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A Survey of Hydrogen Energy and I-Energy Applications: Household Intelligent Electrical Power Systems

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ABSTRACT I-energy and its applications used in the smart grid are chosen as attractive research issues due to their widespread applications in the smart home. In this vein, the optimization of energy demand in smart home appliances, in a smart grid, is considered the main challenge faced by power companies during peak periods regarding its considerable effect on the global power system stabilities. Therefore, this paper aims to show explicitly the performance of smart grid on electricity and hydrogen applications with reused communication methods. To facilitate the understanding of the communication-reused methods in the smart grid, several components are identified and presented in terms of improvements, benefits and lack of features. In the smart grid, most innovation communications are being used as wireline and wireless bundle, where the main features are aggregated. Indeed, reducing consumers' electricity bills in smart home electrical systems relies on increasing the relationship between the highest energy demand and annual energy use. The most appropriate research has been reviewed on optimization approaches discussing the smart home electric system. The examined methods are categorized into trustworthy and metaheuristic algorithms.

INDEX TERMS Smart home, I-energy concept, hydrogen-renewable energy system, smart meter, smart grid, risk management, demand-side management, AMI.

I. INTRODUCTION

Nowadays, industry, technologies, and energy demands have mainly developed in several stations. Traditional demand for non-renewable electricity has increased despite environmental pollution. A random increase in energy consumption from non-renewable resources has become a concern [1]. An intensive power and energy management plan for both connected network modes and the island, have been discussed [2]. Therefore, renewable energy sources have been considered as a potential solution for solving energy consumption and minimizing environmental concerns. Many industries and laboratories have been included for this purpose. Renewable energies have become the focus of attention of all countries, manufacturers, and researchers. A precise way to balance the power load of built-in AC-DC devices based on modified homogeneous control applications. The grid-connected hybrid microgrid is a noticeable pattern containing both AC and DC microgrid. [3]. For example, a comprehensive analysis of renewable energy systems has been addressed using technology, economic and environmental factors variables [4]. The relationship between trade openness and renewable and non-renewable energy consumption for the best-emerging countries has been investigated in 35 years [5]. However, the all-renewable energy sources depends on temperature, weather conditions, which are unstable [6]. Thus, hydrogen energy was selected as an attractive renewable source with widespread interest. In addition to the energy potential, hydrogen has been chosen as the efficient storage energy that allows hydrogen batteries to use a regenerative hydrogen fuel cell [7]. An Accurate Hybrid Residential PV-Wind System Power was designed and implemented with management with battery storage. The proposed energy management proves the efficiency and stability of the proposed system [8]. A Hydrogen-Renewable Energy System (H-RnES) has been developed and is here presented [9]. The proposed system aimed to combine solar energy and the fuel cell system to ensure electrical, cooling and thermal demand.

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Real-time load scheduling, power storage control, and comfort grid management are suggested to provide the required energy for buildings during peak periods [10]. The same configuration was presented in [11]. The obtained results proved the effectiveness of the proposed system. A two-stage optimization method for optimized distributed generation (DG) is discussed in [12]. A distributed Hydrogen-Renewable Energy System (H-RnES) combining photovoltaic with Hybrid Supercapacitor/Undersea Energy Storage System was proposed. The presented system was modeled Grid using a Wave Energy Conversion System [13]. The obtained results proved away towards the high efficiency of the use of the solar spectrum [14]. Hydrogen-Renewable Energy System (H-RnES) is developed to guarantee the maximum energy generated with a minimum capital investment [15]. A Socio-techno-economic design of hybrid renewable energy system using optimization techniques was proposed [16]. An ideal new scheduling model based on Prospecting programming has been proposed to reduce the energy overheads [17].

The aim of the proposed model is to reduce the low cost of electricity generation, and simulation results show that the method demonstrates the flexibility of the designed model and can be considered an essential means of increasing renewable energy consumption. In this vein, I-Energy concept was proposed to control and manage smartly the energy demand and supply within Hydrogen-Renewable Energy System (H-RnESs) [18]. Indeed, the I-Energy concept presents several advantages. It aimed to reduce the carbon dioxide emissions [19]. It can be integrated into various environments like factories, offices, etc. It makes it possible to manage an electrical grid with an information network. A household energy management system was implemented and processed using a predictive control model in [20]. A comprehensive review of studies on hydrogen energy was presented in [21].

The proposed review tends to provide an in-depth introduction to current research, such as electrical energy determination devices, energy consumption models, greenhouse gas interpretation, etc. Some treatments have been provided to address issues related to the smart home electricity system. A bi-directional communication model based on cyber network can be integrated. However, the electricity consumption in the cloud can be sated with electricity sensors and the use of electricity can be managed through a central processor [22]. An autonomous hybrid system for the PV / grid system is proposed. The presented design combined the photoelectric system with a super fuel cell/capacitor battery using a correlating economic technical analysis method [23].

Several Smart Home Electric Systems were developed and tested via various scenarios. For example, a SHES has been developed using Internet of Things (IoT). To analyze and extract electricity consumption patterns from electricity data, a service-oriented architecture (SOA) approach has been proposed, A hybrid system (solar energy/fuel cell) connected to the grid using the ABC-PSO algorithm was developed. The obtained results prove its reliability and efficiency [24].

A SHES was developed and designed with integrating an advanced technology such as sensors, monitors, interfaces, devices, etc. Indeed, the proposed system is integrated with a variety of sensor nodes, which can ensure effective communication, electricity use conversions and record Real-Time electrical appliances. SHES is chosen as an intuitive and convenient strategy to provide suitable operating conditions for electrical appliances with great precision [25]. A secure data uploading Protocol was proposed and implemented to ensure the demonstration of efficiency and safety in light of expected critical constraints [26]. An accurate SHES management approach was developed. To predict and schedule the energy demand and supply during the peak periods. Several scenarios related to electrical power demand and supply models were discussed and verified [27]. A smart home energy management system has been implemented [28]. An intelligent load management system designed and implemented as the main source for smart homes [29]. In this vein, several technologies have been combined to coordinate household appliances and control energy demand during peak periods. Whereas optimal scheduling load was directed for an isolated Microgrid in [30].

The chosen design included advanced technologies like Wireless-Communication-Technologies (WCT) and Personal-Area-Networks (PAN) to control the home devices. SHES should collaborate with many technologies and can support many networks like WAN, Neighborhood Area Network (NAN) and Home Area Network (HAN). A Load Schedulin-Home Energy Management System was developed using Fuzzy Logic [31]. To establish communication between home appliances, a Uniform-Communication-Standard (UCS) should exist. The UCS was selected to ensure efficient communication and allow a secure network A hybrid (photovoltaic-battery) has been developed for Home energy management [32].

As well, SGs were considered a highly anticipated technology that aims to provide sustainable energy infrastructure using bi-directional data flow and electricity enabled by advanced information, communication and control infrastructure. Smart consumers (who are often called ''Prosumers'') who generate and share extra energy with the network and other users are the most important basic components and parts of SGs [33].

Consequently, prosumers not only become an investor in prospective smart grids but also play an important role in controlling peak demand. Therefore, it is important to evaluate and examine the database management structure. Prosumer is a model that attempts to include common platforms to coordinate the distribution of energy and information within the neighborhood or to interact with external energy organizations as a whole [34].

The objective of this paper is to ensure a comprehensive review of best practices linked to common technical challenges across the breadth of that involves a smart grid. A summarize of I-energy and communications will be presented [35]. Previous trends to research on smart meters,

TABLE 1. List of acronyms.

H-RnES	Hydrogen-Renewable Energy System	ROAs	Reliable Optimization algorithms
PV	Photovoltaic	ILP	Integer-Linear-Programming
CPV	Converter Photovoltaic	MILP	Mixed Integer Linear Programming
FC	Fuel Cell	BFOA	Bacterial Foraging Optimization Algorithm
SHES	Smart Home Electric System	PSO	Particle Swarm Optimization
IoT	Internet of Things	ACO	Ant Colony Optimization
WCT	Wireless-Communication-Technologies	WDO	Wind Driven Optimization
PAN	Personal-Area-Network	SGTD	Smart Grid Transmission Domain
WAN	Wide-Area-Network	SGMD	Smart Grid Markets Domain
HAN	Home Area Network	SGUD	Smart Grid Utility Domain
UCS	Uniform-Communication-Standard	SGDD	Smart Grid Distribution Domain
I-Energy	Integrated-Energy	SGBGD	Smart Grid Bulk Generation Domain
SG	Smart Grid	SGCD	Smart Grid Consumer Domain
SM	Smart Meter	SGOD	Smart Grid Operation Domain
SMCS	Smart Meter Compression System	PLCT	Power Line : Communication and Technology
DSM	Demand-side Management	PLPD	Power line Problems Detections
DR	Demand Response	PLM	Power Line Monitoring
SSM	Supply Side Management	ACP	Active Consumer Participation
SGSH	SGs-Self-Healing	PLRR	Power Line Restoration Reliability
SGSM	SG Self-Monitoring	PLG	Power Line Generation
AP	Access Point	HEMS	Home Energy Management System
NIST	National Institute of Standards and Technology	AWT	Average Waiting Time
AOM	Approximate Optimization Method	UC	User Comfort
GA	Genetic Algorithm	AMI	Advanced Metering Infrastructure
TSA	Tabu Search Algorithm	AMR	Automatic Meter Reading
KPMM	Knowledge Project Management Manual	GUI	Graphical User Interface
RAMM	Risk Analysis and Management Manual	SMDMS	SM Data Management Systems
MRM/IT	Manual on Risk Management for IT systems	PSP	Power Scheduling Problem
IEEE/EIA	Institute of Electrical and Electronics Engineers and the Electronic Industries Association	ROM	Reliable Optimization Method
NIST	National Institute of Standards and Technology	SOA	service-oriented architecture
PE	Power Equipment	EV	Electric Vehicle
RMC	Release Message Contents	ATP	Analysis of Traffic Packets
RDS	Reply on Data Stream	MITM	Man in the Middle
MDG	Malware Data Gathering	MGBJ	Micro-Grid-Based-Jamming
RIA	Routing Internet Applications	SM-DoS	Smart Meter DoS
CCL	Cutting in Communication Line	SMDS	Salami Minor Data Security
CDD	Changing Data Diddling	TEN	Trust Exploits on Network
PUA	Password User Account	SHC	Session Hijacking on Computer
MFA	Message Forgery Attacks	SPS	Service Provider Spoofing
SMS	Smart Meter Spoofing	HDS	Household device spoofing
PPS	Power Plant Spoofing	AAG	Autonomous Agents
RID	Risk identification	RAN	Risk Analysis
REV	Risk Evaluation	RTR	Risk Treatment
MMLC	Modular Multi-Level Converters	TG	Traditional Grid
DNNM	Deep Neural Network Model	MDC	Measurement Data Collection center
SMSVD	SM Singular Value Decomposition	SMSAA	SM Symbolic Aggregations Approximations
SMWT	SM Wavlet Transform	SMSC	SM Sparce Coding
SMPCA	SM Principal Component Analysis		

smart home and linked services, and smart home electrical system will be explored. Smart metering systems related to connectivity problems are widely discussed in their hardware and smart software applications [36].

The rest of this paper is summarized as follows. We present the concepts and applications for I-Energy in recent years in the research status and analysis section. In section Smart grid concept and benefits, we summarize existing issues including operational and smart grid benefits. In section smart home electrical system, we summarize Smart Home neighborhood energy management and adapted technologies. In the section discussing, we summarize a comprehensive summary of smart grid issues and the scheduling of smart home appliances operations. We conclude the paper in the conclusions section. The nomenclature in this paper is detailed in Table 1.

