PROPOSE AN INCENTIVE METHODOLOGY OF RENEWABLE ENERGY TO PARTICIPATE IN COMPETITIVE ELECTRICITY MARKET

Le Hong Lam[1]*, Le Quang Son[2], Nguyen Tan Thanh[1]
[1]*The University of Danang - University of Science and Technology, Danang, Vietnam*
[2]*Electricity Regulatory Authority of Vietnam (ERAV) - Ministry of Industry and Trade (MOIT), Hanoi, Vietnam*

*Corresponding author: lhlam@dut.udn.vn

(Received: August 30, 2023; Revised: November 08, 2023; Accepted: December 11, 2023)

Abstract - Today, the rapidly increasing share of renewable energy sources requires a suitable mechanism to promote the development of renewable energy is urgently needed. To solve this problem, the paper will conduct a study to find out the incentive mechanism to promote the development of renewable energy with participation in the electricity market. The article compares different models of Fixed feed-in premium with CAP and FLOOR (month, week, day, and cycle) to point out the advantages and disadvantages of each model, thereby providing comments and assessing the impact of the models on the revenue of renewable energy plants. The result shows that the monthly average revenue of FIXED FIP with CAP and FLOOR (0.19-0.23 million VND/MWh) is less variation than half-hourly (0.16-0.23 million VND/MWh) and daily revenue (0.18-0.23 million VND/MWh). Moreover, the monthly model can mitigate the variation of spot price and cop with the payment period (monthly).

Key words - Renewable energy; electricity market; Fixed feed-in premium; cap & floor; incentive mechanism.

1. Introduction

As recorded in [1], by the end of 2022, the total power capacity of the whole Vietnam system will reach about 77.800 MW. In which, the total capacity from renewable energy sources (wind power, solar power) is 20.165 MW - accounting for 26.4%. Renewable energy sources in Vietnam include Hydroelectricity, solar power, wind power and biomass power. By the end of December 2022, electricity output from renewable energy sources is expected to reach 130 billion kWh, accounting for nearly 48% of the generated electricity output of our country's electricity system, in which wind, solar and biomass power accounts for 13% [2]. With a rapid growth rate, the generation of renewable energy sources has increased from 27% to more than 48% in the period 2010 - 2022, especially with the great contribution from solar power and wind power in the period of 2019 - 2022.

According to [3] in Vietnam, a series of mechanisms and policies related to the development of renewable energy sources have been issued, specifically: Decision 37/2011/QD-TTg and Decision 39/2018/QD-TTg on Feed-In Tariff (FIT) mechanism to support wind power plants, Decision 11/2017/QD-TTg and Decision 13/2020/QD-TTg on the FIT mechanism to support solar power plants. There is also Decision 24/2014/QD-TTg on the FIT mechanism to support the development of biomass power projects in Vietnam. For the FIT mechanism, renewable energy generators are paid a fixed price for each power unit, so the revenue is completely independent of the electricity market price. RE generators only focus on generating full capacity to get maximum revenue, leading to the disadvantage of the mechanism that is not adjusting the source to match the load. FIT also leads to an increase in electricity purchase price. This shows that the FIT mechanism is no longer suitable to encourage RE development in Vietnam. As a result, the FIT for wind and solar power plants stopped providing more, making many wind and solar power plants not put into commercial operation, so the Ministry of Industry and Trade issued Decision 21/QD-BCT to provide a price frame as a basis for Vietnam Electricity Corporation (EVN) and solar and wind power generating units to negotiate electricity generation prices according to regulations.

Regarding international experience, the world has introduced many incentive mechanisms for renewable energy development integrated into the electricity market, such as FIT, Feed-In Premium (FIP) and Contract For Difference (CFD). Accordingly, there have been many studies mentioned on this issue. Articles [4], [5] have pointed out and introduced two popular mechanisms in the integration of renewable energy into the electricity market, namely FIT and FIP. The article [6] provides a comparison of the revenue of Fixed FIP mechanism when there is no limit and when there is a limit, as well as compare different models of Fixed FIP mechanism when applying CAP and FLOOR. The paper [7] made a comparison between sliding FIP and CFD mechanisms and concluded that: CFDs will provide better risk protection for both consumers and producers, and this mechanism will also be easier to gain public support.

