BRICS Smart Grid Report

2022

BRICS
ENERGY RESEARCH
COOPERATION PLATFORM

BRICS
2022 CHINA

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INTRODUCTION

Creating the conditions for the development and exchange of advanced energy technologies is an essential part of BRICS energy cooperation. The development of technological cooperation between the BRICS countries has long been on the agenda of the leaders of the five countries.

In the Xiamen Declaration of 2017, BRICS leaders encouraged continued dialogue on the establishment of a BRICS Energy Research Cooperation Platform (BRICS ERCP). At the 5th Meeting of BRICS Ministers of Energy in 2020, BRICS countries jointly identified 11 priority areas of cooperation for the BRICS Energy Research Cooperation Platform, and smart grid is one of them.

The report presents the current status and plans for smart grid development in the BRICS countries, as well as analysis on potential cooperation areas within BRICS countries.

The report contains three sections. Chapter I surveys the status quo of the smart grid worldwide and analyze global trends of smart grid development. Chapter II presents the progress of smart grids of each country. The policy-framework to support smart grid development and the key technologies promoted by BRICS countries in the field of smart grid, as well as the R&D projects and relevant demonstration projects are also included. The objective of this section is to share learnings and experiences of each country among BRICKS countries and with global audience. Chapter III elaborates prospects for smart grid cooperation between BRICS countries. This section will seek to explore synergy and complementarity within BRICS countries to promote cooperation in smart grid field.

This study will lay a foundation for determining the priority areas and modalities of smart grid cooperation among the BRICS countries.

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Chapter 1

Global Smart Grid Development

[I]

OVERVIEW OF GLOBAL SMART GRID DEVELOPMENT

I. Global Smart Grid Development Status & Quo

Against the backdrop of increasingly severe situation of climate change and energy security, the major factor lying in the economic and social development remains energy science and technology, and for its innovation and development, the smart grid becomes not only a major carrier but also the inevitable trend for modern power grid development.

Different countries have different emphases on the smart grid due to national conditions, development stages, and resource endowment. Thus, there is no uniform definition of the smart grid. Some countries and organizations described the smart grid in terms of its adopted technologies and main characteristics.

US Department of Energy (DOE): The smart grid adopts advanced sensing technology, communication technology, and control technology, the power generation, transmission, and supply can be more efficient, economical, and safe. As a modern gird, it integrates a large number of innovative technologies in the fields of power generation, transmission, and distribution, as well as electrical equipment. All these techniques contribute to society and meet the changing needs of the future.

European Technology Forum: The smart grid employs innovative tools and technologies, products, and services, together with intelligent monitoring, communication, and control technologies in order to provide a one-stop service of power generation, transmission, and distribution for terminal consumer devices and equipment. It enables electricity consumers to become active participants, thus providing more information choices, greater energy output, higher demand participation rate, and energy efficiency.

IBM proposed the smart grid solutions: First, increase the digital maturity of power equipment through sensors. Second, establish a data integration system and collection system. Third, improve the ability of data analysis, optimized operation, and management.

For China, the National Development and Reform Commission & National Energy Administration pointed out in Guidelines on the promotion of smart grids development issued in July 2015 that, the smart grid is a new generation of power system based on the traditional one, which employs new energy, materials, equipment, and advanced sensing technology, information technology, control technology, energy storage technology, and other new technologies. It boasts high levels of IT application, automation, and interaction, thus it can realize a safe, reliable, economical, and efficient operation of the power system.

The above definitions showed that what is a smart grid has no uniform recognition yet. This report regarded the smart grid as a future power system, representing the development direction. Based on the traditional power system, the smart grid employed new materials and technologies including energy storage and power electronics, together with advanced sensing and measurement, communication and information, and control technologies, forming a flexible, reliable, safe, efficient, adaptive, and self-healing grid. As a new grid, it can bear large-scale renewable energy and distributed generation, and respond actively to consumers.

II. Global Smart Grid Development Trend

1. Trends in Developed Countries

In Europe, United States and other developed countries, there are stable power demand, improved power systems, and strong power transmission and transformation capacity. At present, the smart grid in developed countries is growing towards digitization, informatization, comprehensive energy, and low carbon development.

(1) Power system: high automation, digitization, and informatization

In the United States, the key technologies to develop smart grid includes Distribution Operation Automation (DOA) and Distribution Management Automation (DMA). By adding functions to the traditional distribution automation system, DOA technology helps to solve the two-way power flow interaction problems brought by distributed energy and electric vehicle access, and to reduce network loss and energy consumption; DMA technology integrates Outage Management System (OMS) and Advanced Metering Infrastructure (AMI) to improve outage management service, power supply reliability and work efficiency.

(2) Power system: an important platform for developing an integrated energy system

Integrated energy system refers to advanced physical information technology and innovative management in a certain region. It integrated energy sources including coal, oil, natural gas, electric energy, and heat energy, realizing coordinated planning, optimized operation, collaborative management, interactive response, and complementary among various heterogeneous energy subsystems. It is a new system that can improve energy utilization efficiency and energy sustainable development while meeting diversified demand. In such an integrated energy system, electric energy, as the most convenient secondary energy, is an important medium for heterogeneous energy conversion.

Japan attaches importance to integrated energy development. Through the construction of smart power grid, it aims to improve integrated energy efficiency. It was led by the government, urged by industry associations, researched by institutions, promoted by power enterprises, and jointly worked by relevant equipment enterprises. The power grid in Japan owns advanced information technology, high automation level, and reliability. With the increasing number of distributed power sources such as rooftop photovoltaics and fuel cells connected to the power grid, it became the main challenge facing Japan. Therefore, Japan regarded home energy management system (HEMS), building energy management system (BEMS), electric vehicle transportation energy management system, and photovoltaic energy storage system as the direction and mode of the smart grid. Plus, under the liberalization and reform of retail business, Japan has deployed renewable energy, energy management, high-performance energy storage, and other technologies into smart grid construction. The future integrated energy system will be composed of distributed generation, distributed grid energy storage, micro-grid, electric vehicle, fuel cell, gird of cooling, heating, and gas, etc., and the power system would be an important platform.

(3) Power system: adapts to the high proportion of renewable energy

The high proportion of renewable energy power system is an important development trend for the smart grid. European smart grid is led by the European Union (EU), and is committed to building a smart grid for distributed generation and interactive power supply, emphasizing environmental protection and renewable energy power generation. The main characteristics of the EU smart grid include: a) Flexibility to meet the different needs of various customers; b) Easy access to ensure accessibility to renewable energy and distributed generation; c) Reliability to guarantee and improve the safety and quality of power supply; d) Economy to achieve the most effective energy management through reform and competitive regulation.

In addition, the trend of the smart grid in the EU requires an automation grid with high observability, controllability, and flexibility. The high observability and controllability of power grid automation technology have laid a solid foundation for distributed energy construction. At the same time, the EU smart grid also improves the flexibility of power supply side and power consumption side through technology and the market. On the technical level, the research focuses on the management of virtual power plants through distributed information and communication technology; On the market level, the research concentrates on the operation management of virtual power plants and the demand-response market mechanism.

Germany regards renewable energy as the long-term goal of energy development. After the Japanese nuclear crisis in 2011, Germany has resolutely phased out nuclear power and was determined to develop renewable energy. As the largest economy in Europe, Germany plans to double the proportion of renewable energy to 35% in the next decade.

Furthermore, through modern information and communication technology, Germany actively promotes the integration of information technology and the energy industry and realizes the real-time exchange of information among power generation enterprises (or power suppliers), power grid enterprises, and power users. At the same time, it makes sure that the power grid is reliable and safe, providing an important guarantee for the large-scale grid connection of renewable energy.

2. Trends in Developing Countries

Due to different infrastructure and economic development levels, the smart grid in developing countries varies from that in developed countries.

(1) Safe smart grid: improve power supply reliability and energy & power accessibility

Improving the power supply reliability and reducing the population in areas without electricity is the top priority of the smart grid construction in developing countries. The power industry is capital-intensive, and the construction of the smart grid requires a large amount of money. With weak power infrastructure and low reliability rate of power supply, areas without electricity remained. At the same time, the electricity demand will increase rapidly in developing countries according to the economic development and the improvement of people's living standards. Therefore, upgrading the old transmission and distribution lines, and improving the reliability and accessibility of power supply by enhancing the automation level of power grids are important guarantees and directions for growing better productivity, sustainable economic and social development, and people's well-being in developing countries.

(2) Strong smart grid: support large-scale renewable energy development and delivery

For developing countries with abundant renewable energy resources, establishing a safe and stable renewable energy power system is an important direction. At present, due to the narrowing gap between renewable energy power generation and traditional power generation in technology maturity and economy, developing large-scale renewable energy has become a major choice. At the same time, some developing countries have hydro-power resources and have great development potential. However, wind power and photovoltaic power are featured by the random fluctuation of output, and hydro-power stations are inconsistent with water supply in the wet and dry seasons. Thus, it requires the supporting power grid has a high level of dispatching automation and stable operation.