II. RESEARCH ANALYSIS

A. PROSUMER BASED ENERGY MANAGEMENT AND SHARING IN SMART GRID

I-Energy concept is an integrated model that identifies both the electrical and information networks. Each house or group of houses is equipped with solar cells or other type of renewable electricity, while ectricity is bought and sold from a central electricity supplier, depending on the Internet and

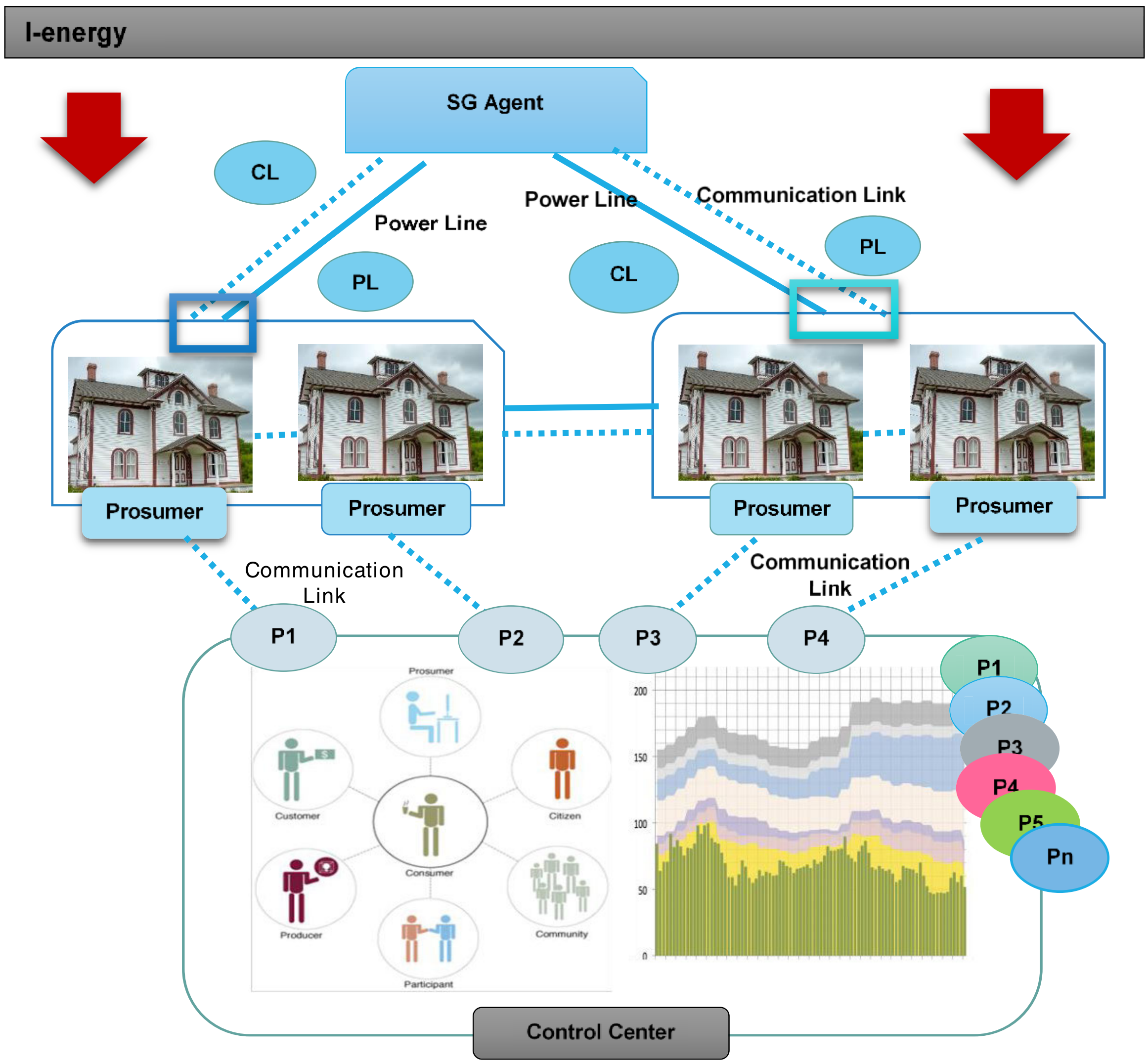

FIGURE 1. Power-sharing focused on the prosumer.

advanced sensors [37]. Electrical sensors are employed to analyze and transfer electricity consumption to the cloud [38]. After analysis of production and consumption, the central cloud processor monitors electricity use Smart Home Electric System (SHES), which combines hydrogen with I-Energy (see Fig. 1) as an attractive solutions to solve the energy demand and storage during the peak periods [39].

The traditional business infrastructure model depends on the relationship between distribution and transportation, but the consumer is not involved. The various specifications on the power grid facilitate efficient customer engagement, such as the newly proposed Smart Grid (SG) [40].

The latter was chosen as the advanced energy infrastructure with interconnected communications infrastructure to allow energy and information to be a bidirectional relay. The idea is used globally with the active involvement of customers to achieve the purpose of stable and sustainable economic supply. In this context, the concept of lateral demand management was used to interact with Metering Infrastructure users and utilities with a home energy management system to provide consumers with information about consumption and energy demand along with pricing and incentives [41].

In fact, Prosumers are sharing the excess energy generated by renewables with the network or other social investors. This trend helps solve environmental, economic and social concerns arising from the increasing demand for energy. SG encourages stakeholders to create communities according to different rules, including energy use habits, to manage needs within energy sharing infrastructure [42].

B. SMART GRID AUTONOMOUS AGENTS

In general, the agent is considered as a default entity due to its ability to collect information from an environment and to create the results that it starts working on. Autonomous Agents (AAG) are mathematical entities that inhabit and operate independently in some complex dynamic environments and thus fulfill the purposes of their activities. In fact,

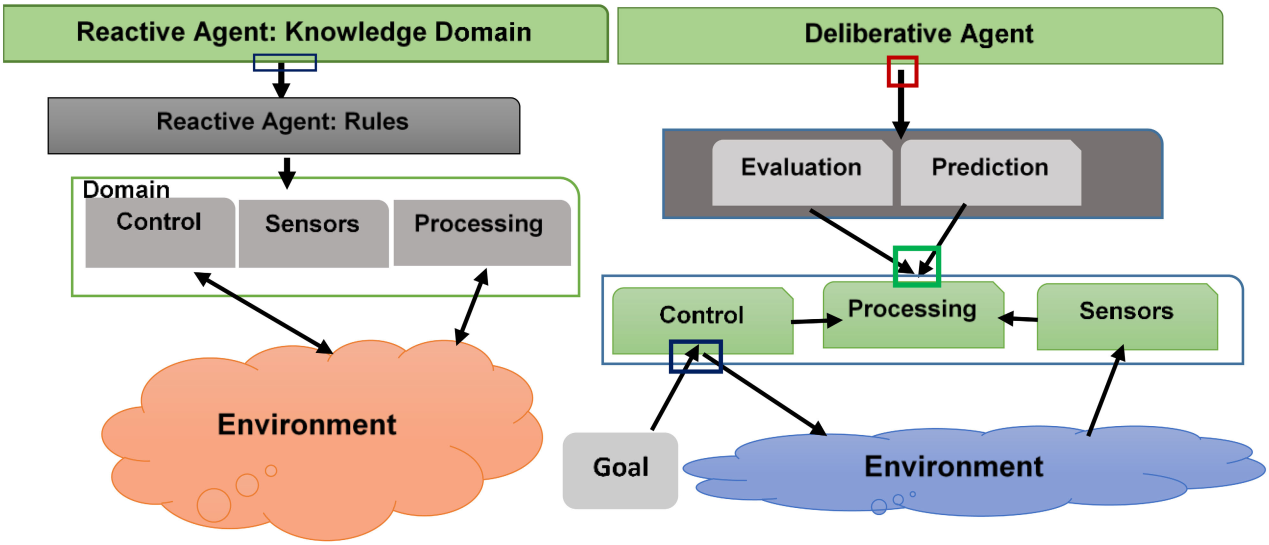

FIGURE 2. Reactive and deliberative agents.

TABLE 2. Properties of agents.

Agent properties	Others abbreviations	Features
Mobile Agents (**MAs**)	Mobile-Code Agent	MAs have been used in network security and data management applications
Autonomous Agents (**AAs**)	Stand-alone Agents, intelligent agent	AAs adjust a part of the system or its state
Reactive Agents (**RAs**)	Acting, Sensing or Reflex	RAs aims to classify procedures in difficult situations when working properly as a central power system
Communicative Agent (**CAs**)	Socially Intelligent Agents	CA aims to communicate with people and demonstrate aspects of human social intelligence, robotics, or computer systems.
Learning Agents (**LAs**)	Adaptive Agents	ADAs aims to react immediately to a complicated situation. Its changes his attitudes based on previous experience
Goal-oriented Agents (**GOAs**)	Purposeful Autonomous Agents	GOA agents do not easily respond to their environment and have rather complex characteristics

physical and virtual entities can also be combined to create an agent [43]. If the agent is already dealing with environmental changes in a timely manner and translating his sensory information into a smart process, then this agent is known as the interactive/reactive agent.

Reactive agents commonly do not sustain the sensory perceptions of the agent and do not predict the consequence of the actions. When the agent predicts the consequences of the actions, it cannot be considered reactive (so the reactive agent can maintain its continuous state as well [44].

Alternatively, if an agent maintains a standing state that you usually expect or engage in some kind of thinking, then it has purposefully acted and has been designated as a deliberative agent (see Fig. 2). AAG are seen as a potential solution in SGs because of their ability to handle and maintain activities in difficult situations when working properly as a central control system [45].

AAG can precisely recognize disturbances, restore energy, handle backup electricity and properly interpret the state of the electrical system. It would be better to have a hierarchy if the final control structure is converted into a multi-agent system (MAS) where agents and sub-agents are considered to be separate entities. Basically, the SG model can estimate the dynamic effect of virtual communication [46].

Two interpretations of an agent are generally accepted by different research groups and closer to visualizing agents by people in energy engineering. An agent is anything that can be seen by sensors and sensor arrays as a perception of their environment. Physical entities, in the case of the power system, can be considered a simple privacy agent, a sequence, or any controller that specifically controls a specific component or part of the power system [47]. Separate agent concepts provide a set of agent properties, and agents are usually categorized based on those properties (see Table 2).