In Vietnam, the FIT price ended at the end of 2020, the Vietnamese government is in discussions to bring RE to be traded directly in the spot electricity market. Therefore, to develop renewable energy in Vietnam, an energy development incentive mechanism that can integrate renewable energy into the spot electricity market is essential. This makes the income of RE generators dependent on the electricity market price, leading to a more strategic bid, such as adjusting the generating capacity when the electricity price increases or decreases. Therefore, in this study, we will introduce two mechanisms to develop RE in Vietnam: FIXED FIP and FIXED FIP WITH CAP & FLOOR (introduced in section 2), To serve the model, the Vietnamese Day-ahead market mathematical model presented in [8] is used. Currently CAP and FLOOR have also been applied in Vietnam for price bid, however in this study CAP and FLOOR of mechanism FIXED FIP WITH CAP & FLOOR are applied to the payment price for RE plants. The application of CAP and FLOOR to the payment price will significantly reduce the risk both for the RE generator and for the support unit (usually the government) when electricity market prices fluctuate.

This study will carry out the following main contents: Section II introduces the mathematical model of the FIXED FIP mechanism and the FIXED FIP WITH CAP & FLOOR mechanism. Section III will present the results, compare the FIXED FIP mechanism and the models of the FIXED FIP WITH CAP & FLOOR mechanism, with two cases with grid constraints and no grid constraints. Finally, section IV will present the main conclusions and recommendations.

2. Introduction to mechanisms

Under the FIP scheme, RE plants will have to participate in the electricity market, which will provide an additional amount of support above the wholesale electricity market price. Therefore, for FIP, the income of renewable energy generators will come from two sides: the first is the income from the electricity market with price fluctuations depending on the market and the second is the income added from the premium [5]. According to [9], FIP can be classified into the following categories: FIXED FIP and FIXED FIP WITH CAP & FLOOR.

For the FIXED FIP mechanism, it will work by adding a fixed amount of support (fixed premium or reference premium) on top of the current electricity market price. In this way, the income of the renewable energy plant will fluctuate depending on the electricity market price, there are times when the income will be very high when the market price is high and vice versa when the market price is low, this leads to a risk for the RE generator and will reduce the attractiveness for investors [5]. In addition, according to [10] to determine the fixed premium we can rely on the levelised cost of electricity (LCOE) and expected market revenue.

To overcome the shortcomings existing in the FIXED FIP mechanism, a FIXED FIP mechanism with the application of the upper limit (CAP) and the lower limit (FLOOR) has been designed or can be called FIXED FIP WITH CAP & FLOOR. According to the author [6], in Spain the Reference premium, CAP and FLOOR limit values will be set by the government in Royal Decree 661/2007 and it will apply to each specific technology [11], [12]. With the upper limit (CAP) has the function of protecting the support unit from supporting the purchase of electricity at too high prices at times of high electricity prices and the lower limit (FLOOR) will have the function of protecting RE generators from having to sell electricity at too low a price when the electricity market price drops sharply. According to [11], For this mechanism the price (electricity market + reference premium) must be halfway between the two pre-set CAP and FLOOR values, otherwise a premium adjustment must be made so that the support price (electricity market + reference premium) does not go beyond the CAP and FLOOR. It can be seen that, when the FIXED FIP WIT CAP & FLOOR mechanism is applied, this mechanism not only retains the advantages of the FIXED FIP mechanism, but it also reduces the risks for the sponsor (usually the government) and RE generators [6], [13]. Ensure the motivation to increase electricity generation output when the price is high and reduce the generation output when the price is low.

2.1. Mathematical model

2.1.1. Day-ahead market optimization model (DAM)

Regarding how to determine Locational Marginal Price (LMP) for each trading cycle of the spot electricity market, this study uses the simple optimal DAM model of the Vietnam DAM [8] as follows:

Objective function:

$$Min \sum_{t\in T} \sum_{a\in A} \left(\sum_{g\in G^a} Q_g^t . P_g^t . x_g^t - \sum_{d\in D^a} Q_d^t . P_d^t . x_d^t \right) \quad (1)$$

Constraints:

$$\sum_{g\in G^a} Q_g^t . P_g^t . x_g^t - \sum_{d\in D^a} Q_d^t . P_d^t . x_d^t = \mathrm{Net}_a^t \ [\lambda_a^t]$$

$$\forall a \in A, t \in T \quad (2)$$

$$Net_a^t + \sum_{f\in F} f_{fa-a}^t - \sum_{f\in F} f_{a-ta}^t = 0, \forall a \in A, t \in T \quad (3)$$

$$F_{min,l}^t \le f_l^t \le F_{max,l}^t, \forall l \in L, t \in T \quad (4)$$

$$0 \le \mathrm{x}_{\mathrm{g}}^{\mathrm{a,t}} \le 1, \forall \mathrm{g} \in \mathrm{G}, \mathrm{t} \in \mathrm{T} \quad (5)$$

$$0 \le \mathrm{x}_{\mathrm{d}}^{\mathrm{a,t}} \le 1. \forall \mathrm{d} \in \mathrm{D}, \mathrm{t} \in \mathrm{T} \quad (6)$$

