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IEVCC - A Mesh Managed Network for Electric Vehicle Charging

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***Abstract*—The implementation and management of Electric Vehicle (EV) charging points in parking spaces (whether in multifamily condominiums or in private company parking lots) presents a challenge, since the available contracted power may be insufficient for the building devices needs and for EV chargers to work simultaneously. The available power is limited to a fixed value generally determined by the expected peak power consumption of the building. An increase in the contracted power leads to unwanted costs and, sometimes, this is not possible without a complete rework of the electrical installation at even higher costs. The available power is not fully used all the time, since not all the buildings devices are always working simultaneously. These spare power can be monopolized by a mesh network of chargers, taking advantage of the full contracted power without increasing costs. In this work we present a manager of a mesh network of chargers that can distribute the available power to an array of chargers based on several conditions, e.g. load balancing, priority of chargers or charging.**

***Index Terms*—EVSE, Electric Vehicles, Intelligent Charging, Mesh Network and Load Management.**

I. Introduction

The sales of EV have increased over the years, specially in last year. Even thought that the COVID pandemic has slowdown the sales, last year there was an increase of 108% when compared with 2020 [1]. Studies shown that EV sales will continue to increase, even if at lower rates [2]–[4], it must be taken in account that the values are always related to the previous years. The legislation adoption by the European Commission on 14 July 2021 intends to achieve climate neutrality by 2050, including an intermediate target of an at least 55% net reduction in greenhouse gas emissions by 2030 [5]. The latest unfortunate events on the political context have putted even more pressure on the reduction on the petrol dependence in Europe. With EVs being two to four times more efficient than vehicles with internal combustion engines and the increase in renewable energy sources it is also possible to generate significant reductions in greenhouse gas emissions and this leads to an increase on the EV adoption. Also, several car makers are stating in their plans they will become fully electric car producers in the horizon time of 2030-2035.

Even with such a increase in sales, most people are reticent in buying an EV, since they don't own a closed parking spot in their residence with an electric connection to their main electric installation. Even with the increase of public chargers, the number and prices demotivate most people, since most times they aren't close to their residence or working places or there is no guarantee that they are not in use when those people need them. One solution goes through the use of the buildings common electric infrastructure (generally used to power lights, elevators and other common devices) to connect vehicle chargers/EVSE. However such infrastructure has a limited power and it would not be difficult to reach the maximum available power just by installing one or two standard chargers with a reasonable power, so a good efficiency charge is attainable [6] and with the risk of tripping the main switchboard.

In this work we present a solution that allows the installation of a high number of the intelligent charger previous developed and presented in [7]. In that work we described the operation of what we called as Intelligent Electric Vehicle Charger Controller (IEVCC) and presented results of it's operation when working as the only charger operating on the same electric circuit. At the time, a mesh version was also described, although briefly. Here we review again the key idea of this version and describe it operation, as results obtained. As far as we know and searched, there's only on the market a system that can operate in a similar way (designed as SMART EVSE [8]), but the description is not very clear if it can establish priorities between chargers and it's limited to four chargers. Also the communication between what is called master and the slaves is wired, which can present a problem in old installations where it's highly probable there's no room for extra wiring passage.

This paper is organized as follows: after this Introduction, the mesh operation of IEVCC is described in Section II. In Section III the experimental results are shown, and the Conclusions are presented in Section IV.

II. IEVCC - Mesh Version

Fig. 1 shows a diagram of the mesh version system, which is composed by the:

- Consumption monitor hardware (a);
- Broker/Manager (b);
- Intelligent Electric Vehicle Charging Controller + energy meter (c);
- Communications infrastructure;