C. SMART GRID MULTI-AGENT SYSTEMS

A SG multi-agent system appears to be a service associated with entities (agents) that work to address problems that go beyond the individual skills or knowledge of each entity. The assumption that MAS collaborate indicates a specific form

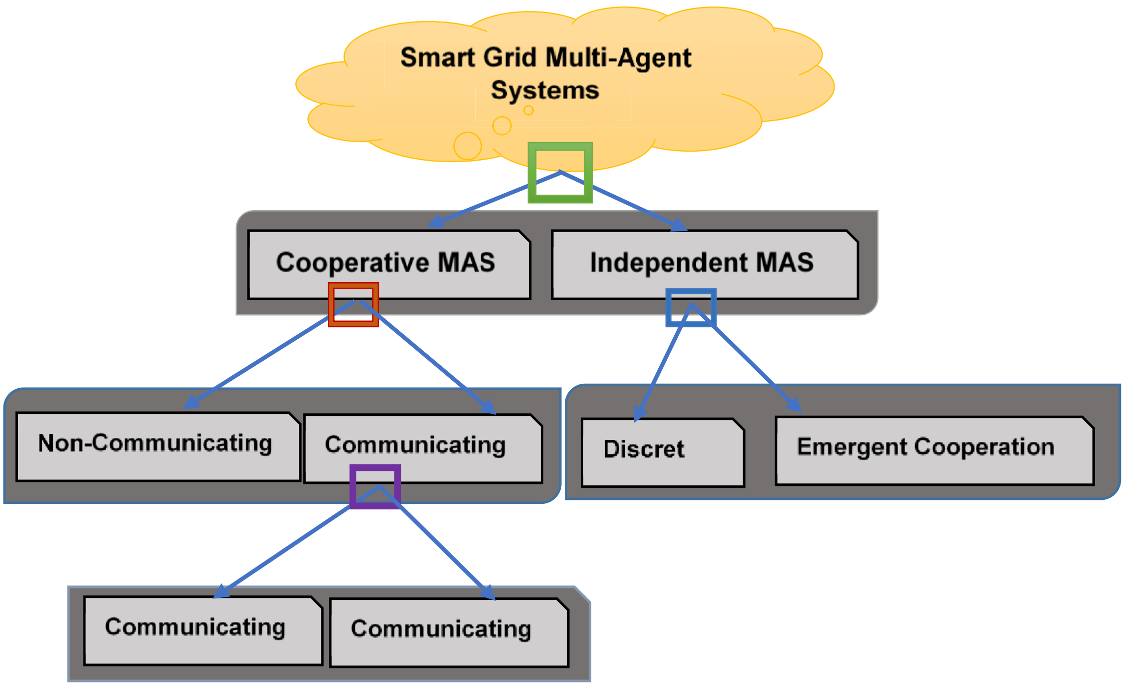

FIGURE 3. Smart grid MAS hierarchical.

of coordination between various autonomous agents. The concept of collaboration in MAS is still complex, and at worst it is very inconsistent, so definitions, potential assignments, etc [48] are more difficult, making it difficult for agents to try to implement MAS. The collaborative model looks better, and this is the standard for MAS classification (see Fig. 3). Each Agent aims to fulfill his own ambitions separately from others. If agent targets are separate and not related to each other, MAS is completely separate [49]. Discreet MAS requires no interaction. Agents can collaborate without intention, and cooperation develops where this is the exception. Depending on the required specifications, the agent developer enters several habits for the agent to achieve collaboration. Indeed, individual agents learn to cooperate with other agents [50].

The benefits of smart grid MAS are durability and scalability. Durability provides how to appropriately control and comply with dealerships within MAS, in which case the system can handle one or more agent's errors. MAS scalability is based on its modules. Developing new agents in MAS should be easier than adding new capabilities to the hierarchical system [51].

III. SMART GRID ENERGY CONSUMPTION

A. SGs BENEFITS

SG combines electrical infrastructure and digital technologies that analyze and transmit information quickly and efficiently. Digital technologies target production, transmission, distribution and consumption that connected to Weak AC have been handled using Modular Multi-Level Converters (MMLC) [52]. Traditional Grid (TG) is a one-way link but a two-way digital interaction is used in the smart grid. In fact, TG requires a central generator while SG uses a distributed system. There are limited sensors in TG while the knowledge system is always equipped with sensors.

The traditional concept was defined as a system that supports various electrical operations, that mainly depends on the distribution and generation of electricity and includes a transmission and control process [53]. Smart Grid (SG) is defined as an adaptive and predictable solution for grid and customers issues. For example, the real-time digital harmonic estimator for future Microgrids Converters is handled in [54]. Indeed, SG is a flexible and sustainable digital system. SG has proven to provide two-way communication between energy suppliers and SHES users. Energy supplier companies employ SG to achieve high-quality energy delivery while meeting diverse power requirements for the benefit of users (see Table 3).

SG functions are cited as follows:

(1) Real-time flow control: Network-installed sensors instantly indicate electrical flows and consumption levels. Network operators can direct energy flow on demand and send price signals to individuals to adapt their consumers (voluntarily or automatically).
Grid interoperability: The entire electricity network includes the transmission network and the distribution network. The transmission network connects the electricity production sites with the consumption areas. The distribution network directs electricity to the end consumers. The smart grid aims to exchange data in real-time over cognitive radio networks [61]. SGs tend to improve the interoperability between the transport system and distribution system operators respectively.

TABLE 3. Comparison between traditional grids and SGs.

Characteristics	Traditional Grids (TG)	Smart Grids (SGs)	References
Power Line : Communication and Technology (PLCT)	▪ Without communication process ▪ One-way communication between provider and consumers.	▪ Two-way communication ▪ A Digital technology was applied. Two-way communication	[55]
Power line Problems Detections (PLPD)	▪ Some sensors was used in the line power. ▪ Difficult to detect the problem's locations.	▪ Several sensors have been inserted to control the power line.	[56]
Power Line Monitoring (PLM)	▪ The power line is controlled manually	▪ Autonomous (Dynamically)	[57]
Active Consumer Participation (ACP)	▪ Uninformed Consumers ▪ Power quality is slow	▪ Quick solution to energy quality problems as a priority. ▪ Consumers are involved in energy issues. ▪ Consumers are actively involved and familiar with it.	[58]
Power Line Restoration Reliability (PLRR)	▪ An urgent need for technicians to repair the PLRR.	▪ Self-management ▪ All problems are quickly fixed without technical intervention. ▪ SG always report technical problems.	[59]
Power Line Generation (PLG)	▪ Centralized generation ▪ Power is distributed from the main power plants to consumers	▪ Distributed generation ▪ Power is distributed from the several power plants to consumers	[60]

(2) Integration of renewable energies in Grid: The production and consumption levels can be predicted in the short and long term due to a sophisticated information system. Renewable energies can be included and depend on the sun and the wind using an adaptive control approach to enhance the stability of SG [62].

(3) Individual consumption management: Advanced smart meters are the first versions of smart grid applications. It is installed with consumers and provides information on prices, peak hours of consumption, as well as the quality and level of electricity consumption at home [63]. Consumers can regulate their consumption during the day themselves. Network operators can detect defects more quickly.

SGs carry many advantages in advanced distribution networks. It aims to change the modern society lifestyle, address all problems and create an evolving environment between providers and consumers. SGs address shortcomings in old electrical networks [64]. The SGs benefits are given as follows:

(1) Improve the power quality and electrical power system reliabilities.
(2) Enhance the electric power system efficiency and capacity respectively.
(3) Reducing the total cost of energy-saving for users
(4) Reduce fossil fuel consumption
(5) Improved communication between providers and consumers
(6) Enabling new energy sources to reduce carbon emissions levels

Applying advanced methods to reducing the consumer electricity bills. SGs improve system efficiency and meet the customers' energy requirements. Indeed, it has advanced features that help it to improve energy demand [65]. SGs features are formulated in the sub-sections below.

B. SGS ARCHITECTURE

The NIST (National Institute of Standards and Technology) is one of the most important references to be considered in all areas, due to its rich content that includes many actors and applications [66]. Actors include several advanced hardware, computer systems, and software. Drafting decisions and exchanging information with real-time actors is done through actors and massages through network interfaces. Either request is implemented through one representative or a number of actors. The communication actors have similar objectives, necessities and characteristics within the same domain. Communications may have similar necessities and characteristics [67]. Domains may contain other domains. The communications between domain and system was ensured using Access Point (AP) interfaces. There are both connections and electrical interfaces like two-way

TABLE 4. SG domains.

SG Domains	Actors functions
Transmission Domain (**SGTD**)	**SGTD** Actor allows to transfer energy demand over long distance
SG Markets Domain (**SGMD**)	**SGMD** Actor is considered as an operators exchange
SG Utility Domain (**SGUD**)	**SGUD** Actor is aimed to provide service to the consumer
SG Distribution Domain (**SGDD**)	**SGDD** Actor was include to distribute energy demand to consumer
SG Bulk Generation Domain **(SGBGD)**	**SGBGD** Actor was used to store the energy for long time for future use
SG Consumer Domain (**SGCD**)	**SGCD** Actor is applied to store and manage the energy demand
SG Operation Domain (**SGOD**)	**SGOD** Actor represented the Managers in the electricity movement

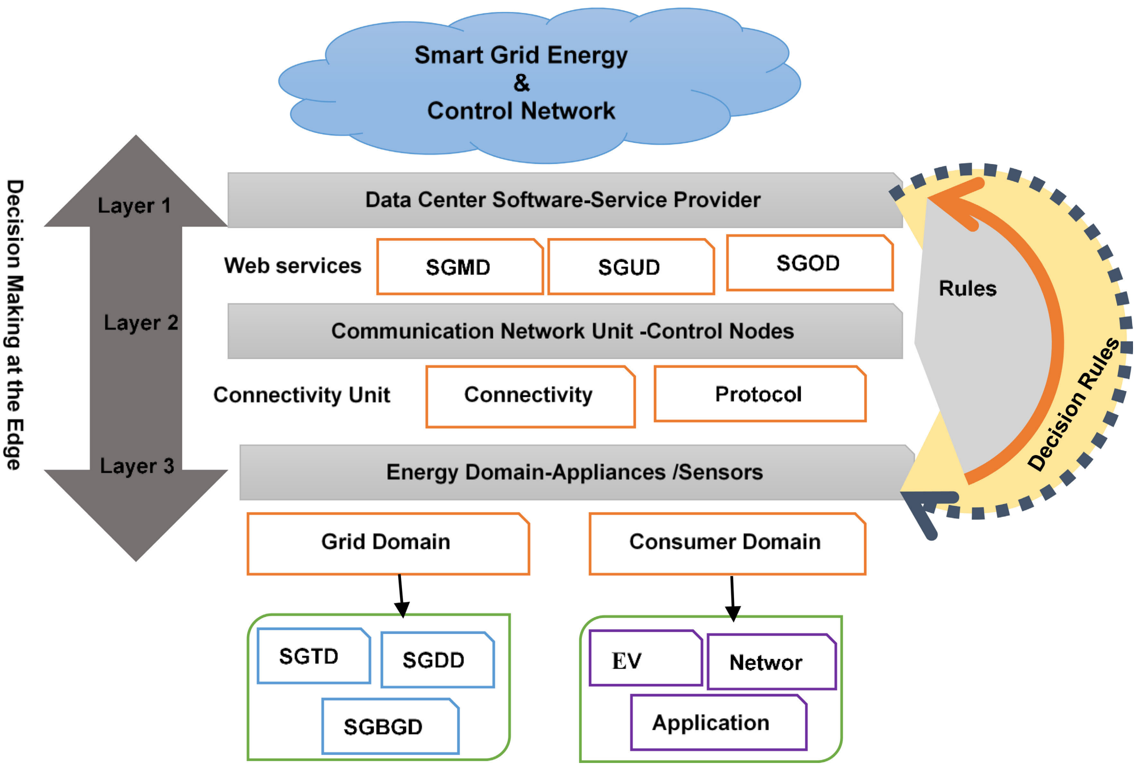

FIGURE 4. SG energy control network.

communication interfaces and the entry point for access domain. A Bluetooth Robotization technology was included in smart home in [68].

It represents logical communication rather than physical communication. It represents logical communication rather than physical communication. The Smart Grid domains are briefly described in Table 4. To avoid poor service, the real smart grid creates an intelligent power grid to detect the early processing of energy generation issues. The included system will be able to respond to local inputs, provide integrated reports on system problems, and then respond promptly in real-time to occurred issues (see Fig. 4).

SMs functions provide the way for an advanced "grid" system that provides enhanced capabilities including bi-directional interactions and smart grid applications according 3 layers (Data Center Software; Control Nodes; Appliances /Sensors). It can also interact with specific and system inputs, provide greater feedback on wider system problems, most notably the quick response to the problems that have occurred.