In objective function (1), the minimize function of total operating cost function in the Day-ahead market is presented, thus it equals to the subtraction of total cost of supply and demand. Here, $Q_g^t, \mathrm{P}_\mathrm{g}^\mathrm{t}$ and Q_d^t, P_d^t are the submitted quantity and price bids of the generator g in G^a, and demand d in D^a, respectively. G^a and D^a are set of generator and demand at bidding zone a. $\mathrm{x}_\mathrm{g}^\mathrm{t}$ and $\mathrm{x}_\mathrm{d}^\mathrm{t}$ are the accepted ratio of supply and demand bid that have been successfully scheduled having a limit of 0 to 1. Equality constraints (2) and (3) present the balance energy at each bidding zone a in A for each period t in T. In equality constraint (2), Net_a^t is the amount of transmit (+), receive (-) power in each zone balanced by the total amount of transmit power in each zone which equals to the subtraction of supply and demand. Here, set A, T and L represent the set of bidding zones, periods, and interconnectors, respectively. The LMP_a^t of each zone a in period t is obtained from the Lagrange multiplier (λ_a^t) of equality constraint (2). Meanwhile, (3) ensures the power flow in (f_{fa-a}^t) and out (f_{a-ta}^t) of each zone a to be balanced with Net_a^t for each period t. Inequality constraint (4) guaranties the power flow f_l^t respects the maximum and minimum available transmission capacity of interconnector l in period t, denoted $F_{min,l}^t$ and $F_{max,l}^t$. Finally, inequality constraint (5) and (6) presents the accepted ratio of supply and demand in the range [0,1].

2.1.2. FIXED FIP mechanism model

The FIXED FIP mechanism is one in which the reference premium or fixed premium will always remain constant for the period of application. Therefore, the electricity price for each cycle of the renewable energy generator when participating in the FIXED FIP mechanism during the survey period (one month) is:

The electricity price for each transaction cycle of the FIXED FIP mechanism during the survey month will be equal to LMP per cycle plus Reference Premium.

2.1.3. Model of the FIXED WITH CAP & FLOOR mechanism with a period of 30 minutes

On the 30-minute cycle model, support levels are calculated by adding the reference premium to LMP for each cycle during the one-month study period. CAP and FLOOR are applied on a cyclical basis. If the support level is higher than the CAP value, then the support level will fall to equal the CAP value. If the support level is lower than the FLOOR value, then the support level is increased to equal the FLOOR. These adjustments are made every 30 minutes. As follows:

- If Price (LMP + reference premium) is between CAP and FLOOR values, the mechanism will work like FIXED FIP mechanism (premium is always fixed by reference premium).

- If the Price (LMP + reference premium) is greater than the CAP value, it is only necessary to support an amount up to the CAP value with the adjusted premium level as new premium.

- If the Price (LMP + reference premium) is less than the FLOOR value, an amount will need to be supported up to the FLOOR value with the adjusted premium as new premium.

- In the case when LMP is greater than the CAP value, the amount of additional premium support will be adjusted to zero, renewable energy producers will have an income equal to LMP.

2.1.4. Daily model of the FIXED FIP WITH CAP & FLOOR mechanism

The daily model works similarly to the cyclical model, except that we calculate the Daily Average Price (DAP) to compare CAP and FLOOR. For the daily model the premium will be applied within one day and changed if the DAP is outside the CAP and FLOOR.

How to calculate New Premium (NP) when Daily Average Price (DAP) is outside the CAP and FLOOR (with symbol i: trading cycle):

- Daily Average LMP:

$$DALMP = \frac{\sum_{i=1}^{48} LMP(i)}{48} \tag{7}$$

$$DAP = \frac{\sum_{i=1}^{48}(LMP(i)+Reference\ Premium)}{48} \tag{8}$$

When DAP is greater than CAP value.

$$- NP = CAP - DALMP \tag{9}$$

When DAP is lower than CAP value.

$$- NP = FLOOR - DALMP \tag{10}$$

Thus, the recalculated earnings for each cycle of that day will be equal to LMP per cycle plus NP.