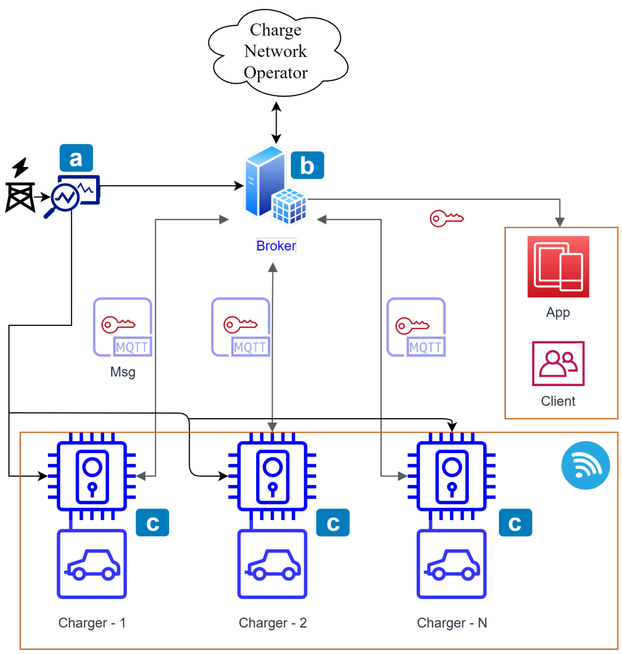

Fig. 1. Diagram of the Mesh Version.

A. Consumption monitor hardware

The consumption monitor (Fig. 2) is responsible to measure the total power consumption of the building and report these values to the Manager using MQTT [9]. It's built using ESP8266 micro-controller [10], a PZEM-0004T V3.0 and a monochrome OLED screen that gives instantaneous information about the measured values and the IP address of the energy monitor.

The first time the system is connected to power, it needs some configuration, which can be done in a web-page provided by the builtin server. To access this, the first step is to connect to the SSID emitted by the consumption monitor hardware (EnergyMeter) using a smartphone and access to a predefined IP address, where a page has the one shown in Fig. 3 is rendered. Here information about the current values being measured can be seen and the IP address of the device on the local network is also shown, if the device is connected to the local network.

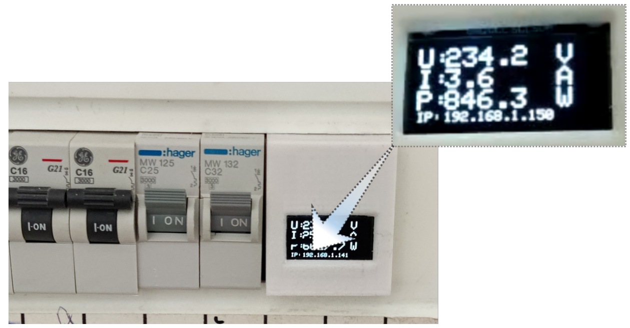

Fig. 2. Consumption monitor hardware/Energy Meter

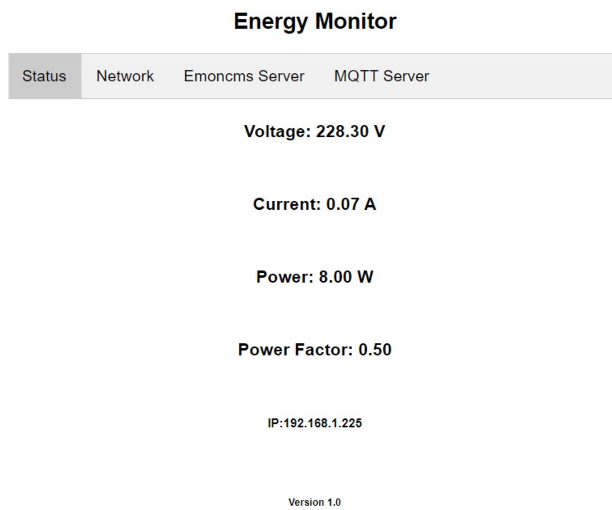

Fig. 3. Energy Monitor Status Web page

The Network tab (Fig. 4) is where information about the local network can be entered, so the device can connect to the local network.

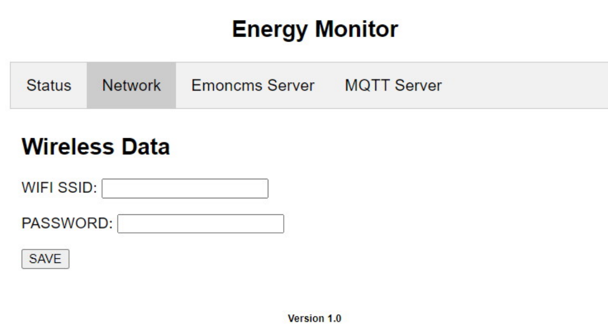

Fig. 4. Energy Monitor Network Settings tab

The Emoncms tab (Fig. 5) allows the configuration of a emoncms server settings (address and api write key) so the Energy Monitor can send information to that server. Emoncms [11] is a open source software that allows the user to keep track of the consumption of his devices and can calculate the user costs with energy, gains/savings with photovoltaic production, etc.