C. INTEGRATION OF DISTRIBUTED GENERATION/WWWWW/AUTOMATION

During peak periods, distributed generation systems remain balanced and power plants are controlled using renewable energy. The distribution automation is included to be a system that helps to detect the early errors and recover energy after disconnecting from control centers (such as Self-Healing Metallic Materials and Self-Healing Metal Matrix Composites) [69].

D. SG ENERGY STORAGE DEVICES

Storage devices in SG devices are included to reduce pressure on systems distributed during peak periods by storing energy during off-peak periods and after that, the energy stored during peak periods is used. Since RES is inconsistent, and there is no match between peak consumption and peak availability, it is important to find ways to store energy for future use and extension of distribution transformer life using Volt-VAr [70]. The storage component improves the reliability and flexibility of utility networks and electrical consumers.

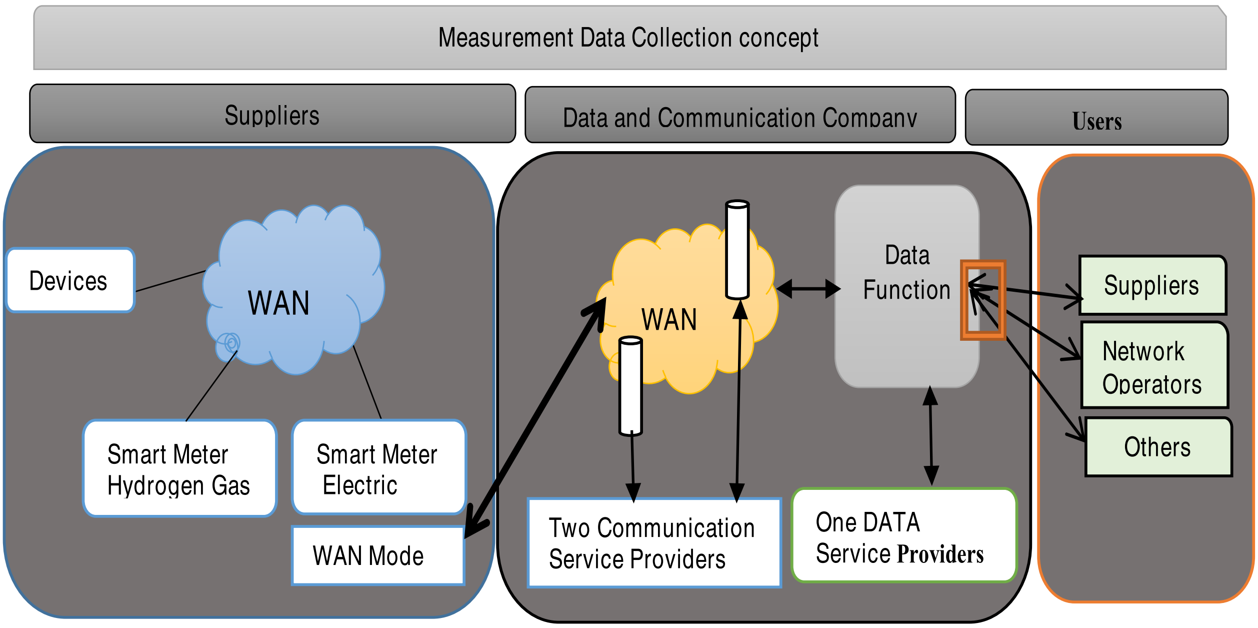

FIGURE 5. End to end smart metering scheme.

Energy storage technologies include flow batteries, Super-Capacitors, etc.

E. BI-DIRECTIONAL COMMUNICATION AND SELFHEALING/WWWWW/MONITORING

To communicate between providers (PSCs) and customers, two-way communication are proposed [71].

--Send power flow

--Receive Data control and feedback report.

SG-Self-Healing (SGSH) aimed to repair issues without technician intervention. Indeed, SGSH provide in real time issues full report to technicians. While, SG Self-Monitoring (SGSM) aimed to monitor and control automatically the distribution power systems without technician intervention using Multiple Sensors. The sensors is equipped with a power line, which used to solve the problem's location with bi -directional influence [72].

F. SMART METERING

1) CONCEPT

Smart Meters (SMs) are chosen as potential devices in SGs. In this context, SM is a smart device that aims to measure smartly the energy consumption and helps users to get a report about their energy consumption [73]. Smart Grid Data Measurement includes infrastructure for coordinating and storing data for AMI applications, including a database for calculating data from smart meters to a Measurement Data Collection center (MDC). Fig. 5 illustrates the complete communication, processing and storage architecture needed to validate the SM management scenario. SM includes valuable information that can be used to improve energy efficiency and gives SGs the ability to improve energy quality to solve issues related to smart home (like Uncontrolled adaptation for the purpose of predicting human movement) [74]. For example, SMs were used to predict electrical loads, the abnormal discovery of electrical power systems, etc. Predicting electrical loads provides a mathematical method for energy production and development of a system for controlling production and demand for electric energy, and it has great importance for economic and safe operation [75]. Predicting electrical load is divided into several sections, long-term forecasting, medium-term load prediction, and short-term forecasting. The forecast includes annual, monthly, and hourly forecasts. Several prediction methods have been used, such as regression analysis, exponential homogeneity, and weighted frequency [76]. In fact, many advanced algorithms have been implemented to predict electrical loads like a Deep Neural Network Model (DNNM) and genetic analysis. High-dimensional smart meters provide many accumulated correct evidence [77]. It is very difficult to directly predict electrical loads using smart meters. Some problems were recorded in aggregation, such as high-dimensional data. Big data compression was used as an important solution to reduce the dimensions.

2) DATA COMPRESSION METHODS FOR SMART METER BIG DATA

Smart meters collect information about the electricity consumption used in real-time. Large amounts of data are sent over Gateway for Smart Home Sensor Network Management [78]. Companies can accurately forecast customers' electrical load. According to the analysis information step, it is possible to reach anomalies and failures in a timely manner quickly (Fig. 6a). Big data SM remains a heavy burden on transmission lines and data storage centers, so it is necessary to compress SM big data [79]. SM Compression

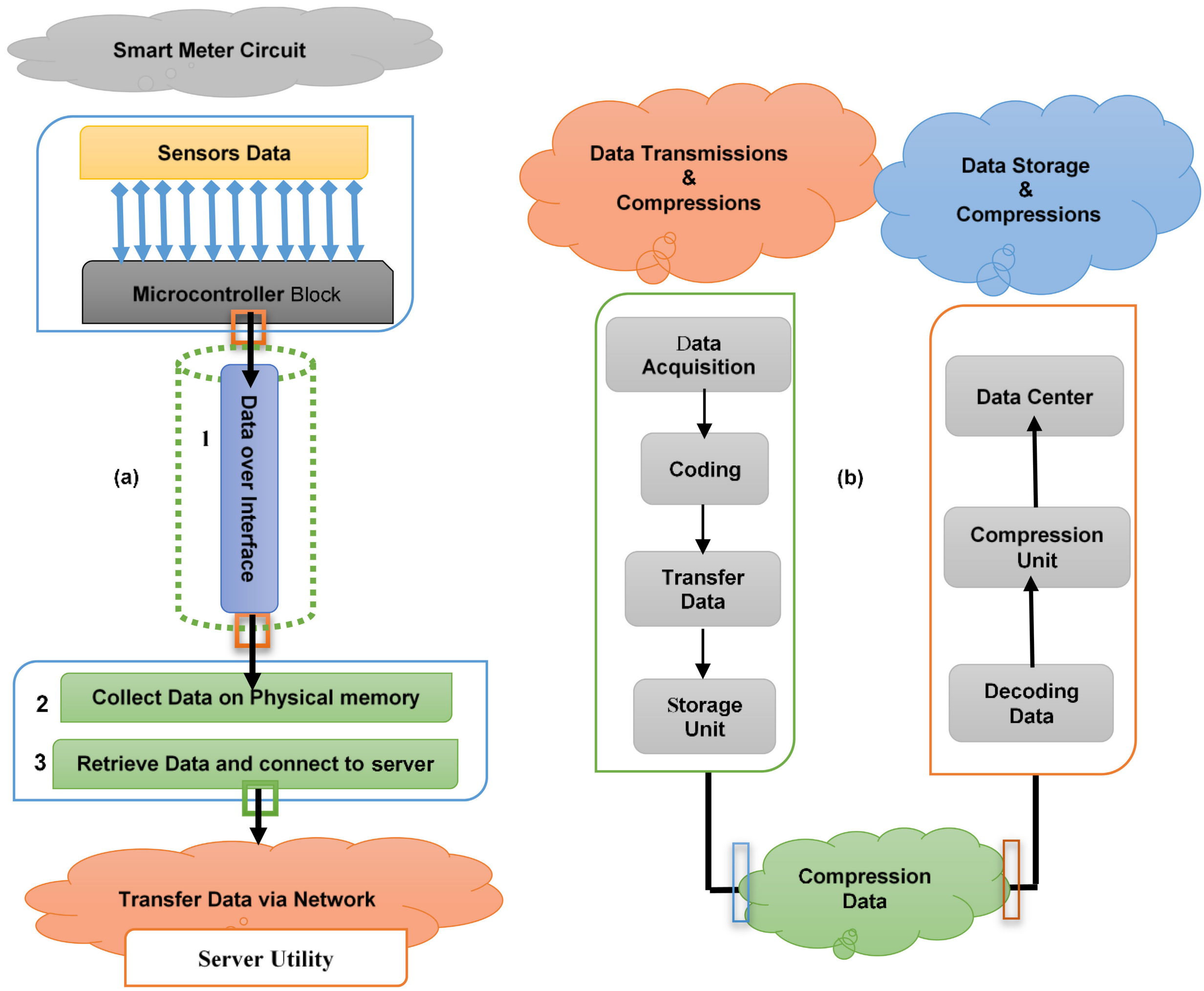

FIGURE 6. Smart meter unit: (a) SM architecture; (b) SM Compression system (SMCS).

System (SMCS) was included to compress the data and keeps the most valuable data using several methods (Fig. 6b).

SMs is considered as a wide field in the search for compression methods. There are three requirements to distinguish between these compression methods:

- -Real-Time compressiom;
- -Static Data Compression;
- -lossy compression.

The lossy compression condenses data once a section of the data is sacrificed, but optimally prevents the most vital information in the original information.

To compress the collected data, several methods are used. The methods used aim to reduce the load on SM data transmission lines (see Table 5). The proposed methods are listed as follows:

- -SM Singular Value Decomposition (**SMSVD**)
- -SM Symbolic Aggregations Approximations(**SMSAA**)
- -SM Wavlet Transform (**SMWT**)
- -SM Sparce Coding (**SMSC**)
- -SM Principal Component Analysis (**SMPCA**)

G. DEMAND-SIDE MANAGEMENT (DSM)

Electricity companies encourage their users to manage electrical energy consumption and guide them on how to reduce energy consumption during peak periods using a SM [85]. DSM allows its customers to convert their peak load consumption during peak times to settle their consumption using Demand Response (DR) program [86]. DR program is chosen as an efficient method to provide a dynamic pricing scheme or other incentive plans (see Fig. 7). DSM aimed to effectively monitor electricity production and combat energy shortages, using two methods which are Supply Side Management (SSM) (by increasing production) and Demand side management (DSM) (saving energy). SSM aims to increase production, develop the transportation and distribution system and establish advanced new power plants. DSM is considered as a process to connect supply and demand with advanced types of energy-saving equipment An accurate real-time DSM was proposed for energy management system [87].

The maximum power can be reached by using unnecessary loads during peak hours with the use of time pricing (TOU).

