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The Long Term effect of Iran’s Photovoltaic Support Policy on Consumers’ Electricity Price

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Abstract— **This article identifies and examines the factors affecting the consumers’ electricity price rise caused by solar power plants’ support policy in Iran. The consumers’ bill is the financial source of the policy, which imposes a direct effect on their total cost. Based on the literature, percentage change in their bill, due to the support plan, is the principal factor in changing their social behavior. In countries such as Iran, where the government determines the electricity price, its variations form stronger political feedbacks. Moreover, since electricity price is highly subsidized and cheap in Iran, its changes result in more significant percentage change, in comparison to countries with higher electricity prices. Therefore, the development of a model for predicting consumers’ price changes due to support policy is of high importance. Scenarios are designed to investigate the effect of different variables on consumers’ price changes. The results show how the variables (static or dynamic) affect the price changes. Moreover, it is evident that how they affect price changes, which can be an excellent guide to deciding how to improve the model.**

Keywords- consumers’ electricity price; photovoltaic power plants; support policy

I. INTRODUCTION

Fossil fuels are the primary energy source of conventional power plants. There have been enormous efforts towards reducing the reliance on fossil fuels in order to decline the environmental pollution in addition to increasing the energy security. Technologies, which use renewable energies to generate electricity, are the best candidates to address mentioned problems because of their everlasting free sources of energy and their little pollution. In Iran, the cost of electricity produced by photovoltaic power plants as one of the renewable technologies is significantly more expensive than conventional power plants attributed to many subsidies allocated to electricity generation. Thus, Governments’ support policy for renewable energies is highly required to enhance investors’ motivation toward the installation of these power plants.

As an effective support policy, feed-in tariff (FIT) has been widely used as a support mechanism to increase the installation of photovoltaic power plants around the world [1]–[5]. Recently, the FIT policy has been implemented in Iran. According to this policy, the government purchases the output of photovoltaic power plants at a price higher than the market price during an extended period [6]. The financial source of the extra payments is consumers’ electricity bill. Therefore, developing the installation of these power plants declines their cost because of learning by doing (LBD) and economies of scale (EOS) [7], but on the contrary, boosting the amount of electricity produced by this mechanism increases the electricity price of consumers [8]. It explains how FIT policy accelerates the grid parity [9].

Being a policy under government authorization that raises the cost of people’s lives is capable of transforming the FIT policy into a crucial factor in the sphere of the political dynamics as explained in [10], [11]. Moreover, Lower per capita income and massive subsidy of electricity in Iran magnify these political consequences. Thus, it is of vital importance to estimate the financial burden of the support policy in countries such as Iran to prevent failure similar to that took place in Spain [12].

In general, there are three methods in modeling FIT. In the first method, which is most used, the cost of technology is the basis of FIT price design [7], [9]. In the second manner, the value of renewable energy is calculated for the electrical system and according to its requirements [13], [14]. Market-based models like Premium-FIT fall into this category [4], [15]–[17]. In the third group, which has a broader perspective, in addition to the cost of technology, constraints like consumer responses are also considered in policy design [10].

The strategic behavior of investors, which leads to delays in investing in order to maximize their profit, is investigated in [9]. Negative consequences of this delay and its reduction strategies are also presented. Under production-based learning, an optimal design of FIT schedules is examined in [7]. In this work, reduction the levelized cost of renewable technologies is considered as the target and found LBD and EOS as the two prime tools to achieve it. The basis of FIT price setting in [7], [9] is the cost of technology which puts them in the first category.

As an example of the second category, in [13], using a system-scale methodology, it is attempted to extract the FIT price not according to the cost of technology, but according to the requirements and metrics of the electrical energy generation system. In this way, hourly variations in the price of energy and

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long-term alterations in the electricity generation mix are the primary references to the calculation of the systemic value of the renewables.

In [10], the German Renewable Energy Support Policy has been studied concerning the closed loop interaction between the policy process and the changes in technology and the market, taking into account the reaction of the public to the results of policies. An increase in electricity prices has been identified as one of the leading consequences of a renewable support policy that could have a negative impact on it.

