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Chapter

Smart Grid Modernization: Opportunities and Challenges

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Abstract

Recently, there have been significant technological approaches for the bulk power grid. The customer demand is associated with conventional grid coupled large central generating stations through a high voltage transmission to a distribution system. Urban transmission systems are consistently progressing to meet the increasing needs for power and to replace old-pattern generation with native renewable generation and power provisions from outward green energy resources. Power grid is undergoing remarkable modernization towards advanced consistency, greater efficiency, and less cost by the incorporation of renewable energy and developed control technology. Quick developing nature of grid, consumer needs, and industrial invention situates substation modernization at the leading of grid transformation. Smart grid is essential to accomplish all the fastest technological reformations occurring in generation, transmission and distribution (T&D) of electric power, with growing application of sensors, computers and communications. In this study the recent trend and application of electric power grid is briefly enunciated.

Keywords: Power grid, renewable generation, transmission and distribution system, substation, electrified transportation system, smart meters, sensors, IoT based smart grid, Big data analysis

1. Introduction

For the past 100 years, substantial revolutionary developments have been made in the mass electricity system. With new developments including easily growing and ecological cordial generation tools, higher voltage apparatus, power electronics as high voltage direct current (HVDC) systems and versatile alternating current transmission system (FACTS) products, the grid network has been constantly modernised. Also, the outcomes of an efficient grid comprise, progression in computerised controlling process, safety and protection, voltage regulation, grid administration systems for development of power network, real-time activities, upkeep strategies for load demand response and energy-effective load management. For delivering of power, generating stations are contained basically of steam power stations that pre-owned non-renewable energy sources and hydro turbines which are turned into large inertia turbines. The transmission framework developed from nearby and provincial grids into a big interlinked system that was overseen by facilitated working and arranging techniques. Maximum load demands, advanced energy utilisation at unsurprising rates, and technical innovations are executed in a comparatively distinct operative and managerial atmosphere.

The electrical grid is a dazzling illustration of human inventiveness and designing of modern power network. It spans a huge number of miles, is taken care of by a large number of manufacturing amenities, and assists hundred millions of consumers. It is the biggest machine ever assembled and one that enables each figuring scheme, system administrations, and corresponding advancement of the Internet Era.

Grid network upgradation has been catch-all expression to allude variations required in the electric grid to familiarise all the fastest innovative changes occurring in the generation, transmission and distribution of electric power. Recent Grid is fundamental to guaranteeing the energy networks that empower our human lives and support our economic aspects that are prevented from future troublesome actions. Nevertheless, beyond just enlightening by reforming the power grid additionally makes a link to achieve significant ground on moderating the future effects of environmental change. All through the nation, efficacies and energy corporations have a remarkable benefit to spend in advancements and resolutions that improve the deceivability and control that operates the electric framework. These advances empower a scope of new capacities that improve flexibility, diminish working expenses and enhancing the effectivity by successfully upgrading the nature of electric assistance. These equivalent advances can likewise strengthen fundamental capacities to producing development on environment.

Inventions for power grid technologies build opportunities to enable T&D workflows. Smart data metering technology, grid management systems (DMS/TMS), resource administration phases and geospacer application structures have also been covered by many rounds of grid engineering expenditures in developed economies. The latest solutions include networks and grids. These frameworks were broadly observed as segregated resolutions providing soloed framework necessities. Therefore, for these reasons, presently the reformation of grid is become troublesome. Service organisations have been reacted by proposing some complete grid-modernization strategies. In 2018, the requested grid modernization initiatives earned a mere $2 billion out of $15 billion. There is clearly a difference between the sort of service organisations suggest and what controls believe to be correct.

However, the grid network modernization ventures may meet a several aspirations. It is significant that the suitable protections are set up to assure benefits, which are exacerbated and consumer expenses are overseen. These incorporations, for adjusting the local arrangement destinations to extensive range distribution strategies, guaranteeing all advantage streams are run after, and checking that the aftereffects of these ventures are estimated against the normal results once they are set up. A few states are presently driving comprehensive partner cycles to guarantee these ventures and different contemplations are represented.

An efficient grid that saves reasonable energy expenses and advances monetary development is essential to our present-day civilization. Over its accomplishment, the grid ensures about the efficiency and excellence of satisfaction of people in the future by assisting with guaranteeing our energy remains consistently accessible and progressively green and maintainable. Specifically, grid modernization technique frequently suggests the growing utilisation of sensing instruments, PCs and communications, i.e., there are several techniques to keep up.

By the incorporation of the environmentally friendly energy sources making the transmission grid intensely complex to comprehend and prototype to apply a new controlling or activation techniques for advancements. This requires a quick prototyping stage for investigation and experimenting under the innovative novel broadcasting illustration. Such a structure ought to be profoundly incorporated, closed loop, and proficient for impersonating a substantive power grid for examining under new controls or algorithms. Though, conventional programming simulation packages generally perform specific errands, for example, dynamic simulation

or state assessment yet come up short on the capacity of giving an incorporated closed-loop platform. To acquire practical information for investigation under the new transmission worldview for working on a genuine power grid network. Moreover, Substation development stays a basic component of state-of- the-art electric power networks. Substation improvements incorporate the utilisation of hardware tests, maintainable practices, digitization, and progressive solutions for the needs of large power network with alongside recompense of reactive power and large-distance renewable incorporation of sustainable power sources. Substations should progressively act not just in light of a legitimate concern for the large grid, yet additionally on the ground of decision making at the neighbourhood level. They are dependent on knowledge processing areas to improve potential costs due to the introduction of technological advances.

2. Necessity of grid modernization

To attaining various goals, one major question is how much should be capitalised in the grid as too much (Distributed Energy Resources) DER schemes assist loads except using the grid for prolonged intervals of time. The consistency and security of the electric power supply load will possibly be impaired when renewable power supply is not available or is not subject to renewable power loss in the transmission and distribution (T&D) grid network. It is therefore necessary to improve the capacity of the T&D structure to host and enable increasing DER penetration ranges.

The transformation of the grid and the spread of DER are certainly related, however, it is not necessary for the prior to this transformation. Benefits like Commonwealth Edison (ComEd) and Centre Point, operating in distribution areas that have evolving DER ranges, have been effectively employed with the continuation of incremental grid continuity to modernise grid networks. Resilience and network performance focus growing network prospects, customer facilities, and substitution of the old configuration. The 2600 numbers of smart on–off switches and 4,000 numbers smart sensor meters have been arranged since 2012, and the ComEd Energy Grid Restoration Act has remained capable of removing nearly 4.8 million customer disturbances. The restructured networks would make it easier to transition to a new trend requiring a deeper penetration of DERs, which has been a further benefit to grid modernisation.

States such as California and Hawaii violently endorse DER's deployment in order to accomplish the RPS objectives and shift a new delivery grid rapidly into successful service. In view of the pre-arranged achievement of grid equivalence by distributed generation in certain marketplaces, a standardised higher-range implementation of DERs is also inevitable. In order to facilitate the usual practice for present and future delivery systems, the accompaniments in grid restructuring infrastructures and schemes should be calculated with necessary savings.

3. Features of changing electric power grid networks

The fast improvement in the electricity grid network is guided by universal rules, finances and technological innovations. The improvement of the power network to ensure that green and sustainable energy supply consistent electricity. The energy grid has switched into the latest two-way power flow scheme with a very fast range and continues as shown in **Figure 1**.
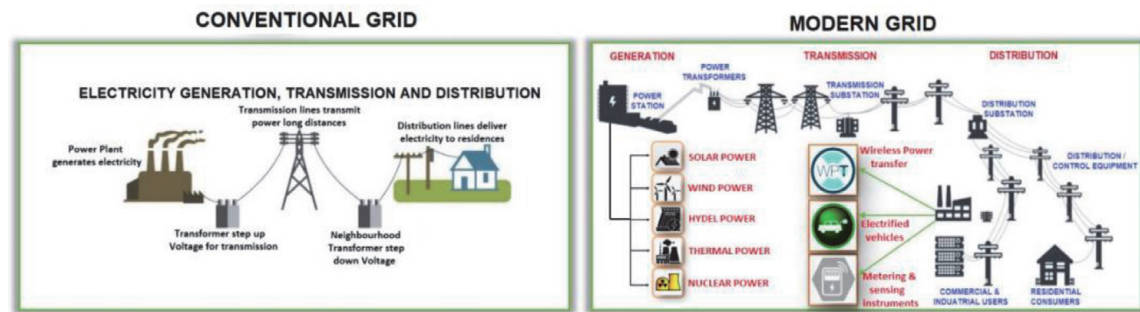
Figure 1.
Transition from traditional to new electrical grid with two-way power flow [1].

The deregulation of electricity utilities in the United Kingdom and elsewhere was a significant cause of electrical markets. Battle eliminated the risk from the stockholders' rate spenders, lowered customer prices and enhanced rapid modernisation. The initiations of the markets and environmental policies have enabled large variations in the mixing of fuel, producing plants that produce coal and nuclear power as a resourceful natural gas-fired connective cycle unit. The current competition among the large electricity markets and universal plans which support or promote other traditions to use energy efficient renewable sources and to respond to huge demands. In terms of financing, such technical advances have steadily benefitted, leading to lower consumer prices, improved ecological management and deployment. The governing reform continues to lead to reforms in the utility company to address the problems of electricity supply system management. The ruling revolution promotes tremendous economic growth. The IoT simplifies additional choices that can be taken at geographic, remote or mechanical levels by customers to promote customer differences and preferences. The distribution system was engineered and developed essentially to meet full demand for load and transmit power initially over radial substructures. Today, however, more customers are increasingly using the grid to offset their own generation and load demand, as well as to be a holdup supply when their regional generation of energy is insufficient.

4. A comprehensive grid modernization technique

Electric grid upgradation is vital to confirming the energy saving schemes that empower our lives and support our budget which prevents from forthcoming troublesome actions. But far basically the grid upgradation also makes a situation to make significant development on modifying the forthcoming influences of environmental alteration.

All over the country, efficacies and energy corporations have an unparalleled benefit to capitalise in machineries and resolutions that improve the perceptibility and monitoring that controls the power network. So, technological innovations empower a series of novel abilities that progress resiliency, decrease working expenses and rise effectiveness. Hence, similar knowledges can also authorise introductory competences to creating development on environment.

However, savings for grid upgradation may synchronise a lot of ideas. It is significant that the proper precautions are in event to confirm the assistances are exploited and consumer expenses are controlled. These comprises line up provincial plan objectives with long-term deployment strategies, guaranteeing all helping streams are followed, and authenticating that the outcomes of these savings are surveyed in contradiction of the predictable results once they are in event.

Numerous countries are now foremost comprehensive and shareholder procedures to confirm these and other contemplations are taken by consideration. Therefore, an efficient grid that retains reasonable energy expenses and supports financial growth is emergent to our existing civilization. Numerous characteristics of Grid modernization are discussed as follows as indicated on **Figure 2**.

4.1 Controlling and sensing for improving system consciousness

With the invention of miscellaneous cost-effective Controlling and Sensing instruments, the efficiency of electric grid in the power network has enhanced intensely. Numerous explanations have been found more specifically throughout the grid network on HV substations or main transmission lines. Nowadays, alike resolutions are discovering their technique down into the distribution system. System operators are capable to sensing how apparatus throughout the network is performing, the disorder for outages, the situation of power delivery and more altogether in nearby actual time.

