BUSINESS PROCESS MODELING FOR SOLAR-POWERED CHARGING STATION IN PARKING LOTS IN THE USA

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Abstract - Current study evaluates the feasibility of solar-powered charging station in parking lots in the USA. As a matter of fact, a business process modeling is proposed in order to evaluate cost of equipping a parking lot to solar-powered charging station, payback period, revenue of the parking lot in a year, customers' energy consumption within a year, charging time, the utilization of resources within a year and amount of energy can be injected to the distribution grid. The result of the study indicates that implementing solar-powered charging station in parking lots is a good business plan which meets customers' need and increases EV adaption.

Keywords - Electric vehicle, Charging station, Parking lot, Photovoltaic panel.

I. INTRODUCTION

Transportation must become less depends on fossil fuel as a result of increasing CO2 emission which is being released by vehicles that consume petrol [1]. Indeed, that is one the reasons why production of electric vehicle have increased since 2011 [2]. Therefore, power plants, as well as power systems will be encountered with a new challenge as a result of increasing electric vehicle. As a matter of fact, the negative impact of charging electric vehicle on power systems is undeniable [3]. In order to decrease the negative impact of charging electric vehicle on power systems, charging stations which are supplied by renewable systems must be implemented in public places [4].

In this paper, we propose a charging station that is supplied by solar systems at a parking lot where wants to provide charging station for their customers. Furthermore, a business process with three scenarios based on customer's arrival time is proposed in Bizagi software in order to evaluate process validation, time analysis and resource analysis based on calendar analysis. Moreover, the cost of our service proposal, revenue of charging station and the payback period of the service proposal were calculated.

II. BENEFIT OF EQUIPPING PARKING LOTS TO SOLAR-POWERED CHARGING STATION

Parking lots are everywhere in America due to Americans high vehicle adaption [5]. Increasing the production of Electric Vehicle create a demand for charging stations. As a matter of fact, the electric vehicle is expected to grow more than 2.7 million in 2023 in the USA [6]. Nevertheless, public charging stations must be implemented for the owner of EV so that they can charge their vehicle in urban areas.

Solar powered charging station is a new concept which widely adopted by authorities as well as investors. This service is being implemented in big shopping centers, malls, workplaces and parking lots [7]. Equipping parking lots to solar powered charging station is extremely beneficial for both service provide and service consumer. In fact, service provider makes profit by selling clean energy and service consumer charge its car with a cheap price and environmentally friendly manner. On the other hand, the power generated by solar panels can be injected to the distribution grid whenever there is no customer to serve [8]. Therefore, service provider makes more profit by injecting power to the distribution grid as well.

III. ENERGY AND PARKING PRICE

There are some charging stations that serve their customers for free. However, charging an electric car in some public charging stations are costly. Utilities in every country have a different way of calculating electricity cost. Therefore, a specific price for energy cannot be found because of the fact it changes every hour [9]. As a matter of fact, some charging stations define energy price based on charging time. Some of them define energy price based on energy consumption per a KWh. In our business scenario, renewable energy has a stable price which is 0.01 per a KWh [10]. However, the price of energy received from grid changes based on customer's arrival time [10]. In fact, grid energy price is 0.12 dollar during off period. Moreover, the price of grid energy increases %90 during peak hours and it reaches to 0.228 dollars per a KWh [11]. Table 1 indicates the energy price (dollar) per a KWh.

Renewable energy	Grid energy during off period	Grid energy during peak period
0.01	0.12	0.228

Table 1: Energy price per KWh

IV. ELECTRIC VEHICLE CHARGING TIME

Time charging of an electric vehicle depends on the onboard circuitry of each electric vehicle as well as its battery capacity. For instance, BMW i3 can be charged by a charging station level 3 under 30 minutes with the charging rate 50kw [12]. According to a study [13] average off-street parking duration is estimated to be 5.11 hour. In our service proposal, we propose 15 charging stations level 2 with the charging rate of 3.7 KWh. Table 2 indicates the power consumption of electric vehicles with charging station level 2 based on vehicle's average off-street parking time.