Therefore, for developing countries where conditions permit, establishing a high-precision renewable energy power forecasting system and a flexible, efficient smart grid dispatching automation system is necessary for large-scale development and utilization of renewable energy.

(3) Economical smart grid: high operation efficiency and automation level

Constructing an economical and efficient smart grid is a major road for developing countries to reduce the cost of social electricity. For developing countries, the power industry is one of the economic lifelines for it involves the costs of related industries. The power grid, as a major part of the power industry, is an end-to-end link, connecting the power generator and the consumer. Therefore, reducing its cost is not only the foundation to ensure the healthy and sustainable development of the power industry, but also a focus to decrease the social electricity cost. Improving the economy of power grid operation and reducing the electricity cost of the whole society are conducive to promoting the sustainable development of the economy and society.

Limited by the level of economic development and historical legacy issues, the power grid facilities in some developing countries have such problems as serious aging, high line loss rate, and low level of automation. In addition, the lack of advanced measuring devices makes the prominent problem of electricity theft so difficult to eliminate in short term, further reducing the economy of the power grid. In order to solve these problems, the smart grid in developing countries should move forward in such ways as follows: a) The use of smart meters is promoted to solve the problem of electricity theft and protect the profits of grid operators. b) The level of power grid automation is enhanced which can reduce the human cost of grid operation. c) Apply the advanced scheduling technology of the smart grid and optimize the output of all kinds of power sources in the power system in order to achieve optimal economic dispatch. d) In some developing countries where power and load centers are inversely distributed, DC power grids are established in time to reduce the operating costs of the transmission network.

Chapter 2

Profile of the Smart Grid Development in BRICS Countries

[II]
BRAZIL

I. Relevant Policies to Promote Smart Grid Development

Brazil has a vast system of interconnected electricity production and transmission, known as the National Interconnected System (SIN). It is considered a large hydro-thermal-wind system, with a predominance of hydroelectric plants and with multiple owners. The National Interconnected System consists of four subsystems: South, Southeast/Midwest, Northeast and most of the North region. The operation involves complex simulation models that are under the coordination and control of the Brazilian National Electric System Operator (ONS), which, in turn, is supervised and regulated by the Brazilian National Electricity Regulatory Agency (ANEEL).

The interconnection of electrical systems, through the transmission grid, provides the transfer of energy between subsystems, allows for synergistic gains and explores the diversity between the hydrological regimes of the basins. The integration of generation and transmission resources makes it possible to serve the market safely and economically.

The installed generation capacity of the SIN is mainly composed of hydroelectricity plants distributed in 16 hydrographic basins in different regions of the country. In recent years, the installation of wind farms, mainly in the Northeast and South regions, has shown strong growth, increasing the importance of this generation for serving the market. Thermal plants, generally located close to the main load centers, play an important strategic role, as they contribute to the security of the SIN. These plants are dispatched based on the prevailing hydrological conditions, allowing the management of water stocks stored in the reservoirs of the hydroelectric plants, to ensure future service. Transmission systems integrate the different sources of energy production and make it possible to supply the consumer market.

The basic transmission network comprises 169,914 km (2021 data), distributed in 230 kV, 345 kV, 440 kV, 500/525 kV, 600 kV DC, 750 kV and 800 kV DC networks.

According to the Ten-Year Energy Expansion Plan (PDE 2031), Brazil has an installed electricity generation capacity of approximately 200 GW, with about 85% renewable, with 58% of the total coming from hydraulic sources. However, the sector has been undergoing major transformations, with the increasing participation of non-dispatchable renewable sources such as wind and solar, which adds greater complexity to the management of the system. For the ten-year horizon, until 2031, an expansion of centralized wind electricity generation of around 70% (67 TWh to 114 TWh) and of solar generation of 214% (7 TWh to 22 TWh) is expected. For Self-Production and Distributed Generation, an increase in electricity generation of around 40% (674 TWh to 945 TWh) is projected, with solar generation expected to increase by around 400% (9 TWh to 45 TWh).

With the modernization of the electricity sector, the Brazilian consumer is gradually assuming a less passive role and also becoming a producer of energy or managing its demand based on economic stimuli and in a decentralized way. In this vein, Law No. 14,300, of January 6, 2022, established the legal framework for microgeneration and distributed mini-generation, the Electric Energy Compensation System (SCEE) and the Social Renewable Energy Program (PERS). The law defined some concepts such as:

- Consumer-generator: holder of a consumer unit with distributed micro-generation or mini-generation;
- Electricity credit: surplus electricity not compensated by a consumer unit participating in the SCEE in the billing cycle in which it was generated, which will be recorded and allocated for use in subsequent billing cycles, or sold to the distribution company in which the consumer-generator central is connected;
- Dispatchable sources: hydroelectricity plants, including those run-of-river, that have the feasibility of variable control of their power generation, qualified cogeneration, biomass, biogas and photovoltaic generation sources, limited, in this case, to 3 MW of installed pocapacity, with batteries

whose amounts of energy dispatched to final consumers have generation modulation capacity through the storage of energy in batteries, in an amount of, at least, 20% of the monthly generation capacity of the generating station that can be dispatched through a local or remote controller;

- Distributed microgeneration: electricity generating plant, with installed capacity, in alternating current, less than or equal to 75 kW and using qualified cogeneration, in accordance with the regulations of the Brazilian National Electricity Regulatory Agency (Aneel), or renewable sources of electricity, connected to the electricity distribution network through consumer unit installations;

- Microgrid: integration of several resources of distributed generation, storage of electric energy and loads in a secondary distribution system capable of operating connected to a main electric energy distribution network and also in an isolated way, controlling the electricity parameters and providing conditions for recovery and restoration actions;

- Distributed mini-generation: generating plant of renewable electricity or qualified cogeneration that is not classified as distributed microgeneration and that has installed capacity, in alternating current, greater than 75 kW, less than or equal to 5 MW for dispatchable sources and less than or equal to 3 MW for non-dispatchable sources, according to Aneel regulations, connected to the distribution grid through consumer unit installations;

- Electricity Compensation System (SCEE): system in which active energy is injected by a consumer unit with distributed microgeneration or minigeneration in the network of the local distributor, granted as a free loan and later compensated with the consumption of active electricity or accounted for as electricity credit from consumer units participating in the system;

- The Social Renewable Energy Program (PERS): is intended for investments in the installation of photovoltaic systems and other renewable sources, in the local or remote shared modality, to consumers of the Low Income Residential Subclass referred to in Law No. 12,212, of January 20, 2010.

Prior to the legal framework for distributed microgeneration and mini-generation, as a public policy for the development of smart grids, MME Ordinance nº 440, of April 15, 2010, can be cited, where a Working Group was created to study the concept of smart grids.

In another initiative, with resources from Eletrobras, Petrobras and the META Project, conducted by the Ministry of Mines and Energy and the World Bank, the Electric Energy Research Center (Cepel) inaugurated, in December 2021, the Smart Grids Laboratory. This facility allows the definition and experimental evaluation of connection requirements that make it possible to optimally integrate high levels of distributed energy resources, such as distributed photovoltaic solar generation, wind generation, storage with batteries and plug-in electric vehicles. This ensures more control to electrical networks and maintains their reliability and robustness.

It is also worth mentioning the Research Center on Smart Electric Grids (NAPREI), a reference in smart grids in Brazil, at the University of São Paulo. NAPREI aims to develop research that establish the technological migration of the Brazilian electricity sector from the current stage to the adoption of the Smart Grid concept.

II. Smart Grid Technology and Application

1. Ultra-high voltage direct current (UHVDC) transmission technology

A Ultra-high voltage direct current (UHVDC) transmission technology features voltage levels of ±800 kV and above DC.

In December 2017, one of the largest transmission lines in the world in UHVDC came into operation in Brazil and the first with this technology, of +-800 kV, with a length of 2,076 km and designed to transmit up to 4 GW of electricity. It is responsible for discharging part of the energy generated by the Belo Monte Hydro Power Plant, in northern Brazil, to the Estreito substation in the southeast region. Among the advantages of this technology is that it allows the transmission of large blocks of energy over long distances economically and that it can be used to connect two alternating current systems that are out of sync or with different frequencies.

2. Smart meters in Copel's Smart Grid program

In September 2020, Companhia Paranaense de Energia (Copel) started the Smart Grid program. With the new system, consumer units receive digital meters, which communicate directly with Copel's operations center.

The technology reduces shutdown time caused by weather and other factors external to the system. In addition, it makes it possible to read consumption at a distance and allows the customer to have the autonomy to monitor their energy consumption in real time, among other benefits.

The Smart Grid materializes with the application of sensors and remote control devices that allow it to reconnect itself in most cases and, if this does not happen quickly, Copel can immediately detect and solve eventual disconnection problems at from the Integrated Distribution Operation Center in Curitiba.

