Managing Knowledge Acquired from Smart Meters in a Distributed Advanced Metering Infrastructure

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Abstract: The primary purpose of this article is to present the functional information and knowledge - acquired from smart electricity meter readings, which are a component of the Advanced Metering Infrastructure (AMI). The relations between the management of knowledge acquired from the AMI system and the new empirically identifieddecision-making processes that make the management of electricity value more efficient, both on the side of the supplier but also, which need to be emphasised, on the side of the consumer/household, often the energy prosumer (micro RES production), are indicated in it. In the first part of the article - the theoretical and cognitive part - justification has been given for the subject matter specified in the title of the paper. Attention was drawn to the dynamic digitization and automation of energy metering readings. The size of the AMI market in terms of the growth in the number of smart meters in households, as well as the size of the market, has been quantitatively described. In the context of the dynamic growth of smart electricity meters, the growth of heterogeneous knowledge on households resulting from high-frequency readings was justified, which in fact reflect not only variable energy demand but also the culture of energy demand and use. In the paper its author has structured the insights gained from the AMI infrastructure. In turn, the second - empirical - part attempts to answer two research questions: 1) What information/knowledge in addition to real-time bi-directional energy readings necessary for energy value management can be generated through the use of high-frequency clocking smart meters?; 2) How to use the acquired knowledge, manage the knowledge, acquired from the readings of the distributed AMI (smart electricity meters) infrastructure, in terms of key decision-making processes that make energy value management more effective, both on the supplier side but also on the consumer/household side, frequently the energy prosumer - micro RES production. In order to answer the above two research questions, a questionnaire survey was conducted and a brainstorming, scientific discourse with inference was carried out with a group of business practitioners, including managers of corporations and energy companies - improving their knowledge, and competences in the area of management and entrepreneurship in energy markets, including RES.

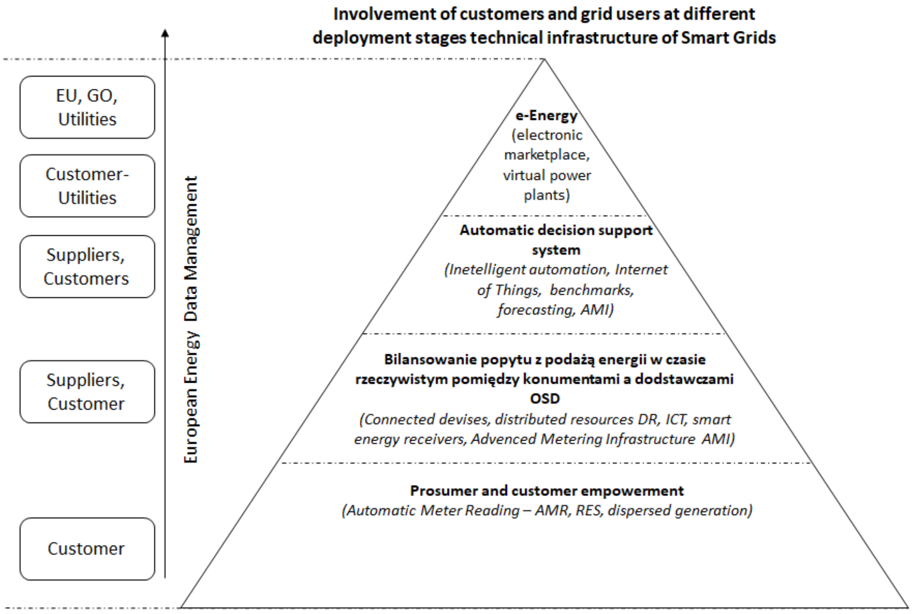
Keywords: Smart meters, Advanced Metering Infrastructure AMI, Knowledge management,Ddecision-making processes