Although, these innovative skills can reinforce the electrical grid efficiency and progress physical framework competence. The information could assist to improve workplaces service and lesser expenses for customers as well. A foundational expertise of controlling and sensing substructure is developed for smart metering technique. In US from 2010 to 2016 the utilisation of smart meters become gradually increasing in the ratio of 8.7% to 42.8% [3]. Over these numerically coupled meters, grid workers are not only capable to protect on operational expenses, but may also get extra precise understandings, well consciousness of disorder for outages and other assistances that come from more power and energy usage information. Nowadays, Grid utilizations are discovering opportunities through an innovative generating skill for resolutions of power system network. Comprehensibly, these are often highlighted on troublesome set-up to avoid disastrous collapse and disturbances like natural disasters. Grid mechanics must work with
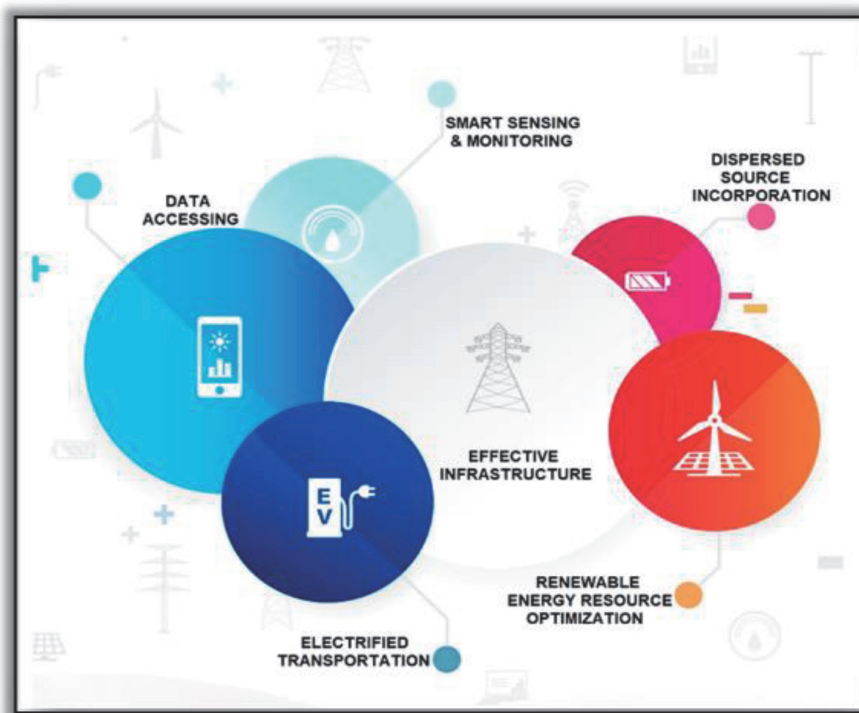

Figure 2.
Schematic diagram of grid modernization aspects [2].

stakeholders to analyse system requirements, contemplate accessible resolutions and describe the commercial event to move elsewhere for demos and keep attention for mounted distributions. For instance, sensing devices at substations can control the health of properties and recognise when pro-active upkeep is essential.

Moving frontward, controlling results will correspondingly comprise sophisticated analytics competences to originate valuable, actionable information from the data streams coming from the propagation of smart meters and sensors monitoring. This system of controlling functions could principally work as a grids nervous system.

Analytical explanations are progressively accessible to solve the 'big data' task of making suitable choices based on massive quantities of data. Information on energy saving schemes can be vary based on ranging from more energy requirements and adequate facility of various grid substructure properties. These explanations frequently run as a grid network cloud.

4.2 Smart incorporation of several dispersed resources

In view of grid modernization, the multiplicity of low-range supply sources and progressively affianced energy subscribers for adding up to a sturdier green energy resource. These sources gradually have the potential to gratify a substantial amount of our forthcoming grid energy needs and while incorporated at the allowable range. These systems can similarly play a greater role in affording other facilities to meet our energy scheme requirements.

Dispersed energy resources cover behind power generation properties, such as roof solar arrangements, to include an increasing set of generating and efficacy opportunities. The associated heat and power systems, micro-turbines turned by airstream or water, energy storing over the usage of batteries, demand side administration resolutions and microgrids where miscellaneous dispersed resources are combined to power the requirements of resident amenities.

Demand side administration, in specific, remains to develop to assist the requirements of energy subscribers and energy system workers alike. Interconnections and controls explanations are making it probable to schedule and regulate refrigeration, heating and additional energy usages in households and industries and minor consumption throughout intervals of highest demand. Logically to handling the energy usage takes suppleness to the network and supports for inspiring the enhanced utilisation of energy throughout time intervals where it is less expensive and/or when the supply has very small carbon strength.

Services, controllers and shareholders are also commencing to assess and arranging the role of 'non-wires alternatives' which could play in acceding or eradicating the necessity to increase transmission, distribution and generation capability. These substitute grid infrastructure possibilities may contain demand side programs, system effectiveness, storing and other smart-grid resolutions that may gratify anticipated demand and necessities of the grid throughout other difficult circumstances of the power system.

When presenting new machineries into the energy network, it's significant to embrace the wide use of standards and reconstruct paths to inspire inter portability once the standards are executed. These steps will support to avert the problems for individuals and industries wanting to link their dispersed assets efficiently into the grid, and will also help prevent grid workers from having stranded resources in the form of solutions to assimilate various dispersed sources. **Figure 3** shows after attaining 1 million solar powers setting up in 2016, the U.S. is composed to reach 2 million in 2018 and 4 million by 2022, which is linked with the new grid set up techniques. [5].
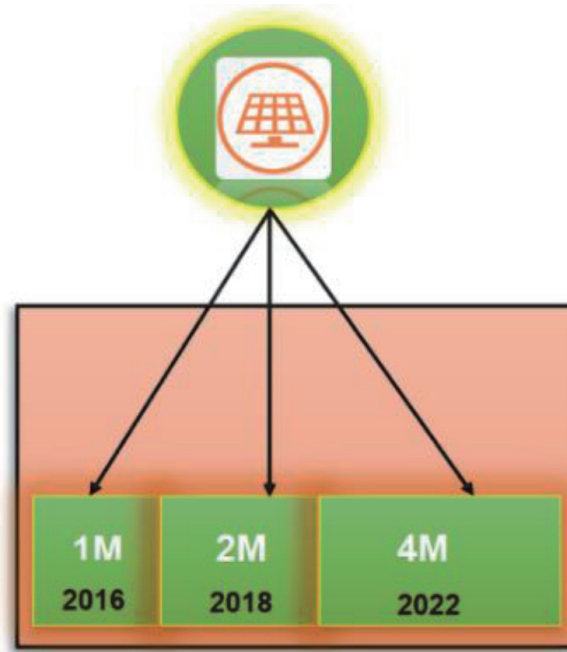
Figure 3.
Graphical diagram of solar power installations related to grid modernization aspects [4].

4.3 Enhancing the role of renewable energy

Renewable energy assets have become a principal generating source of power in the United States. 15% of electricity produce from renewable energy assets in 2016 [6]. Mostly from large upsurges in wind and solar energy, this up about 50% throughout the past five years. The green energy flourishment has become guided by dropping the cost of green energy sources, dynamic awareness from peoples and industries. The loyal (mostly sub- nationwide) policies are decided how to reduce forthcoming low carbon energy emission for green environment. Covering this tendency, those renewable sources make up important portion of the energy mixing, necessitates grid upgradation savings and resolutions at particular range.

For upgradation of electrical grid, the green energy investors are making a path to make it stronger, mainly at the regional level. In few areas, the required driving force make an influence on weather and carbon management, which also marks in clean air across societies. In other aspects it may be career making for financial activity or the reduction in electricity expenses that is capable for renewable energy generation.

Many societies (such as Hawaii and recently St. Louis) throughout the nation have a green energy (solar or wind) prerequisite or aim, contingent in big part on their source and variety of techniques. In particular areas similarly utilise geother-mal, hydro and renewable biofuels, while others may advance in marine/ocean energy generation. Consistent asset management will persist centrally to the dependability of energy schemes with important stages of green energy.

An energy scheme with important levels of renewable resources will require flexible grid reconstruction resolutions to enhance the consumption of green energy. Emerging this suppleness will likely comprise transmission arrangement shape outs and it will contain progress of other important zones. For example, particular grid upgrading implications can result in well predicting and system modelling. Grid workers can plan for the requirements of the system, in consider-ation of environment and atmospheric conditions. Apparatuses used into resource scheduling and effective grid controlling schemes, grid workers will be capable to maximise the efficiency of green energy resources.

Bringing a mix of green energy to unfledged zones where it could be used an extra transmission and distribution arrangement, though, all principal resourceful savings would be considered. A miscellaneous set of grid administration solutions will allow societies and wider areas of the system to run on important levels of green energy sources.

4.4 Electrified transportation systems

Zero emissions vehicles drive new beginnings for conveniences while meaningfully decarbonizing transport systems. The electric power subdivision carbon emissions have dropped for the first time since the late 1970s, under those of the transportation division [7]. To drive carbon and other emissions even lower, the U. S. might strengthen its emphasis on electrified vehicles and guaranteeing they are power-driven with green energy. Additionally, to making noteworthy development on environment, electric cars can generate new marketplaces for products and services that catalyse financial progress and careers.

In the United States approximately 0.2% cars are electrified among more than 260 million recorded travelling cars [8]. However recently the quantity is rapidly rising states. Bloomberg Novel Energy Economics guesstimates that electrified transportation systems will make up 54% of all new low-duty cycle vehicles in the U.S. by 2040 and add as much as 5% of worldwide power consumption [9].

This quick electrified transportation development can reinforce grid worker corporate models as a result of the improved revenues that come from millions of electric cars. Furthermore, empowering the infrastructure to charge and operate electric cars presents an important commercial prospect for grid workers and other service benefactors.

4.5 Admittance to actionable energy information

Serving customers make smart conclusions that assist themselves and the imparted electric grid. Most consumers obtain data on their energy usage once a month in a usefulness bill, and this comes to them some time after they have used up it. Given the postponement and absence of detail intricate with information provided at this stage, this procedure does not authorise consumers to accomplish their energy usage. Evolving information accessing standards allowed by grid reconstruction completely alter this dynamic by providing consumers with expressive, existing and illegal information to take control of their energy usage.

With the advent of new energy opportunities and services including roof mounted solar power, smart thermostats, and building computerization schemes, few customers and industries aren't eager to just take [10] an inactive role when it comes to their energy usage. Rendering to the Smart Energy Customer Cooperative, customers are extremely attentive to take part in real-time reporting of electricity outages (66%), energy usage information (65%) and contribution for certain rating programs (59%).

Massive quantities of information from grid upgrading savings can be composed from smart meters, connected thermostats and other sources. New applications then turn that data into actionable data for energy users in an easy-to-recognise and easy-to-engage format. This data provided by efficacies or other third parties equips people and industries with the tools they need to dispose how to accomplish their energy and power their lives in the ways to maximum gratifying them.