2.1.5. Weekly model of the FIXED FIP WITH CAP & FLOOR mechanism

The weekly model works the same way as the daily model, only instead of calculating DAP we calculate the Weekly Average Price (WAP) to compare the CAP and the FLOOR. For the weekly model, the premium will apply for one week and change if the WAP is outside the CAP and FLOOR.

How to calculate NP when WAP is outside the CAP and FLOOR values:

- Weekly average LMP:

$$WALMP = \frac{\sum_{Day=1}^{7}(DALMP(day))}{7} \tag{11}$$

$$- WAP = \frac{\sum_{Day=1}^{7}(DAP(day))}{7} \tag{12}$$

When WAP is greater than CAP value.

$$- NP = CAP - WALMP \tag{13}$$

When WAP is lower than CAP value.

$$- NP = FLOOR - WALMP \tag{14}$$

Thus, the recalculated earnings for each cycle of that week will be equal to LMP per cycle plus NP.

2.1.6. Monthly model of the FIXED FIP WITH CAP & FLOOR mechanism

The monthly model works similarly to the daily model, except that instead of calculating the Daily Average Price (DAP), we calculate the Monthly Average Price (MAP) to compare the CAP and FLOOR. For the monthly model, the premium will apply for one month and change if MAP is outside the CAP and FLOOR.

How to calculate NP when MAP is outside the CAP and FLOOR values:

- Monthly Average LMP

$$MALMP = \frac{\sum_{Day=1}^{30}(DALMP(day))}{30} \tag{15}$$

$$- MAP = \frac{\sum_{Day=1}^{30}(DAP(day))}{30} \tag{16}$$

When MAP is greater than CAP value.

$$- NP = CAP - MALMP \tag{17}$$

When MAP is lower than CAP value.

$$- NP = FLOOR - MALMP \tag{18}$$

Thus, the recalculated earnings for each cycle of that month will be equal to LMP per cycle plus NP.

3. Research results

To perform the simulation, the author develop mathematical model in General Algebraic Modelling System version 44. Moreover, the test case is artificially created for the bid capacity data for the load based on the typical national electrical load graph characteristics and the plant's offered capacity data will be based on the characteristic curve of each power source type. The bid price data will be based on the regulations [14] and for wind and solar power plants, the bid price will be 0 VND/kWh. The values for the FIXED FIP and FIXED FIP WITH CAP & FLOOR mechanisms will be generated based on the decisions [15], [16], [17] for each plant type, shown in Table 1.

Table 1. *Cap, floor, and ref-premium data (million VND /MWh)*

Type of power plant	CAP	FLOOR	Reference premium
Solar power plant	1.644	1.1849	0.22955
Wind power plant	1.928	1.58712	0.17044

The article will perform a simulation for the power system with two areas A_1 and A_2 linked together through interconnector. With two simulation scenarios (**with grid constraint** and **without grid constraint**) to show the impact of network capacity on the market solution. Here, the network constraint is the available transmission capacity of the interconnector in equality constraint (4) in Section 2.1.1. Using two types of plants to show simulation results for renewable energy plants, which are wind power plants and solar power plants. To present the research results in the most intuitive way while still showing the contrast when the market price fluctuates, the author will show the results on two days that are: the day with the highest load in Fig. 1 and 3, and the day with the lowest load in Fig. 2 and 4.