Therefore, Consumers' financial burden constraints support the policy, which emphasizes the necessity of proposing a method for its calculation and identifying the factors that affect it. Although the way in which consumers react to this financial burden is beyond the scope of this paper, the proposed method in this article is capable of being the first step to study this reaction.

The rest of this paper is organized as follows: Section 2 presents problem formulation. In the third section, by comparing the results of several scenarios with a baseline scenario, the importance of the variables affecting price changes caused by supportive policy has been studied. Finally, Section 4 covers a conclusion of the paper.

II. PROBLEM FORMULATION

Percentage change in consumers' electricity price, induced by photovoltaic power plants' support policy has been considered as the long-term effect of the policy. It persists even after the support policy termination until the last power plant under FIT contract passes its contract duration. Additionally, support policy is capable of affecting the consumers' price in the opposite direction. It is called Merit Order Effect (MOE), which takes place in the wholesale electricity market [18]–[21]. Electricity produced under FIT contracts enters the wholesale market at the zero price, which results in a shift away in generation curve that is called MOE. Theoretically, it leads to a decline in the wholesale price, but empirically, GenCos' market power [18] alongside transmission network nonlinear characteristic [20] cause unpredictable results. Therefore, MOE calculation is beyond the scope of this paper. Formula (1) shows how the percentage change is calculated.

$$FB_n = \frac{RP_n}{Q_0} \times 100 \tag{1}$$

In this formula, RP_n is the added price of a kWh attributed to support policy. Q_0 is the electricity price regardless of support policy, which has been considered to be constant. In countries such as Iran, Q_0 highly depends on government decisions and considering its variations is beyond the scope of this paper. Formula (2) shows how RP_n is calculated.

$$RP_n = \frac{TC_n}{RD_n} \tag{2}$$

TC_n is the aggregate payment under FIT contracts in year n, and RD_n is the total demand in year n which has to endure the added price because of support policy.

Some of the electricity consumers are exempted from the surcharge to decline adverse consequences of support policy in other parts of the economy. For example, some countries exempted industries with a high rate of power consumption. To consider this, the variable ID is defined which is constant during the simulation period.

$$RD_n = D_n \times ID \tag{3}$$

Formula (3) calculates RD_n using D_n and ID. D_n is the total power demand in year n and is derived from (4).

$$D_n = (1 + DC)^n \times D_0 \tag{4}$$

In this formula, D_0 is the total power demand before the support policy. ID is the annual growth rate of electricity demand that is constant.

Power plants installed in different years sign various contracts. Thus to calculate the total payment of year n, it is required to consider this difference. Formulas (5) and (6) show this process.

$$TC_n = \sum_{i=1}^{n} (RC_{i,m} + UC_{i,m}) \tag{5}$$

$$m = n - i \tag{6}$$

Additionally, different types of power plants receive different FITs. In this paper, residential and utility classes are considered, but in reality, there are more types. The FIT is a function of power plants' size. Utility power plants' FIT is lower than residential power plants FIT. In (5), $RC_{i,m}$ and $UC_{i,m}$ represent residential and utility power plants payment respectively. n is the number of years after installation. $RC_{i,m}$ and $UC_{i,m}$ are calculated in the same way as demonstrated in (7) and (8).

$$RC_{i,m} = RI_i \times P_m \times RF_{i,m} \tag{7}$$

$$UC_{i,m} = UI_i \times P_m \times UF_{i,m} \tag{8}$$

P_m is the performance ratio of power plants which depend on geographical circumstance and the quality of equipment which degrades annually for an installed photovoltaic panel. Formula (9) explains how it is calculated.

$$P_m = (1 + DR)^m \times P_0 \tag{9}$$

DR is the degradation rate of material which is a constant value and, P_0 is the performance rate at the installation time which depends on installation place and the nominal output of equipment and is represented as the equivalent nominal hours of power production in a year. To acquire P_0, spatial changes are neglected, and it is introduced as an average for Iran. In these formulas, RI_i and UI_i are residential and utility capacity installed in the year i respectively.