Efficacies and several third-party benefactors have the prospect to strike the right stability of getting deep information to those that demand it, and providing easier options to others who prefer less-involved energy implications. Henceforth

their level of engagement, energy customers want more than just lesser expenses. Their welfares can comprise:

- Improved interconnections for outages and refurbishment;

- Possibilities for retrieving green energy;

- Signing up for demand administration programs;

- Additional resiliency explanations to keep the power on;

- Serving sustenance community-based projects;

- Seeing where their energy arises from; and

- Relating their usage to neighbours or others in alike living circumstances.

These grid competences assist to come back to all energy subscribers in the form of the minor rates.

4.6 Competent transmission and distribution administration

With the variety of available technical solutions, services are capable to not only reconstruct the old substructure and meet future needs, but also proactively capitalise in analytics and controls that upsurge the operation of available apparatuses. These explanations may increase energy scheme competences, profitability, and dependability, while enlightening the excellence of electrical grid facility in a maintainable way.

The power grid has become planned with substantial dismissals in the sequence to confirm that through several active situations, from blackouts to overloading condition, consistent electrical facility might be afforded to all consumers. For example, the electric grid is constructed to maintain the uppermost level of power needs. A cost-efficient modern grid may work as a platform that allows numerous sources to meet requirements of electrical load demand. These principal effective savings in energy substructure help confirm that consumers save currency and net profit for an additional suitable level for the schemes and solutions that consistently tie them into the power grid.

For illustration, permitting dispatch when specific transmission paths are limited for transmits a signal to power workers regarding transmission measurements. This request for changes in power generation stages may be more cost-efficient than supplementary transmission build-outs, and supports to rise the utilisation of present substructure [11]. Other proficiencies empowered by grid reconstruction savings can recover the total quality of electric service. Voltage enhancement, for example, uses sensors for better perceptibility into grid maintenance to allow workers to match network voltage more accurately with the electricity demands of consumers. This cost-efficient, proven implantation can progress service, save consumers currency and accept the need for new generation, transmission and distribution.

Well-organised substructure administration does not completely substitute the need for novel substructure. EEI reports that its investor-owned utility associates increased transmission arrangement savings from around $10B a year in 2010 to around $20B in 2015, a level which likely only upsurges [12]. The country's energy arrangement and planning are ageing, and making investments in transmission

sources to progress dependability, resiliency and to integrate renewable energy. In doing so, however, controllers, customer advocates and others must assess all theoretically reliable solutions to lodge system demands, and incentives should be in place for grid workers to select source active options that align with state and provincial goals.

5. An integrated mechanism to resolve the grid modernization complications

The combined, step-by-step upgrading plan represented in **Figure 4** can be developed with efficiencies first; corporations need to define the performance results that the modernization programs will perform, using the key performance indicator (KPI) and metrics. The first aims to regulate the basic abilities and key investments necessary for achieving the vision. The second aims at furthering business cases for localised grid investments. This can be done in particularly specific uses and are not related to investments. It is crucial to avoid investing in streamlined assets to meet proven needs. Many shareholders – like consumer teams, supply chain players, regulators, and IT firms – do not regularly participate in investment programme development in a soloed investment programme. Investment in grid systems and other business areas is substantially co-related; if this interdependency is not documented and considered, poor implementation plans may arise. The development and implementation of grid modernization plans are assigned insufficient resources. Investments contributing to the objectives of
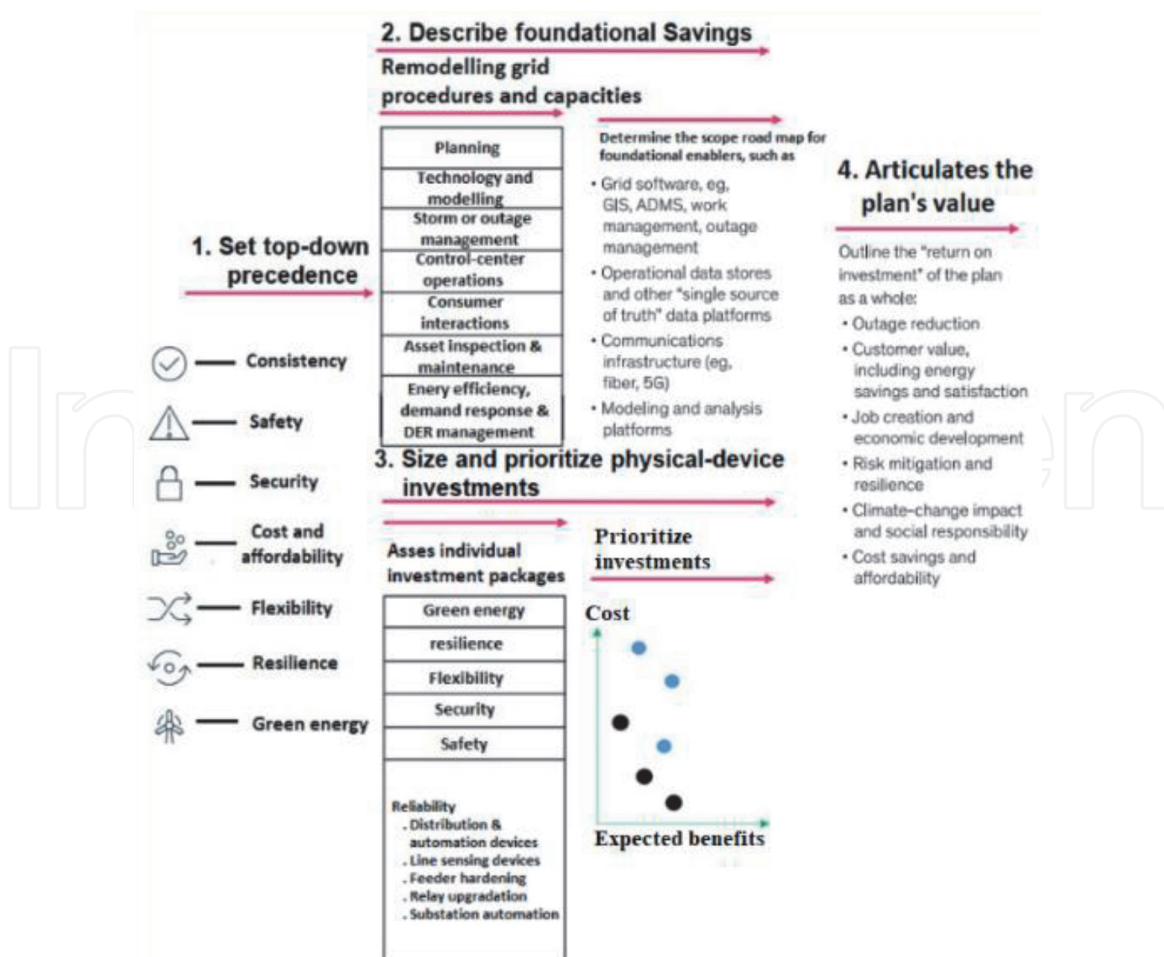

Figure 4.
Grid modernization planning steps [13].

strategic capacity must be given priority, while the immaterial ones should be removed from the capital plan.

T&D personnel who advance a recovery policy to offer maximum client service and persuade controllers of its effectiveness should provide an invented full description of the return of assets to the taxpayer.

5.1 Set top-down precedence's

Utilities used clear and well-known arrangements traditionally for the purpose of justifying their grid projects, namely to endorse their proposals in a dialogue regarding the creation of a consistent electric grid. Utilities have precise metrics (e.g., Consuming Periodic Interruption Index, occupational health and security records) to monitor reliability and safety, and shareholder potential is adversely affected by continuous growth. Otherwise, more capital meant greater market and civilisation reliability. The first step against regulators and consumers is to describe precisely what effectiveness means "modernisation" as seen in **Figure 5**. "Grid modernization" can mean multiple things to different shareholders.

5.2 Define initial savings

Skills are not binary. Some can grow mature and widespread over time across the grid. For example, tracking and control are usually important. Most conveniences therefore have simple monitoring and control skills, though many strive to improve their sophistication over time, as stated in **Figure 6**.
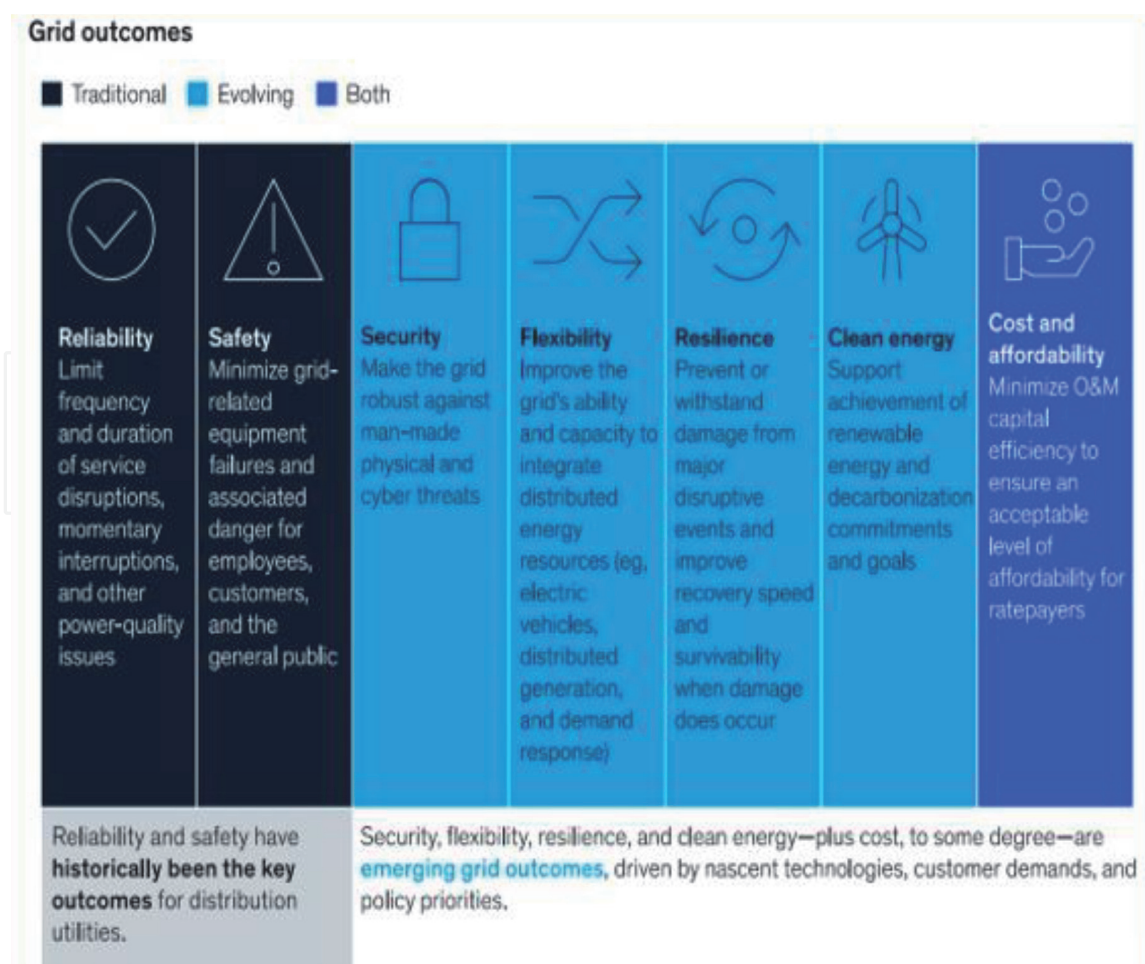