TABLE 5. SMCS methods.

SMCS methods	Characteristics	Application in SM	References
SMSVD	▪ SMSVD is a valuable technique of matrix decomposition based on linear algebra and is an extension of matrix analysis of standardized matrix unit diagonalization. ▪ SMSVD has been implemented efficiently in the processing of images and other areas of data compression. ▪ Example : an Energy Efficient GNSS Signal Acquisition Using SVD was used efficiently to compress Data	▪ SMSVD has been commonly used in Image-Compression(IC). ▪ It's not applied until now in SMs, but big data compression	[80]
SMSAX	▪ SAX is an effective method aimed to reduce and compress data dimensions, in particular for managing time series data with a limited lower Gaussian distance. ▪ It was used to discrete the dataset conceptual strings. ▪ SMSAX method allows for more complex partitioning during heavy-load variations occur.	▪ SMSAX can substantially reduce information size and is widely used in SMs Big Data damage compression.	[81]
SMWT	▪ SMWT was selected to find time-frequency data and interpret signals by extending and translating. ▪ SMWT was considered as a new transformation method, analysis and adopts the idea of change at the local level of the FOT short-term. ▪ Onset detection using SMPCA is used efficiency in image processing	▪ SMWT is used in SMs. ▪ SMWT was used not only to decrease the load on a SM data transmission lines, but was chosen as a remote relay protector.	[82]
SMSC	▪ SMSC is commonly included in image processing and semantic identification as a tool for data compression and extraction of information. ▪ SMSC was considered as an artificial neural network system	▪ SMSC is used in SMs. ▪ SMSC used to compress the Big Data	[83]
SMPCA	▪ For statistical analysis, SMPCA has been widely used. ▪ It is a statistical multivariate approach used to analyze and study relationships between multiple variables. ▪ PCA is often called a linear dimension reduction system that employs as little variables as possible to maintain the original data characteristics. ▪ Convex Formulations for Fair Principal Component Analysis is used efficiently in image processing	▪ SMPCA is used in SMs. ▪ SMPCA was frequently used in data compression.	[84]

The latter is a dynamic pricing system that provides two different prices during the day and peak periods [88]. TOU provides three different prices, including both low and mid-peak and peak period prices. It is also used in scheduling smart home devices.

IV. SMART HOME ELECTRICAL SYSTEM

A. CONCEPT

Various statistics have shown that household electricity consumption exceeds 40% of total energy consumption, which is why the development of smart electricity can be considered an inmportant necessity [89]. To develop an intelligent network that meets consumer needs and is adapted to sudden changes, SHES becomes a prerequisite for the development of this modern network [90]. In this vein, several technologies will be included such as small energy distributors, EVS, energy storage units, etc. Energy suppliers face a major challenge in improving the quality of energy demand for smart home appliances to operate in natural conditions, especially during peak periods [91]. Energy Consumption of Consumer Home Automation System has been used using an accurate pricing schemes. The princing scheme aimed to provide different rates for the time horizon in which electricity prices rise during peak periods due to higher energy demand and lower during off-peak periods [92]. An open source smart home management system based on IOT is proposed designed to offer different tariffs during critical and regular periods [93]. SHES aims to reduce the users' electricity bill while maintaining the stability of the power system and improving the user's comfort level by reducing the device's standby time [94]. The concept of the Grid ranges from traditional to modern.

B. HOME ENERGY MANAGEMENT SYSTEM

SHES was chosen as an attractive technology due to its reliability to serve residents. SHES integrates residential homes with smart technology to provide the comfort of residents by enhancing safety and health care and improving energy consumption [95]. SHES (appliances) can be controlled and monitor remotely using an accurate Home Energy Management System (HEMS). To allow customers to efficiently control the energy demand, HEMS included a hardware and software units. The presented units aimed to control SHES appliances operation time. Several studies have discussed HEMS architectures benefits in terms of safety and healthcare. A real-time certification system for smart homes that use the Internet of Things has been addressed in [96].

Indeed, several prototypes is implemented to optimize power consumption and improve the power systems efficiencies. HEMS is used to monitor energy demand in

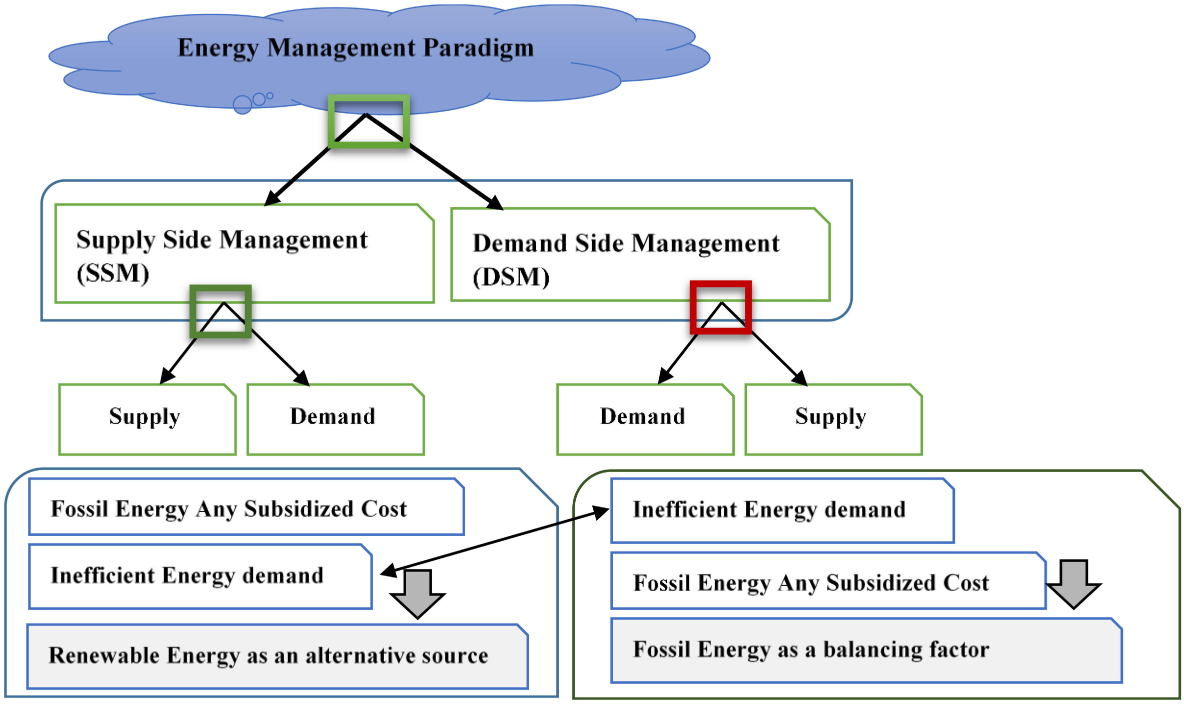

FIGURE 7. Demand side Management & Supply side management concept.

real-time using SM units. To limit Consumer electricity bills, HOME schedule power consumption, and household appliances. Various projects on SHESs have considered Home to home and vehicle to Home a novelty in a sophisticated home power system. For example, an Optimal Sizing Smart Home using Renewable Energy and Battery uas developed using Prosumer-Based Energy Management approach [97]. The Vehicle to home was chosen as an energy storage system in which the electric vehicle was used to provide electricity to the home during peak periods when demand is highest. A Predictive Control Model for Home Energy Management System is presented in [98]. Several real time SHESs platforms have been tested and developed, such as Sensor Technologies, Home Network technology and appliances. For example, a negotiated decision-making approach for a connected devices is proposed for smart home power management system [99]. However, the full potential of SHES is still present, due to the complexity and diversity of designs, as well as repeated supervisor approaches without the problem of optimal level. The SHESs Power scheduling problems are given by Fig. 8.

C. SHES SCHEDULING TIME HORIZON

The scheduling time horizon for household appliances is generally fragmented into an amount of times slots (see Fig. 9) [100]. This time is expressed by (1).

$$d_{SHES} = \frac{v(=60\,\text{min})}{s} \tag{1}$$

where, d_{SHES} represents the length of time slot and s represents the time slot per hour.

The time duration authorized for smart home equipment (E1,…., En) scheduled to be represented in (2):

$$D = [\, d_{SHES} - 1\ d_{SHES} - 2\ ..\ d_{SHES} - n\,] \tag{2}$$

The calculation of the consumed power by equipment during time slots is shown below in (3):

$$PE = \begin{bmatrix} PE_1^1 & PE_2^1 & PE_3^1 \ldots. & PE_n^1 \\ PE_1^2 & PE_2^2 & PE_3^2 & PE_n^2 \\ .. & .. & .. & .. \\ PE_1^n & PE_2^n & PE_3^n & PE_n^n \end{bmatrix} \tag{3}$$

where, PE represents the Power Equipment.

Devices in smart homes require Operation schedule time (SHES_OST) and Operation duration for activity (SHES_ODA). Where SHES_OST is scheduling time and SHES_ODA is scheduling time to complete the job cycle. Two distinctive vectors, starting and ending vectors (OSTs, OSTe, Notably, OSTsi < OSTei, ∀ i ∈ E), are included in SHES_ OST and expressed in (4).

$$\begin{cases} SHES\_OSTs_i = [OSTs_1\ OSTs_2 \ldots.\ OSTs_n\,] \\ SHES\_OSTe_i = [OSTe_1\ OSTe_2 \ldots.\ OSTe_n\,] \end{cases} \tag{4}$$

SHES_ODA is represented, as a vector that contains the ODA for each appliance; two distinctive vectors, starting and ending vectors (ODAs, ODAe) are included in SHES_ ODA and expressed in (5).

$$\begin{cases} SHES\_ODAs_i = [ODAs_1\ ODAs_2 \ldots.\ ODAs_n\,] \\ SHES\_ODAe_i = [ODAe_1\ ODAe_2 \ldots.\ ODAe_n\,] \end{cases} \tag{5}$$

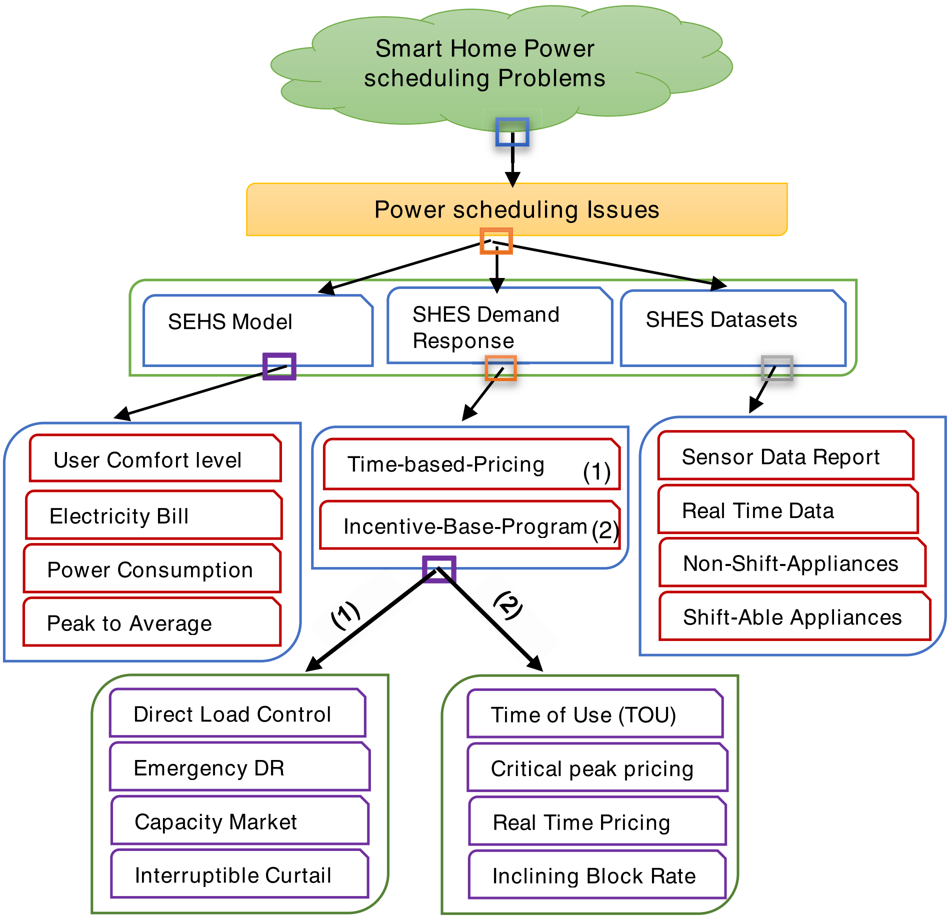

FIGURE 8. SHESs power scheduling problems.