Charging time (min)	Consumed energy (KW)	Energy bill (renewable)	Energy bill (grid) during off period	Energy bill (grid) during peak period
306.6	18.907	0.18907	2.2688	4.3107

Table 2: Energy bill and consumption of EV based on parking duration with charging station level 2, 3.7 rate

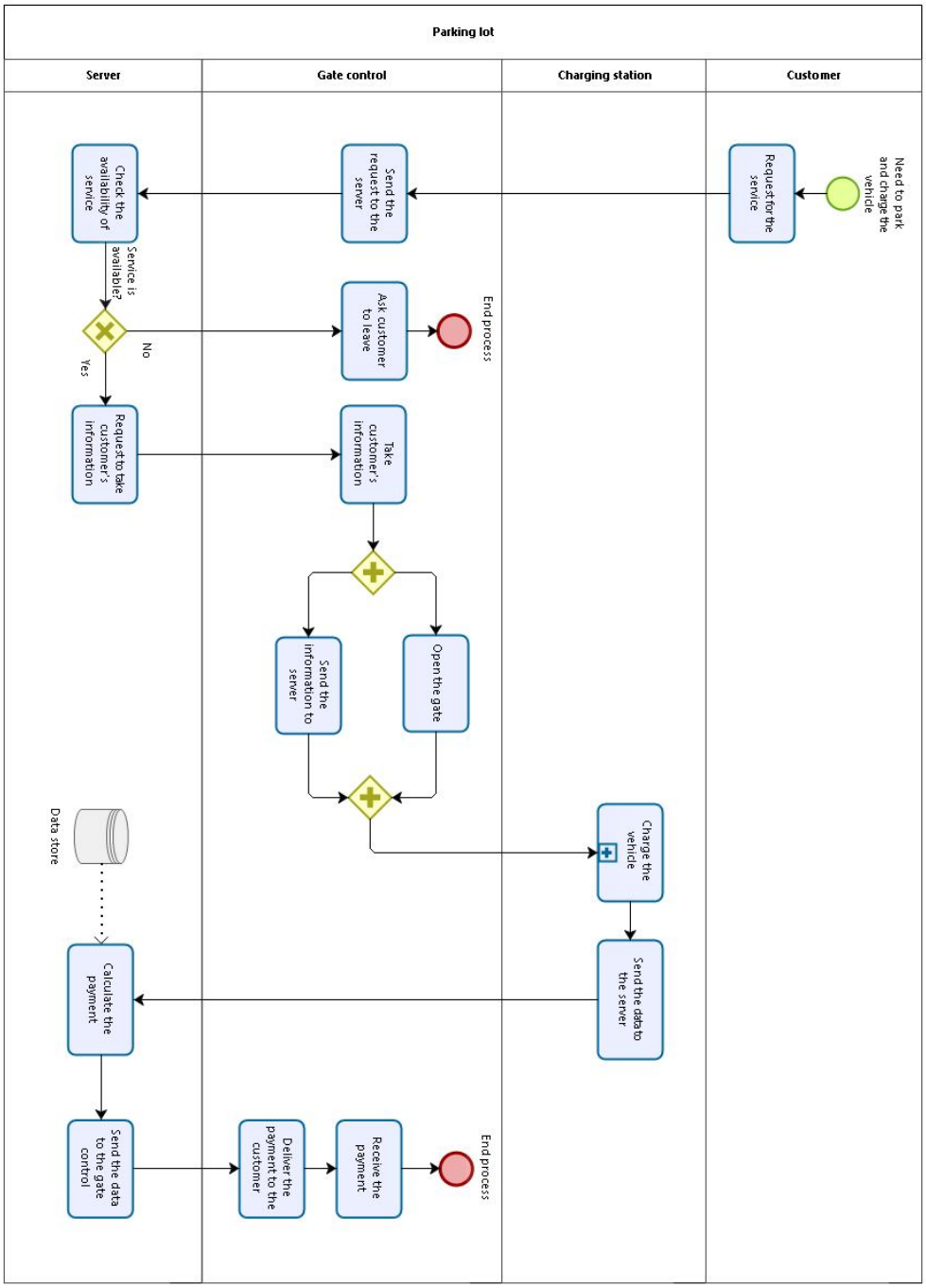


Fig 1: The main business process simulation of solar-powered charging station in a parking lot in Bizagi

