

Experimental Implementation of a Wireless Communication System for Electric Vehicle WPT Charger

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Abstract. Electric Vehicle (EV) market is growing rapidly and the demand for new charging methods is up surging. In order to meet this growing demand, wireless power transmission is a good choice for providing energy because it has many advantages such as convenience, user-friendliness and safety. Such charging method requires a wireless communication between EVs and electric vehicle supply equipment (EVSE) to ensure that power is transferred in a precisely controlled way. This paper proposes a wireless communication system based on Raspberry Pi 4 and TMS320F28335 development kit from Texas Instruments. It consists in acquisition and wireless transmission of analogue data from a client to a server. The system is experimentally verified and the obtained result shows that the system provides a good performance for a range of frequencies. Thus, the proposed solution presents a good basis for the next step of controlling wireless power transmission.

Keywords: Electric Vehicle, EVSE, Wireless Charging, Wireless Communication System, Charging Infrastructure

1 Introduction

Wireless charging technology for EVs has become an active area of research and development in the last years. Such charging system requires a low-latency and reliable communication between the EV and the EVSE to optimize power transfer efficiency. However, most of works on wireless power transfer (WPT) in literature focus on power transmission and control considerations and usually assume that communication is well established. There is a general lack of research on wireless communication part [1] which is the main subject of the present work.

In order to ensure the integration of EVs into smart grids, ISO 15118 was created to standardise the communication between EV and EVSE during all the phases of the

charging process [2]. The standard ISO 15118 including its parts and layers [3] allows actual V2G (Vehicle to Grid) communication on high level IP based standard and communication protocols. Some of the standard features are used in the conception of the communication solution proposed in the present work (see later).

To deal with some reliability issues in the communication process between electric vehicle communication controller (EVCC) and supply equipment communication controller (SECC), some experimental test platforms have been proposed in recent works; in [3], authors propose a testbed consisting of EV and EVSE emulators and a Raspberry Pi 3 with a WLAN module for wireless communication. The approach was applied in the case of wired charging EV and was limited to authentication phase. In [1], authors evaluate the performances of a communication testbed that uses a client-server Raspberry Pi 3 and WLAN module. The analysed performances are mainly the Drop Rate, the Latency and the RSSI (Received signal strength indication) regarding to the two operating frequency bands (2.4GHz and 5GHz) on one hand, and the size of the exchanged packets on the other hand.

In this paper, we propose an experimental platform emulating the data exchange between EVCC and SECC. The platform consists of two Raspberry Pi 4 boards and two TMS320F28335 development kits to simulate the measurement and the exchange of some analogue data (battery current and voltage for example) required for the charging process.

The objective is to evaluate the reliability of the proposed experimental setup regarding to the variation rate of the measured analogue signal.

The remainder of the paper is organized as follows: A brief description of WPT is presented in section 2. The proposed system architecture with the main components are introduced in Section 3. The experimental results are given and discussed in section 4. A conclusion ends the paper.

2 WPT communication system

The general diagram of an EV wireless charging system is shown in Figure 1. The WPT system consists of two independent subsystems: a Vehicle Assembly subsystem (On-board subsystem) and a Ground Assembly subsystem (Off-board subsystem). The energy flows from the off-board subsystem to the on-board one through two magnetically coupled inductors [4].

The main actors involved in the charging scenario are the EV, the EVSE and the communication controllers, i.e. the EVCC and the SECC. EVCC and SECC are electronic systems that manage the communication protocols and control the energy flow between EVSE and EV, control charging port functions and ensure connection and charging.

