New approach for Smart Community Grid through Blockchain and smart charging infrastructure of EVs

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Abstract— **The growing demand for EVs will lead to an increase in charging systems, both to guarantee the capillarity of charging systems and to distribute the demand for energy, which will increase over time. Since it is possible to have an efficient bi-directional energy flow, in fact car batteries can be used like any other energy storage system in the grid, with the added benefit of portability. The bi-directional energy flow would allow electric vehicle owners to participate in trading in energy markets, recharge batteries when energy is available at a low cost and discharge if the smart grid rewards them for their excess energy.**

This type of negotiation and control sharing can allow the network to perform demand management in periods of high demand, (e.g. peak shaving) or provision of additional storage in case of excess generation from RES. Through smart charging systems, it will be possible to decide where, when and which EV to recharge, thus reducing the load. The grid can be structured differently, in networks that serve small communities, in order to better manage RES energy flows, EV recharges and smart appliances.

With this paper we want to determine a model for the smart charging of EVs, through the adaptive EV charging flow chart, through which a software agent, with a specific logic, decides whether to load a machine, in which sequence or if it is better to sell energy to the retail market. The agent learns and adapts to the individual Prosumers of EV, learning the preferences and mobility habits of different users, a fundamental element of the decision-making process, so that the owners of electric vehicles (or charging systems) decide to be part of the system.

Finally, the management through Blockchain, makes every transaction reliable and verifiable, with the possibility of reducing or eliminating intermediaries in energy trading, thus reducing the range of antiexity of electric vehicle drivers, will make it possible to develop a new generation concept distributed: Smart Grid Community.

Keywords— Prosumers; Smart metering; Homer software;Evs; Blockchain; Edge computing;

I. INTRODUCTION

The electrical system is undergoing drastic changes due to distributed generation, the liberalization of the electricity market, the introduction of new technologies and finally the spread of electric vehicles (EVs) and smart appliances, which on one hand are an element of instability for the grid, can become active elements for energy dispatching.

EVs can be seen as distributed units, which among other things being in movement implement network connectivity and data transmission, capable of performing data processing and analysis during participation, in which the sensors are dispersed geographically to establish the different interactions [1], in order to improve the quality of electrical services [2, 3]. The role of EVs becomes innovative, since they must be seen as moving cloud elements, that is Edge Computing, of a new hybrid network, for the interchange of distributed and moving energy (storage and supply of energy, not only to the network, but also to other types of users) and information, including traffic monitoring, detection of the road environment and driving to the nearest charging system, in relation to current data. The use of smart metering together with distributed micro-generation resources, entails a new approach to micro-grids, in which each Prosumer wants to be a (mini) utility.[4]

The Blockchain is introduced as a potential solution, as it allows to obtain two advantages:

1. Decentralize: accounting, archiving, maintenance and data transmission are performed as distributed calculations, without centralized management;
2. Participation: means that all participants can join in transactions based on consensus algorithms.

In this way it will be possible to obtain Smart Community Grids (SCG), in which there is a market based on peer-to-peer and / or autotrading energy, balancing energy flows in a more efficiently way.

II. LOAD SIMULATION FOR THE SMART COMMUNITY GRIDS

The microgrids are spreading following the greater generation from renewable, which connected with the loads, defines the electric boundaries. The implementation of EVs, will have a greater impact on them, by changing the load curve in a very variable way, therefore, the recharge of the EVs will have to be precisely controlled to guarantee their economy and recovery capacity. [5]

Another problem is represented by the establishment of Prosumers and therefore of economic transactions related to energy flows. In this paper we have a microgrid, that we will define Smart Community Grid (SCG) [6] hypothesized in the city of Bergamo and it is composed of different prosumers: residential (midrise apartment), quick service restaurant, small office, supermarket and secondary school, as shown in fig.1, which will be managed by smart metering to control energy

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flows and transitions energy through Blockchain. In the model there are as generation: smart grid, wind and solar source, battery of EVs through the HOMER software we obtained the simulation of the loads for the period of one year and the relative load factor for SCG, as shown in fig.2:

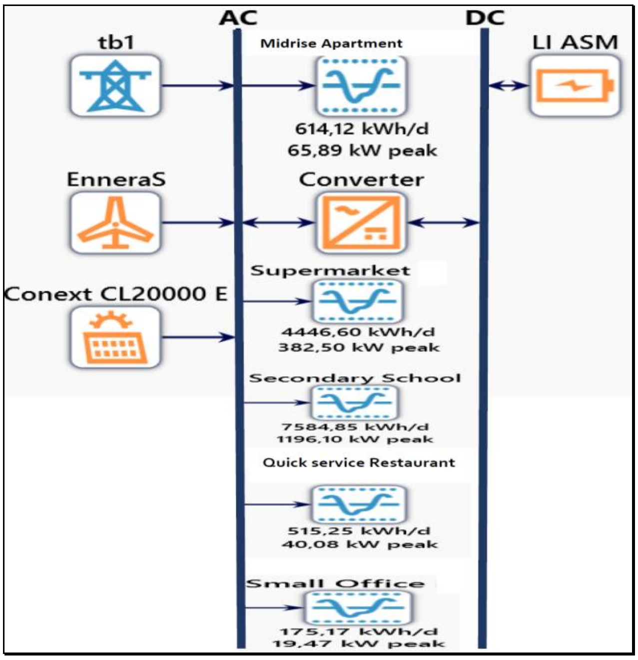


Fig.1 Model of Smart Community Grid, located in Bergamo- Italy

The HOMER energy software was developed by the National Renewable Energy Laboratory (NREL). It is a simulation tool that allows to obtain the optimal combination of generations for a microgrid. The parameters, such as the electrical load, the RES, the generation capacities, batteries and prices for each generation system, must be entered manually. The term "optimal" means that the solution obtained, through a dedicated algorithm, has the lowest value for the total net current cost (NPC) of all possible solutions to obtain the optimal microgrid. [7]

The most significant data are reported in tab I, the load factor is a dimension less number equal to the average load divided by the peak load, for example, if the average load is 614,12 kWh/d (or 25,59 kW) and the peak load is 65,89 kW the load factor is 25,59 kW/65,89 kW = 0,39. The Random Variability inputs on the Electric Load to the load data to make it more realistic, and are Day-to-day and Timestep.

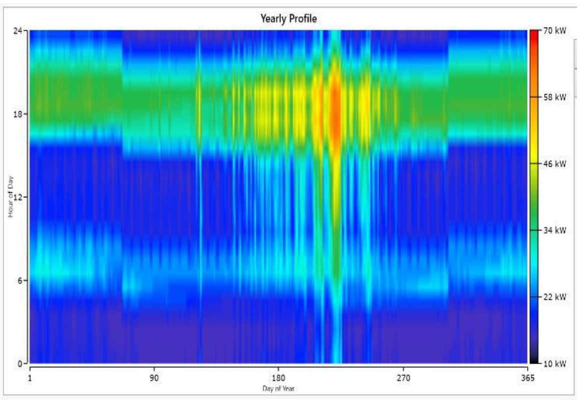


Fig.2: Load Profile for Midrise Apartment at 2020

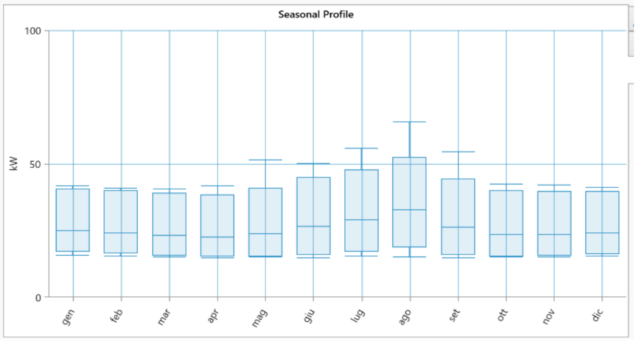


Fig.3: Seasonal Profile for Midrise Apartment at 2020

Metric	Baseline	Scaled
Average (kWh/day)	614.12	614.12
Average (kW)	25.59	25.59
Peak (kW)	65.89	65.89
Load factor	0.39	0.39
Random variability Day to day	7.946%	
Time step	Size 60 minutes	
Peak month	august	
Crest factor	2,42	