1. Introduction

The digitisation of the electricity sector is currently being dynamically implemented on the part of the final consumers of electricity also included in the household group. Directly, these activities are related to the digitisation and automation of energy metering readings, both active and reactive, in integration with the digitisation of electricity bills. This was activated through the use of high-frequency clocking smart meters - usually two-way electricity readings. This has improved communication between electricity end-users (the demand side to date) and DSOs (the supply side to date). According to Allied Market Research, the global smart meter market was valued at USD 21.13 billion in 2019. It is planned that this market could be worth USD 39.2 billion in 2027. The instruments for accelerating the growth of this market segment are financial and non-financial mechanisms, driven by government initiatives in the world's leading economies that are commonly introducing smart meters and upgrading outdated infrastructure. It is important to note that households are a priority for smart metres deployments until 2027. This is also regulated in the European Union. The EU Commission issued the document *"Benchmarking smart metering deployment in the EU-27 with a focus on electricity", jointly drafted by DG ENER and JRC, as COM(2014)356* (European Commission, 2021). The document is a report on smart meter deployments, in EU Member States, based on economic assessments of long-term costs and benefits (CBA - cost benefits analyses), of smart metering of electricity as well as gas. It was assumed that by 2020, almost 72% of European consumers will have a smart electricity meter. Of course, in reality, it can be stated by referring to the indicated scenarios for 2020, that this has been delayed. However, between 2023 and 2027, the diffusion of smart meter deployments is anticipated. In Poland, for example, 80 % of meters are expected to be replaced in 2028 and 100 % by the end of 2030.

2. Implementation of Smart Measurement Infrastructure - Economies of Scale

Smart Meters technologies implemented in Advanced Metering Infrastructure structures are analysed not only from the perspective of the end user - the consumer but also from the perspective of energy suppliers, Distribution System Operators and at the highest level in the context of: National or at the scale of European Electricity Systems (Andreadou, et al, 2016),. According to the European Technology Platform (ETP) (European Technology Platform, 2021), also hierarchically but now in the context of users, four layers can also be distinguished. The different layers show the activities, the involvement of the different user groups of smart metering networks, taking into account the increasing value of the technical infrastructure (Figure 1).



Source: Elaborated based on European Technology Platform, 2021

Figure 1: Involvement of Consumers and Smart Grid Users in the Next Stages of Technical Infrastructure Deployment

In the first layer (Figure 1) of the end user/consumer of electricity, the infrastructure of their electricity receivers (demand side), is connected to the grid, with the functionality of automatic AMR readings. In order to strengthen the position of customers, new roles are being introduced to them in this layer, in addition to energy use/consumption, also the role of energy generation in distributed generation sources, especially in micro RES (Niedziolka, 2018). This has forced bi-directional energy flows, thus necessitating bi-directional readings in Smart Meters (Dorothy, et al, 2017). In the second layer (Figure 1), the user group includes energy suppliers, the local Distribution System Operators, in addition to consumers, frequently prosumers (Kuceba, et al., 2018) of electricity. In this layer of smart metering networks, by connecting the consumption and generation infrastructure of end users to the electricity grid infrastructure, the continuity and reliability of balancing demand with supply of electricity is ensured, obviously in real time. In this layer, DR distributed generation resources and distributed energy receivers are connected to the grid. In order to automate the management of distributed DR resources, including distributed energy receivers, in the third layer (Figure 1), Automatic Decision Support Systems are intended for consumers and energy suppliers. These systems, are responsible for controlling the technical infrastructure of Smart Meters, often on the basis of explanatory and inference models. Many times, through learning and inference capabilities, these are autocratic systems making self-learned decisions. Full automation is now also provided by the Internet of Things IoT (Abu Bakar, et al, 2019), also enabling remote control of distributed technical infrastructure Smart Grids (Rihan, 2019). The final layer of users, the fourth (Figure 1), concerns electricity suppliers, Distribution System Operators DSOs and also Transmission System Operators TSOs, at scales already macro-regional, e.g., national or EU-wide. The fourth layer is e-Energy, an electronic energy market, created primarily by virtual power plants with distributed generation infrastructure (in particular RES) and groups of distributed electricity consumers/prosumers, in cooperative networks (Kuceba, 2022). In line with the subject matter defined in the title of this article, the fundamental layer of smart metering, frequently bi-directional, is the electricity consumer/prosumer layer. From the point of view of the system approach, the management of the distributed metering structure of smart meters and, at the same time, the management of the distributed community of final consumers, the following basic modules and, at the same time, functionalities, are distinguished, which include, among others: Sumary Bills, Automated Meter Reading AMR, Demand Response, Distribution Automation, Time of Use Pricing, Advanced Metering Infrastructure, Critical Peak Pricing (Andreadou, et al, 2016). The implementation of Smart Meters in distribution networks on the low-voltage side, close to final electricity consumers, providing metering and bi-directional flow of electricity, has contributed to the diffusion of energy prosumers, who are assigned two main roles (Kuceba, et al, 2020): 1) the consumer of electricity (the demand side on the smart meter side) and 2) the producer of electricity (the supply side on the smart meter side). Measuring and managing the bi-directional flow of electricity makes it possible to balance the non-linear daily demand for electricity with the non-linear supply of electricity generated on the prosumer side, in distributed and dispersed sources with different characteristics: daily and seasonal dispatchability (including non-linear RES). Due to the non-linear dispatchability of RES, apart from these sources of distributed and dispersed generation a fundamental part become (European Commission, 2021): Electricity Storage, Electricity Vehicles and also technologies categorised as Internet of Things IoT, including Smart Appliances and Home Automation Networks (Ahmed Qarabsh, et al, 2020). Real-time metering provides the final system energy balancing of DSOs - energy surpluses and shortfalls just on the prosumer side. The advantages of smart metering on the household side include: 1) remote reading and configuration through communication via the electricity grid or a built-in wireless communication module; 2) continuous monitoring of energy consumption and energy production at prosumer sources; 3) generation of statistics on habits and trends - the culture of electricity use by households; 4) possibility to pay bills in pre-paid or new payment models; 5) easier diagnosis of faults; 6) implemented advanced analytical algorithms (using also machine learning or deep learning), which ensure the mitigation of illegal electricity consumption; 7) optimisation of energy consumption, which translates not only into lower bills, but also has a positive impact on the environment.