$RF_{i,m}$ and $UF_{i,m}$ are the prices of a kWh of electricity produced by a power plant passed m years of its installation and installed in the year i which are calculated in (10) to (11).

$$RF_{i,m} = RF_0 \times (1 - LR)^k \times RM_m \tag{10}$$

$$UF_{i,m} = UF_0 \times (1 - LR)^k \times UM_m \tag{11}$$

As mentioned earlier, LBD and EOS lead to the decline of photovoltaic power plants' cost. LR represents the effect of these two factors. To avoid investors' over-funding and unnecessary cost, modifying the contracts are annually required according to the learning rate. k is the variable which can represent this annual adjustment. Formula (12) calculates k in which a accounts for the governments' lag in response to the learning rate.

$$k = i - a \tag{12}$$

RF_0 and UF_0 are residential and utility FIT at the beginning of the support policy. LR is the learning rate of photovoltaic technology which is considered the same for both residential and utility power plants and is a constant value. RM_m and UM_m demonstrate the changes of FIT based on contracts. For example, based on Iran's FIT contracts, the promised FIT of utility power plants decreases by thirty percent, ten years after installation. They also show the length of contracts. Formulas (13) and (14) demonstrate RM_m and UM_m.

$$RM_m = \begin{cases} 1 & m \le 20 \\ 0 & m > 20 \end{cases} \tag{13}$$

$$UM_m = \begin{cases} 1 & 0 < m \le 10 \\ 0.7 & 10 < m \le 20 \\ 0 & m > 20 \end{cases} \tag{14}$$

Fig. 1 shows the presented model and its inputs. Dashed rectangle, representing the model and variables outside it, are inputs of the model.

III. CASE STUDY

As mentioned earlier, the percentage change in consumers' electricity price, induced by photovoltaic power plants' support policy is capable of becoming the main factor in preventing the continuation of support policy, which enhances the significance of identifying and examining the factors affecting it. Several scenarios are designed, to identify the variables that have the greatest impact on its dynamics. To this end, the results of these scenarios are compared with the outcome of a baseline scenario. The values of the input variables for the baseline scenario are shown in TABLE I. It is the most similar scenario to Iran's circumstance between all created scenarios.

All variables are explained in the preceding section. The values of the first four variables are calculated based on the data extracted from [22]. Some estimation has been done on data provided by [23] to calculate RF_0 and UF_0. A conservative and pessimistic estimate for DR is taken from [24]. The proposed value for P_0 is presented based on the studies carried out in [25]. Considering what is given in [26] and taking into account the weak relationship between the Iranian market and industry with the rest of the world, this variable is considered equal to 10.

In each scenario, solely one variable is altered in comparison to the baseline scenario to identify its effect on the percentage change. The values of modified variables for each scenario are shown in Table II.