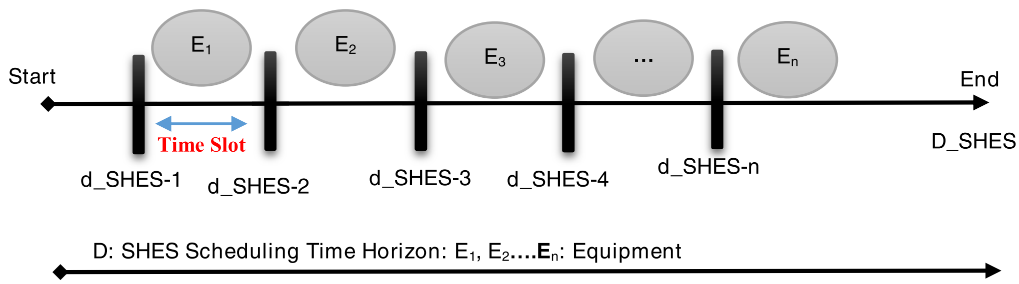

FIGURE 9. SHES scheduling time horizon [101].

The formula used to calculate EB by D_SHES is given by (6):

$$Cost\_SHES = \sum_{j=1}^{n}\sum_{i=1}^{m} p_i^j \times p\_co^j \tag{6}$$

In SHES, the maximum power consumption is identified as a Peak-to-Average Ratio (PAR) and given by (7).

$$\begin{cases} PAR\_SHES = \dfrac{P\_SHES_{\max}}{P\_SHES_{avg}} \\ P\_SHES_{avg} = \dfrac{\sum_{j=1}^{n} P^n}{n} \end{cases} \tag{7}$$

The primary goals of a smart home are improved User Comfort (UC) level. Based on the Average Waiting Time (AWT) for system operations, user satisfaction can be measured (see (8)). UC Decrease (AWT) can increase further because users usually choose to turn on their smart home devices automatically.

$$AWT_i = \frac{ODAs_i - OSTs_i}{ODAe_i - OSTe_i - l_i}, \quad \forall i \in E \tag{8}$$

$$WTR_{avg} = \frac{\sum_{i=1}^{m}(ODAs_i - OSTs_i)}{\sum_{i=1}^{m}(ODAe_i - OSTe_i - l_i)} \tag{9}$$

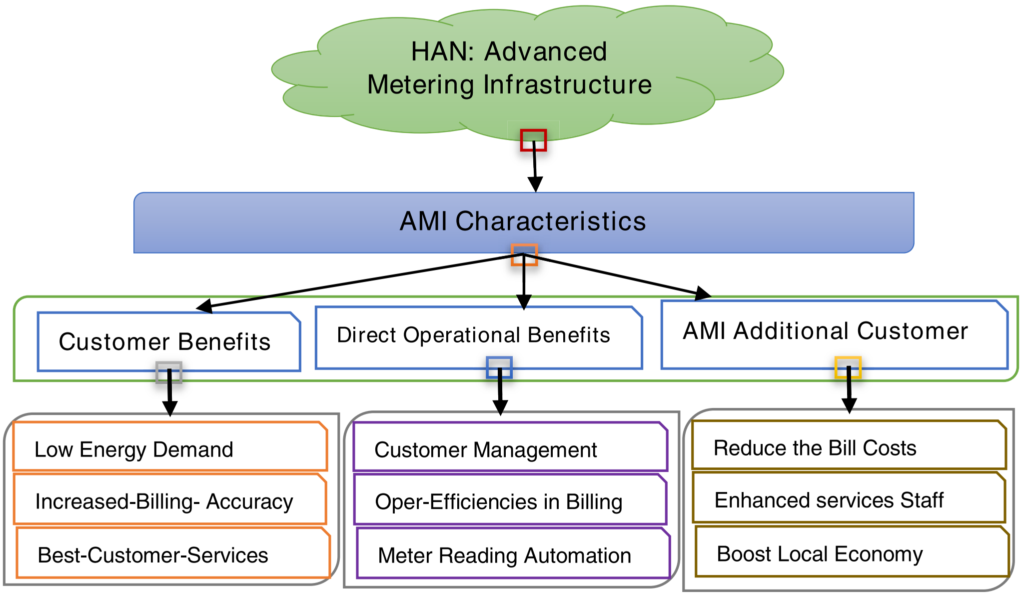

FIGURE 10. AMI characteristics.

D. AMI CONCEPTS

Smart village energy management was tended at controlling the application and data acquisition, the production, transmission and the network electricity. For example, an improve Demand Response was proosed fto manage home appliances [102]. Indeed, this intelligent management type has attracted more interest from the research community to apply a modern automation technology in the smart villages using a real-time DSM approach [103]. The SHESs ensured an accurate communication between utilities and the customers using SM units or Advanced Metering Infrastructure (AMI). This latter is used to ensure a home area network (HAN) bi-directional communication. Indeed, AMI employed IoT technologies to manage energy demand through an adequately scheduling of grid resources [104]. To measure the required energy, Home Area Network included smart plug utilities. AMI is the successor of Automatic Meter Reading (AMR). This latter was considered as an older technology that aimed to collect electrical energy consumption report. The collected data report is transferred from Home electric meter to the provider (one Handshake communication) [105]. To intelligently collect electrical energy at home, AMI was updated for digital data report Nevertheless, AMI will not only monitor the amount of electricity consumed but also measuring the energy used and extended indoors all day long, as its function is chosen as a smart meter. The intelligent meters also are intended to transfer information about costs and resources from the utility to the customer (two Hand check communications) [106]. The implications of two-way communications between utilities, customers, and their loads have resulted in the evolution of AMI versus RAM [107]. Fig. 11 describes the main functionalities of AMI.

Smart plugs are the secret of a transparent smart home that can add voice control, power monitoring and a handful of amenities to ordinary devices [108]. The additional gathered information like Co2, Temperature and Irradiance were collected using intelligent sensors. In addition, gathered Data are showed via a Graphical User Interface (GUI). The proposed GUI are installed in smart phone or tablet application and aimed to provide a vital information to the customers for making the adequate decisions. For example an accurate Middleware Platformwas proposed for Smart Grid Managemen [109]. AMI is a two-way automatic communication interface with a targeted IP address utility. AMI aimed to provide real-time energy consumption data report for utility companies. In fact, AMI is included to provide decisions regarding electricity consumption that can be permitted based on the price at the time of use [110]. AMI technology includes HANs (such as SM Data Management System (SMDMS), Software Platforms, etc.) [111].

E. ELECTRIC VEHICLE CHARGING OPERATION SYSTEM

AMI is the tracking solution for SG, which is a bi-directional energy communication infrastructure that enables energy to communicate information between clients and service providers [112]. The charging infrastructure consists of an operating system and adapter (high speed / low speed), subscription service, an electric vehicle (EV), and an operations management system. The charging system aims to determine fee performance, deal with payment, control the charging schedule and provide complementary services (such as energy status alert). In this vein, AMI provides a very smart step towards for modernizing the entire power system [113]. AMI technology scheme is shown by Fig. 11. To connect EV to Grid, The ISO-IEC15118 standard has been developed for the telecommunications industry [114]. This standard specifies the broadband connection required for ’smart’ charging. The interaction between the charging station and SGs

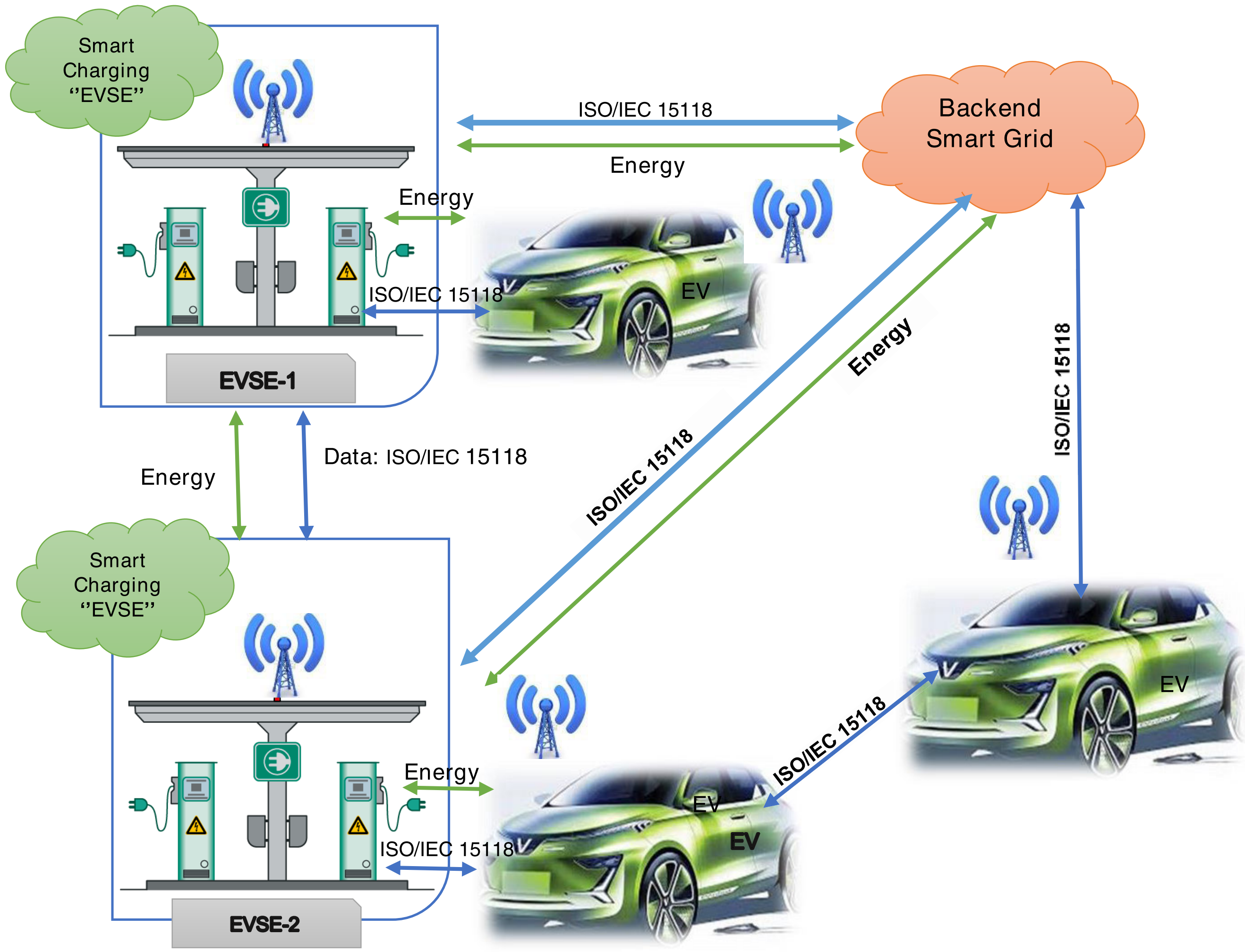

FIGURE 11. **Communication network: Vehicle to grid (V2G).**

will depend on the IEC 61850 technology. The EV charging station has been integrated into SG by combining the two advanced standards [115]. Thus, the EV / SGs combination will allow drivers to reach differential levels of electricity, and also enable the power supplier or provider to integrate EV in SG for power management. ISO 15118 provides a connection and charging process indicating recognition and authorization settings in which the EV driver and EV point user can connect to the charging station (offen called EVSE) at the EV [116]. However, ISO 15118 is not limited to user authentication and message encryption only; it also aims to enable power transmission between EV stations and charging. The reliable energy information collected makes better decisions about load management concepts (also called smart charging) for the backbone station [117].