Figure 5.
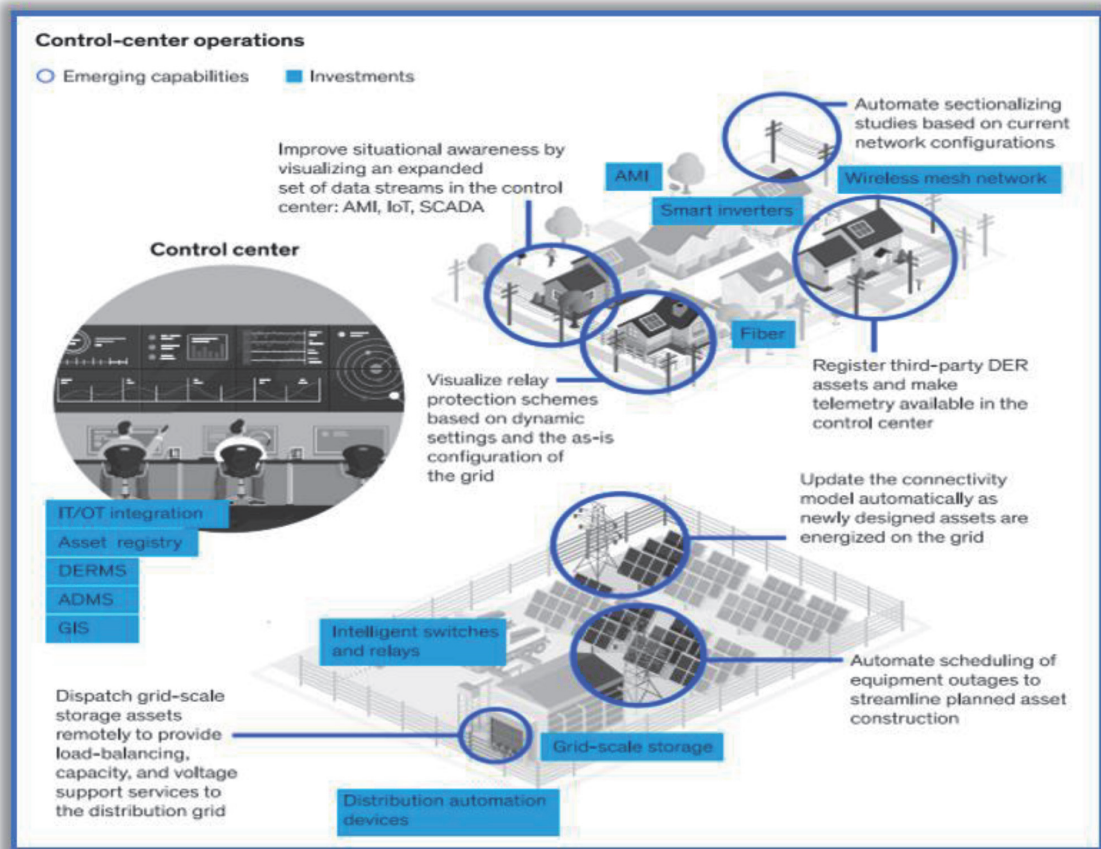*Steps of grid modernization set top-down priorities [13].*

Figure 6.
Step of investments for grid modernization [13].

The basic savings required can be difficult since they are not usually linked to a certain grid or asset. Corporations should concentrate their efforts on the short-comings in current basic workflows such as network infrastructure, asset design, control and duty systems, with topic, line and line leaders.

5.3 Size and prioritise investment in physical equipment

Media stories on grid-modernisation agendas aim to span millions of policy expansions. Smart automated substations, smart metres for future generation and distribution computerization instruments contain these tracking and control poli-cies (recloses or sectionalizes). However, what is not mentioned is that others programmes depend on the update of out-of-date designs, including transforming substation and feeder into higher voltage. The packaging for savings can then be sized according to the target awareness level of the device and then prioritised on the basis of calculable customer outcomes compared with each box price.

5.4 Manifesting the plan's value

Most initiative refusals in the country are embedded in insufficient reporting of the incentives for taxpayers, and is related to cost savings. This pattern will con-tinue—except for efficiencies that speak of the importance of the consequence of the payer and pledge themselves, if mandatory, to goals that their plans permit. The methods for grid modernisation frequently surpass the number of their elements. The painting of the whole image will make controllers and owners alike more productive and also accountable.

6. Numerous features of grid modernization technique

- Substation developments – The heart and brain of the grid are imaginative substations. The improvement achieved by the substation includes infrastructure testing, durable procedures, digitalisation, and advanced technologies for a range of device requirements, as well as reactive energy compensation and long-term clean energy incorporation of renewable energies. Substitutions must increasingly function, both for the benefit of the wider grid and to help local decision-making. They should act as data collection positions that will boost potential investments in emerging technology. Substations can be fully usable, invisible or enticing to the public in particular in very crowded environments, in an effort to achieve their convenience. Sustainability is a further component of creativity in substations such as the replacement of SF6 methane, greenhouse gas, for sulphur hexafluoride for other gases used in lightweight insulated gas substations (GISs).

- The growth and problems of the Urban Power Grid - The urbanisation of the world is growing demand for electricity in big and mega cities. Land expense and shortage find it impossible to obtain modern transmission rights for traditional routes. Advanced transport technology will effectively enhance current system power, reliability, and usage and increase grid stability in extreme contingencies or disastrous circumstances. These innovations for the enhancement and transformation of urban grid have been taken into account and adopted by electric utilities.

Urban grids have grown over decades with population and inflation and now face multiple extension and technical problems to accommodate more demand growth and related (stringent) criteria in terms of reliability. The exponential growth in demand has pushed power grids closer to their capacity limits. In conditions without sufficient voltage and local reactive energy source, where the infrastructure encounters very severe occurrences, the municipal power grid could be vulnerable to voltage collapse or blackouts.

- The Network extension infrastructure options—Electrical providers have the option to add the following to deal with network expansion issues:

  - new circuits to reduce overloads of circuits or to boost current circuits

  - new transformers or advancement of present ones to mitigate substation overloads

  - new or current transformers to reduce sub-station overloads

  - Phase-shifting transformers for the regulation of active power transfer in mesh networks (PST) also called phase-angle regulators (PARS), sen transformers (TS) as well as VFS (Variable Frequency Transformers).

  - Reactive power compensators for voltage balance and energy shift, for example shunting reactor or condenser banks and Static Var (SVcs), or static sync compensators for energy change (Statcoms).

Figures 7 and **8** is the general metropolitan electricity grid structure. It consists of the major transmission networks extra high-voltage (EHV), the sub-high-voltage
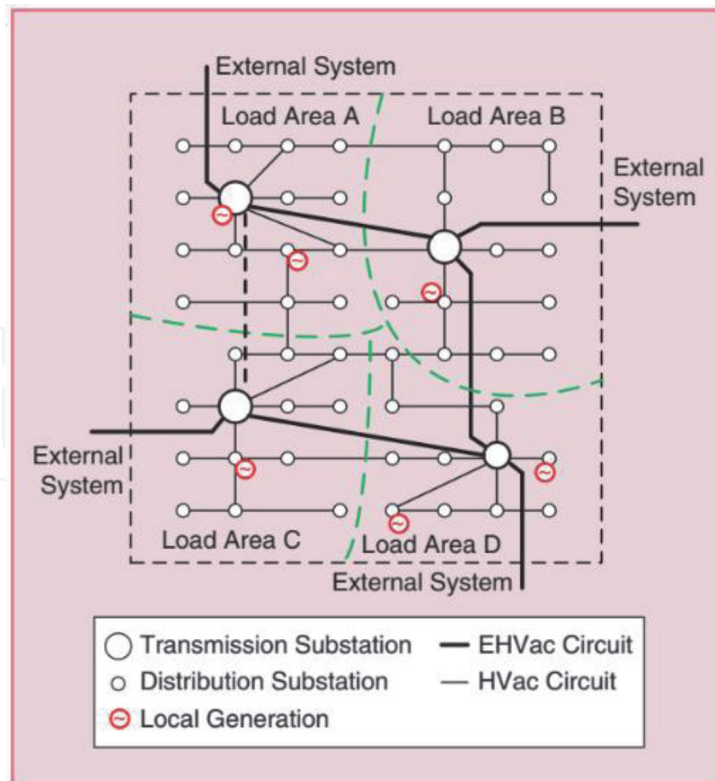
Figure 7.
The urban power grids are typically divided into multiple load areas by electric utilities for convenience in planning and operating of the system [14].
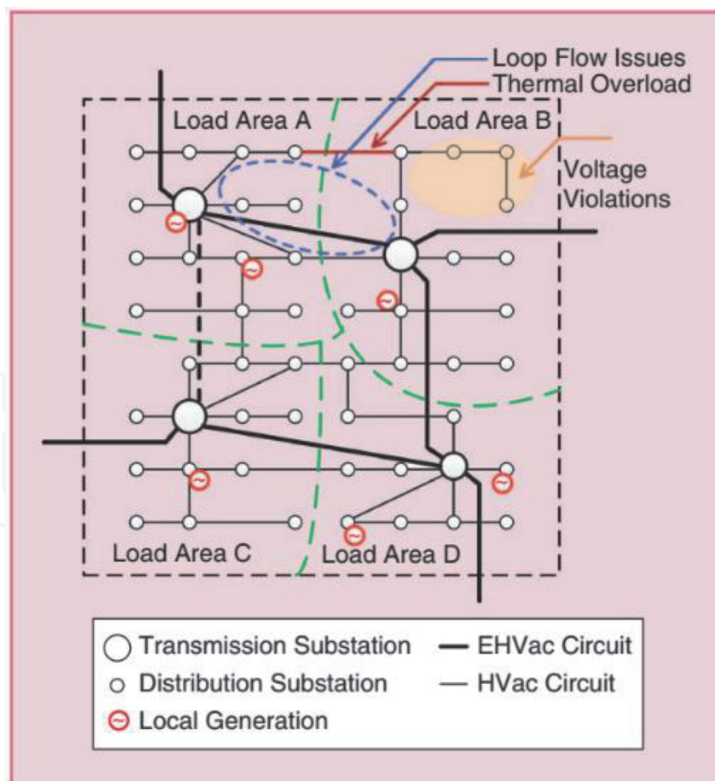

Figure 8.
The optimised network explanations solutions are needed to address for increasing multiple network [14].

transmission networks, transmission substations, primary generation substations and municipal power generation systems. The city grid is normally split into load areas or load areas that determine the portions of the grid allotted to facilitate system planning and electricity operations. The charging areas which have different
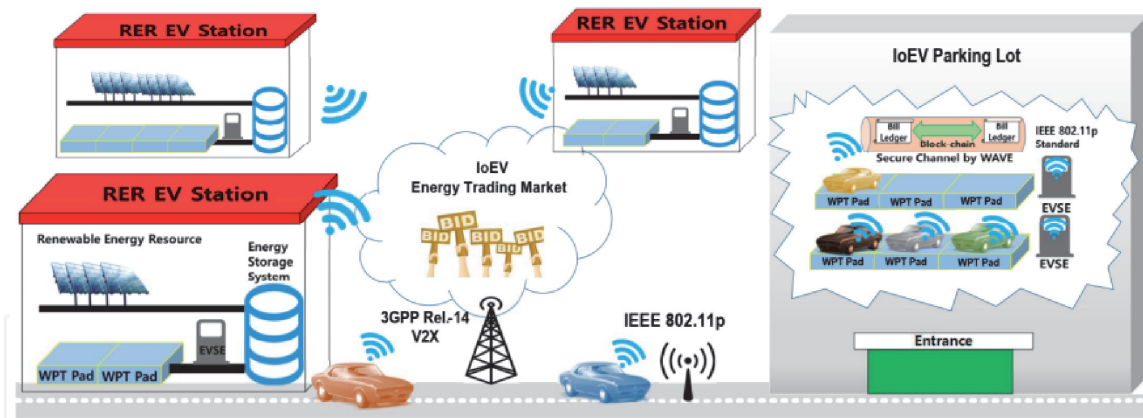
Figure 9.
The architecture of the relaxed framework suggested. (IoEV charges the electricity automatically via WPT in the proposed system. The billing is securely paid via WAVE technology and block chain) [15].

requirement features, service efficiency and specifications for power quality. Usually in the range of voltage from 345 to 500 kV, the eHV main transmission networks transfer bulk electricity from and from external sources. In certain metropolitan power grids municipal power also forms a large proportion of the overall energy supply. Many of these units are old, less effective and dispatched to provide operational reserves and voltage-support functions as consistencies must-run units. Many of these ageing thermal units will possibly be phased out in the near future due to economic reasons and environmental restrictions.