V. BUSINESS SCENARIO

The process starts when customer needs to park his/her vehicle as well as charge the vehicle. First, customer needs to request for the service. Then, the availability of service will be checked by the server. The customer will be asked to leave the parking lot in case the service is not available. If the service is available, customer's information will be taken and saved. After that, the door of the parking will be opened for the customer in order to let customer enter the parking lot and the information of customer will be sent to the server. Then, the charge process will be proceeding after plugging in the vehicle. Charge sub-process which is shown in the figure 1, consist of 15 charging stations with the charging rate of 3.7 KWh. Parking duration is estimated to be 5.11 hours for each customer [13]. When the charge process was finished, energy consumption of the vehicle as well as parking duration time will be sent to the server. Then, the payment will be made by server based on received data. After that, the payment will be paid by the customer and the door of the parking will be opened in order to let customer leave and the process ends at this point.

The business process is done in three scenarios based on customer's arrival time. Scenarios include following below:

- Scenario 1: In all seasons during 8am-4pm
- Scenario 2: In the fall and winter during 4pm-9pm
- Scenario 3: In the spring and summer during 4pm-9pm

PV produces sufficient power during fall and winter from 8am-4pm. However, power generation time increases during spring and summer [14]. In fact, PV generates sufficient power in spring and summer during 8am-7pm due to the fact day is longer in these seasons. Nevertheless, customers will consume power received from distribution grid whenever PV cannot produce sufficient power. Figure 1 indicates the main business process of the service.

VI. PROCESS VALIDATION RESULT

This simulation is the most basic level to evaluate the structure of the process diagram. In fact, it shows the input and output of each task. Therefore, with the help of this level of simulation, we will see how customers distribute between tasks and how many of them will charge their cars. As an example, we evaluate the simulation result (according to table 3) for scenario one.

The process of first scenario starts with 5000 customers who tend to park and charge their vehicle. In fact, 5000 customers request for the service. After that, 1549 of the will be asked to leave due to lack of availability of service. However, the request of 3451 customers is approved and customer's information is taken. Then, the door is opened for the customers in order to park their vehicle and plug-in charger. As a matter of fact, 3451 customers' vehicle is charged successfully and the consumed energy is sent to the server. After that, server calculates the payment and sends it to gate control. Then, payment will be paid by the customers and process ends.
According to process validation result which is indicated in the figure 3, 10000 customers requested for the service. However, the request of 3092 customers was rejected due to lack of availability of service. Finally, 69,080 customers successfully charged their vehicles and paid for their consumed energy as well as parking time.

Task	Type of process	Instances completed scenario 1	Instances completed scenario 2	Instances completed scenario 3
Need to park the vehicle and charge	Start event	5000	3000	2000
Request for the service	Task	5000	3000	2000
Check the availability of service	Task	5000	3000	2000
End process	End event	1549	924	619
Request to take customer's information	Task	3451	2076	1381
Take customer's information	Task	3451	2076	1381
Open the gate	Task	3451	2076	1381
Send the information to sever	Task	3451	2076	1381

Charge the vehicle	Process	3451	2076	1381
Charge the vehicle-station 1	Task	237	131	96
Charge the vehicle-station 2	Task	249	137	91
Charge the vehicle-station 3	Task	232	147	98
Charge the vehicle-station 4	Task	228	151	104
Charge the vehicle-station 5	Task	227	144	88
Charge the vehicle-station 6	Task	233	133	92
Charge the vehicle-station 7	Task	257	171	118
Charge the vehicle-station 8	Task	234	141	87
Charge the vehicle-station 9	Task	214	122	83
Charge the vehicle-station 10	Task	206	117	78
Charge the vehicle--station 11	Task	246	139	85
Charge the vehicle-station 12	Task	222	138	87
Charge the vehicle-station 13	Task	236	145	94
Charge the vehicle-station 14	Task	210	126	86
Charge the vehicle-station 15	Task	220	134	94