Thus, when the intervention of technicians is necessary for repairs in the network, the operation center knows how to indicate the exact point that generated the power outage. This eliminates the need for a team to traverse the entire affected network to identify the location where the problem occurred. Consequently, the time for the restoration of energy drops drastically, which makes a big difference in the lives of communities in general and for agribusiness in particular. The smart grid also has automatic voltage regulators.

3. Pilot project in Microgrids

Microgrids can help resolve issues of meeting the growing energy demands of utilities, by developing and integrating diverse energy sources and storage systems with consumers.

Microgrids also make it possible to reduce congestion on transmission and distribution lines, in addition to reducing costs and losses in electricity transmission.

Meeting energy demands, using local resources and encouraging distributed generation, is another exceptional advantage of microgrids.

In the first half of 2021, Companhia Paranaense de Energia (Copel) held an unprecedented public call in Brazil for the purchase of energy from small and medium-sized independent producers, including mini-generators that will set up microgrids. A microgrid can be considered an independent electrical system, which works as an “energy island”, integrating generation, storage and consumption into the distribution network.

The self-generators that will constitute the microgrids must deliver the energy contracted to Copel and, with that, will be able to supply a group of nearby consumers.

The call covers system users that generate from 1 to 30 MW.

This pilot project lasts for five years, as Aneel's authorization is configured as a regulatory sandbox – a kind of "regulatory protection box" in which some rules can be relaxed and/or changed, with a duration and conditions previously defined, so that the agents of the sector can carry out innovations.

4. 5G technology

Brazil, through the Brazilian National Telecommunications Agency – ANATEL, held in November 2021, the 5G Auction, which is the latest technological standard for mobile services, which includes high data transmission rates and low latency. Technology offers a wide range of possibilities, yet to be explored. Furthermore, the coverage commitments that the public notice imposed on the winning companies are highlighted, which will provide greater digital inclusion.

III. Prospects and Outlook for Smart Grid Development

1. Flexible Alternating Current Transmission Systems

Empresa de Pesquisa Energética – EPE has been following ongoing studies on the application of new technologies for the transmission system, such as FACTS devices (Flexible Alternating Current Transmission Systems) and DC/AC converters, through VSC (Voltage Source Converter) solutions.

FACTS devices are technologies based on power electronics developed with the objective of improving the control and stability of the system, making it possible to increase the energy transfer capacity between certain points in the network.

Recent technological advances associated with the DC/AC conversion process, through VSC (Voltage Source Converter) solutions, constitute a potential solution for problems of DC link integration to weak networks, as well as for the reduction of multi-infeed interactions. In this sense, the reduction of technological gaps, which constituted barriers to the application of this technology in the transmission of power over long distances, as in the Brazilian case, has been provided through the use of new converter arrangements, such as the Full-bridge MMC (Modular Multilevel Converter).

Within this context, a survey to identify potential suppliers of new technological solutions is also being carried out by EPE, with the objective of verifying if there are sufficient competition conditions to guarantee the good results of future transmission auctions and, also, balanced prices of maintenance and modular replacement of equipment throughout the life cycle of transmission assets.

2. Energy Storage Systems

Energy storage technologies, such as electrochemical batteries, electrochemical capacitors, among others, can provide several services in the transmission sector.

Such technologies provide multiple applications, among which are: load balancing, frequency control, voltage control, network stabilization, among others.

Despite the technical possibility and legal provision, in Brazil, the use of batteries in consumer units, "behind the meter", has still low usage due to its high cost. However, given the expectations regarding cost reduction of the technology, the EPE sought to assess the prospects for its entry into the ten-year horizon, until 2031. Three main use possibilities for batteries were analyzed:

I - Increased self-consumption of distributed microgeneration;

II - Displacement of consumption with White Tariff; and

III - Displacement of consumption with Tariff A4.

Additionally, 2 forms of supplementary revenue for the use of batteries were evaluated in the PDE 2031 to assess the impact on the financial viability of the investment:

I - Valuation of the cost of the deficit (by providing backup in times of blackout);

II - Sale of carbon credits with the replacement of diesel generation at peak hours.

However, the simulation results for these possibilities showed that there is still no economic feasibility of investing in batteries in Brazil, considering the current ten-year horizon, unless there is a strong reduction in the price of batteries, to about a quarter of the current values. One of the aggravating factors of feasibility is the fact that the lithium-ion battery market in Brazil is still quite restricted, with few options for suppliers and equipment available. A higher supply can drive prices down further than expected. Changes in the regulation of the MMGD may be necessary to make the use of batteries viable, as there is currently no specific regulation for the use of batteries with injection into the grid.

EPE will continue to deepen its analysis and monitor this market to identify new opportunities and trends in the sector.

[III]

RUSSIA

The development of the electric power industry, including through the introduction of digital technologies and smart systems in Russia has its own distinctive features caused by the excessive use of traditional energy sources, Russia's large territory and low population density in many parts of the country, the high level of participation of the state in the energy sector and the economics, and other economic and social factors.

Up to year 2035 electric energy systems of the Russian Federation will be developed with an overall goal to form a unified power system that provides both the economic system and the population with energy and power capacity they need in a timely manner. This would be achieved particularly through facilitation of flexible technological interaction of all of the grid's elements, facilities and objects with wide application of ICTs.

The energy grid management system would ensure due account of interests of all involved subjects on the basis of risk management, as well as with the maximum application of economic (market) principles of interaction and organization of technological system management that flexibly responds to user requests given the continuous changes in the external environment.

I. Definition and Key Parameters of Smart Grids

The key priority for the development of the power system is the application of emergency override protocols and manual control systems, as well as technical solutions for remote management. All of these would eventually form a basis for operational and technical control system that enables application of artificial intelligence for control, protection and management. The information exchange between the entities of the system would be ensured through the application of standard synchronized protocols. The system would fulfil the following functions:

- enabling instant shifts of system's energy modes, including through interaction with central and remote terminals, allowing system's operation in normal, emergency and post-emergency regimes;
- establishing the pool of available information resources and technologies for the situation analysis and decision-making;
- implementing algorithms to balance the pressure on the system based on market tendencies;
- collecting and processing large amounts of information on the current state of the power grid and its elements, as well as external environment (illumination, precipitation, ice, wind loads, and other weather factors);
- enabling remote handling of power facilities by operators, control centers and centers for distributed renewable generation.

Respectively, the key element of the system would be the development of smart grids that fulfil the following functions:

- automated accident-prevention adjustable system that enables reconfiguration of grid in response to changes in parameters and topology;
- providing specialized services to various categories of consumers (diversified on the basus of time, volumes, quality and price of electricity supply, regulation of demand and generation, charging of electric vehicles)

The development of power grid's control system is enabled through:

- multiple sensors that measure the current operating parameters to assess the state of the grid;
- system for collecting and processing data,
- application of solutions for automated monitoring and evaluation of the actual situation;
- high-speed operation of integrated information exchange system.

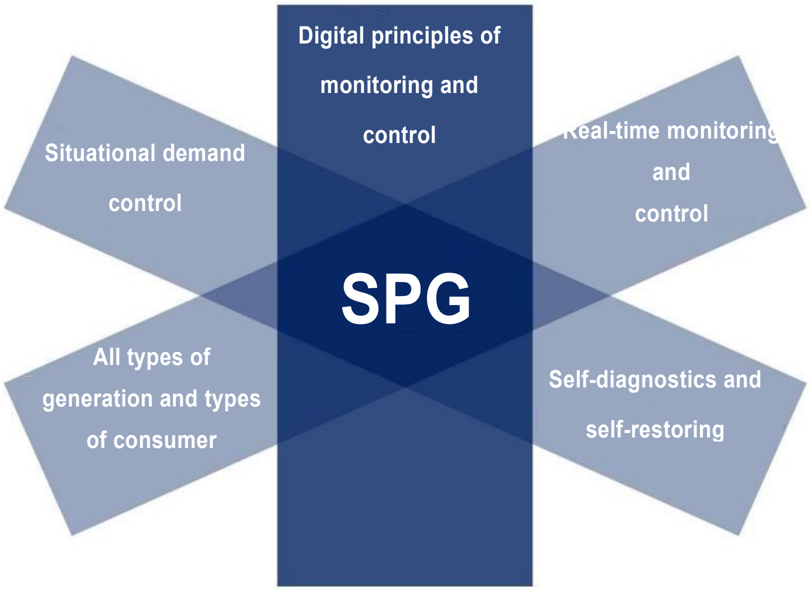
- The operation of the energy system integrates the following key elements
- traditional power generation;
- renewable distributed energy sources and microgeneration;
- energy storage devices;
- smart grid.

It also ensured the application of the following technologies:

- planning and forecasting
- remote management of modes and exploitation parameters of the power grid;
- monitoring and smart account systems;
- smart and economically optimal demand management ('Energy Internet').