New problems of hybrid electric car wireless power transfer and safe Internet billing Intelligent grid modernisation and Internet incorporation of electric cars (IoEVs) have gained significant interest because of the power and speed they provide as represented in **Figure 9**. Furthermore, growth of magnetic resonance or wireless inductive transmission (WPT) technologies can increase performance and convenience in power transmission. However, there are many issues that need to be overcome to incorporate such a convenient method. Moreover, it is especially difficult to develop an effective and stable accounting method when IoEVs are loaded automatically in the anticipated convenient system.

7. Internet of things based smart grid modernization approach: technological aspects, designs, implementations, architypes, and future investigation guidelines

In the face of the one-way data source, the power loss, increased electricity requirements, the depth of confidence and protection of traditional electric grids are transformed into smart grids (SGs). The Smart Grid offers two-way energy streams between sources and consumers in conjunction with electricity generation, transmission, distribution and operating systems. A bulk quantity of SGs are utilise to different equipment's for observation, examination and control of the grid network, positioned at generating stations, delivery stations and in customers' premises. Thus, a Smart Grid needs interlinking, mechanisation and the tracing of such equipment's. The Internet of Things helps to do this (IoT). In addition to connecting, mechanising and tracking of these facilities, IoT provides the means to support Smart grid frameworks for diverse network purposes during generation, transmission, delivery and power uses through the integration of IoT devices (such as sensor devices, actuators and smart metres).

A conventional electric grid comprises bulk quantity of broadly interlinked synchronous Alternating Current (AC) grids. It conducts three major roles: generation, transmission and distribution of electrical energy [16], where unidirectional electric power flows from supplier to the customers. Initially, in power production, a huge amount of power generating stations produce electrical energy, generally from burning of coal and nuclear power stations. Then the electricity is distributed from power generation plants by high tension transmission lines from a remote load terminal. Next, the delivery network assigns electrical power at lower voltage levels to the load centres. Any network of grids is centrally managed and tested to ensure that the generation stations deliver electricity in line with consumer specifications under the power system network limitations. About any electricity generation, transmission and distribution is possessed by utility companies that supply consumers with electricity and charge them adequately to recover costs and to generate income.

From its beginning in 1870 to 1970 the traditional grid worked admirably [16]. Despite the drastic rise in energy consumption by the consumers, it was also somewhat shocking. But since 1970 the concept of using electricity has been modified considerably, due to the burden of electronic devices, new sources for high-strom use, such as electric vehicles, have risen to be the fastest growing portion of full power requirements (EVs). Such influences as excess machinery and insufficient smart innovation for clients, inconsistent management, electrical privileges and untrustworthy communication and observing – particularly the absence of components in the stockpiling of generated electrical power [17–19] – make grid networks an essential factor in consuming electricity. Furthermore, electricity grids are confronted with other problems as well, including the development of energy interests, coherence, security and the development of eco-friendly energy supplies and maturing basic problems.

The basic Smart Grid concept was a challenge with a range of data and correspondence developments to resolve these difficulties. The adequacy, efficiency, reliability, protection, longevity, consistency and extensibility of the traditional network can be improved by such developments [20]. SG differs in numerous angles from traditional grid networks. SG, for instance, gives vendors and purchasers a two-way correspondence stream while a traditional electricity grid only provides single way connections from providers to consumers. SG has gradual measurement Setup, intelligent metering technology, adjusting for vital clearance of defects, find of unsubscribed use and load change [21–24], and self-rescue [25].

SG transmits various types of equipment for grid network observation, analysis and control. This test facilities were installed at power generation facilities, electricity transmission lines, power transmission centres, delivery areas and consumer locations. One of the main concerns of SG is the interconnection, computerization and detection of such a vast amount of gadgets, where swift, universal and bilingual advanced digital correspondences need scattered observation, investigation and activity. For these gadgets or "material," it calls for dispersed SG mechanisation. In fact, this is now recognised by invention in the Internet of Things (IoT). The IoT is described as a device that can connect any object on the Internet based on a data trading convention and correspondences between various intelligent gadgets in order to achieve recognisable purposes for observing, detecting, managing and area [26]. Over the past years, IoT engineering has taken on a number of dimensions and took into account internet intercommunication to various network-based devices used in daily life.

The Internet Technology initially supported individuals and people as a network. While the volume of Internet-related items surpassed universal levels in 2008, the impact of IoT creativity continues to increase. The results are also increasing. IoT is

a system of actual Internet technology products or things. These products are equipped with implanted innovation to interact indoors and outdoors. These items detect, test, run and jointly select individually or with different items through a broader tempo, self-governing and pervasive bi-directional device correspondence. This is what the Smart Grid really needs. Through the integration of IoT gadgets (such as sensor devices, actuators, and smart metres), the Io T-innovation will support smart grids with various device capacity, during power production, storage, transmission, delivery, and consumption.

The only big use of the IoT is the automation of the intelligent grid [27]. Today, while many home-grown devices that use energy are linked to the Internet, there are also many home-grown devices, which do not come with the web. For example, in the world there is a significantly less amount of microwave ovens and washing machines connected with the Internet than of units not linked to the Internet. Basically, all power uses by connecting to the Internet are more beneficial (for example, microwaves and clothes washers, that are associated with the Internet can be worked distantly and at off-busy times, consequently saving expense, just as give solace to human beings through robotization). Therefore, we will later forecast that the IoT-coordinated intelligent grid will be greater than the intelligent grid, and that the existing intelligent grid will not be feasible save for the IoT breakthrough. New entrances will be exposed to enhance future growth possibilities by addressing IoT engineering as a worldwide standard for intercommunications and the justification for smart grid. Since the IoT and the smart grid must be incorporated, a new session on SG and IoT has begun, as is an exceptional question on the Smart Grid Internet of Things. The need and importance of the combination of IoT and SG is also shown.

8. An outline and integration of internet of things based smart grid

A. **Internet of Things**- The IoT is a system that can interface any person with the Internet that is reliant on a data exchanging convention and on communications with various smart devices for observation, tracing, management and region recognition purposes [16]. The IoT focuses on the recognition of three major concepts, in particular stuff, the internet and the semantic. The theory involves intelligent gadgets such as RFID stickers, sensor units, actuators, photographic sensors, optical scanners, GPS, and near-Field Communication. Smart gadgets are the basis of this approach (NFC). The Internet-based concept facilitates connectivity between smart devices and connects them via the Internet through various advances in correspondence, such as ZigBee, WIFI, Bluetooth or smartphone connection. The semantic concept comprises a number of applications with the help of intelligent devices. The IoT breakthrough has gained a great deal of attention over recent years in various implementations, taking into account the Internet's interconnection with different network-implanted gadgets used for daily life [28]. The activities of various frameworks have been robotized: for example: medical care, transport, defence, home automation, security, monitoring, agro-industry and electric grids. IoT devices, including the external objects (e.g. people) enable the recognition of fully mechanised systems that make it a basic part of the Internet, include the most common objects equipped with routers, micro-controllers and traditional stacks.

B. **Smart Grid**- The SG is being promoted to be a demanding response for reducing electricity spending and for tackling the problems of traditional grid system, making future progress in terms of expertise, adequacy, reliability,

protection, constantans and increasing electrical energy needs. The main features of the smart grid are self-mending, improving power efficiency, scattered generation of and load consumption output, joint business and customer participation and effective management of the source. As implemented in **Figure 10**, in four sub-frameworks SG completely reforms energy generation, transmission, delivery and consumption. It includes three systems: a home zone network (HAN), an area network for neighbourhoods (NAN) and a network for wide areas (WAN). HAN is the main layer; it addresses the demand power requirements of customers

This includes intelligent devices, home appliances (counting clothing laundries, TVs, air conditioning, fridges and stoves), electric vehicles and renewable energy sources (like solar cells). HAN is arranged within housing, factories and corporate systems, and integrates with smart metres for electrical devices. The NAN is the second stage of the CS which consists of smart metres with a large number of HANs which is otherwise called the Field Area Network (FAN). NAN underpins correspondence for power delivery frameworks between dispersion substations and field electrical gadgets. It collects the data from several HANs and passes it on to the information authorities the interface NANs to a WAN. The WAN is the SG's third level which encourages the correspondence of doors or complete centres as a backbone. It promotes the interplay of mechanisms on power delivery, large power generating schemes, renewable sources of power and zones control [30].