Table 3 (a): Process validation result

Send the data to the server	Task	3451	2076	1381
Calculate the payment	Task	3451	2076	1381
Send the data to the gate control	Task	3451	2076	1381
Deliver the payment to the customer	Task	3451	2076	1381
Receive the payment	Task	3451	2076	1381
End process	End event	3451	2076	1381

Table 3 (b): Process validation result

VII. RESOURCE ANALYSIS BASED ON CALENDAR ANALYSIS

Resource analysis defines the revenue of the proposed service based on each scenario. Table 4 indicates the revenue of each station within a year. According to the resource analysis result, 8,355.87 dollars was earned by those customers who charged their vehicles.

Resource	Revenue scenario 1	Revenue scenario 2	Revenue scenario 3
Station 1	44.80	349.61	172.61
Station 2	47.07	365.62	163.62
Station 3	43.86	392.31	176.21
Station 4	43.10	402.98	187.00
Station 5	42.91	384.30	158.23

Station 6	44.05	354.95	165.42
Station 7	48.59	456.36	212.17
Station 8	44.24	376.30	156.43
Station 9	40.46	325.59	149.24
Station 10	38.94	312.24	140.25
Station 11	46.51	370.96	152.83
Station 12	41.97	368.29	156.43
Station 13	44.62	386.97	169.02
Station 14	39.70	336.26	154.63
Station 15	41.59	37.61	169.02

Table 4: Resource analysis based on calendar analysis

Resource	Utilization scenario 1	Utilization scenario 2	Utilization scenario 3
Station 1	70.90%	70.60%	81.35%
Station 2	74.49%	80.11%	77.11%
Station 3	69.40%	85.96%	83.04%
Station 4	68.21%	88.30%	88.13%
Station 5	67.91%	84.21%	74.57%
Station 6	69.70%	77.77%	77.96%
Station 7	76.88%	99.99%	99.99%
Station 8	70.00%	82.45%	73.72%
Station 9	64.02%	71.34%	70.33%
Station 10	61.62%	68.42%	66.10%
Station 11	73.59%	81.28%	72.03%
Station 12	66.41%	80.70%	73.72%
Station 13	70.60%	84.79%	79.65%
Station 14	62.82%	73.68%	72.88%
Station 15	65.81%	78.36%	79.65%

Table 5: Utilization of resources based on scenario

VIII. COST OF INSTALLING PHOTOVOLTAIC PANELS AT A PARKING LOT TO FEED CHARGING STATIONS

PV produces sufficient power during fall and winter (8am-4pm) as well as spring and summer (8am-7pm) [14]. In fact, 117.478.7 MWh must be produced by the renewable energy systems of our service proposal. According to the simulation result, 80.577.16 MW was consumed by the customers during scenarios 1 and 3. In order to increase the sustainability of our system, we propose PV that can produce 117.478.7 MWh annually. Therefore, we need 35 PV panels and each panel (4kw) produces 3,400 KWh annually.

Actually, the typical cost of PV that can produce 3400 KWh annually is 6,723-8,965 dollars. Nevertheless, the estimated cost of PV for our service proposal is 235,620-313,775 dollars [15].

IX. COST OF CHARGING STATIONS

The cost of charging station depends on some factors including amperage range, design, cord length, country of production and smart technology. Moreover, charging stations transformer is one of the reasons why they are expensive. According to [16], installation of charging station level 2 costs 5,300-13,150 dollars. Therefore, installation of our service proposal costs 79,500-197,250 dollars.

X. POWER INJECTION TO THE DISTRIBUTION GRID

According to the simulation result, 80.577.16 MW were consumed by electric vehicles in scenario 1 and 2 where renewable energy systems produce sufficient power. Therefore, 36.901.54 MWh can be injected to the distribution grid in a year by our service proposal in order to decrease pressure on distribution grid.