The introduction of new technologies should ensure a transition to risk-oriented management. Generalized key components of a smart power grid are shown in Figure 2.1-1:

Figure. 2.1-1 SPG features



The key feature for the development of technological base of power systems is the use of digital technology.

II. Relevant Policies to Promote Smart Grid Development

The basis for the development of smart energy in Russia is the provisions laid out by the "Energy Strategy of Russia up to 2035" (hereinafter referred to as the Energy Strategy) and the action plan for its implementation, the "Doctrine of Energy Security of the Russian Federation", Decree No. 474 of the President of the Russian Federation, dated July 21, 2020, "On the national development goals of the Russian Federation up to 2030", "Strategies for the scientific and technological development of the Russian Federation".

As part of the Energy Strategy, goals have been set out that include both digital transformation of and introduction of smart technology to the fuel and energy complex industries, the result of which should be that processes in the energy sector should increase in quality, and consumers of products and services from the fuel and energy complex industries should receive new rights and opportunities. From the perspective of technological development, whose application may lead to organizational and technological changes in the management and functioning of power grids and contribute to the transition of the energy sector to a new technological basis, the Energy Strategy makes special mention of grid technologies in the electric power industry, and distributed generation as one of the priorities.

Russia's strategy of scientific and technological development determines one of the big challenges as "the transition to environmentally friendly and resource-saving energy, the formation of new sources, and methods of transportation and storage of energy...".

The set of key measures outlined in the Energy Strategy providing a solution to the challenge of increasing the efficiency of the power grid complex includes:

- improving the quality of development of the documents for future development of the electric power industry, including on data on the implementation of investment projects within the administrative regions of the Russian Federation;
- increasing the efficiency, including economic efficiency, of electricity transmission technology;
- improving the system of operational management in power energy and operational-technological control in grids and generation organizations;
- transition to risk-oriented management in the power grid complex;
- creation of smart electricity metering systems.

According to the Energy Strategy, the new technologies for distributed production of electric energy, micro-generation, controlled consumption, and virtual aggregation of resources create fundamentally new conditions for the development of a competitive retail market, built on the basis of automated local trading floors for electricity trading, which, at once leads to containment of rising electricity prices, is a source of additional investment in the development of flexibility management systems on the consumer side, and reduces the predictability for investors regarding the return on investment in wholesale generation facilities.

Guided by the Energy Strategy, the challenges, and the provisions of the Decree of the President of the Russian Federation, the Russian Ministry of Energy is implementing a number of projects aimed at transforming the energy infrastructure of the Russian Federation via the introduction of digital technologies and platform solutions to improve its efficiency and security. A number of measures are being contemplated to achieve the key objectives for the digital transformation of the energy sector:

- creating the conditions for the design and development of digital services and solutions, for which a system for managing, coordinating, and monitoring the digital transformation of the Russian fuel and energy complex is planned — creating the conditions for the design and development of digital services and solutions in a single information environment;

- implementation measures to develop and adjust legislation, the regulatory legal and regulatory technical framework, select and implement pilot projects for the introduction of digital technologies and industry platform solutions;
- forming a system for coordinating, and monitoring the digital transformation of the Russian fuel and energy complex;
- creating electricity industry centers of competency, designed to identify priority areas and introduction of advanced production and information technologies for relevant industries, eliminate regulatory and technological barriers to their implementation.

In addition to their own projects, the government entities support a number of measures that contribute to the development of the electricity industry in general, as well as its digital transformation in particular, implemented as part of the Action Plan (the “roadmap”) of the National Technology Initiative outlined in the address to the Federal Assembly on December 04, 2014 President of the Russian Federation as one of the priorities of the state policy and a strategic direction for the development of the country’s technological leadership.

The following technologies are of priority in the framework of the mentioned roadmap:

- smart technologies and tools for monitoring and diagnosing the condition of equipment in power grids;
- anticipatory maintenance of equipment to detect deviations in operation in a timely manner and prevent unforeseen operational idling and breakdowns;
- new technical tools for creating smart power grids, including a highly automated substation, smart electricity metering systems, highly sensitive sensors, devices that allow gradual regulation of electricity supply for power consuming appliances, relay protection and automatization;

- methods and technical tools for smart real-time management of end-user consumption of electrical energy based on economic criteria, with the integration of power grids and information networks (‘Energy Internet);
- cost-effective means of accumulating large volumes of electrical energy.

The Association of Digital Development Organizations of the Industry “Digital Energy” was created to meet the challenges of digital transformation of the electricity industry in Russia, to form a consolidated position, and to unite the efforts of the sectoral business communities and government authorities, research, and educational organizations in the electric power industry. The founders are the largest Russian energy corporations, mostly state-owned, such as JSC “Inter RAO — Electric Power Plants”, Rosenergoatom JSC, JSC “System Operator of the Unified Energy System” and PJSC “Rosseti”.

In the recent years, the introduction to the Russian power grid of smart control systems based on digital technologies has been carried out as part of an overall process of introducing digital technologies and platform solutions to various sectors of the national economy on the basis of the Presidential Decree No. 474 “On the National Development Goals of the Russian Federation up to 2030”, dated July 21, 2020.

III. Smart Grid Technology and Application

The main smart grid technologies that have the potential for gradual application in the Russian power grid complex include:

- Remote controlled highly automated electrical substations;
- switching devices with integrated connection controllers and the ability to integrate into a single information management system, operationg withthin Plug-n-Play concept to the maximum possible extent, supporting high-speed data exchange;
- metering devices, with the ability to integrate into a unified control system, providing remote control functions and output;
- automatic voltage and reactive power control systems using devices for flexible regulation of electric mode parameters with power electronics

(including DC links, phase-shifting transformers, series compensation devices, static thyristor compensators, controlled shunt reactors, phase shifters, static compensators, systems for balancing and compensating for voltage harmonics);

- systems for determining the location of damage in the grid;

Smart systems for monitoring and diagnosing the operation of grid equipment (including remote diagnostic tools and tools integrated into the equipment), with the ability to integrate into a single control system:

- remote monitoring and localization of places of icing;
- modern technology and equipment for melting ice;
- automated systems for monitoring the state of electrical equipment and control systems based on data from transient monitoring systems;
- systems for monitoring the condition of secondary equipment;
- PCS (Power Control System). Control and monitoring of electrical grids with distributed generation;
- DERM (Distribution Energy Resources Management). Modeling, monitoring, forecasting and control of distributed energy resources;
- customer services and customer relationship management systems (energy consumption management/consumer demand management);
- creation of new power grid services for consumers: charging infrastructure for electric transport, engineering services, customer service and customer relationship management systems.

The use of smart grid technology is developing in the following areas:

1. Development of automation and control system:

- phasor measurement units (PMU) with the introduction of WAMS/WACS/WAPS technologies;
- equipment for DC links and transmission of direct current (rectifier units,

inverters) implemented on thyristor and transistor semiconductor devices. In addition to the basic functions of DC links and transmission of direct current on transistor converters, they can provide the effects implemented by STATCOM [1] type devices;

- controlled means of reactive power compensation, including static thyristor compensators and controlled shunt reactors, the introduction of which allows a given voltage level to be maintained automatically in the electricity grid's nodes;
- technology for monitoring and diagnostics, and forecasting technology of the state of overhead line equipment, including information output to personnel's mobile devices;
- introduction of automated monitoring systems for primary and secondary equipment based on IoT devices to analyze equipment status parameters and functions in real time and respond to emergency events in a timely manner using smart predictive fault detection models based on the processing of received information — reducing maintenance time and transitioning to maintenance by condition;
- creation and implementation of next-generation operational information suites;
- monitoring and predictive analysis of man-made accidents and emergencies associated with external weather conditions, risks of icing, fires, and extreme wind;
- development of emergency systems and automated mode-shifting solutions;

2. Increasing the efficiency of business processes and automation of management systems (life cycle management for innovative projects):

- BIM technologies (CAD for primary and secondary equipment, engineering, and communication facilities);
- PLM technologies (life cycle management in the energy sector);

1 STATCOM — Static reactive power generator

- process control systems at control center level (SCADA/NMS/EMS) and facility level;
- technologies for ensuring information security of power facilities;
- automated asset management systems (AMS), including those with decision support functions in terms of failure probability, maintenance and repair management, and minimization of damage as a result of failures;
- robotic complexes for monitoring and diagnosing overhead lines (automated aerial vehicles, drones, quadcopters, geolocation diagnostic tools);
- augmented and virtual reality devices for training and assistance in performing operations;
- radio frequency identification equipment and systems (RFID tags, NFC technology);
- cross-cutting digital technologies (artificial intelligence, Big Data, neural grid, digital twins). Transition to the use of technological part object-oriented information models (IEC 61850) and the general model (IEC 61970) — object binding of physical processes and equipment to an abstract information model allows modeling (digital double) to be performed and the current state to be assessed with the goal of further improvement.