C. **Significance of SG in Smart Metropolises**- Smart urban areas are contained of various factors, like administration, structures, safety, medical services, economy, transport and energy demand. Between them, energy is the most vital segment for moving towards a more bearable metropolitan life, also for incorporating different shareholders and complex network. As such, smart urban communities are firmly combined with the upgradation of customary electric grid, i.e., SG due to if the power is inaccessible for a specific timeframe, any remaining activities of smart urban areas will be paused. SG gives three fundamental capacities which are extremely needed by a smart city. The traditional grid is first and foremost transformed into SG by robotics, remote control and checks. In addition, SG enables consumers to know about their electricity use, costs and thus allows customers to adjust their quality of energy. Finally, the SG is empowered to coordinate renewable and distributed
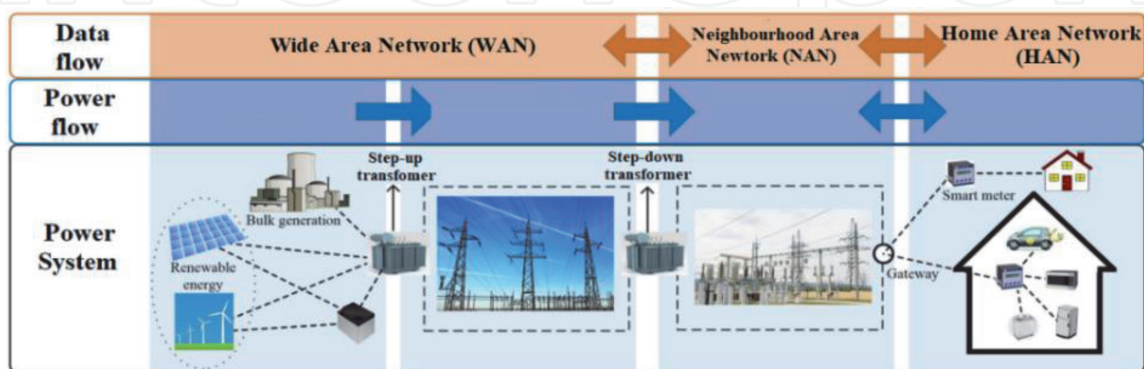

Figure 10.
Architecture for smart grid (SG) presenting power grids, power flow and flow of knowledge. The SG consists of five major subsystems (power generation, storage, delivery and usage) and three network groups (WAN), community area (NAN) and home area networks (HAN). Power passes through the subsystems, while knowledge passes via the networks. [29].

energy reserves. Thus we may conclude that smart urban societies cannot fully survive apart from such practises [31, 32].

D. **Combination of the IoT and SG-** In data detection, transmission and handling, the SG has effectively carried out large selection, and IoT creativity now plays an important part in the grid growth. The key driver of SG's operation is the advancement of the organisation, maintenance and functioning of each section of the power grid by ensuring that it is able to "hear" and "speak" and to empower robotic systems in SG [44]. For instance, in conventional power grid, the service organisation possibly thinks about the disturbance of service when a consumer advises other partners of the grid network. In SG, the service organisation will mechanically contemplate about the interruption of service in light of the fact that specific parts of SG (like smart meters in the fondness area) will stop distribution of the gathered sensor information. Here, the IoT assumes the major part in empowering this situation since every segments of the grid framework (indicated in **Figure 11**) should have IP addresses and ought to be equipped for bi-directional correspondence. This is empowered by the IoT. IoT innovation gives collaborative real-time system linking with the customers and gadgets through different correspondence advances, power hardware through different IoT smart gadgets, and the collaboration needed to acknowledge continuous, bi-directional and very fastest information allocation across different applications, improving the general effectiveness of a SG [32]. The IoT can be divided into three types of Smart grids, depending on tri-step IoT engineering [31, 33]. IoT is primarily used to arrange various IoT smart equipment for testing the conditions of equipment (i.e., at insight layer of IoT). IoT is also applied to include data on devices by means of their correspondence developments with the help of their associated IoT Smart Gadgets (i.e., at network level of IoT). Finally, for the regulation of the SG across application borders, IoT is introduced (i.e., at application level of IoT).

IoT gadget detectors are commonly radio sensor systems, RFIDs, M2M gadgets, camera systems, infrasound sensors, laser detectors, and GPS gadgets. IoT creativity will extraordinarily boost and support the data detection in an SG. In addition, IoT Invention also plays a key role in the substructure positioning and dissemination of
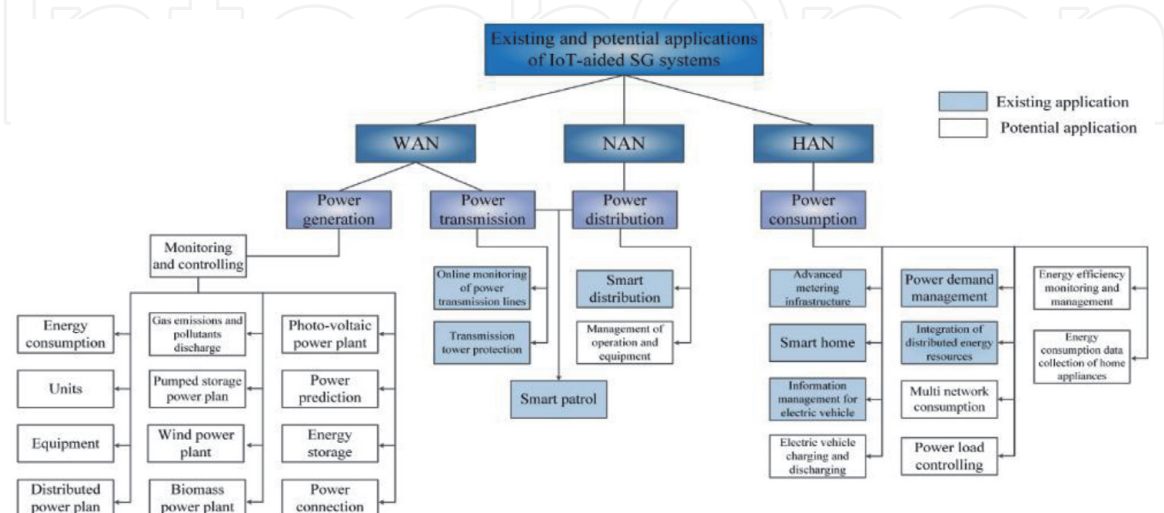
Figure 11.
Existing and future implementations of the WAN, NAN and HAN IoT-aided SG networks. These structures are often known as subsystems, i.e. power generation, storage, delivery and use. The blue boxes represent the implementations that exist, and the white boxes (empty) represent future uses [29].

SG information, supporting the creation of the network, operations, management welfare, maintenance, security surveillance, data collection, evaluation, customer cooperation and so forth. In addition, the IoT enables data streaming, power flow and distribution to be combined in an SG [33, 34]. Furthermore, present SG structures principally highlight around the necessities of power suppliers to deal with the total grid system [34]. The consumers are getting in touch with a smart metering system by methods for General Packet Radio Service (GPRS) or other cellular networks. The modern realism in which consumers will now have other intelligent home frameworks (such as Wi-Fi) has not yet been introduced into existing SG's network correspondence. While some mechanisms grant current smart home frameworks, the adaptability of large investments is not expected. These conventions, which are explicitly applicable to IoT and SG framework, cannot be extended directly in the IoT-supported SG frameworks because they only take into account the specific features of either IoT or SG frameworks which are insufficient for an integrated IoT-supported SG framework.

9. Sum-up and understandings of IoT based smart grid

The complete investigation of the present applications of IoT-based smart grid to make the total system more comprehensive. Though there might be several applications of IoT-based SG schemes, as illustrated in **Figure 12**. Few IoT-based SG systems implementations have been already deployed but much more needs to be done as all the instantaneous information capacity and large data processing are taken advantage of. Current applications threaten a number of focus areas, for example:

- Observation of buildings or of power apparatus establishments (towers and electrical transmission networks);

- Regulating home utilisation by active energy scheduling, which exploits changeable estimating;
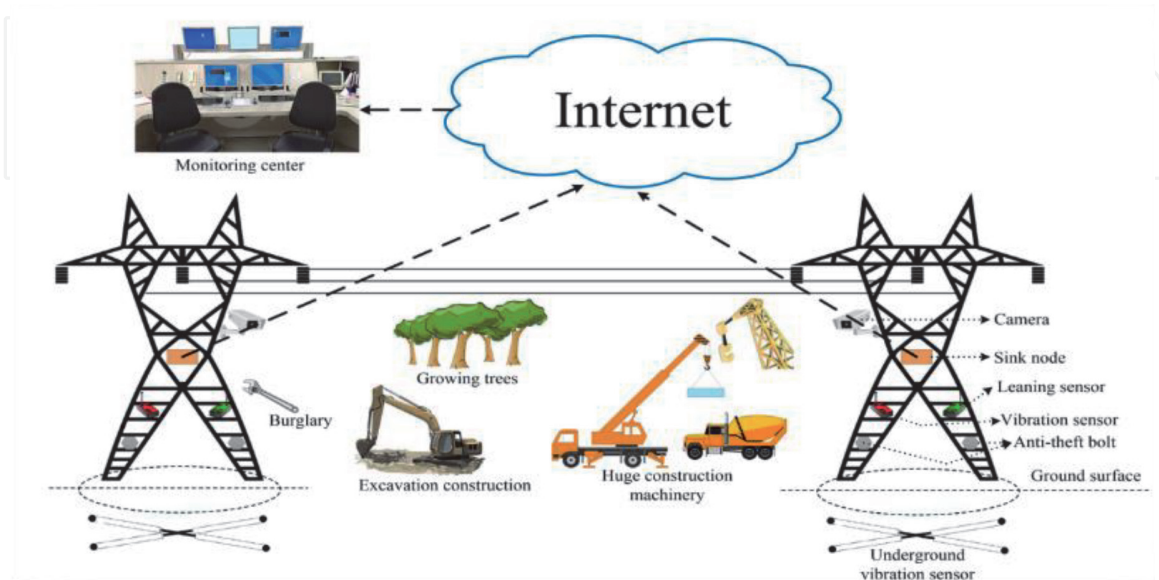

Figure 12.
IoT assisted transmission tower safety towers security system against buggy attacks, natural hazards, barbarians and the growth of trees. Transmission tower protection systems this device includes a sink node and numerous sensors to provide the monitoring centres with early warnings of threats to high-voltage transmission towers. [43].

- Meter perusing and utilisation checking, private and business sector;

- Electrified cars charging and parking;

- Power requirements and source administration, including incorporated environmentally friendly power sources; and.

- Caring of power supply frameworks, by identifying line faults and breakdowns.

This analysis found that little work is being done on the use of IoT-based SG frameworks for nearby stations, transmission and power consumption. For example, IoT-based forecasts of the climate conditions that will guide energy stream between many areas and the effectiveness of the connecting equipment can be dependent on the capacity of environmentally-friendly sources (solar cells, wind turbines etc.).

10. Smart grid architecture model (SGAM)

The SGAM is a reference architecture intended to show the cases of SG architecturally. This was the result of an EU Mandate M/490 reference working group [35, 36]. SGAM primarily consists of five component layers: business, functionality, content, communication and layers. These are referred to as interoperability layers. Each interoperability layer contains a smart grid plane covering electrical space and knowledge processing areas. The main aim of this model is to show which areas of data management communicate with each other.

Three-layered Architecture- The three-layer IoT-assisted SG architectures have been used extensively in [37], focusing on the IoT-assisted method's characteristics. As seen in **Figure 13**, the architecture consists of three layers, a vision layer, a network and an application layer.

1. **Perception Layer**- The aim of this layer is to detect and gather information using different IoT-assisted SG devices. They have various types of IoT system for the collection of data in an SG system, such as RFID tags, sensors, WSN, GPS and M2M. It consists of two substrates, a vision control sub-layer and a connectivity extension sub-layer. The vision of a sub-layer controlling knows how to physically handle IoT equipment, obtain, monitor and manage information, while a communications module connecting IoT to network levels exists in the sub-layer extension communication.

2. **Network Layer**- The network layer consists of the converged telecommunication and internet networks [38]. Owing to its advanced architectures, the network layer has been generally embraced. The aim of the protocol is to map data from IoT systems on the perception layer of the telecom protocol [39]. The mapped data is then transferred to the application layer through the corresponding telecommunications network. The central network, i.e. the Internet, is responsible for the routing, transmission and control. Other telecommunications networks are the basis for the network of access. The IoT and Knowledge Centres are also part of the network. The network layer may be based on public communication networks, as well as industries.