Tab.I: data Load of Apartment

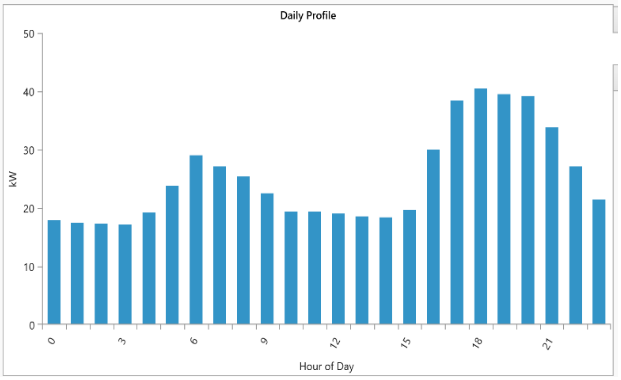


Fig.4: Daily Profile for Midrise Apartment at 2020

Weekdays Weekends

Hour	gennaio	febbraio	marzo	aprile	maggio	giugno	luglio	agosto	settembre	ottobre	novembre	dicembre
0	17.92	17.51	16.01	15.7	15.83	17.14	18.36	20.51	17.31	15.53	16.32	17.18
1	17.45	17.03	15.69	15.45	15.44	16.45	17.55	19.53	16.71	15.26	15.81	16.68
2	17.24	16.81	15.55	15.34	15.26	16.06	16.98	18.89	16.36	15.14	15.57	16.46
3	17.16	16.73	16.97	17.44	17.33	17.99	18.8	20.67	18.36	17.24	15.66	16.37
4	19.26	18.87	20.73	21.5	18.43	18.22	20.12	24.47	23.04	21.79	17.99	18.47
5	23.77	23.4	24.72	22.46	22.04	23.39	24.71	26.31	25.67	26.58	22.59	22.97
6	29.02	26.78	24.32	24.7	25.08	27.06	28.77	30.27	26.88	25.05	25.65	28.18
7	27.17	26.05	24.19	23.73	24.2	26.32	28.31	30.34	26.19	23.7	24.67	26.24
8	25.45	24.97	21.84	20.87	21.59	24.05	26.27	29.11	23.9	20.92	23.47	24.67
9	22.49	22.02	18.91	17.97	19	21.85	24.49	28.56	21.9	18.12	20.67	21.76
10	19.41	18.96	18.11	18.17	19.56	22.68	25.59	30.9	22.94	18.44	18.05	18.71
11	19.4	18.99	18.01	17.99	19.49	22.89	25.98	32.28	23.46	18.27	18.19	18.74
12	18.98	18.63	17.72	17.73	19.36	22.9	26.2	33	23.81	18.08	17.95	18.39
13	18.58	18.28	17.51	17.63	19.37	23.29	26.26	33.69	24.1	17.97	17.62	18.05
14	18.38	18.08	18.34	19.02	20.96	25.36	28.09	35.63	25.7	19.36	17.57	17.91
15	19.73	19.43	23.81	26.5	28.81	34.04	36.35	43.66	33.61	26.88	19.43	19.29
16	30.04	27.03	30.28	32.56	35.18	41.17	43.09	50.22	40	33.87	31.12	31.87
17	38.43	37.43	35.2	34.68	37.54	43.61	45.59	52.18	43.53	40.1	37.78	37.97
18	40.46	40.2	38.98	37.48	37.07	41.79	43.8	51.84	45.45	39.19	39.58	39.99
19	39.55	39.28	38.33	38.45	40.58	44.6	46.85	52.17	44.44	38.64	38.64	39.06
20	39.18	38.9	34.46	32.92	34.68	38.76	40.89	44.92	38.23	33.06	37.73	38.67
21	33.82	33.53	28.01	25.9	27.15	30.37	32.35	35.85	30.16	25.95	32.12	33.27
22	27.08	26.75	21.82	19.99	20.74	23.17	24.79	27.9	23.21	19.93	25.29	26.47
23	21.38	21.03	17.49	16.29	16.64	18.38	19.72	22.39	18.61	16.18	19.65	20.72