3. Application of new technologies in the power industry:

    - wires with increased throughput capacity, improved aerodynamic and anti-icing properties;
    - high temperature superconducting materials / equipment and systems using high temperature superconductor technology;
    - durable functional coatings for wires.

4. Automatic process control systems.

Automated process control system tools are used to collect, process, and transmit large amounts of process information (data for monitoring the condition of equipment, recording emergency events and processes, monitoring the quality of electricity, etc.) necessary for grid operation.

Automated process control systems are being introduced in energy facilities as part of the multifaced technological improvement and reconstruction, as well as operationalization of new energy facilites. The system implements a wide range of basic informational, control and auxiliary functions necessary for the effective organization of both the operational and dispatch as well as operational-technological control of a substation in normal, emergency, and post-emergency modes, and maintenance of equipment of power facilities.

5. Highly automated substation:

Highly automated substation — a substation using integrated digital measurement systems, relay protection, control of high-voltage equipment and optical current and voltage transformers, and digital control circuits built into the switching equipment. All the components of a highly automated substation operate on a common standard information exchange protocol — IEC 61850.

6. The use of smart electricity meters in automated information and measuring systems for commercial metering of energy companies (electric energy meters are the property of sales companies) and industrial enterprises — the transition from automated information and metering systems for commercial metering to an smart metering system for electrical energy to collect up-to-date information on consumption, as well as ensuring the introduction of the institution of payment for energy supply services, taking into account the actual indicators of reliability and quality of energy supply and switching off/on consumers if necessary.

IV. Prospects and Outlook for Smart Grid Development

1. Developing a regulatory framework in terms of simplifying the rules for technological connection of microgeneration.
2. Creation of smart systems and new control models (EMS, DMS, OMS) to improve the reliability of power supply and the efficiency of power balance regulation.
3. Development of a remote control system for equipment from dispatch centers and power grid control centers;

4. Creating new high-tech devices for flexible control of power mode parameters with power electronic.

5. Developing a mechanism for managing the demand for electricity in retail markets including the use of aggregators for managing the demand for electricity.

6. Introducing smart control algorithms for relay protection and automation devices with automated analysis of the functioning and diagnostics of devices;

7. Implementing the pilot projects of highly automated 35–110 kV substations with the aim of receiving the experience operating with the IEC 61850 standard;

8. Creating a distribution grid of 6–110 kV within substation grounds, which provides for the creation of an integrated management system on the scale of a grid section of a power grid region with advanced calculation and analytical functions using a database based on a full digital informational CIM-model [2] of a grid, testing of innovative technologies on the scale of a district power grid section characterized by the predominance of household load in order to optimize the costs, architectural development and the development of new automation systems.

9. Implementing an automated platform for the operational and process management of power grid districts SCADA/DMS/OMS based on a comprehensive solution for automating the processes of operational and process management of power grid facilities, expanding the functions and data volumes of the existing SCADA system and creating an integrated system of control, observability, analysis on based on the SCADA, DMS, OMS, and GIS systems.

10. Digital modeling of a power grid and its elements based on open CIM standards.

11. Applying machine learning models to perform predictive analysis of steady-state and transient power grid modes, and the construction of mode and emergency automation algorithms.

12. Creation of smart system for monitoring and analyzing the functioning of relay protection devices and emergency protection automation devices.

13. Development of remote control of power plant load schedules from dispatch centers

2 Common Information Model

[IV]

INDIA

I. Understanding of the Smart Grid

Indian electricity sector has witnessed tremendous growth with respect to energy generation, network infrastructure and adaption of advanced technology. With increasing penetration of renewable energy, adaptation of decentralized generation, inclusion of smart meters and communication system, electricity sector in India is on the threshold of a paradigm shift toward smarter Grids. What makes a grid "smart" is the inclusion of Automation, Communication and IT systems that can monitor power flows from generation to points of consumption (even down to appliances level) and control the power flow or curtail the load to match generation in real-time or near real-time. Smart Grids enable the interaction of digital applications with physical grids for carrying out the functions of communication, control, data computation and information management in real time in routine operation management. Grid modernization systems such as advanced IT/OT technology, grid integrated devices, cyber security along with wholistic system planning shall be key to achieving Smart Grids. Smart grid solutions help to address vulnerabilities in grids, protection of critical functions, real-time power flow in system, reduce T&D losses, Peak load management, improved quality of Service, increased reliability, better asset management, renewable integration, better accessibility to electricity, etc, thereby helping the electric utilities to take appropriate technical and managerial actions to improve the efficiency and performance, leading to self-healing grids.

1. Smart Grid: Enabler of grid automation

Solution architecture of Smart grids have multiple features that not only differentiate them from conventional electrical grids but also show superior control functionalities and advanced characteristics making them dynamic. Some of the positive features that give

INDIA

direct benefit to consumers are mentioned below:

- Real-time monitoring of power flow with efficient two-way communication.
- Automated outage management and faster restoration.
- Increased grid visibility and self-healing grids.
- Better energy management to reduce and conserve electricity etc.
- Transparency in energy use/transactions through Web portals and mobile apps.
- Better asset management and condition-based maintenance.
- Automated billing at scheduled frequency
- Availability of granular data for analytics

One of the key features of Smart Grids is facilitation of distributed generation, especially the rooftop solar generation, with existing grid by allowing movement and measurement of energy in both directions using control systems and net metering to help "prosumers," i.e. the consumers who both produce and consume electricity, to safely connect to the grid.

2. Benefits of Smart Grid Deployment

Smart grid implementation have direct benefits to utilities as well as provide positive impact to other stakeholders such as consumers, regulators, industries etc. Here are some of the benefits:

- Reduction of AT&C losses with accurate and well-timed meter reading.
- Efficient peak load management, improved QoS and reliability.
- Reduction in power purchase cost.
- Renewable integration through net metering and access to electricity.
- Track and manage energy usage to induce consumers behavioral changes based on pricing signals during different times of the day such as ToU/ToD

etc.

- Help better monitoring and improvement in performance making financially sustainable utilities
- Better service and reliable supply resulting in satisfied customers

3. Smart Grid Vision for India

Ministry of Power (MoP), Government of India in consultation with stakeholders of the power sector has formulated a smart grid vision and roadmap for India. The Vision of India on Smart Grids is to "Transform the Indian power sector into a secure, adaptive, sustainable and digitally enabled ecosystem that provides reliable and quality energy for all with active participation of stakeholders"[3].

In this regard, India has launched **National Smart Grid Mission (NSGM)** in 2015 to accelerate the deployment of smart grid in India.

II. Relevant Policies to Promote Smart Grid Development

NSGM is responsible for planning and monitoring the implementation of policies and programmes related to Smart Grid activities in India. NSGM envisages the transformation of last mile connectivity ecosystems i.e, distribution through AMI, microgrids, distributed generation, outage management, power quality improvement, peak load management, EV charging infrastructure, etc. Under NSGM, DISCOMs can achieve self-sustenance in power supply distribution focusing on reliability, quality and security by implementing Smart Grid interventions using innovative financing models.

Since the launch of NSGM, the focus has been on the sustainable deployment of Smart Grids. In the years 2020 and 2021, widespread acceptance was witnessed for AMI deployment on OPEX model amongst utilities, funding agencies and Smart Grid Implementation Agencies[4]. Currently, two projects under NSGM, viz. Chandigarh Sub Division No. 5 and integrated project in 6-towns in Rajasthan for 1.79 lakh consumers are under various stages of implementation. As of June 2022, more than1.4 lakh smart

3 https://www.nsgm.gov.in/en/smart-grid

4 CEA Annual Report 2020-21, Central Electricity Authority, Ministry of Power, Government of India.

meters have been installed at fields in these projects.

NSGM has also finalized a Model Standard Bidding Documents for appointment of Advanced Metering Infrastructure Service Provider (AMISP) on Design-Build-Finance-Own-Operate-Transfer (DBFOOT) basis to help states in implementation of smart meters. The same has been adopted with additional modification by M/s REC Limited for implementing AMI projects under Revamped Distribution Sector Scheme (RDSS) of Ministry of Power, Government of India. Utilities have started adopting AMISP SBD for Smart Prepaid Metering projects under RDSS.

Further, Department of Science & Technology (DST), Government of India has funded around US$ 46.5 million towards R&D on Smart Grids[5]. Indian academic institutions including Indian Institute of Technology (IITs), Indian Institute of Science (IISc) and private industries have been engaged in R&D on Smart Grids in India.

Moreover, to boost the deployment of smart grids in India, POWERGRID has established Smart Grid Knowledge Centre (SGKC)6 at Manesar, Haryana with support from the Ministry of Power. The Centre was inaugurated by Hon'ble Union Minister of Power and New & Renewable Energy on 19th September 2018. SGKC will support utilities and other stakeholders in power sector by bringing awareness & capacity building on application of Smart Grid technologies. It is equipped with working models on smart grid technologies including state-of-the-art training infrastructure to provide hands-on training in this domain. The Smart Grid Knowledge Centre has already provided training and demonstrations to 500+ power sector professionals at the national & international level.