3. **Application Layer**- The implementation layer consists of integrating IoT technologies into a wide range of IoT-aided SG applications as well as market experience. Its purpose is to process and monitor IoT devices and the SG
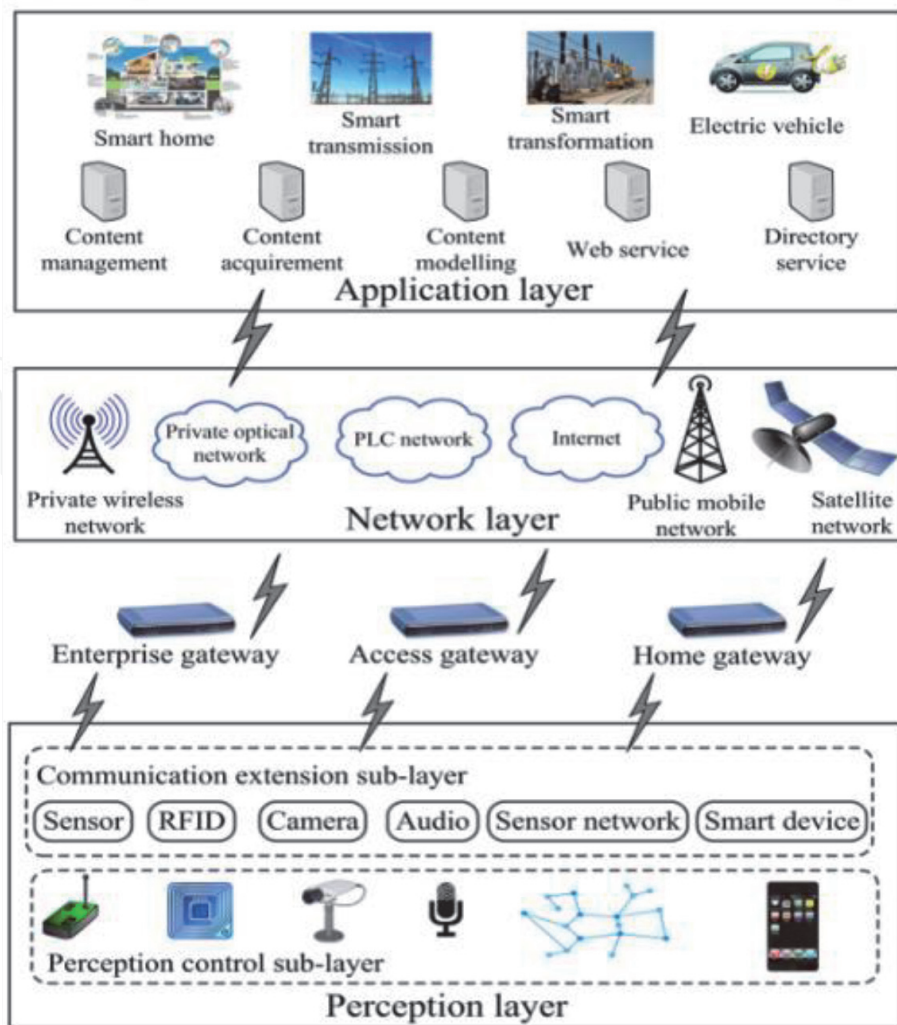
Figure 13.
IoT-aided SG structures, with a vision layer, network layer and device layer, have a three-cover architecture.. The layer consists of two sub-layers, a sub-layer for contact expansion, and a perception [43].

ecosystem in real time based on the information obtained by the network layer. There are several aspects of the IoT-assisted SG systems presented in **Figure 3**. It comprises an infrastructure/middleware frame and various types of records, web and directory resources servers. IoT technology computing, delivery and services are offered through the application/middleware infrastructure. The key components of the application layer are information sharing and secrecy. The deployment layer would particularly increase for SGs who can provide far richer data sets.

4. **Four-layered Architecture** – A characteristic feature of the SG Information and Communication Systems was proposed in a four-layer IoT-assisted SG interface architecture. As seen in **Figure 14**, this architecture consists of a terminal layer, a layer of the field network, a distance layer and a layer of devices. The terminal and field networks are consistent with the design with the IoT knowledge layer, the IoT network-level remote communication layer and the IoT application-level MATS interface layer with the IoT three-layer hierarchical model.

5. **Cloud-based Architecture** An essential component of SG, needed for global sustainable growth, is improving the energy efficiency of a building. Smart energy is also an important area of IoT science. Buildings account for about 71 per cent of the total energy usage of green buildings in the US. However, green buildings like this have not been as strong as expected to date. This can be
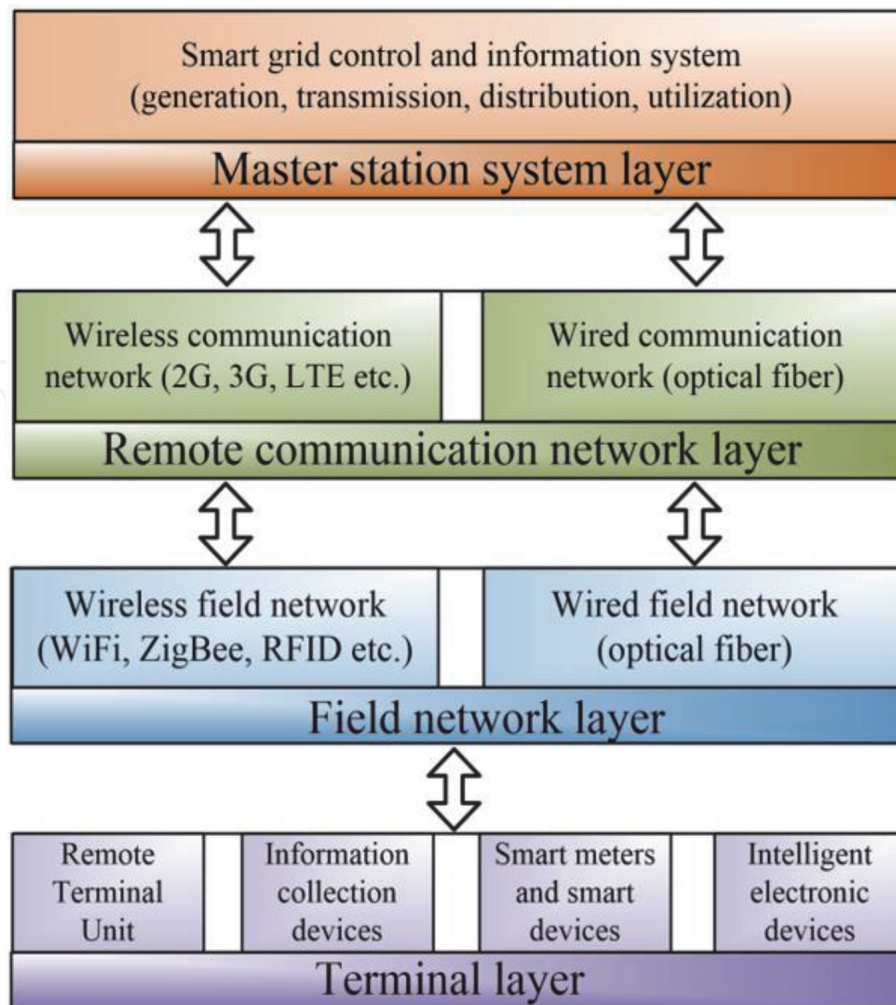
Figure 14.
IoT-aided SG systems' four-layered architecture built on the SG features. It consists of a terminal layer, a field network layer, a remote connection and a system layer for the main station. [43].

because fixed and stagnant schedules do not fit in with consumer lifestyles or because there are volatile business dynamics. Users are now using their smartphones or PCs to change energy conditions using IoT technology. This allows users to comply with their own schedules by adjusting policy as and where necessary to easily respond to accidents. The IoT interface has been proposed in 2015 for the effective control of smartphones and cloud computing services. This new framework transforms the existing statically energy management system and central control modes, which generally consists of different buildings, to complex and dispersed energy control on the user side of SG. This frame is seen in **Figure 7**, which includes four key elements, (i) energy conservation policy for multiple sources, (ii) telephone tracking and monitoring, (iii) automated access position-based control and (iv) data storage and computing cloud network. The premise of an enterprise consists of a variety of separate sections, including campuses, houses, offices, laboratories and offices, each with different energy needs and regulations, which are essential in terms of energy use management. Each family member often has a preference for energy usage in a single home, which has to be taken into account. As seen in **Figure 15**, there are several layers in different stages in this scheme of energy saving techniques. This management strategy framework (e.g., building, department, lab and room).

6. **Web-enabled SG Architecture**- In [41], for IoT-assisted SG frameworks, Web architectures have been proposed (**Figure 16**). A number of IoT
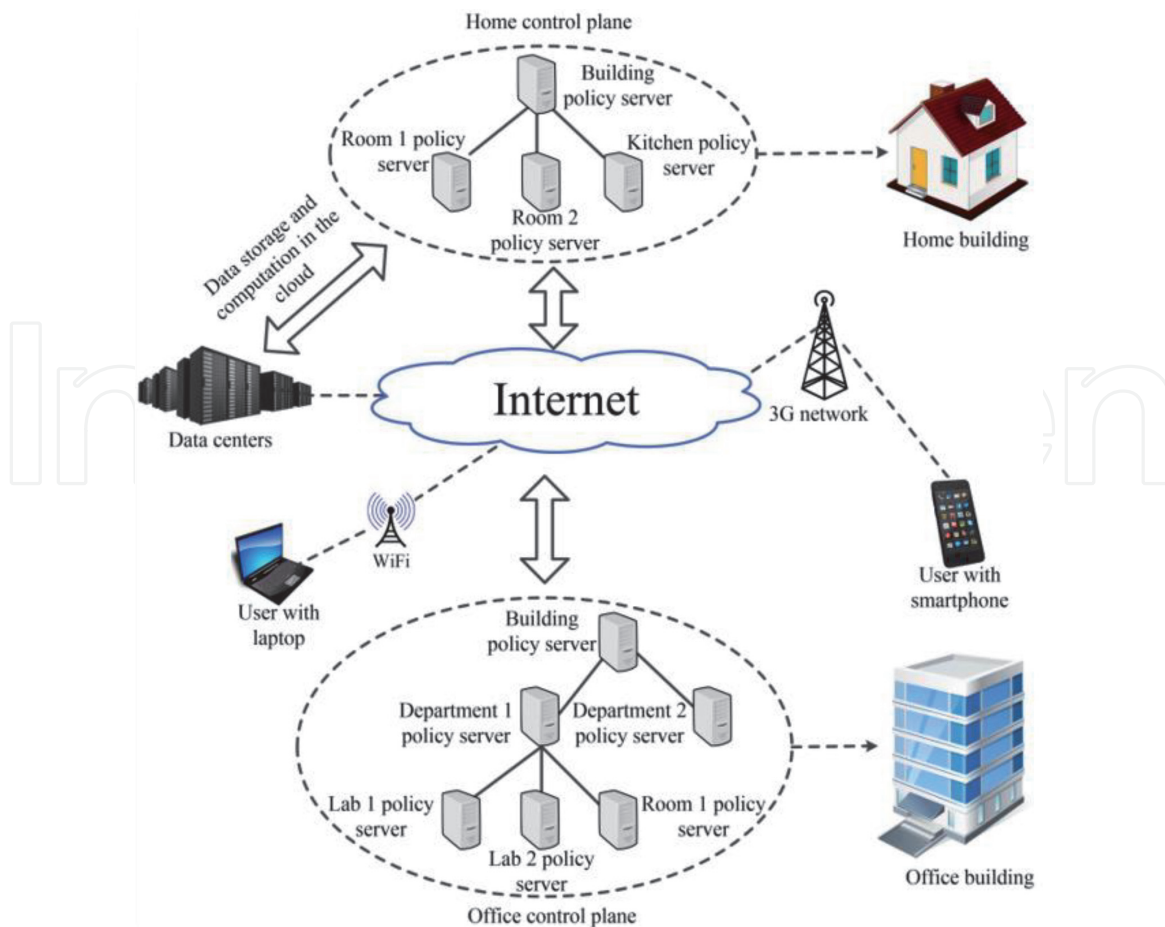
Figure 15.
Network-enabled SG architecture with IoT-advanced web services [40]. There are two different categories of renewable and non-renewable energy sources, all linked to modern energy metres. [43].

computers provide access to online services, which are the guidance of the web browser to these web services. There are several online sites in the Internet. Two forms of energy exist: non-renewable and renewable energy. Non-renewable energy sources are thermal energy stations like coal and oil fires, which release carbon dioxide into the air and the nuclear power stations. Renewable energy is an environmentally friendly alternative which comprises hydropower, wind turbines, solar, biogas and biological fuel as well as geothermal, tidal/wave fuels.