When justifying the research topic in relation to the title of the present paper, it is important to emphasise that electricity meters provide high-frequency (usually clocked to take readings taken every 15 minutes) various categories of data, information and also knowledge, such as: actual meter readings of active energy taken from the DSO network (readings in kWh); actual meter readings of active energy introduced into the DSO network (readings in kWh); meter readings of active energy taken from the DSO network in peak and off-peak hours (readings in kWh), interruptions in electricity production and consumption, failures on the prosumer's side of electricity demand and supply; peaks in daily peak load and energy production on the prosumer's side. Generating a large number of readings on the prosumer side with a high clock frequency and, at the same time, taking into account the dynamic growth of smart metering in households over the last three years and the planned growth in 2023-2027, requires distribution system operators DSOs as well as commercial operators COs and commercial-technical operators CTO, to look for systemic solutions to manage big data and also to manage the acquired knowledge resources (Maurer, et al, 2011) (Shanker, et al, 2017). The foundation for the acceleration of any new solutions in this area, while at the same time taking as a prerequisite, are appropriately designed and configured knowledge bases. The aggregation of big data in knowledge bases, the definition of explanatory and inference models ensures the correct implementation of processes for the management of large amounts of data and information and, indirectly, the management of smart metering infrastructures, heterogonous electricity users, especially households, including prosumers (Fadaeenejad, et al, 2014). Thus, this paper attempts to empirically identify the decision-making processes that make knowledge management, the value of electricity, more effective, both on the supplier side but also, it should be emphasised, on the consumer/household side, often the energy prosumer (micro RES production).