F. SMART HOME NEIGHBORHOOD ENERGY MANAGEMENT

In this section, the concept of smart home neighborhood Energy Management is introduced. In this vein, some control structure entities (such as: Utility operator, aggregators and end-users) are defined. The entities aimed to explain the communication and the coordination process between neighbor's homes and node units [118]. The Smart neighborhoods (defined as Group of houses) are developed to ensure the best health, welfare as well enable each community to take charge. In addition, Smart neighborhoods aimed to start the connection between communities and enable a variety of mechanisms for managing energy. Similarly to a Home are network (HAN), a smart Neighborhood Area Network (NAN) are used to communicate and coordinate with smart homes (for example: each with its own HAN) [119]. NAN gathered data using smart meters installed in each smart home. The home smart meters collected the energy demand and consumption data and aggregated to a remote feeder or sink node (backbone server) through an installed gateway. Indeed, the gateway aimed to coordinate with the aggregators [120] (see Fig. 12).

G. SHES-I- ENERGY POWER SCHEDULING PROBLEM

SHES-I-Energy Power Scheduling Problem (PSP) is designed as a scheduling problem where the main goal is to schedule devices to run at the lowest cost [121]. Optimization problems are used to identify the best possible solutions that

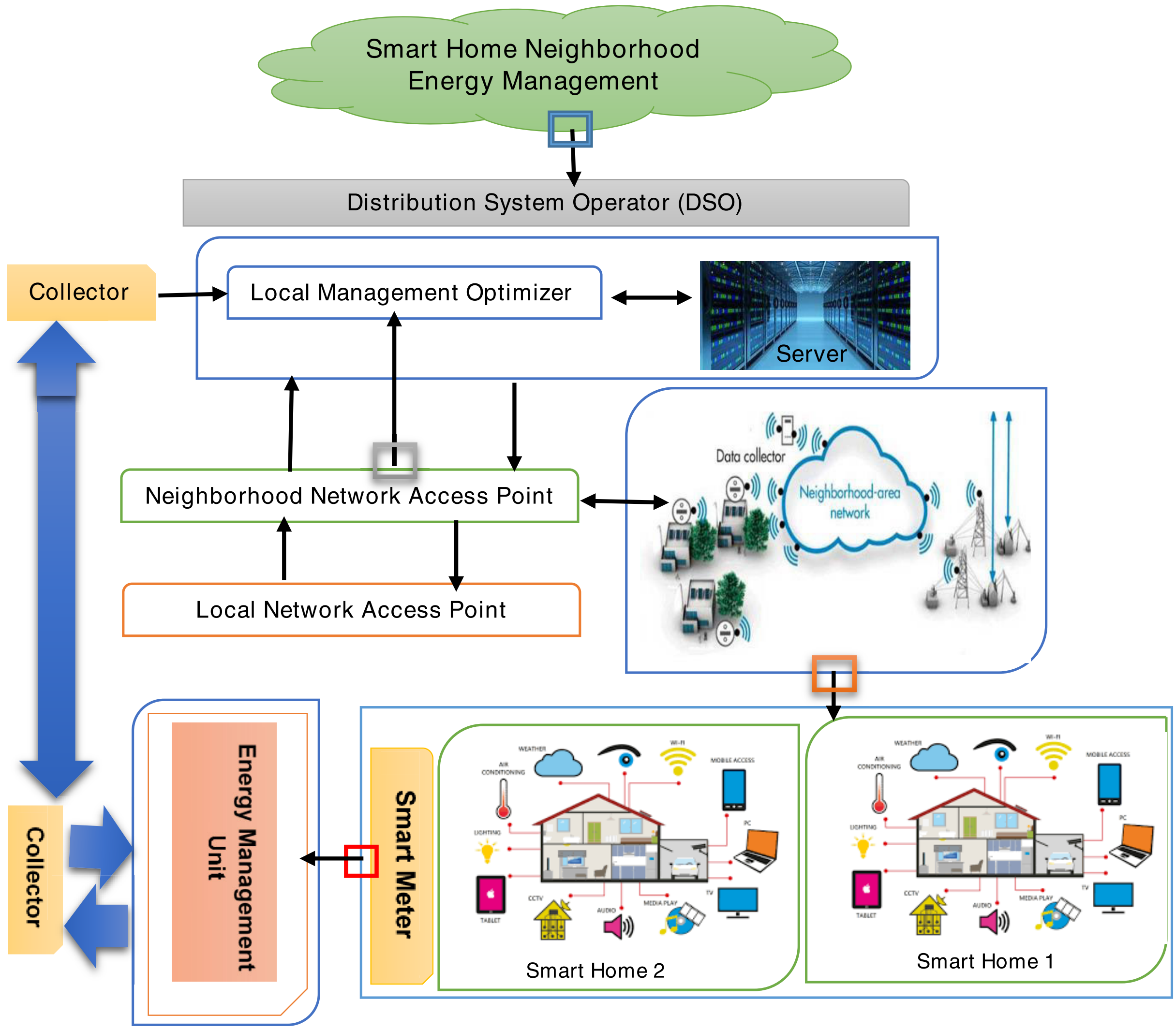

FIGURE 12. Smart home neighborhood energy management.

can be solved using optimization methods. The latter are categorized in Reliable Optimization Methods (ROMs) and Approximate Optimization Methods (AOMs) (see Fig. 13). ROM are useful for minimal optimization problems where an ideal solution can be found. On the other hand, it is unable to solve high dimensional detection problems [122]. AOM are more effective than ROM in term of PSP because of their efficiency in analyzing high-dimensional search space. AOM included two groups: Heuristic and Meta-Heuristic algorithms [123]. Several Reliable Optimization algorithms (ROAs) are used to implemented and developed for PSP like Integer-Linear-Programming (ILP) and Mixed Integer Linear Programming (MILP) algorithms. For example, to minimize the energy demand cost for single or group home, an accurate ILP generic management methodology was used and discussed. The obtained results prove that energy demand is generated by increasing electricity cost. An ILP scheduling system for home appliances was used to manage power consumption [124].

The proposed mechanism for ILP home was tested using seven SOM appliances [125]. Due to their success in exploring a search space to find the optimal solution, meta-heuristic algorithms are more efficient than ROAs. Several Metaheuristic Algorithms have been successfully applied to treat PSP issues. The Metaheuristic Algorithms are cited as follows:

1) Bacterial Foraging Optimization Algorithm (BFOA)
2) Particle Swarm Optimization (PSO)
3) Ant Colony Optimization (ACO)
4) Wind Driven Optimization (WDO)
5) Genetic Algorithm (GA)
6) Tabu Search Algorithm (TSA)

V. I-ENERGY SMART GRID SECURITY SYSTEMS

A. PROJECT RISK MANAGEMENT

In this section, we discuss the potential aspects of improving data integration in smart home applications after identifying applications and various processes. These aspects include

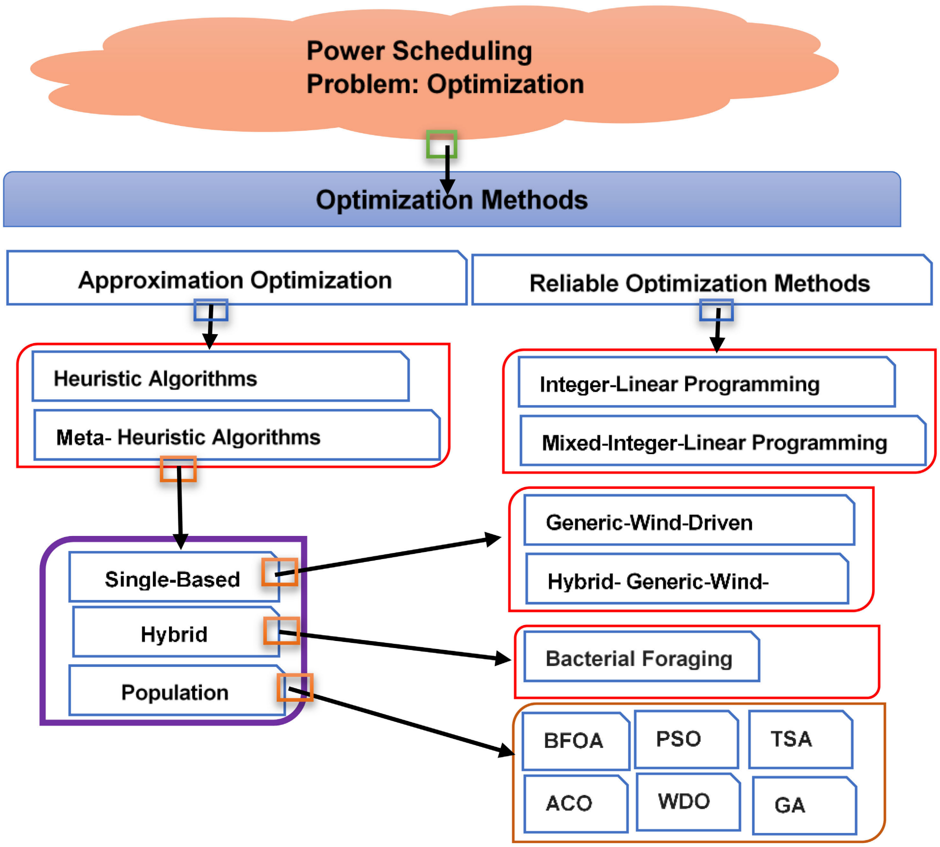

FIGURE 13. SHES-I-Energy power scheduling problem scheme.

possible categories or perspectives not discussed in the previous sections [126]. For the I-Energy concepts and the intelligent village, four main research directions have been considered as the most important:

1) Data quality
2) Data representation
3) Privacy and security
4) Data fusion technique

The content of the data source explicitly determines the reliability of the results, provided that the processing unit follows the principle of "rejected and output data" which implements the data sources. Therefore, we are studying two things to improve SHES sources, coverage and longevity sensing. Coverage detection was selected as an important research issue to explicit the quality of data sources using Cyber-Physical Security [127].