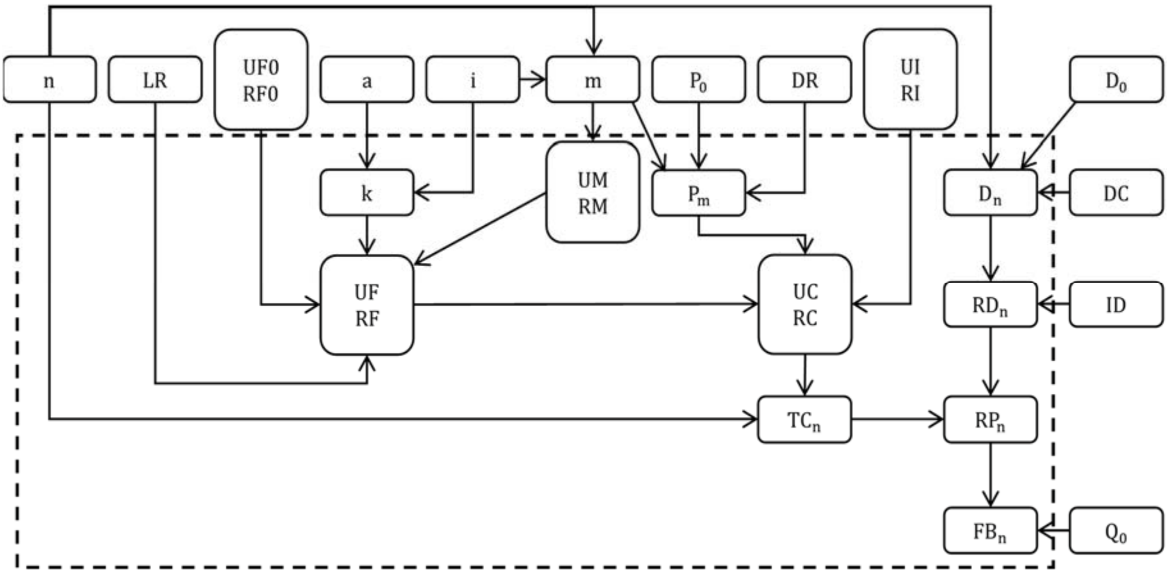

Figure 1. Proposed model and its inputs

TABLE I. BASELINE SCENARIO INFORMATION

Variable	Value	Unit
D_0	241090	MWh
Q_0	19	\$/MWh
ID	100	%
DC	5	%
RF_0	210	\$/MWh
UF_0	116	\$/MWh
DR	1	%
P_0	1900	h
LR	10	%
RI_i	100	MW/year
UI_i	900	MW/year
a	2	year

TABLE II. MODIFIED VARIABLE IN SCENARIOS

Scenario	Variable	Value
1	Q_0	80
2	ID	50
3	DC	10
4	DC	-5
5	UC_i, RC_i	1800,200
6	UC_i, RC_i for $i \le 10$	2700, 300
	UC_i, RC_i for $i > 10$	900, 100
7	P_0	2200
8	LR	0
9	LR	20
10	a	0

A. Baseline Scenario

Fig. 2 shows the consumer price increase caused by the installation of one GW of solar power plants per year. This rise could be catastrophic and lead to a rapid defeat of supportive policies considering the high sensitivity of the Iranian people to the price of electricity. The one-gigawatt photovoltaic power plant installation annually, increase their share in providing energy demand approximately to 6 percent which is inadequate considering Iran's high solar capability and its summer peak of demand stem from thermal wave which is in harmony with solar power production.

B. Scenario 1

Fig. 3 shows the profound and destructive impact of policies implemented in the Iranian electricity sector. Subsidizing electricity price now acts as an enormous obstacle to the support policy or any other useful change in this industry. It reveals why the Iranian government has decided to make the electricity price more realistic independent of renewables support strategy over the near future years [22].

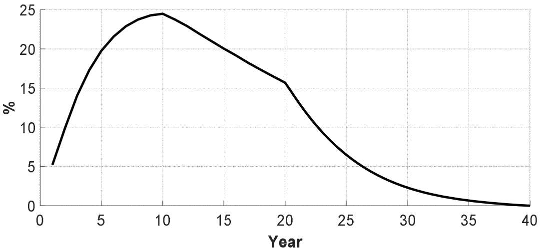

Figure 2. Percentage change in consumer price in the baseline scenario

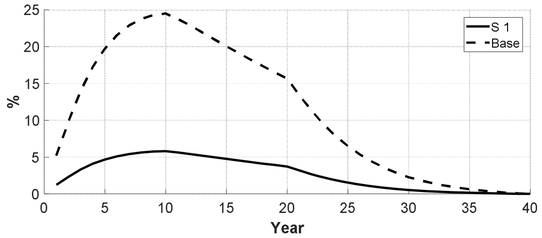

Figure 3. Comparison between baseline scenario and scenario 1

C. Scenario 2

Fig. 4 shows the dilemma that the Iranian government is facing. It has to choose between protecting its productive sections including industry and agricultural and decreasing consumer price variation caused by the support policy. As mentioned before, the subsidized electricity price is the source of this problem.