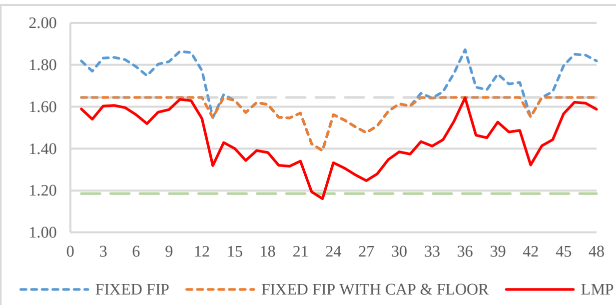

Figure 1. *Cyclic model of solar power plant with maximum load day*

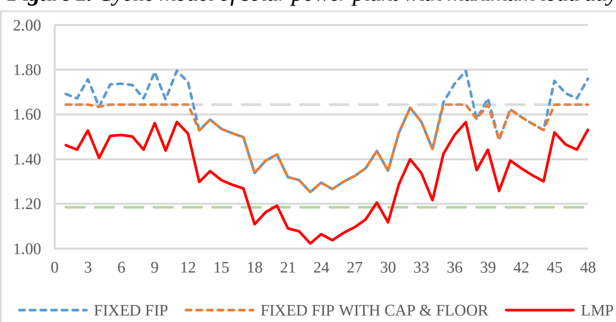

Figure 2. *Cyclic model of solar power plant on minimum load day*

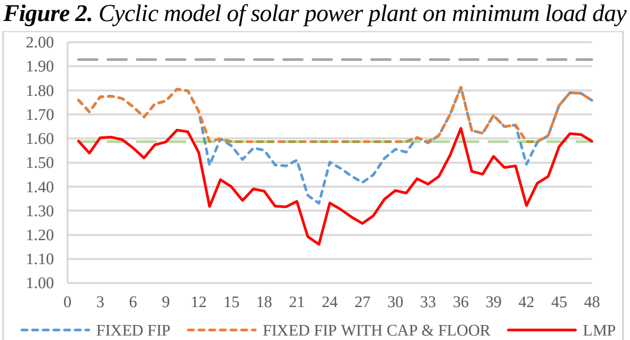

Figure 3. *Cyclic model of wind power plant on maximum load day*

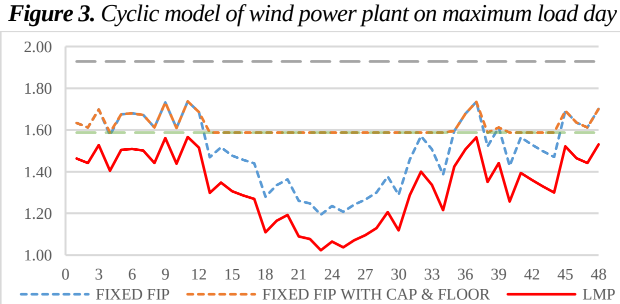

Figure 4. *Cyclical model of wind power plant on minimum load day*

3.1. Model results with a 30-minute cycle

Table 2. *Premium of cyclical models (million VND /MWh)*

			Solar power plant		Wind power plant	
		areas	Maximum load date	Minimum load date	Maximum load date	Minimum load date
Reference premium FIXED FIP	Without or with grid constraints	A1, A2	0.23	0.23	0.17	0.17
Average daily premium (FIXED FIP WITH CAP & FLOOR)	Without grid constraints	A1, A2	0.16	0.20	0.21	0.29
	With grid constraints	A1	0.16	0.24	0.24	0.34
		A2	0.14	0.20	0.18	0.27

Based on Table 2, cases **without grid constraints**, in the case of solar power plants, the day with the maximum load percentage of electricity price (LMP + ref-premium) exceeding the CAP limit is 56.25% (Figure 1) and the day with the minimum load this percentage decreases to 36.9% (Figure 2). This rate is quite high because the CAP limit is set too low, making the average daily premium amount when applying the FIXED FIP WITH CAP & FLOOR mechanism to decrease (0.16 million VND/MWh and 0.20 million VND/MWh, respectively, for two days of maximum and minimum load) than the FIXED FIP mechanism (0.23 million VND/MWh). In this case, the insurance premium for solar power plants when applying FIXED FIP WITH CAP & FLOOR mechanism will be lower than applying FIXED FIP mechanism. For wind power plants, the ratio of time the electricity price (LMP + ref-premium) is below the FLOOR limit on the day of maximum load is 43.75% (Figure 3) and for the day of minimum load this rate increases to 60.4% (Figure 4), the main cause of the problem. This ratio difference also originates from the reason that the electricity price on the day with the minimum load is reduced lower than the electricity price on the day with the maximum load. In addition, the FLOOR limit set too high also causes the electricity price (LMP + ref-premium) to be lower than the FLOOR value for many periods. Table 2 results show, the average daily premium was adjusted up from the ref-premium value (0.17 million VND/MWh) to 0.21 million VND/MWh and 0.29 million VND/MWh respectively in the two days of maximum and minimum load. Therefore, in this case, the wind power plant will achieve a higher premium when applying the FIXED FIP WITH CAP & FLOOR mechanism.

In the case of **grid constraints**: in general, the results tend to be the same as in the case of no constraints, but due to transmission capacity limitations, electricity prices differ between the two regions (Area A_1 electricity price is higher than area A_2). As a result, the premiums of the two regions are also different (See Table 2) for the FIXED FIP WITH CAP & FLOOR mechanism. This shows that the area (A_1) has a low LMP, the premium will be high, and the area (A_2) has high LMP, so the premium will be low, this helps to reduce the income disparity of renewable energy plants in the two regions when bound. As for the FIXED FIP mechanism, the premium remains the same in the case of no constraints.