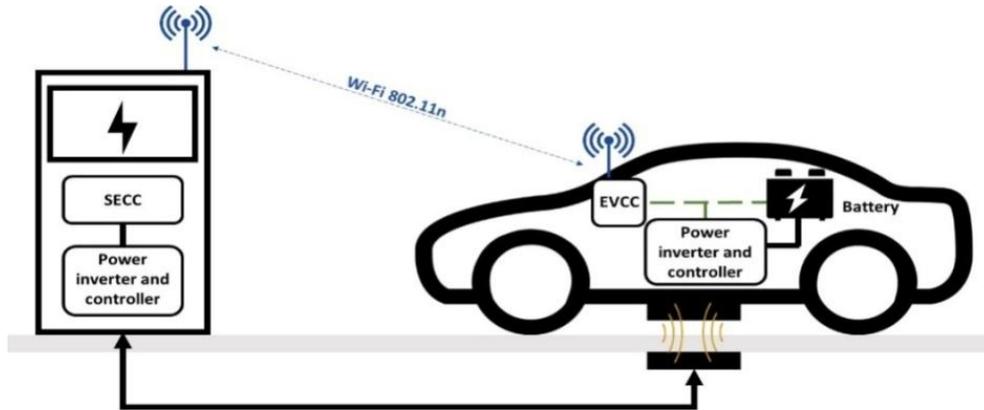


Fig. 1. Schematic diagram of EV wireless charging system with wireless communication

The EVCC sends real-time battery status information to the off-board controller through wireless local area network (WLAN) to make sure that the charging process is correct, safe and stable.

The present work focuses on the emulation of the two controllers; EVCC and SECC. The experimental setup is presented in the next section.

3 Proposed solution

Figure 2 shows the proposed experimental platform. It consists of single-board computers (Raspberry Pi 4) for the wireless communication and DSPs (TMS320F28335 development kit) for analogue signal measurement and processing.

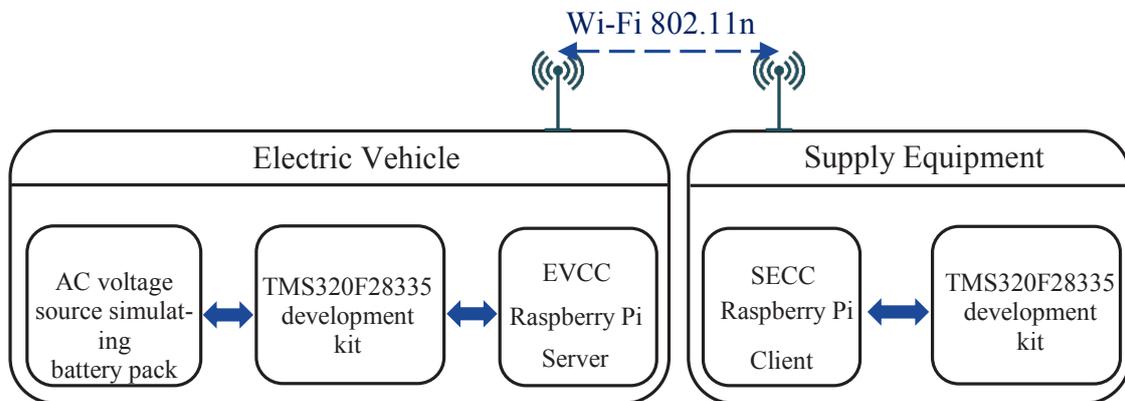


Fig. 2. Global architecture of the proposed solution

The Raspberry pi 4 presents a good trade-off between price, performances and features. It comes with an on-board 802.11n Wireless Local Area Network (WLAN) module, which allows wireless communication without need for external Wi-Fi dongle or device. It is worth noting that the IEEE 802.11n is the technology selected for wireless communication in the ISO 15118 (refer to part 8 of ISO 15118 [6]). However, the Raspberry Pi 4 has no analogue GPIOs (i.e. ADC), thus, it cannot sense

analogue inputs. The ADC task will be performed using the integrated ADC modules of the TMS320F28335 development kit (See later).

The TMS320F28335 DSP is a less expensive controller that has proven an excellent real-time signal processing and control [7]. In the complete wireless charging solution, the TMS320F28335 development kit could be used in both EV and EVSE sides to:

- 1- Control the power transfer;
- 2- Sense the analogue variables to be exchanged between the two Raspberry Pi terminals.