D. Scenarios 3,4

Fig. 5 and Fig. 6 show the effect of electricity demand dynamics on consumer price changes. According to these results, Demand increase, which is a typical characteristic of developing countries such as Iran, can facilitate their support policy by a decline in its consequences.

E. Scenario 5

Fig. 7 shows that doubling the share of solar in providing demand equates to a double increase in consumer price attains the peak of 50 percent in some years. It is another consequence of a highly subsidized electricity price.

F. Scenario 6

In Scenarios 5 and 6, the total amount of installation is the same, but different pattern of installation as shown in Fig. 8 leads to a considerable difference in the consumer price. It reveals the

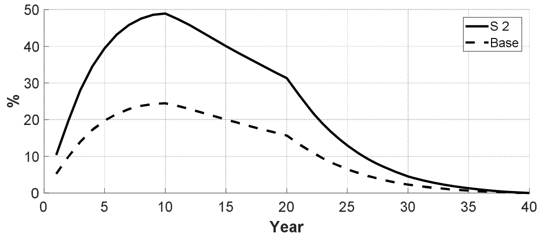

Figure 4. Comparison between baseline scenario and scenario 2

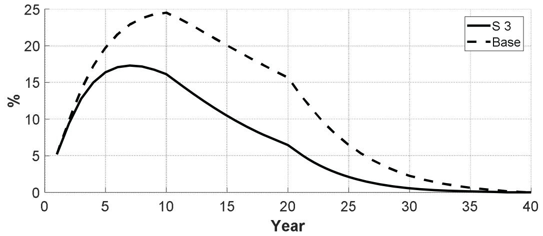

Figure 5. Comparison between baseline scenario and scenario 3

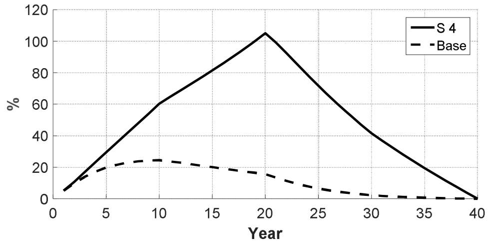

Figure 6. Comparison between baseline scenario and scenario 4

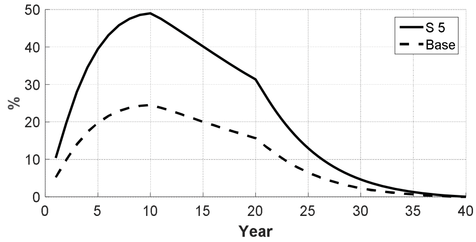

Figure 7. Comparison between baseline scenario and scenario 5

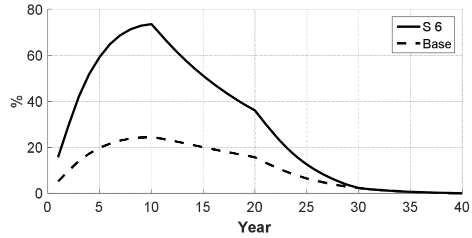

Figure 8. Comparison between baseline scenario and scenario 6

significant importance of a dynamic model for investors' reaction simulation.

G. Scenario 7

According to Fig. 9, the performance ratio is not a serious issue because, for the case of Iran, most of the country is the beneficiary of an exceptional solar performance.

H. Scenario 8,9

Fig. 10 and Fig. 11 shows how learning rate is capable of diminishing the consumer price increase. In scenarios 3 and 9, which the learning rate and demand increase are respectively doubled, the peak happens even before year 10. Despite the inevitable role of learning rate and demand increase in reducing the financial burden of consumers, there is another factor, which enforced the peak point to happen at year 10. UM_m which described by the (14) is the crucial cause of this decline. This equation shows that the FIT of utility power plants falls by thirty percent ten years after installation. This decrease commence at year eleven of policy commencement to make year ten the peak point concerning ninety percent share of installation allocated to utility power plants in all scenarios which make this factor more effective. The base scenario is repeated omitting UM_m, and the result is shown in Fig. 12 which illustrates the ability of learning rate and change in demand to decrease the consumer price increase.