It consists of three key components, the network of a sensor and drive, the simulator and IoT server. The sensor and actuator network comprises sensor and actuator nodes and IP gates. The IoT system has an IoT message sending computer, an SG database, a data processing server, a software setup, a settings unit, a device log and a safe Access manager. User interfaces are a visualisation interface, a gui settings, and an API Web Server.

11. BIG data analytics in multiple cloud for IoT-based smart grid architecture

A. **Need of Big Data Management in IoT-aided SG Systems-** IoT technology is combined with SG at an expense that requires vast quantities of data to be managed routinely and saved. This information covers market load demand, electricity usage, status of network components, power lines failures,
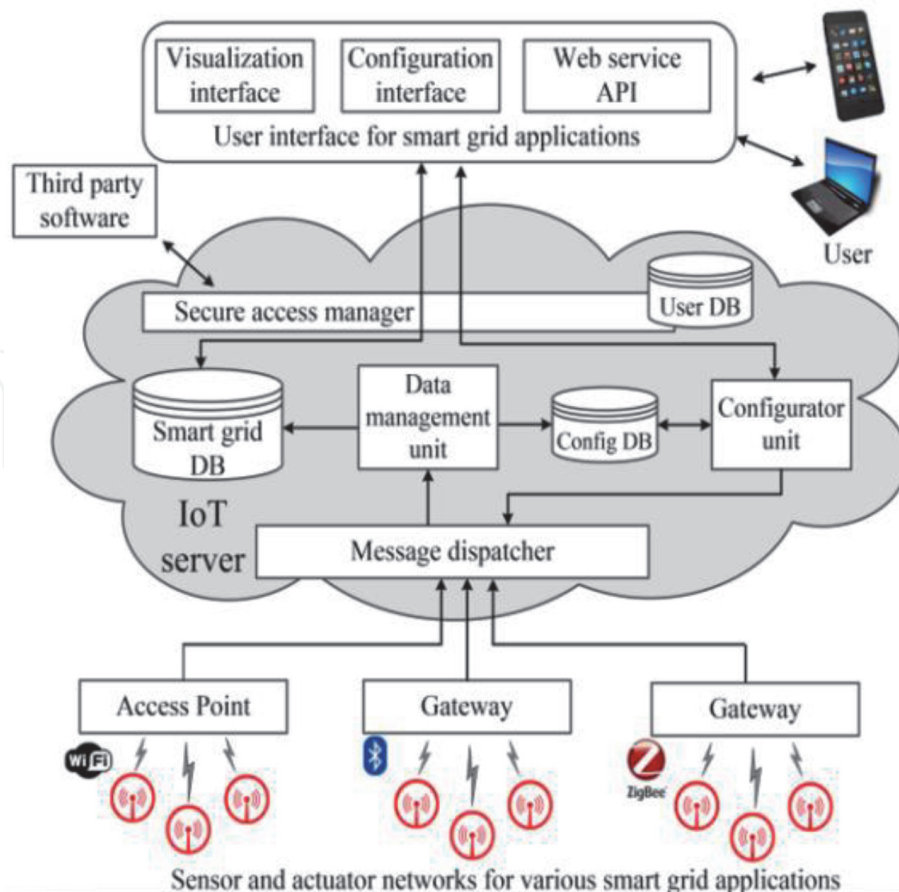
Figure 16.
Fixed metre IoT embedded SG architecture. The components, sensor and power supply networks, IoT server and user interfaces. The sensor and actuator networks are made up of sensor and actuator nodes as well as IP passages. The IoT server has a message dispatcher, an IoT client, a data processing unit, a settings database, a user database and a safe access manager. The user interfaces include the visualisation interface, the web service API and the configuration interface. [43].

advanced metering reports, failure control records and requirements for forecasting. In other words, the service companies must be able to store, handle, and process information obtained from IoT devices safely and easily using hardware and software [42]. From application to application, the rate of data processing and stored for IoT-aided SG systems varies. Some programmes, for instance, execute their functions at a certain day time, including weather forecasts, which can be done every day at night. Another programme performs its functions at any point, such as online real-time tracking of transmission power lines, which means that the management and analysis of its data needs attention. Big data analytics can help handle tremendous knowledge in real time.

The key decision-making feature in SG is the Supervisory Control and Data Acquisition (SCADA) scheme. It gathers data from IoT sensors spread around the grid and provides online surveillance and control in real time. It also helps control network power flow to achieve consistency of use and stability of power supply. It is typically situated at separate locations of services on local machines. As the SGs increase in complexity, utilities are facing a challenge to update and expand SCADA networks. Cloud storage is a good option for hosting SCADA systems in order to solve this problem.

On-demand cloud infrastructure provides access to a common pool of computing resources, including storage, computing, networking, device, server and operation.
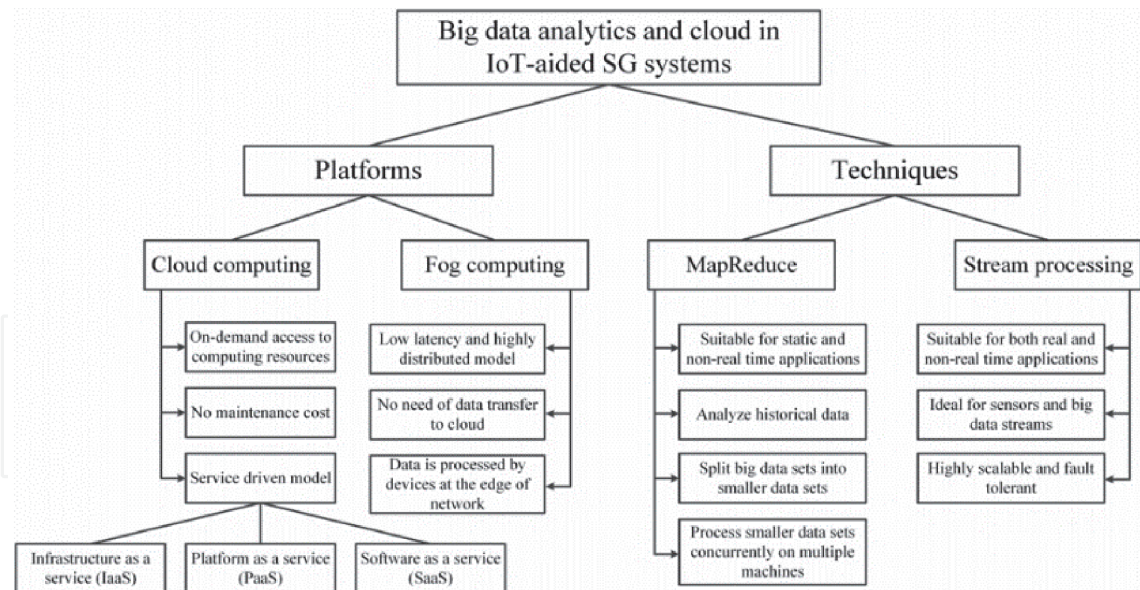
Figure 17.
Big data processing classification into platforms and methods of IoT-assisted SG programmes. Cloud and fog processing are on the platforms, while MapReduction and stream processing are the techniques. [43].

A. **Platforms-** A business model can be divided into three kinds in the cloud computing environment, namely, service infrastructure (IaaS), service platform (PaaS) and service software (SaaS). IaaS offers IT infrastructure, mostly through VM, including Amazon EC2, Flexiscale, GoGrid, and Joyent as a service. PaaS assists developers in building operating systems and smartphones by using their cloud-based applications, such as Microsoft Windows Azure, Force.com and the Google software engines. SaaS is an on-demand Internet service-on-demand multipurpose network. It is a ready-to-use technology for IBM, Microsoft, Oracle, SAP and others. The services migrate their SCADA programmes in their entirety into the cloud and use the provision of storage, computing and other cloud related tools. Which allows the utilities to take advantage of many advantages, including no costs overhead and repairs, increased communication, payment for usage and reduced power costs (**Figure 17**).

B. **Techniques-** MapReduce and stream processing consist of two principal processes. Map Reduction can be used for IoT aided SG systems (e.g., weather forecasts) for static and non-re-time applications, whereas for online monitoring, auto healing and fraud detection and non-real-time applications. The MapReduce technology is a tool for analysing and using extensive historical information. It splits big data sets into smaller data sets and processes smaller data sets with the same code on several machines simultaneously. Sensor streaming and massive data streams are considered to be adequate for transmission. The architecture has been developed to handle massive data in real-time with high scalability and defect tolerance. There is also enormous scope for big data management in streaming of the IoT supported SG systems.

12. Future perspectives of the grid modernization

The change in the delivery stage of the electrical power system depends on several factors. The vision might be brief as follows:

- With continued developments in energy efficiency, the need for electricity will increase.

- The population will continue to rise and the need for affordable electric power

- Electrical transport proliferates by electric trains and electric vehicles Electric transport (cars, buses, and trucks).

- Green energy supplies are the gateway to fuel revolution.

- Consumers need a stronger, cleaner more secure and more efficient grid that requires system and process upgrades.

13. Conclusions

In future urban grids, powerful, reliable, versatile, protected, robust and inexpensive electrical supply will be needed. The most versatile advancement strategy choice for accessing different planning problems related to urban grid enhancement and transformation, suggested by submission resolutions sponsored by the VSC-HVDC. The organisational versatility and stability of urban grids can be greatly improved by launching direct input of electricity into load centres and improving intercity power generation capacities and dramatically decreasing the need for the regional generation and spinning supplies. The technology of VSC-HCDC is evolving and developing continuously. New architecture concepts rely on modular products and lightweight systems which will have the ability to incorporate urban power grids.

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