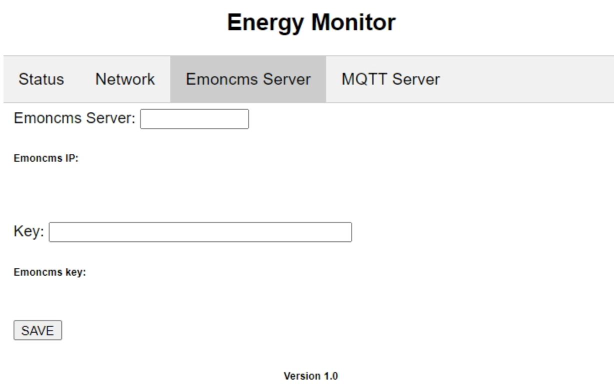

Fig. 5. Energy Monitor Emoncms Settings tab

The last tab (MQTT server, Fig. 6 is where the MQTT server configurations can be done. This server is usually the device identified as Manager/Broker and is described on the next section.

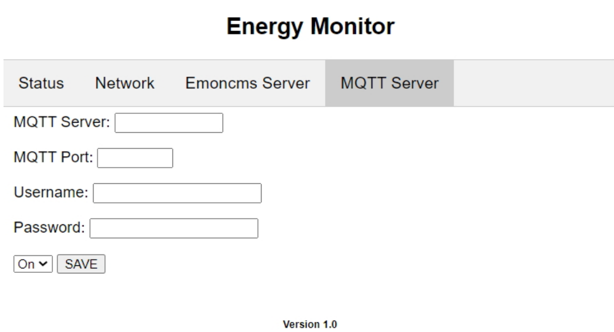

Fig. 6. Energy Monitor MQTT Settings tab

B. Manager/Broker

The management of all entities involved in the charging process is carried out by the ”Manager”. Dependent on the MQTT broker, it subscribes to all existing MQTT topics and manages clients (chargers and electrical energy meter). The settings allow us to limit the number of chargers operating at the same time, as well as set priorities for the chargers. In the performed tests, priority was given to the charger that was connected first.

According to the established protocol, the ”Manager” will be the first entity to connect to the MQTT broker. By subscribing to a connection topic, the chargers and electrical counters must announce themselves. After they have been properly identified and given permission to access, they will be added to the ”Manager” registers. The ”Manager” will then contact each of the parties through a separate MQTT topic.

Through the aforementioned message protocol, it is possible to announce through the MQTT topic the connection or charging intention, in the case of a charger. In the case of the electric meter, it is important to report the energy value that is being consumed globally. This will allow the ”Manager” to calculate the difference between the contracted power and the amount of energy value being used, which represents the amount of energy value that can be shared among all chargers that are actually charging. These messages exchange is depicted in Fig. 7.

The time for updating this data can also be customized to ensure that the contracted limits are not exceeded and thus cause power outages. This update of the total energy available to the chargers also makes it possible to balance the charging within the minimum limits for each charger. If each charger has less than 6A available, one or more chargers will be put on standby (waiting for a charging signal), increasing the availability for each charger in charge and making sure that the charge stays above the minimum required.

The ”Manager” is also responsible for ensuring the persistence of all generated data. Locally in a database, which ensures only local operation and also sends all activity to a cloud database storage.

C. IEVCC + Energy Meter

The third element of the mesh version is composed by at least one IEVCC, which has already been described in [7] and a simple energy meter composed by up to 3 PZEM-0004T V3.00 [11]. This version of the IEVCC is a little bit more complex, because includes the energy meter and can include a NFC card reader [12]. The energy meter allows to account costs to the user that used the charger. The NFC card allows different users to use the same charger, when available, setting priorities on the charger to the manager.

III. Experimental Results

At this phase, the experimental results where conducted in a simulation environment, where besides the manager, 3 chargers that replicate some of the cycles already performed and described in [7] where also simulated.