XI. PAYBACK PERIOD OF SOLAR-POWERED CHARGING STATION IN A PARKING LOT

Actually, customers need to pay for parking duration as well as charging. In fact, 6,908 customers have been served in our simulation. As a matter of fact, each customer parked his/her car 5 hours. Therefore, according to [17] 69,080 dollars was paid for the parking time by the customers of our service proposal. Apparently, total revenue of our service proposal is 85,160.88 dollars in a year. On the other hand, our service proposal costs 315,120-511,025 dollars. Nevertheless, the payback period of our service proposal is estimated to be about 3.7-6 years. Furthermore, the payback period can be decreased by

reducing the addition of tax incentives and partnership [1].

CONCLUSION

In this paper, we clarified electricity as a product in power engineering and we proposed a new service with this product for the owners of the electric vehicles. Our service proposal helps reducing pressure on distribution grid and it will encourage people to use EV as a result of its clean and cheap energy. We simulated our new service in Bizagi software in order to clarify how many customers can be served based on their arrival time. On the other hand, the simulation clarified the revenue of our service proposal within a year. According to the simulation result, our service proposal will pay back its invested money between 3.7-6 years. Therefore, implementing solar-powered electric vehicle charging station can be a good business plan which meets customer's need. Expending these services encourage people buy electric vehicle.

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REFERENCES

[1] Robinson, Jessica, et al. "Business models for solar powered charging stations to develop infrastructure for electric vehicles." Sustainability 6.10 (2014): 7358-7387.
[2] Navigant Research, "Plug-in electric vehicles on roads in the United States will surpass 2.7 million by 2023,"
[3] Bayram, I. Safak, et al. "Smart vehicles in the smart grid: Challenges, trends, and application to the design of charging stations." Control and Optimization Methods for Electric Smart Grids. Springer New York, 2012. 133-145.
[4] Schill, Wolf-Peter, and Clemens Gerbaulet. "Power system impacts of electric vehicles in Germany: Charging with coal or renewables?." Applied Energy156 (2015): 185-196.
[5] Segrave, Kerry. Parking Cars in America, 1910–1945: A History. McFarland, 2012.
[6] Navigant Research, "Plug-in electric vehicles on roads in the United States will surpass 2.7 million by 2023,"
[7] Xi, Xiaomin, Ramteen Sioshansi, and Vincenzo Marano. "Simulation–optimization model for location of a public electric vehicle charging infrastructure." Transportation Research Part D: Transport and Environment22 (2013): 60-69.
[8] Ciwei, G. A. O., and Z. H. A. N. G. Liang. "A survey of influence of electrics vehicle charging on power grid [J]." Power System Technology 2 (2011): 127-131
[9] Chan, C. C., and K. T. Chau. Modern electric vehicle technology. Vol. 47. Oxford University Press on Demand, 2001.
[10] Lefebvre, Gilles, Elena Jiménez, and Beatriz Cabañas, eds. Environment, energy and climate change II: Energies from new resources and the climate change. Vol. 34. Springer, 2015.
[11] Kempton, Willett, and Jasna Tomić. "Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy." Journal of power sources 144.1 (2005): 280-294.
[12] Chang, Daniel, et al. "An-An (Angel) Tsao, and Jason Snyder. Financial viability of non-residential electric vehicle charging stations, 2012."
[13] Lam, William HK, et al. "Modeling time-dependent travel choice problems in road networks with multiple user classes and multiple parking facilities." Transportation Research Part B: Methodological40.5 (2006): 368-395.
[14] Sayigh, Ali, ed. Renewable Energy in the Service of Mankind Vol I: Selected Topics from the World Renewable Energy Congress WREC 2014. Springer, 2015.
[15] Roundy, Shad, et al. "Improving power output for vibration-based energy scavengers." IEEE Pervasive computing 4.1 (2005): 28-36.
[16] http://insideevs.com/how-much-do-public-and-home-ev charging-stations-really-cost/
[17] Shoup, Donald C. The high cost of free parking. Vol. 206. Chicago: Planners Press, 2005.

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