Finally, when comparing the premium of the FIXED FIP WITH CAP & FLOOR mechanism between the minimum load day and the maximum load day, we see that the day with the maximum load premium will tend to be lower than the day with minimum load. (See Table 2).

The paper will perform calculations for the following sections, but for simplicity, we only show the results of the models through the data tables below.

3.2. Daily model results

Table 3. *Premium of the daily model (million VND /MWh)*

			Solar power plant		Wind power plant	
		areas	Maximum load date	Minimum load date	Maximum load date	Minimum load date
Reference premium (FIXED FIP)	Without or with grid constraints	A1, A2	0.23	0.23	0.17	0.17
Average daily premium (FIXED FIP WITH CAP & FLOOR)	Without grid constraints	A1, A2	0.20	0.23	0.17	0.26
	With grid constraints	A1	0.23	0.23	0.17	0.31
		A2	0.15	0.23	0.17	0.24

Based on Table 3 cases **without grid constraints**, for solar power plants, on the day of maximum load, the daily premium of FIXED FIP WITH CAP & FLOOR has been adjusted down to 0.2 million VND/MWh, lower than 0.23 million VND/MWh of FIXED FIP mechanism and the date of minimum load, there is no change to the daily premium (ref-premium = 0.23 million VND/MWh = daily premium). Besides, for the case of wind power plants, we see that the day of maximum load of the FIXED FIP WITH CAP & FLOOR mechanism is still equal to ref-premium (0.17 million VND/MWh), and days with minimum load, the premium value of this day has been adjusted to 0.26 million VND/MWh, higher than 0.17 million VND/MWh of FIXED FIP mechanism.

Based on Table 3 cases **with grid constraints**, the results still tend to be the same as the case without constraints, in addition, for the FIXED FIP WITH CAP & FLOOR mechanism, due to the different electricity prices in the two areas, the premiums of the two zones are also different (the A_1 premium area is still higher than the A_2 area), this helps to reduce the income disparity of renewable energy plants in the two regions. As for the FIXED FIP mechanism, the premium remains unchanged compared to the case with no constraints.

In addition, when comparing the premium of the FIXED FIP WITH CAP & FLOOR mechanism between the days of minimum and maximum load we also see, days with maximum load, premium will tend to be lower than days with minimum load (see Table 3).

3.3. Weekly model results

Since the two days of minimum and maximum load are not in the same week (23rd and 27th) but still within 7 days. Therefore, the author will convert these two days to a week to better evaluate the model. It should also be noted that with the weekly model, the premium will be constant throughout the cycles of the same week.

Based on Table 4 cases **without grid constraints**, for solar power plants when applying the FIXED FIP WITH CAP & FLOOR mechanism: the calculation results show that WAP (1.649 million VND/MWh) is larger than the CAP value (1.644 million VND/MWh), so we need to recalculate to reduce the premium support, so we have the new premium value = 0.22 million VND/MWh, a bit lower than the reference premium of the FIXED FIP mechanism (0.23 million VND/MWh). For wind power plants, because WAP (1.59 million VND/MWh) is between the CAP and FLOOR values, we see this week's premium of FIXED FIP and FIXED FIP WITH CAP & FLOOR mechanisms is the same (0.17 million VND/ MWh).

Table 4. *Premium of the weekly model (million VND /MWh)*

			Solar power plant		Wind power plant	
		areas	Maximum load date	Minimum load date	Maximum load date	Minimum load date
Reference premium (FIXED FIP)	Without or with grid constraints	A1, A2	0.23	0.23	0.17	0.17
Average daily premium (FIXED FIP WITH CAP & FLOOR)	Without grid constraints	A1, A2	0.22	0.22	0.17	0.17
	With grid constraints	A1	0.23	0.23	0.20	0.20
		A2	0.19	0.19	0.17	0.17

For the case of **grid constraints**, see Table 4, we see: FIXED FIP WITH CAP & FLOOR mechanism, premiums of the two areas are still different, area A_1 has low electricity prices, so premium tends to be high and area A_2 has high electricity prices so premium tends to be low (both types of plants). This helps to reduce the revenue disparity between the two regions when applying the FIXED FIP WITH CAP & FLOOR mechanism.

