Electrical Power and Energy Systems 53 (2013) 1–9

Contents lists available at SciVerse ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

A methodology for analysis of the renewable electricity feed-in tariff markets

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ARTICLE INFO

Article history:
Received 27 April 2012
Received in revised form 3 April 2013
Accepted 5 April 2013

Keywords:
Methodology
Feed-in tariff
Market

ABSTRACT

A feed-in tariff model has been enacted in most countries and is well accepted by the European Commission. In principle, the model offers long-term contracts to eligible renewable energy producers, typically based on guaranteed prices for fixed periods of time for electricity produced from renewable energy. This paper presents a methodology that has been developed for the feed-in tariff market approach, which should gradually help eligible producers become better prepared for market competition after long-term contracts expire. The central part of this methodology is the correction of the current guaranteed prices, based on the calculation of the cost-effectiveness ratio of the market model to the current feed-in tariff or non-market model. The common features of the designed market models are the market component, a combination of the guaranteed price with and without market indexing, and the sum of the reduced guaranteed price and the spot electricity price. The methodology has been applied to the current non-market model implemented under Croatian jurisdiction. In this case, seven different market models were designed, which are compared to the existing non-market model. The results of the cost-effectiveness ratio according to different types of renewable energy and market models for a certain period of time are given, described and used for the correction of the current guaranteed price. The first market model has been selected as the most appropriate to replace the existing non-market model in Croatia.

1. Introduction

A feed-in tariff (FIT) is a policy mechanism designed to accelerate investment in renewable energy technologies. It achieves this by offering long-term (10–25 year) contracts to eligible renewable energy producers, typically based on guaranteed prices for fixed periods of time for electricity produced from renewable energy. These prices are generally offered in a non-discriminatory manner for every kW h of electricity produced, and can be differentiated according to the type of technology, the size of the installation, the quality of the resource, the location of the project, as well as a number of other project-specific variables [1–4]. This enables a greater number of investors to participate, including homeowners, farmers, municipalities and small business owners, while helping to stimulate rapid renewable energy deployment in a wide variety of technology classes [5–8].

As of 2011, at least 61 countries and 26 states/provinces had different variations of FITs, more than half of which were enacted in 2005 [9]. In 2008, a detailed analysis by the European Commission concluded that "*well-adapted feed-in tariff regimes are generally the most efficient and effective support schemes for promoting renewable electricity*" [10]. This conclusion has been supported by a number of recent analyses, including those by the International Energy Agency, the European Federation for Renewable Energy and Deutsche Bank [11–13].

Another variation of a FIT policy is a premium FIT or feed-in premium (FIP), a market-dependent mechanism developed principally by Spain and emulated elsewhere. Here, two remuneration components exist instead of one: a reduced FIT payment (i.e., premium) plus the hourly spot market price for electricity. To ensure that the combination of the two does not pay producers either too little or too much, the Spanish version uses a lower floor and upper cap [14].

In order to allow greater investor choice, some jurisdictions (e.g., in the Czech Republic, Estonia, Slovenia and Spain) offer both the fixed price and premium price option to renewable energy developers, allowing them to choose which policy option is best suited to their individual risk appetite and investment model. However, the added transaction costs of marketing one's electricity on the spot market arguably make the premium price option better suited to larger market participants, rather than individual homeowners or community-based investors [15].

Since FITs provide lower risk and greater revenue certainty over a longer period of time, the eligible renewable energy producers are apathetic and not concerned about the electricity market trends and price movements. Once their long-term contracts

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http://dx.doi.org/10.1016/j.ijepes.2013.04.002

expire, they will be faced with these attitudes, presumably more or less prepared for market competition. In order to mitigate such stressful entry on the market, a methodology for the FIT market approach will be developed in this paper.

The first step of this methodology will be to design a certain number of models as combinations of the guaranteed price, with and without market indexing, and the sum of the reduced guaranteed price and spot electricity price over different numbers of years within a fixed period. Market indexing means the guaranteed price indexed to the spot electricity price for a certain period of time (daily, monthly or annually). All these models share a market component. Therefore, from this point they will be considered as market models. Individually, each market model will correlate with the FIT model or from the point called a non-market model. A cost-effectiveness ratio is the central part of this correlation. The results of the ratio will prove which market model is more cost effective than the non-market model and, therefore, the most appropriate to replace the existing, non-market model.

The methodology will be applied to the Croatian FIT system enacted in 2007, under which the fixed period of time for electricity produced from renewable energy is 12 years [16]. Seven different market models will be designed, assuming that least one will be the most appropriate to replace the existing non-market model. In the case of other countries with adopted FITs, the methodology can be similarly applied but the market models in a smaller or bigger number might be designed differently, assuming that one is the most appropriate to replace the existing non-market model.

