new French wind tariff system is particularly easy to adapt to different local conditions and to different types of projects as it is based on explicit and simple formulas derived from the profitability index method. The main characteristics of this method and of this tariff system are presented. The possible adaptation of two parameters of the French tariff system are discussed. The first one is an alternative way to characterise the energy yield, using the ratio of energy delivered by year and by square meter of rotor swept area instead of the average annual capacity factor, and the second one is the level of protection of the tariff versus inflation. Three case studies of adaptation of the tariff system are presented and discussed. The first one is an example of adaptation to locations with very good wind potential such as Ireland. The second one is related to countries like Canada where a wind power production incentive has been set up and the third one is related to offshore wind projects.

1. ADVANCED TARIFF SYSTEMS

To facilitate a market penetration of renewable energy technologies and namely wind power, a market regulation is necessary.

The best tool for market development of renewable energy technologies is to ensure for private investors a “fair and sufficient” profitability. And it was demonstrated clearly that it was through a price regulation system that this profitability was easier to demonstrate and to achieve [1].

So, the choice is between a regulation by the price paid for each clean kilowatt hour, leading to “advanced tariffs systems” preferably such as the ones adopted in Germany in 2000 or in France in 2001, or a regulation by quantities based on competitive calls for tenders or based on quotas associated to green certificates and relevant penalties in case the quantity of certificates to be purchased is not achieved.

An other important condition is to lower the over-cost for electricity consumers generated by such a price regulation. This implies to set up specific tariffs for each renewable energy technology or application and also within a specific technology such as wind power, to lower the tariffs for the “best case conditions” compared to the medium and the lower case conditions, so that undue profits are impossible on high quality sites and so that a minimum profitability is possible on low quality sites.

Of course, advanced tariffs systems must be also flexible so that investment and operation costs decreases should be easily taken into consideration.

And particularly in Europe such advanced tariffs systems must not be a state aid, and so their extra cost must be easily defined and charged to all electricity consumers.

Last, but not least, such advanced tariffs systems must be easy and simple to define, to control and to adapt.

At the end, it is clearly the market regulation by the prices from such advanced tariffs systems which is compatible with those criteria, and which is more efficient and simple and no more costly than a market regulation by the quantities.

2. THE PROFITABILITY INDEX METHOD

The "Profitability Index Method" (PIM) has been used in France by ADEME to design the new wind power tariff system [2] which was published in 2001 [3]. As the PIM is so simple and powerful to define a tariff system, it will be described shortly before main results for the French tariff system and its potential adaptation to other contexts and application are described.

2.1 Definitions, basic parameters and formulas

The profitability index (*PI*) is simply the ratio between the Net present Value (*NPV*) of a project and the required initial investment *I*: $PI = NPV / I$

The discount rate to use with the PIM is not the targeted internal rate of return (*IRR*), but the Average Weighted Cost of Capital (AWCC). Its reference value used to define the French tariff was t = 6.5 % (real, corrected from inflation, as all tariffs and parameters will be defined in constant 2001 euros).

Other basic parameters and reference values used to define the tariffs are:

- The depreciation period n (15 years in France).
- The capital recovery factor *Kd*, defined by:

$$Kd = Kd(t,n) = \frac{t(1+t)^n}{(1+t)^n - 1} \quad (1)$$

- The investment cost ratios: $Iu = \frac{I}{P}$, or $Ius = \frac{I}{S}$ (P and S being the rated power and the swept area) and the residual value *Valres* of the project after n years of operation, expressed as a fraction of the initial investment.
- The yearly constant average O&M expenses ratio $Kom = \frac{Dom}{I}$, where *Dom* is the mean annual O&M expenses (including provisions for big repairs).

- The yearly average energy yield ratio expressed as $Nh = \frac{Ey}{P}$ (hours per year at rated power), or as $Eys = \frac{Ey}{S}$ (in kWh per year and per m^2) where Ey is the mean yearly amount of energy sold to the grid.

For a targeted profitability index value *PI*, the required constant tariff *Teq* from year 1 to year *n* is:

$$Teq = \frac{(1+PI)Kd(1-\frac{Valres}{(1+t)^{(n+1)}}) + Kom}{Nh} Iu \quad (2),$$

or the same equation using *Ius* and *Eas* in place of *Iu* and *Nh*, and of course, for *PI* = 0, the tariff *Teq* is equal to the Overall Discounted Cost (*ODC*) of the kWh.

2.2 The link between PI and the Internal rate o Return

From (1), there is a direct relation between the *PI* value of a project and its IRR (Internal rate of return) value:

$$Kd(IRR, n) = (1+PI)Kd(t, n) \quad (3)$$

For example, for *n* = 15 years and *t* = 6 %, for *PI* = 0.3, IRR = 10 %, an IRR value considered as a minimum to attract private investors in long term projects such as wind power projects.