Hon'ble Minister of Power also launched the Virtual SGKC[7] on 8th March 2022 which is a digital twin of the actual Smart Grid Knowledge Center. The VSGKC is a platform to showcase advanced technologies in power distribution sector. It has been developed by POWERGRID with technical support from NSGM and USAID. The virtual version of SKGC replicates the facilities available in the physical center on a virtual online platform. It will -

(i) Provide service offerings that can be significantly expanded without limit of

5 Dept. of science and Technology, GOI - India country report on R&D and deployment of smart grids in India report, June 2017

6 https://www.nsgm.gov.in/en/sgkc

7 https://sgkc.powergrid.in

physical space,

(ii) Give more access to wider audience even during times when mobility is disrupted,

(iii) Allow larger set of global solutions to be brought under the ambit of Centre of Excellence (COE),

(iv) Be responsive to the charging power sector technology landscape through timely upgradation.

This initiative was taken considering the futuristic digitization of SGKC facilities and enable wider dissemination of knowledge covering national as well as international stakeholders. The Virtual SGKC platform demonstrates smart grid solutions to Discoms and other power sector stakeholders with easy access from anywhere in the world through internet. Integration of other functionalities like online conferences, trainings, webinars etc. on virtual SGKC is in progress. Further, the provisioning of physical infrastructure for technology demonstrations by various technology players at SGKC, Manesar, is also under development.

In the next phase of SGKC, establishment of Innovation Park & Incubation hub is envisaged. This is in line with the vision of AatmaNirbhar Bharat Abhiyan and to establish SGKC as one of the leading Centre of excellence (CoE) by fostering innovation, entrepreneurship, promotion of start-ups and partnerships in smart grid technologies. Enabling development of Modern, Future Ready, Efficient Distribution Network and Operations is the overarching theme of SGKC.

III. Smart Grid Technology and Application

India has started Smart Grid journey in 2013 by releasing the Smart Grid Roadmap and launch of Smart Grid pilot projects. Twelve (12) smart grid demonstration/pilot projects were sanctioned by Ministry of Power under IPDS (erstwhile RAPDRP-Part C). As of July 2022, all these pilot projects have been completed and the utilities are taking up large scale deployments as per their requirements.

The following are the details of these pilot projects:

S.No.	Functionalities	Area of implementation	Description	Key Facts
1.	Advanced	Satguru Feeder,	Test pilot for implementation	• Project Type: Smart

	Metering Infrastructure (AMI)	Ajmer City	of AMI with co-existence of smart meters and over-the-top module retrofitted meters for approximately 1000 consumers.	Grid Pilot in Power Distribution Sector • Total Cost of Project: Invested by USAID, supported by NSGM
2.	AMI, Peak Load Management(PLM), Outage Management (OMS) & Distributed Generation (DG)	Guwahati Distribution Region	The pilot project covers about 15,000 consumers involving 90MUs of input energy. Under RAPDRP Part-A, SCADA / DMS is also being implemented which shall be utilized as basis infra for Smart Grid development. Distributed Energy Integration (solar and available DG backup) is also considered for the pilot project.	• Project Type: Smart Grid Pilot in Power Distribution Sector • Funding Programme: IPDS • Status: Completed • Functionalities – AMI, PLM. • Consumers – 14,519.
3.	ALM, PLM, OMS, DG &Microgrid (MG)	V VMohalla (Additional City Area Division, CESC, Mysore)	Project involves 21,824 consumers with a good mix of residential, commercial, industrial and agricultural consumers including 512 irrigation pump sets covering over 14 feeders and 473 distribution transformers and accounting for input energy of 151.89 MU. Additional functionality like Agriculture DSM with community portal, consumer portal to support DSM/DR, employee portal for knowledge sharing and benefit realization, KPI based MIS and data analytics for decision support are also proposed	• Project Type: Smart Grid Pilot in Power Distribution Sector • Funding Programme: IPDS • Status: Completed • Functionalities – AMI, OMS, PLM, MG/DG • Consumers – 21,824
4.	AMI, PLM, OMS and Power Quality Measurement (PQ)	Kala Amb Industrial Area, HPSEB, Himachal Pradesh	The project area covers a base of 1,355 consumers dominated by HT consumers with a peak demand on 97MW. High-end power quality meters are also being installed at HT consumers to capture power quality data remotely for identifying decisions on corrective actions in collaboration with consumers.	• Project Type: Smart Grid Pilot in Power Distribution Sector • Funding Programme: IPDS • Status: Completed • Functionalities – AMI, OMS, PLM. • Consumers – 1,335

5.	AMI	Division 1 of Puducherry	The project proposes covering about 34,000 no. of consumers with dominant being domestic consumers. The proposed project area is also covered under RAPDRP Scheme for IT implementation and system strengthening. Common Meter Data Management System is proposed to be developed that shall take data from MDMS of Different meter manufacturer/solution provider and integrate the information for use with Time of Use and Net Metering tariffs.	• Project Type: Smart Grid Pilot in Power Distribution Sector • Funding Programme: IPDS • Status: Completed • Functionalities – AMI • Consumers – 33,499.
6.	AMI, PLM	Electrical Division No. 1, Agartala, TSECL, Tripura	The pilot project covers 45,290 no. of consumers. The proposed project area is covered under RAPDRP Scheme for IT implementation and system strengthening. Time of Use models and Net Metering tariff mechanisms were also proposed for adoption.	• Project Type: Smart Grid Pilot in Power Distribution Sector • Funding Programme: IPDS Status: Project declared go- live in June 2019. TSECL to complete Smart Grid Pilot from own resources.
7.	AMI, PLM, OMS, PQ	Jeedimetla Industrial Area, TSSPDCL, Telangana	The proposed project area covers about 9000 single phase consumers for Smart Meters installations. The project area is covered under RAPDRP Scheme for DAS, IT and SCADA implementation.	• Project Type: Smart Grid Pilot in Power Distribution Sector • Funding Programme: IPDS • Status: Completed • Functionalities – AMI, PLM, OMS, PQ. • Consumers – 8,882.
8.	AMI, PLM, OMS	Panipat City Sub Division, UHBVN, Haryana	The pilot project covers around 11,000 consumers with 70 MU input energy consumption. The proposed project area is covered under RAPDRP Scheme for IT implementation and system strengthening.	• Project Type: Smart Grid Pilot in Power Distribution Sector • Total Cost of Project: Under Grant from NEDO, Japan • Status: Completed • Functionalities – AMI, PLM, OMS. • Consumers – 10,188.
9.	AMI, PLM, OMS	Naroda of	The pilot project proposes	• Project Type: Smart

		Sabarmati Circle, UGVCL, Gujarat	covering 22,230 consumers in Naroda. Some additional functionalities like Load forecasting and Asset Management are also proposed and functionalities of load forecasting, peak power management, and outage management are also considered at utility level, which will indirectly impact all utility consumers.	Grid Pilot in Power Distribution Sector • Funding Programme: IPDS • Status: Completed • Functionalities – AMI, OMS, PLM, PQ. • Consumers – 22,230
10.	AMI, PLM	WBSEDCL, West Bengal	The proposed project area had 5,265 consumers with two no. of 11kV feeders and 46 DTs. The overall consumption of around 7.46 MUs per annum.	• Project Type: Smart Grid Pilot in Power Distribution Sector • Funding Programme: IPDS • Status: Completed • Functionalities – AMI, PLM • Consumers – 5,265.
11.	AMI, Smart City Control Center, Smart Homes, Advanced IT Infrastructure & Renewable Integration	IIT Kanpur	The project was aimed to develop a Smart City prototype and R&D platform for smart distribution systems and demonstrates the future capabilities of a Smart City. The project area includes three substations for implementing substation automation, institute residential flats for smart home system implementation. Grid connected solar PV will also be installed for RE integration. Robust communication network shall also be developed for seamless exchange of information across the prototype.	• Project Type: Smart Grid Pilot in Power Distribution Sector • Funding Programme: IPDS • Status: Completed
12.	AMI, OMS, MS/DG, EV with Charging infra (EVCI), Home Energy Management Center (HEMS),	SGKC, Manesar	The Smart Grid Knowledge Center acts as a resource center for providing technical support to NSGM in all technical matters, including development of technical manpower, capacity building,	• Project Type: Smart Grid Pilot in Power Distribution Sector • Funding Programme: IPDS • Status: Completed • Functionalities: AMI,

	Cyber Security & Training Infra		outreach etc.	OMS, MG/DG, EVCI, HEMS, Cyber Security & Training Infra.