3. Methodology

The identification and analysis of the activities of data and information management processes (Bylok, 2021) aggregated from smart meter levels was carried out in two research stages - 1) a questionnaire survey (focus method) conducted in a group of experts from the widely understood electricity industry; and 2) a scientific discourse panel with inference (brainstorming) conducted in a group of experts, business practitioners strictly in the areas of electricity markets, electricity trading and electricity value management. The aim of the research carried out was to answer the main two research questions, research problems, convergent with the topics identified in the article: 1) What information/knowledge, in addition to real-time bi-directional energy readings necessary for energy value management, can be generated through the use of high-frequency clocking smart meters; 2) How to use the acquired knowledge, to manage the knowledge, obtained from the readings of the distributed AMI infrastructure (smart electricity meters), regarding the key decision-making processes that make energy value management more effective, both on the supplier side but also on the consumer/household side, frequently the energy prosumer (micro RES production). In the first research part, a questionnaire survey was conducted among a group of business practitioners, including managers of corporations and energy companies - managers improving their knowledge, and competences in the area of management and entrepreneurship in energy markets, including RES (Kasaei, et al., 2017). The respondents were students of the Executive MBA-ESG programme. In total, the population in the two training groups of the surveyed energy company managers, was N=41. The lead expert was the Author of this publication at the same time - acting as an expert/lecturer leading tutorials in the areas of energy security, energy efficiency, smart grid and smart metering. In the second stage of the research, six domain experts, managers, decision-makers strictly in the area of electricity markets, and in particular in the field of electricity trading and value management, were selected (purposive selection) from the first group of respondents. The author of this publication was also leading the panel of experts, who is an expert and practitioner in the fields of, among others, Smart Grid, Smart Metering and also virtual power plants, which meant that the population of the group of domain experts was n=7.

4. Results

The first stage of the research attempted to answer the research question: What information/knowledge, in addition to real-time bidirectional energy readings, necessary for electricity value management, can be generated through the use of high-frequency clocking smart meters? Each of the 41 respondents to the survey, using a questionnaire based on the focus method, indicated a maximum of 5 areas of information/knowledge that could be extracted from two-way electricity readings (...). The focus method adopted, limiting to 5 responses, reduced the occurrence of random responses, focusing each respondent on the relevant responses that are automatically perceived, foregrounded. This resulted in 18 relevant pieces of information/knowledge, essential for managing the sustainable value of electricity. The results obtained are summarised in Table 1. The individual information/knowledge generated from the readings from the electricity meters was assigned a percentage and a number of indications. The information and knowledge obtained from the AMI system, as the results of the research carried out, have been summarised according to the descending criterion - from the highest number of indications to the lowest. Table 1 visualises the individual categories of knowledge information identified by the survey respondents in the AMI system.

Table 1: Information and Knowledge Extracted From the AMI System (smart meters)

Information and knowledge extracted from the AMI system (smart meters) Number of indications		
1.	Raw metering data obtained from all metering systems of the AMI infrastructure	**92,7% (38)**
2.	Information/knowledge necessary for the generation of daily/seasonal calendar characteristics Pd=f(t), in real time: a) individual on the customer, electricity prosumer side; b) aggregated on the node, transformer, power district side	**78,0% (32)**
3.	Information/knowledge necessary for the generation of daily/seasonal integral characteristics Ed=f(t), in real time: a) individual on the consumer, prosumer side of the electricity system; b) aggregated on the node, transformer, power district side	**73,2% (30)**
4.	Information/knowledge on balancing evening peak loads by transferring loads to off-peak periods	**51,2% (21)**
5.	Information/knowledge about overloading - excessive power input from prosumer sources into the electricity grid	**29,3% (12)**
6.	Information/knowledge of actual charges as a function of daily tariffs or other prepaid payment models	**26,8% (11)**
7.	Information/knowledge about energy consumer preferences and behaviour	**21,9% (9)**
8.	Information/knowledge about the actual energy balance of the prosumer of electricity - feeding IoT applications of the control of smart energy consumers in households, for the actual on-line balancing of demand with supply on the part of the consumer group and also on the part of individual consumers/prosumers	**19,5% (8)**
9.	Information/knowledge on consumption and production at prosumer electricity sources, e.g. in 15-minute, hourly, daily, monthly modes (...)	**19,5% (8)**
7.	Real-time information/knowledge on the quality parameters of distributed electricity from prosumer RES sources, as well as information on the availability of these sources during peak and off-peak demand periods	**14,6% (6)**
10.	Information/knowledge on loads on LV networks , MV/LV (medium/low voltage) transformer stations/switches	**14,6% (6)**
11.	Information/knowledge on schedules (at intervals of e.g. 15 minutes and hours) of operation of prosumer RES sources on MV and LV networks	**12,2% (5)**
12.	Information/diagnostic knowledge about the state of electricity networks, location and causes of faults or failures, on-demand power quality control, detection of cases of illegal energy consumption	**9,8% (4)**