Insufficient data coverage will generate an unrepresentative result, which often means that more sensors must be installed to increase detection coverage. An indirect impact on deployment costs is detected, as hardware that is more physical is needed to compensate for detection coverage [128]. In addition, the communication design system becomes more complicated, since it requires more physical sensors to transmit data, and therefore theoretically complicates the communication platform. These two factors are typical barriers to large-scale implementation by increasing the scale of employment in I-Energy applications [129]. There are two common detection methods and mobile detection platforms for the issues listed above. Because it can cover more information, long-standing data collection provides specific aspects of knowledge discovery. Miniature progression greatly reduces the sensors and power consumption of IoT devices while maintaining similar sensor performance [130]. As a result, a long-lasting sensor solution can be created by combining both energy harvesting technology and energy-saving tools. Without external power sources, physical sensors may operate independently (Sensor longevity data). For example, Smart Grid Cyber-Physical Security model was proposed to enhance cistomers power services [131]. In terms of power generation, transportation, and real-time distribution, smart grids (SGs) represent a fundamental shift in traditional electric power infrastructure. The large-ranging integration of information technology is a critical factor in empowering consumers through smart energy services. SG technology enhances the complexity of accessing and managing these facilities, increasing the risk of appropriately assessed and controlled security threats. An example of a Cyber-security Threats model for SGs was proposed [132]. Several SGs guidelines have been addressed on risk management protection, planning flexibility, recognition, evaluation and risk optimization. Many projects

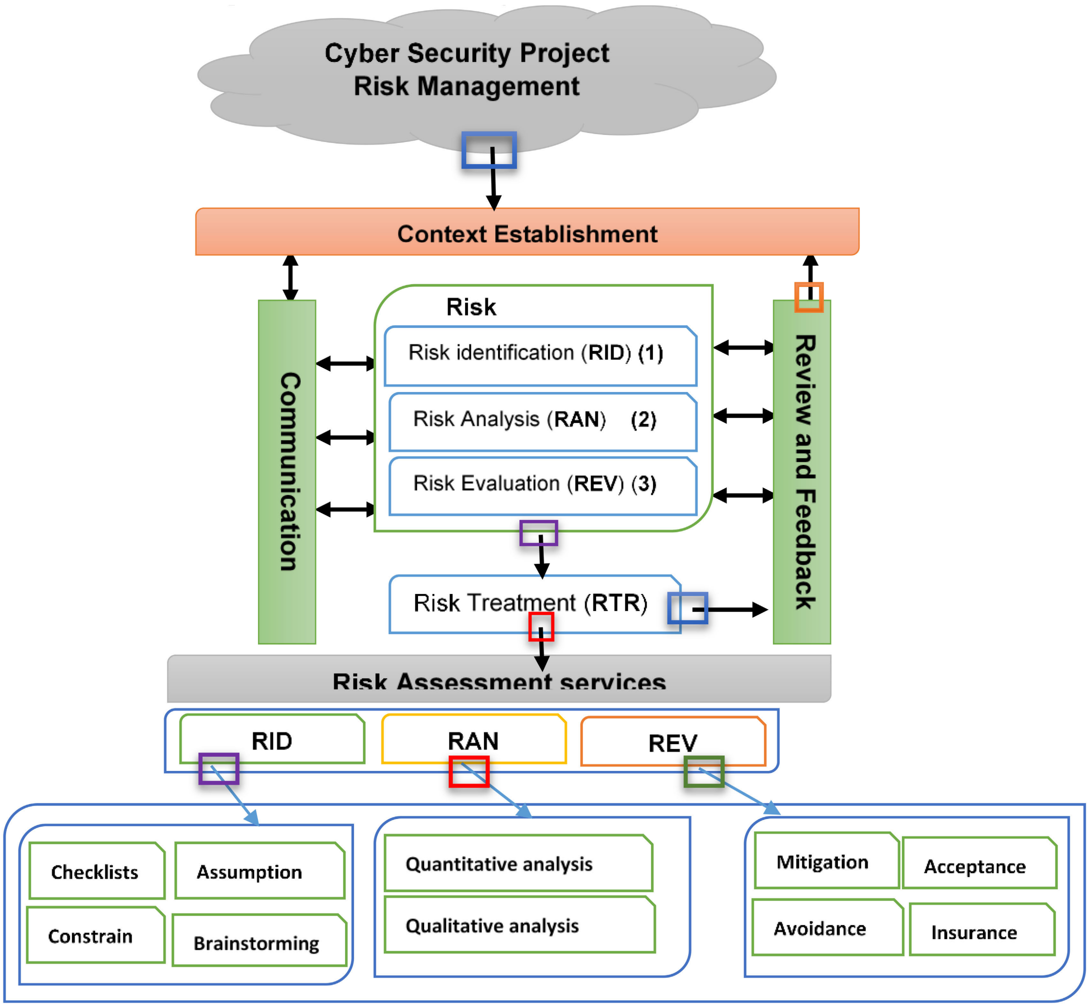

FIGURE 14. I-Energy: Risk management manual scheme.

illustrate the varieties of cyber threats confronting the smart grid, the numerous literature security processes and studies gaps in smart grid security in this context [133]. In general, depending on the area in which instructional design is applied, the concept of risk can be defined [134]. In the Information and Communication Technology (ICT) context, the probability of a credible threat using the specific vulnerability of the device may be identified as a risk [135]. In SGs, the risk can be seen as an uncertain occurrence that could influence the task. It can be described as the possibility of an unexpected occurrence or circumstance that might have a direct effect on the targets of the project. Project risk management is an important project risk assessment operation. For example a Risk Based Maintenance related to Structure was treated in [136]. It is an ongoing process for defining, assessing, prioritizing and reducing project risks (see Fig. 14). Additionally, it may be seen as a procedure that can be standardized and implemented at all stages of the project development cycle in stages depending on the project goals [137]. Different criteria and requirements for determining, measuring and tracking project risk have been established and approved such as:

1) Knowledge Project Management Manual (KPMM): The Project Management Institute Project has developed a manual for the project management of information and defined the whole project risk management mechanism as an integrated part of project planning.
2) Risk Analysis and Management Manual (RAMM): addressed all aspects of the risk management process and methodologies that must be modified to achieve project objectives [138].
3) Manual on Risk Management for IT systems (MRM/IT): To prioritize, target and manage risk processes, ownership data, and important mission information, National Institute of Standards and Technology (NIST) produced a Risk Management Manual [139].
4) IEEE/EIA Standards: To define the risk management context and specific procedures for the proper implementation of the software development life cycle, IEEE/EIA standards have been developed.

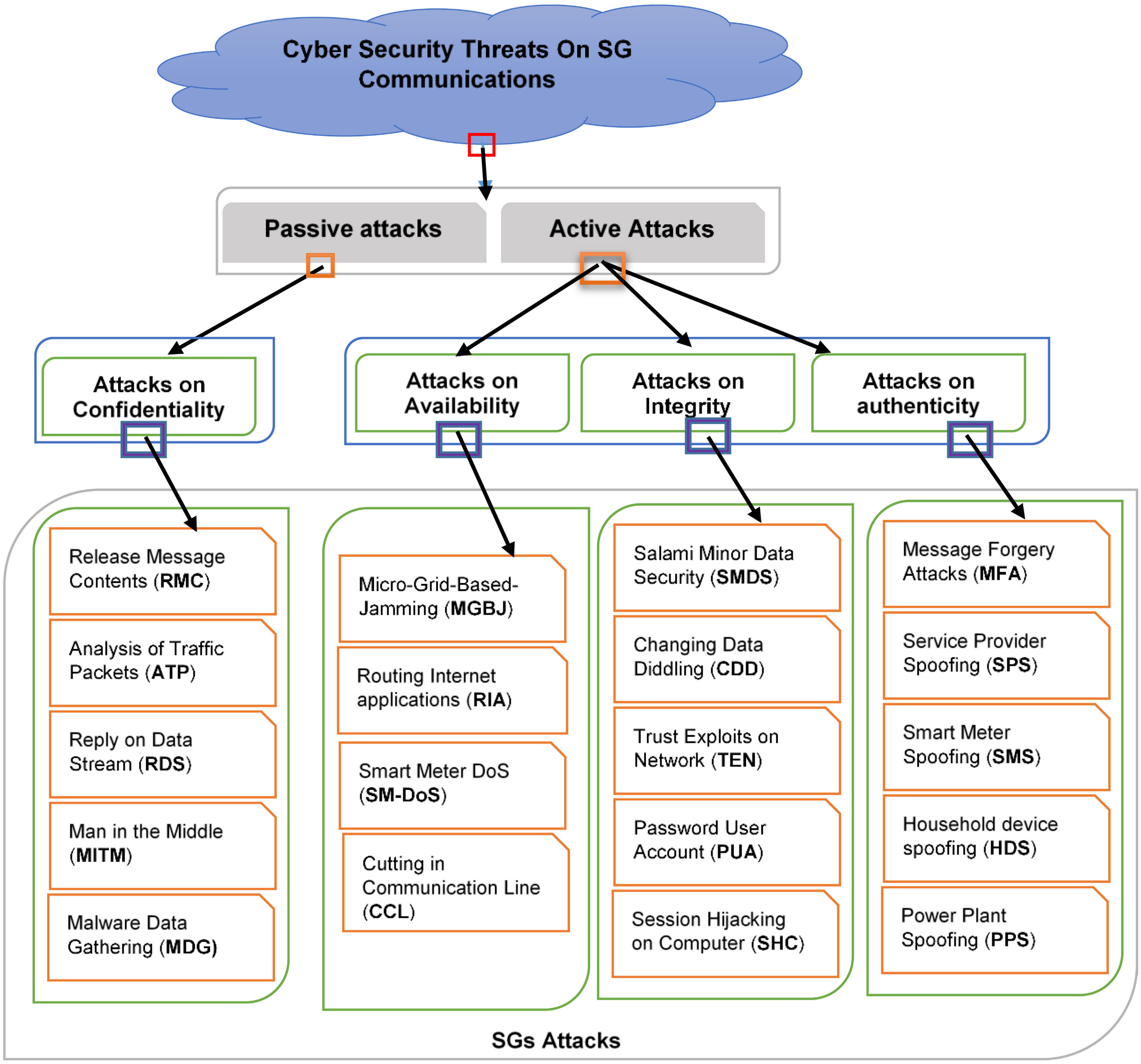

FIGURE 15. SGs: Cyber threat types.

Risks to the are among the risks to the smart grid most openly discussed and documented [140]. For example, a power information risk analysis based on SG was proposed and explained. Due to the number of major vulnerabilities, cyber-threats in several smart grids have been extensively studied [141].

B. CYBERATTACKS

Cyber-Attacks could contribute to the collapse of power systems. SG groups attacking designated networks and communications can be operated in two groups which are the active and passive attacks [142]. While attacks on various protocol layers may be launched, we specifically address SG attacks, which can be released on the network layer [143]. Cyber-Attack treats are given by Fig. 15.

VI. CONCLUSION

Some important applications are described in this paper to highlight current techniques and methodologies for home automation and SGs. The purpose of this paper is to demonstrate the important role of emerging technology, such as smart meter sensors, in future energy and smart home. Innovative design and development methods have been proposed with new technologies in relation to the latest current technologies. The use of the Smart Agent and Multiagent concepts in the smart grid sector are designed to improve service quality, make buildings more efficient, improve performance, and efficient cooperation between scammers and home appliances. Likewise, future study groups should include sophisticated methods and innovations to meet energy demand. Estimated methods aim to meet increased energy requirements during peak periods. Distributor Generation, bi-directional energy flows, and energy quality requirements are some new concepts of the power grid. In brief, the use of emerging technology and advanced services such as smart energy meters and smart energy management is recommended to enhance the reliability of the power grid. Thus, the network connection can centrally manage data remotely, communicate with adjacent networks, and prevent consecutive power outages. This will enhance IoT-based energy management systems for future smart grid management. SG security challenge concepts are revealed based on integrated physical analyzes and cybersecurity. In this context, this paper provides a detailed and systematic examination of the crucial attacks that can be confronted by both Smart Home and SG.

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