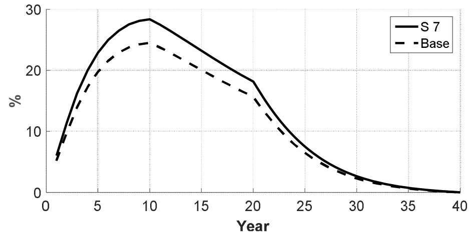

Figure 9. Comparison between baseline scenario and scenario 7

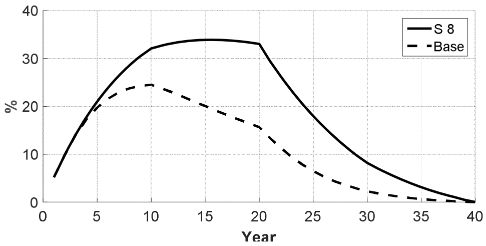

Figure 10. Comparison between baseline scenario and scenario 8

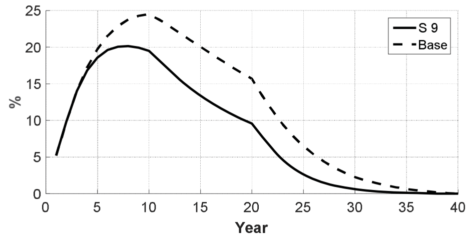

Figure 11. Comparison between baseline scenario and scenario 9

I. Scenario 10

Fig. 13 show that the delay in government decision making in the one-year and two-year intervals has a lesser impact than other variables. Of course, this delay, due to the effect on the price agreed on in contracts, can affect the reaction of investors and the annual installment. Therefore, it is necessary to study its impact by using a more comprehensive model.

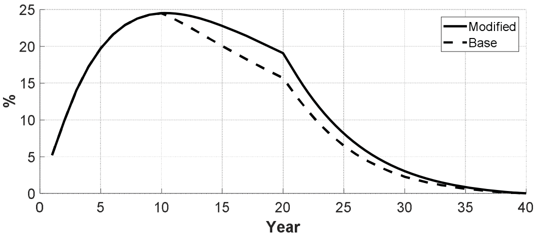

Figure 12. Comparison between baseline scenario and modified case

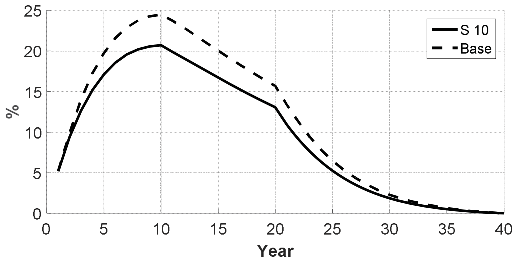

Figure 13. Comparison between baseline scenario and scenario 10

IV. CONCLUSION

The factors influencing the price rise resulting from the supportive policy of solar power plants studied here are subdivided into two dynamic and static categories. The static group includes Electricity price before the support policy, percentage of demand subject to price increases and the performance ratio of the panels. The dynamic group comprises the change in demand, learning rate, investors' reaction and government delay. According to the results, the electricity price independent of support policy and the percentage of demand subject to price increases can considerably affect the price increases. However, these two factors are entirely determined by the government, and they are part of the government model. As a dynamic factor, investors' reaction is the most unpredictable element, which is highly required to be modeled and examined. The demand model as a part of the generation expansion planning problem, has some excellent models. Moreover, a comprehensive economic model is capable of resulting in better predictions for it. The government model has to cover its strategy versus the learning rate of technology and investors' reaction to the support policy. In summary, models of the government, investors, and demand are required to develop the results of this paper. Additionally, it is crucial to analyze consumers' reaction to the price increases.

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