Information and knowledge extracted from the AMI system (smart meters) Number of indications		
13.	Information/knowledge about the utilisation rate of electrical networks, network losses, flow rates	**7,3% (3)**
14.	Information on the electrical parameters of all MV/LV transformer stations/switching points	**7,3% (3)**
15.	Information/knowledge of trading losses	**4.9% (2)**
16.	Information/knowledge on aggregate demand and supply of electricity to ensure optimal operation of SCADA systems	**4.9% (2)**
17.	Information/knowledge on distribution of MV and LV nodes	**4.9% (2)**
18.	Information/knowledge on the location of consumers and distributed prosumer sources feeding into the GIS. Full information on MV and LV networks in terms of topological data and technical parameters of infrastructure elements.	**4.9% (2)**

The results obtained provide a broader perspective on the value of electricity meter readings and, above all, in the context of aggregable knowledge and its value in sustainable electricity management. The information/knowledge extracted from aggregated smart meters can constitute, with an appropriate decomposition, a set of attributes and values that can feed heterogeneous decision-making systems, using algorithmised and also non-algorithmised methods using artificial intelligence (Deng, et al, 2015) (Tounquet, et al., 2019). The compilation of information and knowledge that can be extracted from elementary readings of bi-directional electricity flows in a distributed AMI infrastructure, according to the experts involved in the study, constitutes an aggregated tabular 'Real Consumer Behaviour Knowledge Map', which can be expanded under any heading, with the possibility of adding further information/knowledge items of course.

In the next stage of the research, in line with the assumptions made, an attempt was made to answer the second research question: How to use the acquired knowledge, manage the knowledge, obtained from the readings of the distributed AMI infrastructure (smart electricity meters), in terms of key decision-making processes that make energy value management more effective, both on the supplier side but also on the consumer/household side, frequently the energy prosumer (micro RES production). In accordance with the research methodology adopted, a panel discussion with inference (adopted as: brainstorming) was conducted at this stage, with the participation of domain experts - managers, decision-makers strictly in the area of electricity markets and, in particular, in the field of electricity trading and value management.

On the basis of the brainstorming, scientific discourse with inference, in the group of domain experts, a selection was made of key decision-making processes in which high relevance is attributed to heterogeneous information/knowledge extracted from the AMI system (smart meters). his refers to the information/knowledge summarised in Table 1, as indicated by the first group of respondents surveyed.

The domain experts, identified new decision-making processes, or significantly modified, unambiguously to be emphasised, decision-making processes that can be implemented using knowledge generated from smart meter readings in a distributed AMI structure. Furthermore, a portfolio structure of methods and tools was proposed and an attempt was made to justify its structure. These are methods and tools that can support the identified decision-making processes as well as digitise them (Deng, et al, 2015) (Tounquet, et al, 2019) using, inter alia, artificial intelligence, obviously where the source of knowledge constitute its identified areas (Table 1). Interesting from a cognitive point of view in the use of the information and knowledge identified and grouped in Table 1, was the identification by the experts participating in the study of six decision-making processes that are important in the management of energy demand and supply, especially in non-linear RES, both on the supplier side but also on the consumer/household side.

The order of the summarised decision-making processes is not random, as it was adopted according to the relevance of the knowledge information, which is determined according to the number of indications by respondents in the first stage of the research (Table 1).

The first process identified, which is accelerated by the knowledge gained from the AMI system, is:

The creation of tailored electricity supply portfolios to meet the actual needs of final consumers. This matching is linked to the scheduling and organisation of two-way transmission of electricity and information on its created value, as well as the generation of new services for heterogeneous electricity consumers. The research process emphasises that the source of knowledge in this decision-making area is the metering data obtained from all the metering systems of the AMI infrastructure, the cumulative metering knowledge on the basis of which the calendar characteristics Pd=f(t) and the integral characteristics Ed=f(t) are generated in real time, with high reading frequencies: a) individually on the side of the consumer, the electricity prosumer; b) aggregated on the side of the node, transformer, electricity region.