Tab.II: Hour Profile weekdays for Midrise Apartment at 2020

Weekdays Weekends

Hour	gennaio	febbraio	marzo	aprile	maggio	giugno	luglio	agosto	settembre	ottobre	novembre	dicembre
0	18.45	17.63	16.07	15.68	16.26	17.27	19.88	21.33	16.99	15.68	16.29	16.85
1	18.01	17.17	15.78	15.4	15.83	16.56	18.84	20.25	16.41	15.42	15.78	16.34
2	17.82	16.98	15.64	15.24	15.56	16.14	18.16	19.34	16.07	15.29	15.54	16.12
3	17.76	16.93	17.25	17.3	17.55	18.09	19.93	20.98	18	17.38	15.7	16.03
4	19.89	19.05	21.23	21.26	18.57	18.32	21.27	24.82	22.53	21.92	18.09	18.14
5	24.42	23.57	25.45	22.21	22.41	23.59	25.82	26.44	24.89	27.02	22.72	22.67
6	29.65	26.9	24.53	24.65	25.57	27.29	30.07	30.56	25.78	24.9	25.43	27.92
7	27.71	26.07	23.71	23.22	24.18	26.1	29.43	30.04	24.28	23.01	24.43	25.82
8	25.25	24.26	21.16	20.36	21.65	23.91	27.65	28.42	21.97	20.16	22.88	23.54
9	22.26	21.26	18.29	17.49	19.19	21.9	26.17	27.58	20.13	17.23	19.98	20.65
10	19.12	18.12	17.85	17.71	19.81	23.02	27.66	29.68	21.09	17.39	17.41	17.61
11	19.05	18.09	17.73	17.55	19.99	23.57	28.66	31.04	21.62	17.2	17.48	17.68
12	18.67	17.77	17.43	17.07	19.81	23.98	28.89	31.59	21.94	16.8	17.16	17.43
13	18.11	17.3	17.21	16.84	19.88	24.76	29.46	32.03	22.16	16.67	16.8	17.01
14	17.9	17.1	18.17	18.19	21.43	26.84	31.74	33.69	23.61	18.06	16.83	16.85
15	19.3	18.43	24.21	25.71	29.17	34.57	40.23	41.84	31.09	25.57	18.97	18.24
16	29.64	26.11	30.97	32.18	36.31	41.71	47.51	48.93	37.77	33.68	30.77	30.86
17	38.81	37.21	35.72	34.42	38.58	44.58	50	50.86	41.23	39.86	37.63	37.72
18	40.97	40.05	39.16	37.16	37.8	42.95	47.76	50.44	42.84	38.99	39.4	39.87
19	40.09	39.17	38.57	38.24	41.33	45.91	50.5	51.37	41.99	38.54	38.53	38.93
20	39.77	38.82	34.19	32.73	35.41	40.1	43.9	44.39	36.01	33.02	37.48	38.54
21												
22												
23												