The second task is provided by the proposed system while the complete solution is being dealt with and will be presented and discussed in future works.

A client-server prototype test bench was developed to emulate the exchange of the measured data during the charging process. The objective is to evaluate the ability of the proposed solution to communicate, in real-time, the parameters of the battery (voltage, current, state of charge etc.) for different rate of variation on these parameters.

The signal from the AC voltage source (simulating battery signals) is sensed by the DSP kit through an analogue GPIO set up as input with a sampling time of 1e-5s. Then, the Analogue to Digital Converter (ADC) of the DSP is used to convert the sensed voltage to digital data.

The ADC cannot read an input voltage higher than 3V and does not support negative voltage; therefore the input signal needs to be carefully adjusted before being applied to the ADC.

After the ADC conversion, the data is sent to the Raspberry Pi through Inter-integrated Circuit (I2C) bus. The I2C is a serial communication protocol that allows data to be exchanged bit by bit with a frequency up to 100 kHz. The Raspberry Pi is configured as the master of the I2C bus and the TMS320F28335 development kit as the slave.

The Raspberry Pi (client) uses the TCP/IP protocol to send the received data from I2C bus to a distant Raspberry Pi (server). The data is then transferred through I2C bus to the TMS320F28335 development kit in order to be used in the control of the energy flow.

The TMS320F28335 Controller could be programmed using C/C++ language or MATLAB/SIMULINK [7]. The second one is chosen in this work as it does not require handwritten code, it saves time and it is more efficient. On the other side, the programs ensuring the TCP/IP and I2C exchanges in the Raspberry Pi boards are written in Python programming language.

The steps of the process discussed above are given in the flowchart given in Fig. 3.