2.3 The margin between cost and price

The first advantage of the PIM is to make a clear difference between the "cost" of a kWh ant its "selling price" (the tariff), the difference between the two values defining the margin and creating the profitability of the project.

Using the "Margin on cost" *MOC*, defined as:

$$MOC = \frac{(Price - Cost)}{Cost} = \frac{Teq - ODC}{ODC} \quad (4),$$

then for all power plants with constant annual cash flows:

$$MOC = Kfuel \frac{Kd}{Kd + Kom} PI \quad (5)$$

With $Kfuel = \frac{NFCP}{ODC}$ (6) where NFCP is the non-fuel cost part of ODC, and as demonstrated in [2] when comparing the margin of cost of a RE based without fuel cost (index *r*, *Kfuelr* = 1) and a fossil fuel based power plant (index *f*, *Kfuelf* < 1 : around 0.5 for coal based power plants and around 0.33 for natural gas combined cycles power plants), the relation between them is:

$\frac{MOCr}{MOCf} \geq \frac{1}{Kfuelf}$ (7) which demonstrates the "Zero fuel cost renewable energy technologies paradox": in order to get the same profitability from a zero fuel cost RET power plant project and from a fossil based one, the margin on cost for the renewable project must be around two times the margin in case of a coal based power plant and around three times the one in case of a natural gas combined cycle power plant !

In liberalised electricity markets, the minimum margin on cost for coal power plants is around 10%. As this margin corresponds for a modern coal plant to a profitability level PI = 0.3 (see example in reference [4]), the minimum profitability index level for a wind power plant project should be also 0.3, a minimum value also derived as seen above from the link between *PI* and *IRR*.

3. PRINCIPLES FOR FRENCH TARIFF DEFINITION

3.1 Basic principles, parameters and formulas

Referring to the figure 1 below, the main parameters of the French wind tariff system for projects under 12 MW are:

- *T1*, a fixed tariff for all new contracts in a specific year for their first 5 years of operation (years 1 to *j*).
- *T2*, the specific different tariff for each project for years *j*+1= 6 to *n* = 15.
- *Teq*, the equivalent fixed tariff from year 1 to *n* resulting from *T1* and *T2* and *t* and leading to a final economic profitability *PI*.

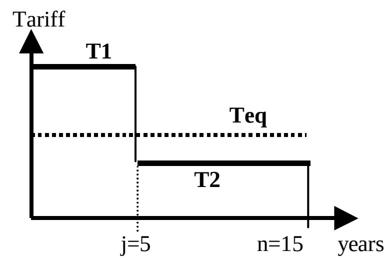

Figure 1: parameters for the French tariff system

3.2 Final data

Figure 2 give the *Nh*, *T1* and *T2* values defined in the "June 8th *arrrêté*" [3] for 2002 projects in continental France.

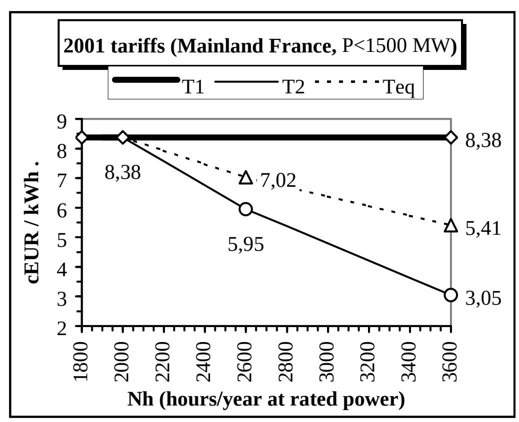

Figure 2: Tariffs *T1, T2 and Teq* versus *Nh*

3.3 A first possible adaptation of the tariff system

From figure 2 one can see that using a lower value of capacity factor by choosing a larger than required generator (so decreasing the Nh value for a specific diameter) can give an advantage as the resulting tariff is higher and the yearly energy production is also slightly higher.

In order to lower such an advantage it would be possible to use the energy yield ratio related to the swept area *Eys* instead of the capacity factor expressed in *Nh* values. In the case of a reference site with an average wind speed of 7 m/s, using reference [5] for calculations for a wind turbine of a diameter of 56.4 m and different rated power values and specific power value per square meter of swept area *Ps*, as indicated in table I the advantage on the average turn over would be only 8 % instead of 20 %.