Tab.III: Hour Profile weekend for Midrise Apartment at 2020

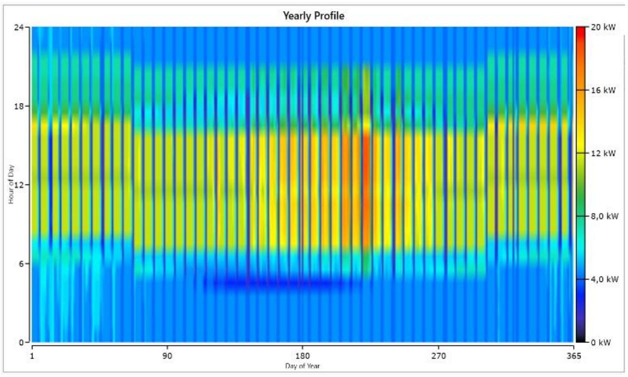


Fig.5: Load profile for Small Office at 2020

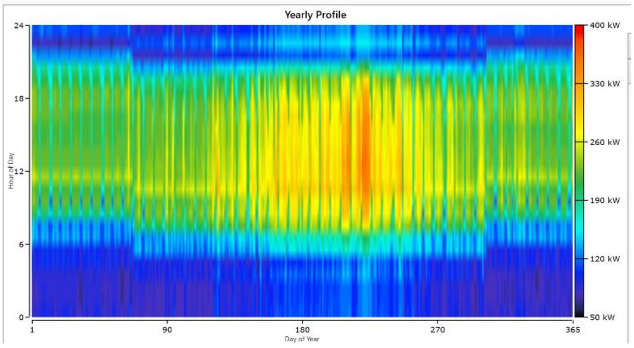


Fig.6: Load profile for supermarket at 2020

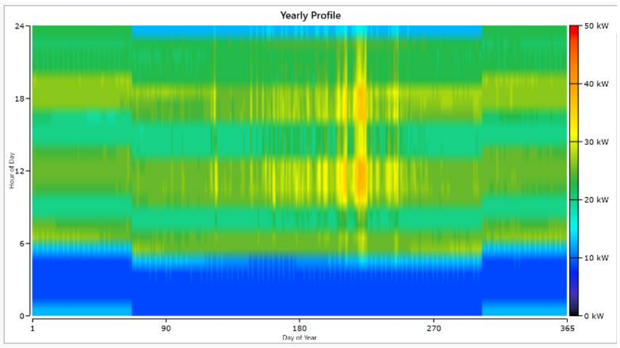
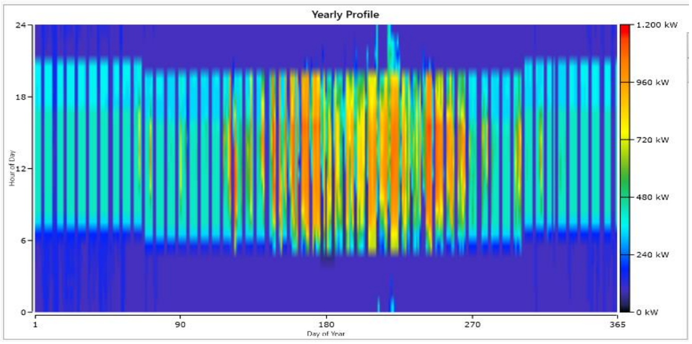


Fig.7: Load profile for Quick service restaurant at 2020



III. Blockchain and Smart Agent for the Management and Control of the Smart Community Grid

The connection of the electric vehicle can balance the energy and are one of the ways to reduce mobility-related emissions, this is amplified if the vehicles are recharged via Renewable Energy Sources (RES) [8].

Unfortunately, it is difficult to manage intermittent sources, in relation to weather conditions and with a widespread generation.

Due to the temporal and spatial variability of charging systems for electric vehicles, load demand will increase and recharging in the distribution network will create higher power peaks, voltage drops and line overload.

Demand management, especially in relation to Prosumers, is seen as a valid solution for managing distribution networks.

The EVs through the flexibility of recharge and discharge times, allow a management mode of the demand side, especially in relation to peak hours.

Once obtained the predictive data from the simulation, using HOMER, of the microgrid should be used to be managed by smart metering, which must work through smart agent with learning capacity and establish in real time the energy flows and the energy price to be exchanged in the same SCG, with Blockchain type contracts.

Smart contracts are containers of code that code and translate contractual agreements in the real world. The contracts represent a binding agreement (enforceable by law) between two or more parties, in which each entity must fulfill its obligations according to the agreement.

The key element is that smart contracts do not have intermediaries, commissions, dependence on third parties, by automatically executing the code that is allocated and verified by the network nodes in a blockchain network.

Smart devices can communicate via IoT, through the BC can send and store information and transactions, peer to peer.[9]

The arrangement of innovative technologies may give a new approach to productive power: combining meter with smart agent software, blockchain distributed, RES, may enable the realization of distributed Virtual Power Plants (VPPs)[10], that support peer-to-peer energy trading through Blockchain, allowing integration with a global market.