Subsequently, two full Smart Grid projects were also sanctioned with part funding from Ministry of Power, Government of India. The details of these projects sanctioned under NSGM are mentioned below:

S.No.	Functionalities	Area of implementation	Description	Key Facts
1.	AMI, Substation Automation including SCADA, Integration of Rooftop Solar & Distribution Transformer Monitoring (DTMU)	Sub Division No. 5 under CED Chandigarh	Project covers about 30,000 consumers with a good mix of residential and commercial consumers. The area was not covered under RAPDRP scheme of GoI. SCADA is also considered for implementation	• Project Type: Smart Grid Project under NSGM • Funding Programme: Grant under NSGM • Till date, 24,149 smart meters installed in field. • Functionalities – AMI, DTMU, SCADA. Consumers – 29,433.
2.	AMI	6 Towns under JVVNL Rajasthan (Baran, Bharatpur, Bundi, Dholpur, Jhalawar and Karauli)	Project covers about 1.5 lakh consumers with a good mix of residential and commercial consumers. The current AT&C losses of these project areas combined stands at 34.68%. The project intends to deploy AMI to reduce the AT&C losses.	• Project Type: Smart Grid Project under NSGM • Funding Programme: Grant under NSGM • Till date, 1,15,608 smart meters installed in field. • Functionalities – AMI. Consumers – 1.5 lakh.

Source:https://www.nsgm.gov.in/en/sg-pilot, https://www.nsgm.gov.in/en/sg-projects, https://www.nsgm.gov.in/en/sg-status

Smart Metering in India

Smart Metering in India has gained importance and utilities are pacing ahead for deployment of Smart Meters across their regions. Some states have started deployments and some floated tenders. NSGM has been collating the details of smart metering deployments happening across the country through utilities, implementing agencies, nodal agencies etc. and has developed multiple dashboards for use by the stakeholders and for public awareness.

These dashboards can be accessed from the following links : -

https://www.nsgm.gov.in/en/sm-stats-all, https://www.nsgm.gov.in/en/state-wise-map, https://www.nsgm.gov.in/en/monthly-sm-progress

As of 15th July 2022, more than 46 lakh smart meters have been deployed and about 65 lakh smart meters are under deployment across various states/schemes in India.

IV. Prospects and Outlook for Smart Grid Development

The Indian power sector is amidst a paradigm shift as it transitions towards a more distributed consumer-centric ecosystem. Smart Grid facilitates efficient and reliable end-to-end intelligent two-way delivery system from source to sink through integration of renewable energy sources, smart transmission and distribution. Two-way power flows and enhanced intelligence are likely to become the norms of this new energy future.

The key mandates shaping the power sector landscape of India are:

- GoI's commitment to provide 24x7 affordable and reliable electricity to all households
- Changing consumer expectation with increasing demand and embracing distributed energy resources.
- Tariff policies emphasizing protection of consumer rights and enhancing consumer service levels.
- GGOI's aggressive target of 500 GW of non-fossil fuel capacity addition by 2030, necessitates the requirement of grid flexibility, and strong network visibility with control for dynamic grid operations.
- Increasing penetration of Distributed energy resources and electric vehicles are expected to introduce challenges in peak load management and at the same time open up new opportunities for distribution companies.

In this direction, Government of India has taken many initiatives under Ministry of Power. Below are some of the Centrally Sponsored Schemes executed by Government of India :

- **Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY):** With a view to improve distribution infrastructure in rural areas including metering at distribution transformers, feeders and consumers end, DDUGJY was launched in 2014. Under the scheme, Energy Meters in 153.80 Lakh consumer premises, 2.53 Lakh Distribution Transformers & 0.13 Lakh 11 KV Feeders have been installed[8].

- **Integrated Power Development Scheme (IPDS):** Was launched in 2014 to strengthen sub-transmission and distribution network including metering in urban areas. Under this scheme, Rs 228 Crores were released for Smart metering works[9] for 12 states.

- **North-Eastern Region Power Systems Improvement Project (NERPSIP):** The scheme was launched to create a reliable power grid and improve NER States' connectivity to the upcoming load centers. It is being implemented by POWERGRID, a Public Sector Undertaking (PSU) under Ministry of Power in association with six beneficiary North Eastern States namely, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura

- **National Smart Grid Mission (NSGM):** NSGM has been in operational since January 2016 with dedicated team. NSGM has its own resources, authority, functional & financial autonomy to plan and monitor implementation of the policies and programs related to Smart Grids in the country.

- **Smart cities program:** The Smart Cities Mission is an innovative and new initiative by the Government of India to drive economic growth and improve the quality of life of people by enabling local development and harnessing technology. The mission will cover 100 cities in phase 1. It includes Assured electricity supply with robust electricity infrastructure.

- **Digital India:** Digital India is a flagship programme of the Government of India with a vision to transform India into a digitally empowered society and knowledge economy.

To take one step further in the field of improving the Indian power sector, a Revamped Distribution Sector Scheme (RDSS) has been launched by GoI in July 2021 to promote

8 https://recindia.nic.in/ddugjy

9 https://www.ipds.gov.in/IPDS_Login_Res/IPDS_Summary_Sanctioned_SmartMeter.aspx

deployment of smart metering for about 250 million consumers by 2025 and strengthening distribution infrastructure of DISCOMs. The RDSS[10] aims to improve operational efficiencies and financial sustainability, by providing result-linked financial assistance to DISCOMs for strengthening of supply infrastructure based on meeting pre-qualifying criteria and achieving basic minimum benchmarks. Further, the scheme envisions 100% feeder metering by December 2022 and 100% DT metering by December 2023 to ensure proper energy accounting and further making the metering infrastructure of the sector more robust.

10 https://recindia.nic.in/revamped-distribution-sector-scheme

[V]
CHINA

I. Relevant Policies to Promote Smart Grid Development

China's energy structure is dominated by coal power and most of the coal resources for power generation are distributed in the western and northern regions, while the power consumption demand is concentrated in the more economically developed central and eastern regions and the southern regions, resulting in a mismatch in terms of geographic space between China's energy production and consumption patterns. With the increasing speed of energy development moving northward and westward, the distance between the energy base and energy-consuming area is increasingly considerable, and the large-scale, long-distance, and high-efficiency transmission of the power grid is, therefore, more and more urgent. At the same time, as an increasing number of renewable energy is connected, the safe and stable operation of the power grid faces tremendous challenges.

To solve the above problems, China's 2010 Government Work Report stressed that "We will vigorously develop a low-carbon economy, promote high-efficiency and energy-saving technologies, actively develop new and renewable energy sources, and strengthen smart grid construction". This is the first time that the Chinese government has proposed the smart grid as a basic national development strategy. The State Council, the National Development and Reform Commission (NDRC), the National Energy Administration (NEA), and government departments at all levels have since issued a series of smart grid-related documents and guidelines, organized and implemented a number of smart grid-related demonstration projects. In 2015, the NDRC and the NEA introduced *Guidelines on the promotion of smart grids development*, which specifies the development significance, guiding ideology, basic principles, development goals, and main tasks of the smart grid. In recent years, especially with the birth of the "Internet Plus" strategy, smart grid development has ushered in a huge opportunity for development. Since 2015, China has carried out pilot and demonstration projects such as new energy micro-grid, multi-energy complementation, integration and optimization, flexibility renovation of thermal power plants, “Internet plus” smart energy, and other projects, exploring new ideas and models for energy and grid development and promoting the development of China’s smart grid.

II. Smart Grid Technology and Application

1. Ultra-high voltage transmission technology

Definition: Ultra-high voltage (UHV) transmission technology features voltage levels of 1000 kV and above AC and ±800 kV and above DC.

Benefits: With the advantages of large transmission capacity, long-distance, and high efficiency, UHV transmission technology can realize the large-scale interconnection of power grids, which is beneficial to clean energy consumption.

Application: By the end of 2020, China’s UHV projects under construction have a cumulative length of 41,000km and a cumulative power transmission of more than 1.6 trillion kWh. At the same time, the Belo Monte Phase I and Phase II UHVDC projects built by the State Grid in Brazil had been put into operation one after another as the main passageway connecting the Brazilian grids with each other, thus realizing the optimal allocation of resources.

Typical case: As the first UHV transmission line in China, the southeastern of Shanxi province-Nanyang-Jingmen 1000kV AC UHV pilot project is also the first 1000kV commercial transmission line in the world. Most of the key equipment used in the project such as 1000 kV reactors and 1000 kV high voltage AC transformers is developed by major domestic manufacturers, which testifies to the fact that China is already capable of independent design, equipment R&D, and construction of UHV transmission and transformation projects. China’s UHV transmission technology, one that reduces long-distance transmission loss, plays its global leading role, can also be promoted and applied around the world.

2. Flexible Alternating Current Transmission Systems(FACTS)

Definition: Flexible Alternating Current Transmission Systems, (FACTS) is a new transmission system for flexible and rapid control of AC transmission which combines power electronics technology, microprocessor and microelectronics technology, communication technology, and control technology.