The ability to adjust charging power based on global consumption remains, and aggressive update intervals ($<$10 second) are not required.

In figure Fig. 8 for a sample interval, it is possible to check the load balance with 3 connected chargers. Changes in consumption that aren’t related to charging a vehicle cause a quick change in how much energy each charger can use without going over the maximum load (30 A) that was previously set. This happens faster than a Residual Current Breaker

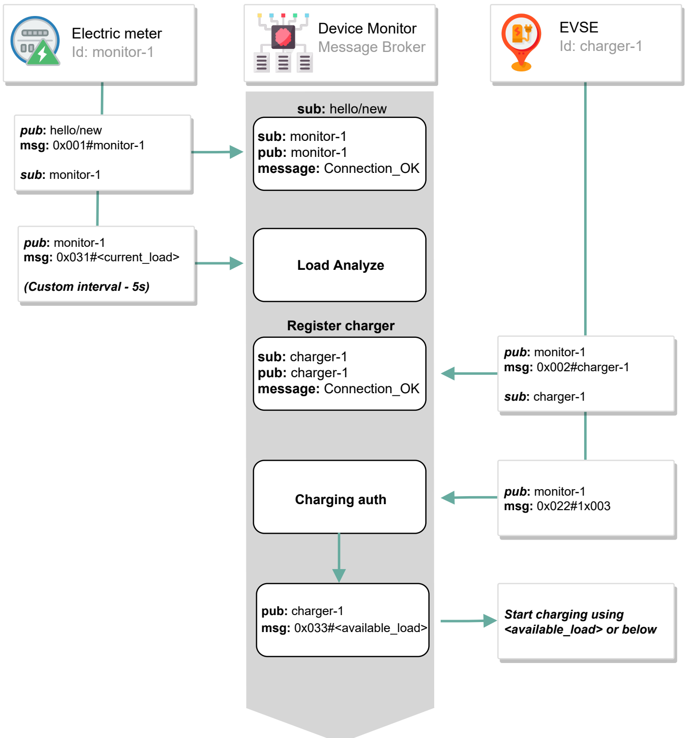

Fig. 7. Protocol time-lapse

with Over-Current (RCBO) in case the current equivalent to the contracted power is over-passed. Several situations are depicted in Fig. 8, which are described below. Priority is given to chargers by order of registration/request for charging. In this example, charger 1 was the first to register, followed by charger 3 and charger 2 was the last one. In each situation, this is what is happening:

a) Here charger 1 is already registered and has request to start charging. The available current to charging is 19.9A, but since chargers only work in integer values (between 6A and 32A), the charger starts charging with 19A. At the same time, the consumption of the house appliances raised to 12A, leaving only 18A for the charger, and thus in next cycle the charging current is reduced to 18A.
b) In the previous instant to this moment, charger 3 registered in the network and request to start charging. So at this moment, the available power was divided equally by the 2 chargers, and both can charge at 9A.
c) Here the building consumption raised and the contracted power was over-passed, so the available power to charge must be reduced.
d) As a result of previous over-passing of the contracted power, the charging power of both chargers was reduced.
e) Charger 2 (that probably registered on the manager previously to this instant) requested to start charging. Since the available power allows that all chargers can be used at the same time, charger 2 can start charging.
f) In the instant before this, the building consumption reduced, so the available power to each charger increased and the chargers increase the charging current to 9A
g) In the previous sampling time, the building consumption increased again and the available power is not enough for all chargers to charge at the minimum power (6A of current), so charger 2 (the last charger to register in the manager) must be put in standby mode.
h) Once again the building consumption increases and the remaining power only allows one charger to work. So at next step, only charger 1 is working.
i) One more time, the building consumption increased (registered at previous time step) and charger 1 also was ordered to stop charging, since there is no available power to charge at the minimum allowed by the standard.
j) In previous time step the building consumption decreased enough to allow charger 1 to start charging again.
k) Another reduction in the building consumption made it possible to charger 2 enter in charging mode again. At this moment, the building consumption slightly increased, so in next time step the chargers reduced the charging current from 7A to 6A.
l) Here charger 1 has finished the charging session and the building consumption has also decreased, so charger 3 could increase the charging power and charge 2 could resume the charging session.