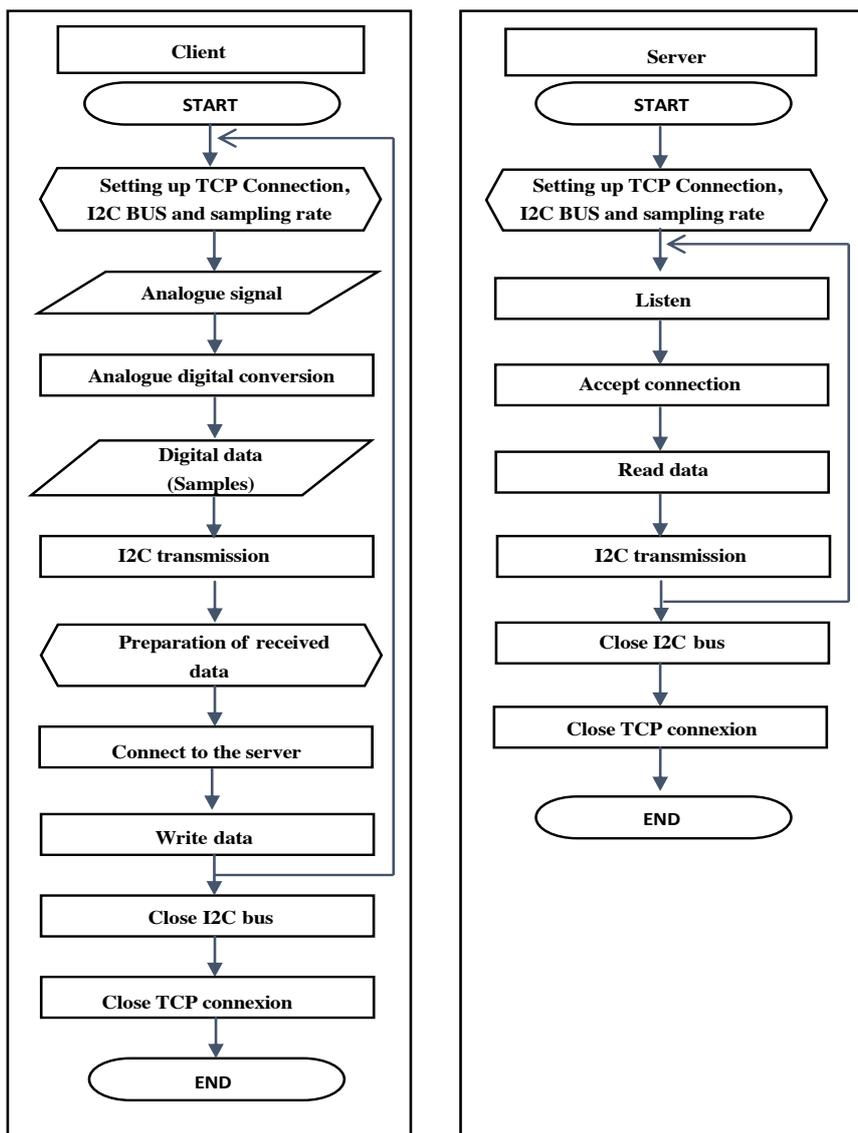


Fig. 3. Flowchart of the steps of the wireless communication and data exchange

4 Results and discussion

The experimental set up in Fig. 4 was implemented to evaluate the proposed platform for the SECC - EVCC communication system. Thus, the AC voltage source emulating the battery generates sinusoidal signals with different frequencies: 1kHz, 2kHz, 3kHz, 5kHz and 10kHz and an amplitude of 0.5V with an offset of 1V. This signal is sent through the communication chain and examined at its end to verify the reliability of the communication and the ability of the proposed chain to follow the variations of the transferred signal (i.e. variation of the parameters of the battery in real charging process situation). The results of the experiment are given in Fig. 5.

Figure 5 shows the plot of the data received at the end of the communication chain. It is worth noting that the digital values of the sensed signals were rescaled in the py-

thon program to go from the range [0, 3V] supported by the analogue input to [-10V, 10V] plotted in the figure.

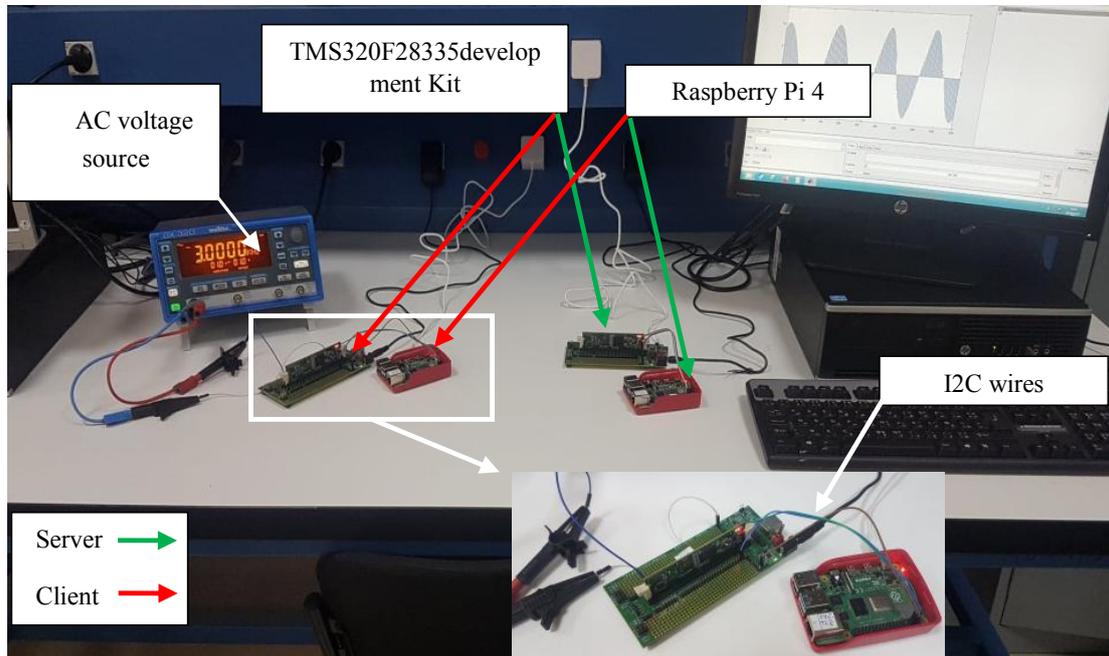


Fig. 4. Laboratory testbed for wireless communication

It is clear from the figure that the signal acquisition was correctly done and the data was correctly exchanged between the different devices of the system (TMS320F28335 development kits and Raspberry Pi boards) with the selected communication protocols (I2C and TCP/IP).