Table I: influence of rated power on the turn over increase

Vm = 7 m/s at hub h. D = 56,42 m Case	Ps W/m2	Nh based tariff Tariff cEUR	Nh based tariff Turn over kEUR/y	Eys based tariff Tariff cEUR	Eys based tariff Turn over kEUR/y
Low Ps : **750 kW**	300	6.4	144	8.58	**193 (+8%)**
Reference 1000 kW	**400**	7.45	**179**	7.45	**179**
High Ps : **1250 kW**	500	8.58	**214 (+20%)**	6.4	160

3.4 A second possible adaptation: protection against inflation

For renewable investments such as wind power, profitability comes from the fact that the sum of future discounted cash-flows will be greater than the huge initial investment. If the power purchase of the tariff is decreasing because the tariff is constant in current currency or is not completely corrected from inflation, profitability will decrease as inflation increases. In the case of the French tariff system, up to 40% of the tariff value is not corrected from inflation [3] and figure 3 shows that for an inflation rate *i* of only 2 % per year during the 15 years of operation, profitability will decrease from 25 % to 50 % from the case where there is no inflation or from the case where the tariff is 100 % corrected from inflation.

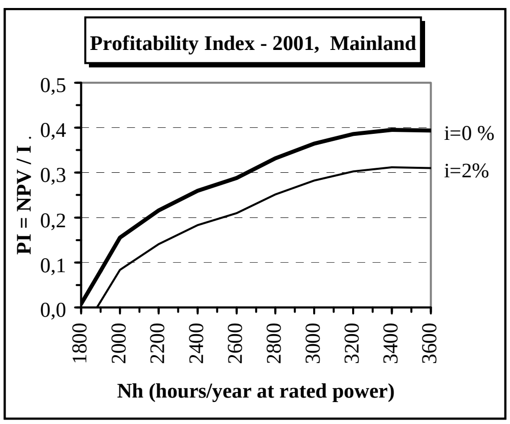

Figure 3: Profitability Index of a 2001 reference project

In present economy, a "100 % insurance" against inflation is not recommended, but it would be logical to correct tariffs for renewables such as wind power up to 80 to 90 % as the required operation period is very long.

4 ADAPTATION TO OTHER CONTEXT

4.1 Adaptation to different wind conditions

The first example of an adaptation of this advanced tariff system using the profitability index method is related to the case of a country with different wind conditions. Such a case was discussed between ADEME and IEC and was presented at a recent IWEA Conference [4].

Due to very good wind conditions in Ireland, in this case it is sufficient to consider wind speeds over 7 m/s, corresponding to a Nh value around 2600 h/year instead of 2000 in France. So, as shown in figure 4, the resulting T1 value of 6.8 cEURO/kWh is lower than the T1 value of 8.38 in France. To design the relevant tariff system option shown here, the increase of profitability index is from 0.3 at 2600 hours per year to 0.5 at 3600 hours per year on power purchase agreements of 15 years, and the related average investment cost was 1067 EURO per installed kW. Of course, those hypothesis and results should be discussed in details before considering an implementation of such a system. In particular, specific fiscal incentives which could be used by investors should be taken into account. In such a case the economic profitability index values to be considered could be lower, with as a result, lower values of tariffs.

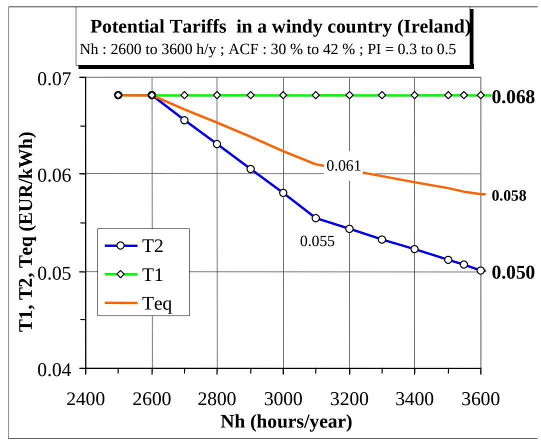

Figure 4: Potential wind tariffs in a windy country

4.2 Adaptation to an other incentive policy

This second example of adaptation using the profitability index method is related to countries like USA and Canada where the federal government has established a production tax credit (PTC) or a wind power production incentive (WPPI). In Canada this WPPI is 1.2 cents per kWh for j = 10 years of operation for projects put in operation in 2002. This value will then decrease down to 0.8 cents in 2007 for other new projects.

Referring to the above figure 1, this WPPI could be considered as a "fixed difference" between a tariff *T1* constant during the first j = 10 years and a "base rate" *T2* defined as a fixed tariff set up by the local states or the local market conditions for the total n = 15 or 20 or 25 years of operation of the relevant wind projects.

Here also, *T1* and *T2* can define an equivalent tariff *Teq* defining the same economic profitability of the project.