Smart Agent is a system of problem-solving, with well-defined, boundaries and interfaces; located or embedded in a detail environment, where it has control, receives input state of

the environment through sensors and can act on it through actuators;
Features of a Smart agent:

- manifest aspects of AI, such as learning or reasoning
- change the path through which they reach their goal
- distributed on separate physical machines
- move their execution to another processor

This approach requires the use of very sophisticated software and micro controller with hardware resources to allow the execution, in Real Time, via IoT to Cloud, with TCP/IP connection, so to make it as a neural system.[11]
The Virtual Power Plant (VPP) will have a module for the management of EVs, as "Adaptive Flowchart of EV Recharge" with the objective of determining the optimal sequence of recharge with Smart Agent, to obtain control strategies for reducing costs of recharging the batteries, both in Swap mode and in public and / or private EVs mode, and maximizing revenues for EVs.
The VPPs have control centers, with Smart Agent, with the aim of optimizing resources in relation to the market.
Through the IoT it is possible to monitor and then control, in real time the resources such as:

- individual EVs recharge points, at public and private level;
- swap battery pack;
- management of energy consumption in a smart home, in relation to Prosumer's preferences;
- utilities;

and prepare bids and related adjustment requests, resolution of intrazonal congestion, creation of energy reserve, real-time balancing, for

- ✓ First Day Market - MGP
- ✓ Intra-day market - MI
- ✓ Dispatching Service Market - MSD

based on generation and demand forecasts (obtained through simulation with HOMER).
In Italy, in the MGP and MI - also called Energy Markets - producers, wholesalers and end customers, as well as "*Acquirente Unico*" (AU) and "*Gestore Servizi Energetici*" (GSE) buy and sell wholesale lots of electricity for the day following. These markets, managed by the Energy Markets Operator (GME), define equilibrium prices to which the negotiated energy is valued.
The flow chart for Energy Management within a Smart Community Grid (SCG) is illustrated in the figure 9, where we start from the generic Prosumer 1, which can be residential (midrise apartment), quick service restaurant, small office, supermarket and secondary school, as shown in fig.1.
In relation to the production and demand of the Prosumer, the energy flow is managed, which if in surplus will feed the SCG or the SG in case of Peak load.
The economic transactions related to these energy flows will be managed by the market in terms of RESCoin, bitcoins dedicated to RES, through Blockchains, in order to make them safe and without the need of the intermediaries or Aggregator.