It can also be noted that the received data corresponds exactly to the samples of the sensed signal. Thus, the received data allowed the reconstitution of the initial signal generated by the AC voltage source.

However, the above statements remain valid for signals of a few kHz (1kHz to 5kHz as shown in Fig. 5 (a-d)), while for 10kHz, the received and plotted data did not allow the reconstruction of the initial signal (Fig. 5 (e)).

These results give a general idea about the performances of the proposed solution and its limitations, especially in terms of the variation rate of the sensed signals. It then follows that, for the proposed platform with the fixed parameters (refer to previous section), the communication and data exchange can be well performed for signals with variation frequencies below 10kHz which is the case for the battery status parameters (Voltage, current, temperature, etc.). Otherwise, other higher speed solutions such as SPI or CAN protocols could be considered.

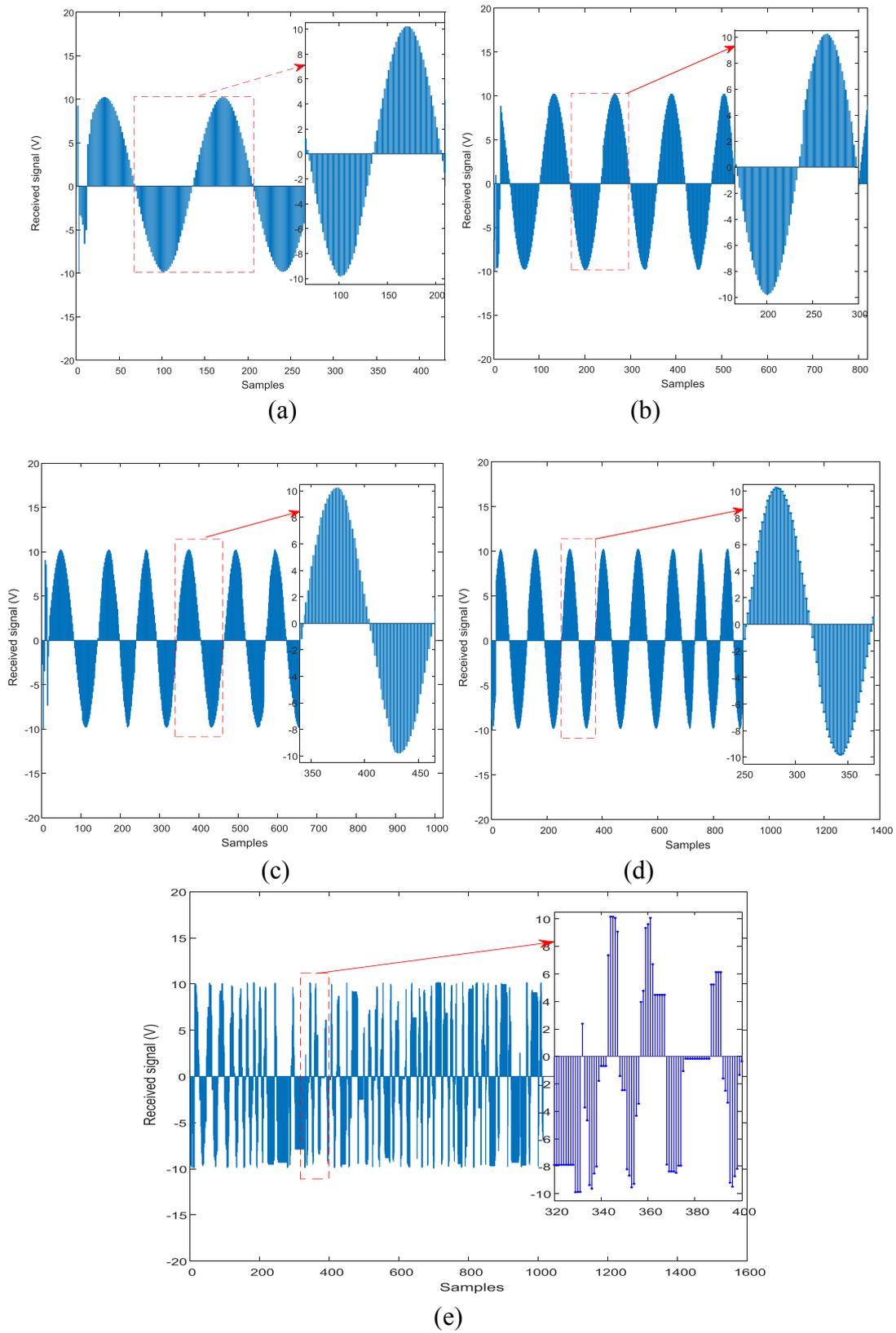


Fig. 5. Plot of reconstituted samples of received data for different frequencies; (a): 1 kHz, (b): 2 kHz, (c): 3 kHz (d): 5 kHz, (e): 10 kHz.

5 Conclusion

This paper proposed and evaluated a new platform to be used for the wireless communication with EV wireless charging system. The platform is composed of two blocks emulating the EVCC and SECC. Each block consists of a Raspberry Pi 4 and a TMS320F28335 development kit. A server-client mode, I2C and TCP/IP protocols were used for the communication purpose. The experimental results show that the wireless communication between the two blocks was reliable and the acquisition of analogue signals, for the fixed configuration parameters, was valid for frequencies below 10kHz, which is often the case for batteries parameters (such as voltage, current, temperature, etc.) necessary for EV wireless charging.