3.4. Monthly model results

Table 5. *Premium of the monthly model (million VND /MWh)*

			Solar power plant		Wind power plant	
		areas	Maximum load date	Minimum load date	Maximum load date	Minimum load date
Reference premium (FIXED FIP)	Without or with grid constraints	A1, A2	0.23	0.23	0.17	0.17
Average daily premium (FIXED FIP WITH CAP & FLOOR)	Without grid constraints	A1, A2	0.22	0.22	0.17	0.17
	With grid constraints	A1	0.23	0.23	0.20	0.20
		A2	0.19	0.19	0.17	0.17

According to the monthly model, the premium will be constant throughout the cycles of that same month. Therefore, the general results for two types of power plants all day with maximum and minimum load are as follows:

Based on Table 5 cases **without grid constraints**, for solar power plants when applying the FIXED FIP WITH CAP & FLOOR mechanism, because MAP is higher than the CAP limit, we have, premium of that month will be adjusted down to 0.22 million VND/MWh. For wind power plants when applying the FIXED FIP WITH CAP & FLOOR mechanism: because the MAP of wind power plants is between the CAP and FLOOR limits. Therefore, it is unnecessary to adjust the premium, the premium value of the month is equal to ref-premium (0.1704400 million VND/MWh).

The cases **with grid constraints** get similar results to the weekly model.

3.5. Compare the average monthly premium of the models with the reference premium

Based on the results of Table 6, the difference between the reference premium and the Premium monthly average of the models tends to decrease as the model has a longer application period. This happens for both types of renewable energy plants and both cases (**without grid constraints and with grid constraints**). This shows that, the longer the FIXED FIP WITH CAP & FLOOR model, the less volatile the premium will be.

Table 6. *Compare the average monthly premium of the models with the reference premium (million VND /MWh)*

	Solar power plant				Wind power plant			
	without grid constraints		with grid constraints		without grid constraints		with grid constraints	
	Ref-premium	Premium monthly average	Premium monthly average		Ref-premium	Premium monthly average	Premium monthly average	
areas	A_1, A_2	A_1, A_2	A_1	A_2	A_1, A_2	A_1, A_2	A_1	A_2
cyclical models	0.23	0.17	0.18	0.16	0.17	0.23	0.26	0.20
daily models	0.23	0.21	0.23	0.18	0.17	0.19	0.20	0.18
monthly model	0.23	0.22	0.23	0.19	0.17	0.17	0.20	0.17

4. Conclusion

The paper is successful in developing a model in which renewable energy can be traded in the Spot market with an explicit incentive. Firstly, the simulation results of FIXED FIP WITH CAP & FLOOR mechanisms show that, it helps to reduce risks for both the renewable energy generator and for the government, i.e., FLOOR helps to ensure a minimum income for RE generators when electricity market prices fall too low, and Cap helps reduce over-supporting when electricity market prices rise too high for the government). This is considered as the main advantage of the FIXED FIP WITH CAP & FLOOR mechanism over the FIXED FIP mechanism. Besides, in the case of grid constraints, the FIXED FIP WITH CAP & FLOOR mechanism also has the effect of reducing the income gap between the two regions (A_1 and A_2) for RE generators when the electricity market price has a difference between the two regions due to congestion. Therefore, in terms of mechanism, the paper proposes that the FIXED FIP WITH CAP & FLOOR mechanism will have an advantage over the FIXED FIP mechanism.

The paper also compares the daily, weekly, and monthly model with FIXED FIP WITH CAP & FLOOR mechanism. The monthly model can overcome the disadvantages of excessive complexity brought by the above mechanisms, due to the longer setup time. In addition, this model offers more premium stability than the rest of the mechanisms (cycle, day, week). As the analysis results also show, the average monthly premium tends to get closer to the reference premium value. This matches the aspirations when designing the FIXED FIP WITH CAP & FLOOR model, i.e., it is good when the price of the support price is between the CAP and FLOOR values. In addition, it also overcomes the disadvantage of lack of compensation for electricity prices between the time of high electricity price and the time of low electricity price that cyclical and daily mechanisms are caught. Therefore, in this study, the monthly model is assessed as a more suitable mechanism in the application of incentives for renewable energy development.

Finally, through the results obtained, the paper proposes that the FIXED FIP WITH CAP & FLOOR mechanism with a monthly model will be a more appropriate mechanism and can be applied to encourage the development of renewable energy.