The above decision-making process, based on readings in the AMI system, should be methodologically supported, according to the domain experts, by visualisation of current and cumulative (integral) characteristics in real time, analyses of energy load and supply in prosumer sources, at arbitrary time intervals, including analysis of energy production from RES on the prosumer side. Tools supporting these analyses and, indirectly, the decision-making process in the area in question were also assigned. In particular, multivariate statistical analysis systems and the generation of dynamic econometric models, e.g. classes, GARCH, were distinguished. With regard to the creation of tailored electricity supply portfolios to meet the actual needs of final consumers, the need for integration with the internal CRM system/contract registration system (contracts with customer groups) on the part of the commercial operator was identified. Due to the non-linearity of electricity production in prosumer RES sources, it is proposed to carry out appropriate analyses using Business Intelligence tools, e.g. PowerBI, as well as machine learning systems, e.g. GNU R interpreted programming language or IBM SPSS Modeler.

The second decision-making process identified by the expert team that is possible with the aggregation of information/knowledge gained from the AMI system is:

Customer relationship management with the aim of customer segmentation, acceleration of customer confidence through flexible adjustment of tariffs, new payment models to the actual preferences of electricity consumers. Indirectly, this process involves: comparing - at specific time intervals - actual loads with the daily function of tariffs, preparing price offers to encourage the use of electricity consumers during off-peak hours, personal matching of energy consumers/customers to the DSR (Demand Side Response) programme. In the context of the above decision-making process, domain experts distinguish that it can generally be improved on the basis of information/knowledge about balancing evening peak loads by shifting loads to off-peak periods, information/knowledge about the preferences and behaviour of energy consumers, as well as information/knowledge about the consumption and production of prosumer sources of electricity, high-frequency readings, e.g. in 15-minute, hourly, daily, monthly modes. Similarly to the first decision-making process, also in this scope the domain experts attribute tools to support the identified above decision-making process. In particular, they distinguish intelligent systems for matching the prosumer to electricity tariffs and other payment models, e.g. in an R or IBM SPSS Modeler (Learning Machine) environment - due to individual consumer behaviour, non-algorithmised models are proposed.

The third decision-making process identified by the expert team that is possible with the aggregation of information/knowledge obtained from the AMI system is:

Maintaining and ensuring the stability of electricity grids through the management, by the commercial operator, of the key electricity loads of heterogeneous consumers/prosumers. Indirectly, this concerns the generation of schedules (time intervals favourable to the consumer) of energy consumption based on feedback from smart electricity receivers. In this respect, the information/knowledge relates to the actual on-line energy balance of the electricity supply on the prosumer side, with the aim of balancing it by means of a consumer-AMI-integrated - consumer application - Internet of Things (IoT) to control of smart household energy receivers. In technical terms, this involves the integration of stationary/mobile smart meter applications with IoT mobile applications - control of smart energy receivers in households/on the side of heterogeneous electricity consumers (allocation by tariff groups or other payment models introduced). In terms of tools, the experts highlight the importance of implementing integrators, integration and communication hubs of smart meter applications with IoT applications.

The fourth identified area requiring improvement of existing decision-making processes, according to the experts, is:

Network condition diagnosis, fault detection and localisation, on-demand power quality monitoring, detection of illegal energy consumption, diagnosis of network disturbances, expansion of the use of network infrastructure to include distributed smart meter infrastructure, including consideration of prosumer RES penetration. Indirectly, this also includes support for on-demand monitoring of medium-voltage MV and low-voltage LV networks. In this decision-making scope, the key information/knowledge acquired from the AMI system, concerns: information/knowledge obtained in real time about the quality parameters of distributed electricity from prosumer RES sources, as well as information/knowledge about the availability of these sources during peak and off-peak demand periods, information/knowledge about the loads of MV LV networks , MV/LV transformer stations/junctions, as well as information/diagnostic knowledge about the state of electricity networks, location and causes of faults or failures, on-demand energy quality control, detection of cases of illegal energy consumption. In this case, the analysis of metering data from smart meters in the AMI infrastructure, according to the domain experts, should be carried out using multivariate statistical analyses and dynamic econometric models, e.g. class, GARCH. In this respect, it is important to design a diagnostic model, this time based on models of deep learning libraries, machine learning and automated learning. The aim is to create and select a model that can predict the state of the network (justification of non-algorithmised methods), detect and localise faults, and control power quality. At this stage, the domain experts propose and at the same time justify the use of libraries such as KERAS, xgboost (eXtreme Gradient Boosting), randomForest (random decision forest), H2O and autoML (Automated machine learning libraries) available within the R development environment.

