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Stochastic Model of Electric Vehicle Parking Lot Occupancy in Vehicle-to-Grid (V2G)

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Abstract

The Vehicle-to-Grid (V2G) is a concept of connecting group of electrical vehicles (EV) to the grid for power transaction. The EVs can get connected to the grid through the charging slots available in the electrical vehicle parking lot (EVPL). The Markov chain based stochastic model is proposed for EVPL occupancy in V2G for Smart Grid application.

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Keywords: Stochastic Model, Markov Chain; V2G.

1. Introduction

The EV can be integrated to the grid through home or other interface and contributes power to meet the grid requirements. EVs are usually parked for 90-95% of the time in residential apartment, office buildings and parking station [1]. EV connected to the grid through home interface is known as Vehicle-to-Home (V2H), EV connected to the other EV is known as Vehicle-to-Vehicle (V2V) and group of EVs connected to the grid is Vehicle-to-Grid (V2G). V2G can be used for peak shaving, valley filling, and load leveling. It also provides reactive power support to the grid and helps in maintaining grid stability [2]. EVs are parked in EVPL and get connected to the grid through the charging slot as shown in Fig.1.

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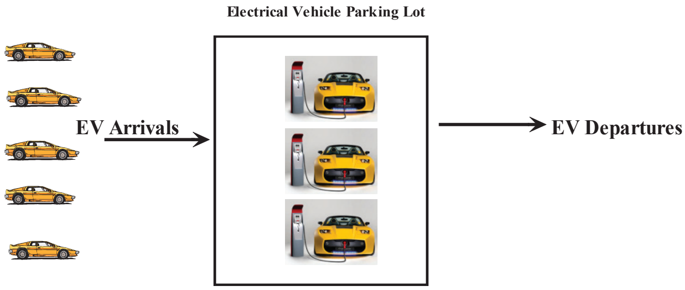

Fig.1. EV arrivals and departures in EVPL.

2. Stochastic Modeling of EVPL Occupancy

A Stochastic model based on Markov chain is developed for EVPL occupancy. Let X_n be the number of EVs in the system at time n, then $X_n \in S := \{0, 1, 2, 3,\cdots, L-1, L\}$ where, n is the time slot enough to transmit one EV, L is the size of the parking slot in number of EVs. EVs arrive at the parking lot with a probability a in time slot n. EV that arrives at time slot n is available to be forwarded in the next time slot n+1. The charging slot in the parking lot is involved in charging the other EV and allocates b for forwarding the EVs. As a consequence, the parking lot is able to forward EV with probability b in a given slot. With the probability of (1−b), the charging slot is performing task. The arrivals and departures are independent of each other [9, 10]. The proposed Markov Model for EVPL occupancy is shown in Fig.2.

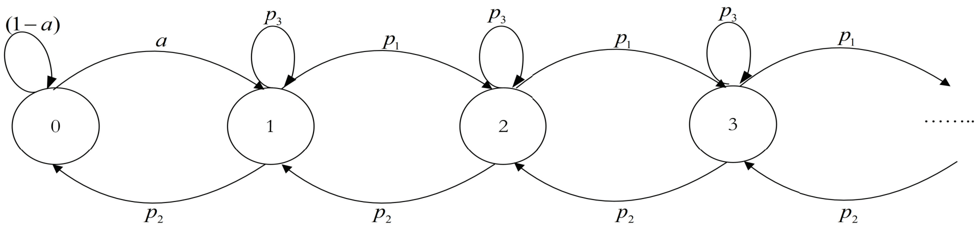

Fig. 2. Markov Model for Electrical Vehicle Parking Lot Occupancy.

2.1. Transition Probabilities

The state transition occurs when an EV arrives or departs. When an EV arrives at time n, the parking lot occupancy X_n either stays in the same state or moves to the next state based on the departure: $X_{n+1} = X_n$; if there is a departure in the same time slot and $X_{n+1} = X_{n+1}$; otherwise. Similarly, $X_n = X_n$; if there is no arrival in time slot n and $X_{n-1} = X_n$; otherwise.

$$p_{i,j} = \begin{cases} p_1 = a\,(1-b), & j = i+1,\ i = 1,2,....; \\ p_2 = (1-a)\,b, & j = i-1,\ i = 1,2,....; \\ p_3 = ab + (1-a)(1-b), & j = i,\ i = 1,2,...; \\ a, & i = 0,\ j = 1; \\ (1-a), & i = 0,\ j = 0; \\ 0, & otherwise \end{cases} \quad (1)$$

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