Acknowledgement: This research is funded by the Ministry of Education and Training, Vietnam under the grant number CT2022.07.DNA.02.

REFERENCES

[1] N. T. Son, "Vietnam Electricity in 2022 – Challenging development direction", *nangluongvietnam.vn*, 2023, [Online] Available: https://nangluongvietnam.vn/tap-doan-dien-luc-viet-nam-nam-2022-thu-thach-huong-phat-trien-30102.html, [Accessed June 19, 2023].

[2] N. A. Tuan, "Vietnam Renewable Energy in 2022: Events, achievements and identify challenges", *nangluongvietnam.vn*, 2023, [Online] Available: https://nangluongvietnam.vn/nang-luong-tai-tao-viet-nam-nam-2022-cac-su-kien-thanh-tuu-va-nhan-dien-thach-thuc-30046.html, [Accessed Jun. 19, 2023].

[3] N. T. Trang, N. T. Cuong, and P. C. Huy, "FIT electricity purchase mechanism in Vietnam – Current situation and solutions", *tapchicongthuong.vn*, 2022, [Online] Available: https://tapchicongthuong.vn/bai-viet/co-che-gia-mua-ban-dien-fit-tai-viet-nam-thuc-trang-va-giai-phap-97509.htm, [Accessed Aug. 09, 2023].

[4] A. Çiçek, S. Güzel, O. Erdinç, and J. P. S. Catalão, "Comprehensive survey on support policies and optimal market participation of renewable energy", *Electric Power Systems Research*, vol. 201, p. 107522, 2021.

[5] M. del P. Pablo-Romero, A. Sánchez-Braza, J. Salvador-Ponce, and N. Sánchez-Labrador, "An overview of feed-in tariffs, premiums and tenders to promote electricity from biogas in the EU-28", *Renewable and Sustainable Energy Reviews*, vol. 73, pp. 1366–1379, 2017.

[6] J. Schallenberg-Rodriguez, "Renewable electricity support system: Design of a variable premium system based on the Spanish experience", *Renew Energy*, vol. 68, pp. 801–813, 2014.

[7] M. Kröger, K. Neuhoff, and J. C. Richstein, "Contracts for difference support the expansion of renewable energy sources while reducing electricity price risks", *DIW Weekly Report*, vol. 12, no. 35/36, pp. 205–213, 2022.

[8] L. H. Lam and D. X. Bach, "Uniform purchasing price approach for Vietnam wholesale electricity market: modeling and discussing", *International Journal of Electrical Power & Energy Systems*, vol. 148, p. 109012, 2023.

[9] A. Ebrill, "Key support elements of RES in Europe: moving towards market integration", *erranet.org*, 2016, [Online] Available: https://erranet.org/download/ceer-key-support-elements-of-res-in-europe/, [Accessed May 28, 2023].

[10] M. Welisch, "Multi-unit renewables auctions for small markets - Designing the Danish multi-technology auction scheme", *Renew Energy*, vol. 131, part C, pp. 372–380, 2019.

[11] Ministerio de Industria, Turismo y Comercio, Real Decreto 661/2007, de 25 de mayo, por el que se regula la actividad de producción de energía eléctrica en régimen especial, «BOE» núm. 126, de 26/05/2007.

[12] J. Schallenberg-Rodriguez and R. Haas, "Fixed feed-in tariff versus premium: A review of the current Spanish system", *Renewable and Sustainable Energy Reviews*, vol. 16, no. 1, pp. 293–305, 2012.

[13] Held, Anne, *et al.*, "D5. 2: Best practice design features for RES-E support schemes and best practice methodologies to determine remuneration levels", DIA-CORE Project Report, 2014.

[14] Deputy Minister, *Decision 820/QD-BCT on promulgating the 2022 electricity generation price bracket*, Ministry of Industry and Trade of Vietnam, 2022.

[15] Deputy Prime Minister, *Decision 13/2020/QĐ-TTg on Mechanisms to Promote the Development of Solar Power Projects in Viet Nam*, The Prime Minister, 2020.

[16] Deputy Minister, *Decision 21/QD-BCT on Promulgation of the transitional framework for electricity prices of solar power plants wind power plants*, Ministry of Industry and Trade of Vietnam, 2023.

[17] Prime Minister, *Decision 39/2018/QĐ-TTg on Amending and supplementing a number of articles of decision no.37/2011/QD-TTG dated june 29, 2011 by the prime minister on support mechanism to develop wind power projects in Vietnam*, The Prime Minister, 2018.