The fifth identified decision-making process which, in the opinion of the domain experts, can certainly be made more effective using information/knowledge gained from the AMI system is:

Real-time monitoring of commercial losses and their elimination/reduction through balancing energy demand with supply on the part of heterogeneous consumers. The relevant information/knowledge in this regard, also summarised in Table 1, includes: information/knowledge on commercial losses, information/knowledge on aggregated electricity demand and supply, ensuring, among other things, optimal operation of SCADA systems, and information/knowledge on the magnitudes of flows at medium-voltage MV and low-voltage LV network nodes. Here, the importance of a real online analysis of the relationship between electricity supply and demand is highlighted. Due to the non-linear nature of this relationship in reality, the use of a machine learning model is proposed - a model for intelligent matching of demand and energy production on the prosumer/line branch/transformer/energy district side. In this area of machine learning, the GNU R- interpreted programming language environment and also optionally the IBM SPSS Modeler system are proposed in the tool context. It was reasoned that the application of machine learning to analyse supply-demand relationships and detect abnormal behaviour can be fully implemented on the basis of historical data using libraries of automated machine learning etc. Libraries such as KERAS, xgboost (eXtreme Gradient Boosting), randomForest (random decision forest), H2O and autoML (Automated machine learning libraries) available within the R development environment can also be used at this stage.

The sixth decision-making process that can be made effective on the basis of the information/knowledge acquired from the AMI system is:

Management of the movement, switching on and off of all appliances, energy receivers, energy sources in the electricity grids covered by smart metering. In this case, the decision-making processes should be fed with all the information/knowledge that is highlighted in the previous five decision-making cases and also with information/knowledge about the location of consumers and distributed prosumer sources feeding into the GIS system (full information about MV and LV networks, in terms of topological data and technical parameters of infrastructure elements).

In this case, it was proposed to implement or expand an IT system of the GIS type, containing information on MV and LV networks in terms of topological data and technical parameters of AMI infrastructure elements, as well as information on current parameters of supply, energy consumption on the part of heterogeneous electricity consumers (breakdown by tariff groups, or other payment models).

5. Conclusion

In this paper, the cognitive focus has been on two main aspects: 1) Identification of the information and knowledge that can be extracted from the bi-directional readings of electricity (high frequency) in AMI systems, necessary to manage the value of energy both on the supplier side and, above all, on the consumer/prosumer side; 2) Identification of key decision-making processes, fed by the identified information/knowledge. Processes that make energy value management effective, both on the supplier side but also on the consumer/household side, frequently the energy prosumer (micro RES production). It was reasoned that the analytics of the large metering data sets acquired in the distributed AMI infrastructure, provide a knowledge stream for, among other things: 1) the creation of tailored electricity supply portfolios, in the context of the real needs of households; 2) the scheduling and organisation of bi-directional electricity transmission and value-created information; 3) the creation of new services for heterogeneous electricity consumers; 4) the management of electricity grid stability on the part of the Operator; 5) real-time monitoring of commercial and technical losses and their elimination; 6) integration of smart meter applications with IoT applications - on the side of electricity consumers/prosumers - for the ongoing monitoring of electricity consumption and ongoing balancing of demand with energy produced, in households in micro RES. Referring to the future, managing knowledge aggregated in terms of knowledge and information identified in Table 1, has measurable value in the context of energy efficiency, energy security, energy conservation and also in the dimensions of sustainability and social responsibility. Future research directions will focus on defining IF-THEN learning rules that are digital representations of the six decision-making processes identified and highlighted in this paper. Learning rules relevant for machine learning.

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