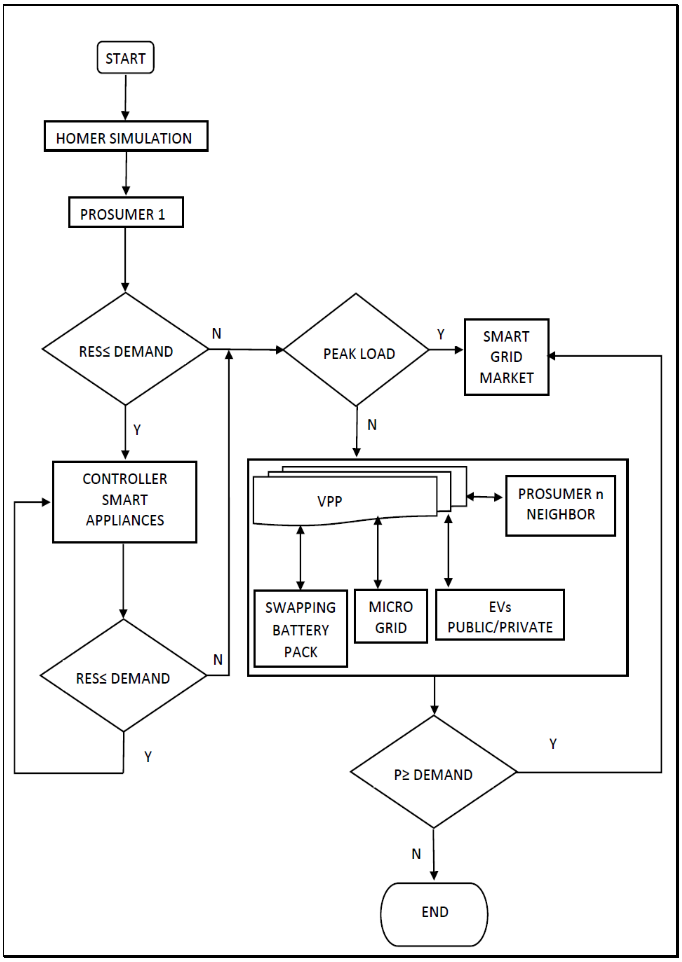


Fig.9: Energy Management Flow Chart for SCG

In this way a new approach of Virtual Power Plants (VPPs) is obtained, in which starting from smart metering and smart appliances within a house of a given SCG, it will be possible to control and manage energy consumption, through Smart Agents, who are able to make decisions (autonomous); pursue goals over time (proactive); interact with other agent (collaborative) and finally able to perform social processes that connect devices, people, and situations, or Pervasive-Learning.
Thanks to the IoT, the energy produced can thus be managed and exchanged with neighboring prosumers, when the Smart Grid has no Peak Load, with an energy and monetary trading that is implemented through the Blockchains and the virtual currency dedicated, the RESCoin [12], for to identify the nature of the origin of the revenues, in a sure and certain fashion, since it is a Peer to Peer exchange. The above-mentioned is shown in figure 10.
We observe that in the literature different methods and applications can be found on Demand Side Management (DSM) [13-18], which appears to be obsolete or otherwise to be made even more specific in relation to the fact that the demand side is represented by the Prosumers, so as to modify

its management model in Prosumer Side Mangament (PSM) [12].

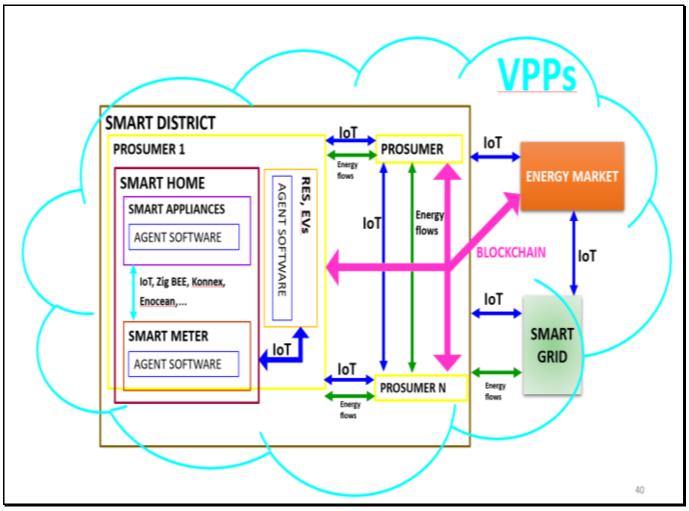


Fig.10: scheme for VPP into SCG

IV. Conclusion

This paper aims to outline a new approach to smart grids and the management of electric vehicles. In fact a model is obtained, in which a prosumer, which belongs to a specific microgrid, called Smart Community Grid (SCG), can exchange energy produced first with the Smart Grid in case of Peak Load, as an alternative with the other Prosumers inside of the same SCG, so as to limit the losses and to reduce the same Peak Load to the same time.

The SCG will also be made up of public and / or private EVs, utility microgrid and Swap Battery Pack, for the exchange of batteries, in this way the management of energy flows will take place in a bidirectional way and have energy flows that compensate themselves the demand within the same SCG. Pre-emptively a simulation is carried out with the Homer software, to establish the ideal microgrid in relation to the SCG that has been set up, so as to obtain as close as possible to the demand, the constitution of the generation in RES terms to be installed.

The control process must be adaptive, through the use of Smart Agent, so that the controller can learn from the consumption and behavior of prosumers [19], how to properly manage energy flows, even within smart homes, for limit the Peak Load and at the same time get an efficient and reliable EVs recharge. To make economic transactions, which must meet these energy flows, safe, reliable and paid will be used RESCoins, that is dedicated BITcoins, which thanks to Blockchain allows energy trading on the energy markets, as well as safely without further intermediaries or aggregators.

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