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7 References

1. El-Shair, Z., Reimann, E., Rawashdeh, S. A., Ayachit, A., Abdul-Hak, M.: Review and Evaluation of Communication Systems for Control of Stationary Electric-Vehicle Inductive Charging Systems. In 2020 IEEE Transportation Electrification Conference & Expo (ITEC), pp. 1178-1183. IEEE, USA (2020)
2. Mültin, M.: ISO 15118 as the Enabler of Vehicle-to-Grid Applications. In 2018 International Conference of Electrical and Electronic Technologies for Automotive, pp. 1-6. IEEE, Germany (2018).
3. El Sayed, N.: A prototypical implementation of an ISO-15118-based wireless vehicle to grid communication for authentication over decoupled technologies. In 2019 AEIT International Conference of Electrical and Electronic Technologies for Automotive (AEIT AUTOMOTIVE), pp. 1-6. IEEE, Germany (2019).
4. Lassioui, A., El Fadil, H., Rachid, A., Bouanou, T., El Idrissi, Z., Giri, F.: A high gain observer design for wireless power transfer charger for BEV. In 2020 International Conference on Electrical and Information Technologies (ICEIT), pp. 1-6. IEEE, Morocco (2020)
5. Gong, L., Xiao, C., Cao, B., Zhou, Y.: Adaptive Smart Control Method for Electric Vehicle Wireless Charging System. *Energies*, 11(10), 2685. (2018).
6. Song, N. O., Kwak, B. J.: International Standard Trend of Vehicle to Grid (V2G) Communication Interface for Wireless Communication and RPT. In 2019 IEEE Transportation Electrification Conference and Expo, Asia-Pacific (ITEC Asia-Pacific) (pp. 1-5). IEEE, Korea. (2019).
7. Elrajoubi, A., Ang, S. S., Abushaiba, A.: TMS320F28335 DSP programming using MATLAB Simulink embedded coder: Techniques and advancements. In 2017 IEEE 18th Workshop on Control and Modeling for Power Electronics (COMPEL), pp. 1-7. IEEE, USA (2017).