IV. Conclusions

In this work, the mesh version of the IEVCC was presented. This system allows the installation of multiple chargers in a shared private parking space taking advantage of the available contracted power without the need of an increase in the maximum peak power. The installed chargers are managed by a central manager/broker that controls the available power to each charger in function of charger priority and the remaining available power. At the extreme case, when is not possible to maintain multiple chargers , charging at the same time (charging current bellow 6A), the manager will disable lower priority chargers in order to distribute the remain available power to the remaining chargers. Once the available power allows the reintroduction of the disabled chargers, the manager will authorize the chargers to recover the charging process.

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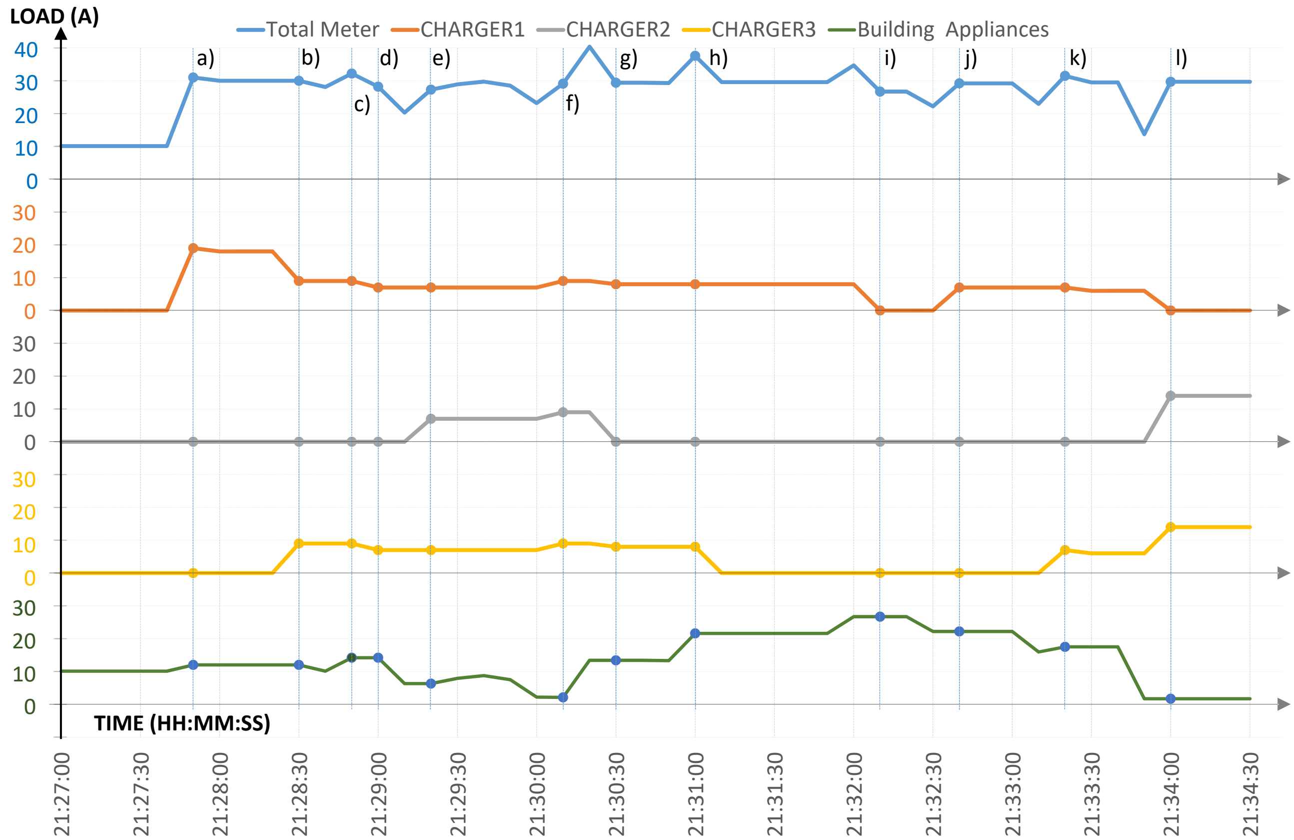

Fig. 8. Mesh Charger Network Simulation

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