The first step of adaptation consists in calculating the *Teq* value from equation (1), using a recommended value such as the minimum value of PI = 0.3 as determined in the paragraph 2.2 above. Using the profitability index method, it is then easy to calculate the base rate *T2* from year 1 to n from *Teq* and *T1* (from years 1 to j) using the following formula:

$$T2 = K\left(\frac{Teq}{Kd(t,n)} - \frac{T1}{Kd(t,j)}\right) \quad (8),$$

$$\text{where } \frac{1}{K} = \frac{1}{Kd(t,n)} - \frac{1}{Kd(t,j)} \quad (9)$$

where *Kd* is the capital recovery factor calculated from equation (1) and defined by the actual discount rate considered as the average weighted cost of capital and the duration of the tariff, either *j* years for *T1* or *n* years for *T2*.

4.3 Adaptation to the offshore case

The profitability index method and advanced tariffs systems principles can also be used for offshore wind projects.

For that, the first principle to use is that a minimum visibility on future tariffs is required by investors.

The second principle is that tariffs should be higher during the first period of operation when the debt service is higher.

The third principle is that tariffs should decrease on the mean and long term in order to compete with tariffs of new projects and in order to lower the future over-cost for electricity consumers or renewable energy certificates buyers.

Different actual or potential tariffs systems can comply with those principles. The Danish system used for the 40 MW Middelgrunden project was originally based for example on a six years fixed tariff followed by a fourteen years minimum value for renewable energy certificates over the avoided cost of conventional energy. The equivalent fixed tariff is around 7.1 cEURO/kWh. In the future, the Denmark tariff system intends to be based only on green certificates. In Germany there is already a fixed tariff for years 1 to 9 (9.1 cEURO/kWh), then 6.2 cEURO for years 11 to 20 for offshore wind projects built before 2006. The "Calls for tenders" which may be used in France for offshore projects beyond 12 MW could also incorporate a decrease of tariffs defined by each proponent or defined by the terms of reference of the tenders. In the case of a pure renewable energy certificates system, the decrease of tariffs should be based only on market forces. In that case it would be difficult to attract private investors because of a limited visibility on resulting tariffs.

The following case study from [6] concerns a virtual offshore project on a rather good site with a *Nh* value of 3 000 hours/year, with an hypothesis of an investment cost of 1 600 EURO/kW. Four successive decreasing values of tariffs are assessed as shown in figure 5. The operating and maintenance *Kom* coefficient includes a 30% part of the initial investment for a huge retrofit around year 15, and its final equivalent value is 4 % of the initial investment. For an average weighted cost of capital of 6 % and a profitability index of 0.4, corresponding to an IRR of 9.9 % over 25 years (a minimum value to attract investors in such risky projects), the equivalent constant tariff is 7.81 cEURO/kWh, of which 21% are devoted to the profit margin, 52 % to the investment costs, and 27 % to the O&M and retrofit costs.

In this example, the equivalent constant tariff results from a constant tariff of 9 cEURO/kWh during the 10 first years of operation, followed by mean annual tariffs of 7 then 6 and then 5 cents for the three successive periods of five years.

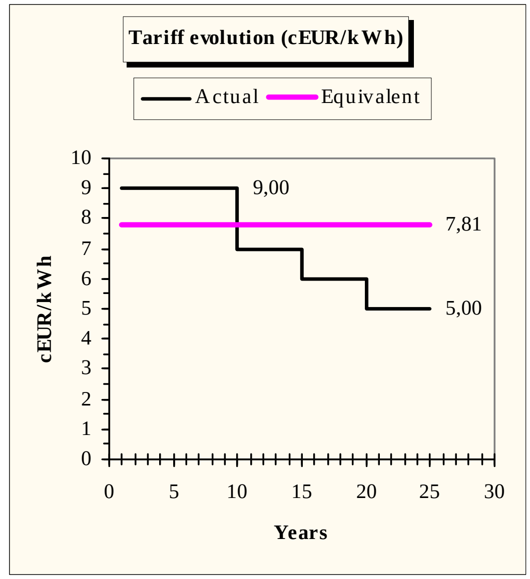

Figure 5: example of potential tariffs for offshore wind

5. CONCLUSIONS

The first conclusion which can be drawn from this analysis is that designing an efficient advanced tariff system within a deregulated electricity market is possible, taking into account existing “success stories” like in Germany and France which proved to be very efficient.

The second conclusion is that the Profitability Index Method gives a rational basis for minimum values of wind power projects profitability and that this method is based on simple formulas to define and implement or to adapt an advanced tariff system.

And such adaptation to other contexts could benefit from the suggestions developed here, such as using the energy yield per unit of swept area (instead of the capacity factor expressed as *Nh*) and taking care for the protection of the related tariffs from the damage of inflation.

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