2. Mathematical design of market models

2.1. Assumptions

The following assumption will be taken in consideration:

- The cost-effectiveness ratio of the market to non-market model with regard to the revenues from selling electricity. The ratio can be less or greater than one. The observed market model is more cost effective than the existing non-market model if the ratio is greater than one and less cost effective if the ratio is less than one.
- Every market model will be designed from at least one market component consisting of the market indexed guaranteed price and/or the sum of the guaranteed price and spot electricity price.
- There are no particular explanations why a certain market model is selected to be designed. It is rather a pure assumption, assuming that at least one of the market models will replace the existing non-market model.
- The guaranteed price is based on the real costs of electricity (including costs such as fuel, O&M, labor, administration, and insurance) produced from different types of renewable energy such as biogas, biomass, small hydro, solar, and wind. Explicitly, biogas and biomass will be considered as fuels for combined heat and power generation in order to achieve, in view of useful energy and renewable source utilization, the highest overall efficiency possible. The real costs of useful energy production will be split between the costs of thermal and electric energy production. Hence, the production costs of electricity will refer to the guaranteed price.

2.2. Definition of the cost-effectiveness ratio

The ratio of revenues from selling electricity by applying a concrete market model, R_{M_n}, to revenues from selling electricity according to the existing non-market model, R_N is equal to:

$$\eta_n = \frac{R_{M_n}}{R_N} \tag{1}$$

defined as the cost-effectiveness ratio. From this point, the abbreviated forms of the models will be used with the following parameters: $R_G(x_1)$ is the revenue from selling electricity at the guaranteed price in the first part of the fixed period x_1, $R_{G(m)}(x_2)$ is the revenue from selling electricity at the guaranteed price indexed to a change in the spot electricity price in the second part of the fixed period x_2, while $R_{GM}(x_3) = [pR_G + R_M](x_3)$ is the sum of the revenues from selling electricity at the guaranteed price R_G, but reduced by the percentage p, added to the revenues from selling it on the spot market R_M at the spot electricity price in the third and last part of the fixed period x_3. The sum $x = x_1 + x_2 + x_3$ refers to the fixed (long-term) period of selling electricity from the eligible renewable energy producers.

Combining the models in a general form, the cost-effectiveness ratio from Eq. (1) can be described as:

$$\eta_{n1} = \frac{R_{M_{n1}}}{R_N} \frac{R_G(x_1) + R_{G(m)}(x_2) + [pR_G + R_M](x_3)}{R_G(x)} \tag{2}$$

Some models will combine different percentages of a reduced value of the guaranteed price p_1, p_2 and p_3 divided over two or more parts of the fixed period. The general form of these models is described as follows:

$$\eta_{n2} = \frac{R_{M_{n2}}}{R_N} \frac{[p_1R_G + R_M](x_1) + [p_2R_G + R_M](x_2) + [p_3R_G + R_M](x_3)}{R_G(x)} \tag{3}$$

In the Croatian case, the following seven market models will be designed, assuming that at least one will be appropriate to replace the existing non-market model. The cost-effectiveness ratio is designed for each market model individually.

2.2.1. The cost-effectiveness ratio of the first market model

The first market model consists of the following market and non-market components:

– The revenues from selling electricity at the guaranteed price $R_G(x_1)$ in the first part of the fixed period x_1 (non-market component).
– The revenues from selling electricity at the market-indexed guaranteed price $R_{G(m)}(x_2)$ in the second part of the fixed period x_2 (market component).
– The revenues from selling electricity at the guaranteed price reduced by 50%, $0.5R_G$, added to the revenues from selling it on the spot market at the spot electricity price R_M in the third and last part of the fixed period x_3 (market component).

Therefore, the cost-effectiveness ratio of the first model can be written in the following way:

$$\eta_1 = \frac{R_{M_1}}{R_N} = \frac{R_G(x_1) + R_{G(m)}(x_2) + [0.5R_G + R_M](x_3)}{R_G(x)} \tag{4}$$

For example, the cost-effectiveness ratio is calculated in the following way:

– The revenues from selling electricity at the guaranteed price in the fixed period of $x = 12$ years amount to $R_G(12) = 2{,}966{,}515$ €.
– The revenues from selling electricity at the guaranteed price in the first 4 years of the fixed period amount to $R_G(4) = 984{,}654$ €.
– The revenues from selling electricity at the market indexed guaranteed price in the next 4 years of the fixed period amount to $R_{G(m)}(4) = 985{,}942$ €.
– The revenues from selling the electricity at the guaranteed price reduced by 50% and the spot price in the last 4 years of the fixed period amount to $[0.5R_G + R_M](4) = 711{,}516$ €.