Benefits: FACTS can enhance the stability of the AC power grid and reduce the cost of power transmission. The mechanism of FACTS is using power electronic devices with single or integrated functions at the main parts of the power transmission to flexibly and quickly control the main parameters of the transmission system such as voltage, phase difference, reactance, etc., so as to realize the reasonable distribution of transmit power, reduce power loss and generation cost, and greatly improve the system stability and reliability.

Application: In 2004, China's first domestic-made thyristor controlled series compensation (TCSC) project, Gansu Bicheng 220 kV TCSC, was put into operation successfully, signifying that China became the fourth country in the world to master this technology. In 2007, with the largest capacity, the most complex operating environment, and the most difficult design in the world back then, the Yifeng 500 kV TCSC project came into function. In 2015, the State Grid Major Science and Technology Demonstration Project, Jiangsu Nanjing 220 kV *Unified Power Flow Controller (UPFC)* project officially entered into service. This is China's first UPFC project with independent intellectual property rights, marking China's FACTS ranking the top of the world.

Typical case: On December 19, 2017, the 500 kV UPFC technology demonstration project in Suzhou Southern Power Grid with the highest voltage grade and capacity in the world was put into operation. The project independently designed, developed, and built by China is a major demonstration project of SGCC. Overcoming a great many technical difficulties, it developed the independent series transformer with the highest voltage grade and capacity and the self-cooled AC thyristor valve with the highest voltage grade globally. For the first time in the world, the project realized the flexible and accurate control of 500 kV grid power flow, increasing the capability of Suzhou Southern Power Grid to consume clean energy by about 1,200 MW. It is also a great breakthrough in the application of FACTS technology.

3. VSC-HVDC

Definition: The concept of VSC-HVDC refers to the high-voltage direct current transmission backed by the voltage source converter (VSC), which is a new DC transmission method after AC and conventional DC transmission.

Benefits: VSC-HVDC, important equipment for constructing smart grid, has strong technical advantages in isolated island power supply, capacity enhancement and transformation of urban distribution network, interconnection of AC system, large-scale integration of wind energy into the power grid, etc. It is also a strategic option to change the development landscape of large power grid.

Application: China is a major force in the advancement of flexible DC technology. Several projects that are making breakthroughs in the key equipment of DC circuit breakers have been completed, including the Flexible DC Transmission Project in Zhoushan and Nan'ao and the Flexible DC Back-to-back Project in Luxi with well-established flexible DC equipment systems.

Typical case 1: The zhangbei Flexible ±500 kV DC Grid Demonstration Project focuses on China's flexible DC transmission technology, with maximum transmission capacity of 3.75 million kilowatts and a transmission line length of 666 km. With domestic-manufactured and world-leading flexible DC power grid technology, the project has the characteristics of strong controllability, fast power regulation speed, and high operation mode flexibility, which can effectively suppress AC voltage fluctuation, reduce the influence of power fluctuation on the receiving-end power grid and effectively eradicate the problem of large-scale consumption of grid-connected new energy. Taking the flexible DC power grid as the center, through multi-point convergence, multi-energy complementation, space-time complementation, and source-grid-load coordination, the technology can achieve free fluctuations of new energy side and controllable and stable power supply on the load side. At the Beijing 2022 Winter Olympics that just wrapped up, the project provided 100 percent green power for 26 venues.

Typical case 2: In 2020, the Kunliulong DC Project invested and built by China Southern Power Grid Co. Ltd. went into full operation, which is the first UHV flexible DC transmission project in the world. As the "major channel" of west-to-east power transmission of the world's seventh-largest hydropower station, Wudongde Dam, the project starts from Yunnan Province and crosses high mountains, rivers, and lakes of 1,452 kilometers, sending abundant hydropower to the load centers in Guangdong Province and Guangxi Zhuang Autonomous Region. With a total investment of 24.249 billion yuan, the project is the multi-terminal hybrid DC project with the world's highest voltage level (only ±500 kV before) and transmission capacity, using a ±800 kV three-terminal hybrid DC system with a transmission capacity of 8 million kilowatts. The project applies the 19 best power technologies around the world, with 100 percent autonomy in major equipment. Moreover, it symbolizes that China takes the lead in UHVDC technology, providing valuable experience for the development of the global power grid.

4. Microgrid technology

Definition: Microgrid refers to a small power generation and distribution system composed of distributed generation, energy storage device, energy conversion device, load, monitoring and protective device, etc.

Benefits: Microgrid is proposed to realize the flexible and efficient application and solve vast and various grid-connected problems of distributed generation. The development and extension of microgrid can fully promote large-scale access to distributed generation and renewable energy, and realize the reliable supply of various energy forms for load. Microgrid is a powerful supplement to large power grid and an important part of smart grid.

Application: Island power supply is an important field of new energy microgrid application. By building renewable new energy sources such as photovoltaic power generation, wind power generation and tidal power generation, islands can be provided with a continuous supply of pollution-free energy. For islands with existing diesel generation, they can use both diesel generation and renewable resources to reduce diesel consumption, increase economic benefits, and reduce environmental pollution and carbon emissions.

Typical Case 1: China has built several new energy microgrid demonstration projects on islands. Among them, Zhuhai Dong Ao Island microgrid project is the first successfully commercialized microgrid project in China. It has solved the long-standing electricity shortage issue on the island by maximizing the use of abundant solar and wind resources on it and minimizing the use of diesel to generate power to provide green power. With the operation of the whole microgrid system, the proportion of renewable energy power generation in Dong-Ao Island has increased from 30% to 70%.

Typical Case 2: In August 2015, Yantai Changdao distributed generation and microgrid access control project passed the acceptance of the National Development and Reform Commission and was officially completed and put into operation. This is the first island microgrid project in northern China, which can realize isolated operation when the external large power grid collapses, ensure continuous power supply for important users, which has greatly improved the power supply capacity and reliability of Changdao Power Grid and enhanced the consumption capacity of island power grid for abundant renewable energy such as wind and light.

5. Intelligent transformer substation

Definition: Intelligent transformer substation refers to a substation that adopts advanced, reliable, integrated, low-carbon and environmentally friendly intelligent equipment. With the basic requirements of digitalized information, a networked communication platform and standardized information sharing, it can achieve the basic functions of automatic information collection, measurement, control, protection and monitoring. At the same time, transformer substation has advanced functions such as supporting the power grid to achieve real-time automatic control, intelligent adjustment, online analysis and decision-making, and collaborative interaction.

Benefits: With the goal of achieving a highly integrated system, rational structural layout, advanced and applicable equipment, economical and sustainable development, and unified support and regulation, intelligent transformer substation applies integrated intelligent equipment such as disconnected circuit breakers and small cubicle gas-insulated switch-gear, and outdoor and indoor stations respectively adopt secondary equipment integration cabinets or onsite secondary devices, thus reducing the floor area, in which the area of indoor stations is reduced by 15%-25%, the area of outdoor stations is reduced by 45%-64%, and the construction period is shortened by one quarter.

Application: In 2006, China built a digital transformer substation characterized by the application of IEC61850 standard and electronic transformers; In 2009, two batches of intelligent substation pilot projects were carried out; In 2013, the construction of six new-generation intelligent substations was started. Through the technical research and engineering practice of the new generation intelligent substation, China has made major breakthroughs in substation design, technical research, equipment manufacturing and engineering construction, laying a solid foundation for leading the development of substation technology and equipment in the world.

Typical case 1: In May 2018, the 500 kV Bijiang transformer substation in Guizhou province was officially put into operation, which is the first 500 kV intelligent transformer substation in China Southern Power Grid. The substation has adopted many new technologies, such as intelligent alarm, analysis and decision-making, intelligent telecontrol, intelligent lighting, intelligent maintenance of communication battery, etc., which can greatly improve the ability of intelligent early warning and online monitoring for failure, extend equipment life, reduce the maintenance cost of the substation. It shows the construction concept of resource conservation and environmental friendliness.

Typical Case 2: In June 2021, Shaoguanbei 500 kV intelligent transformer substation was officially put into operation, and the transformer substation was designed with the combination of 3D design and BIM for the first time in China Southern Power Grid. The full coverage of 5G signals in the substation provides more stable signal support for intelligent inspection of the unmanned aerial vehicle (UAV) in the future, which can have comprehensive inspection over equipment, and inspection time can be shortened by 4 hours compared with the traditional way, which greatly improves the efficiency of equipment operation and maintenance, finds hidden troubles of equipment as early as possible and ensures the safe operation of the power grid.

6. Distribution automation technology

Definition: Based on primary distribution network and equipment, distribution automation is a technology that uses the computer and network technology, communication technology, and modern electronic sensing technology, takes the distribution automation system as the core, and integrates the real-time, quasi-real-time and non-real-time data of distribution network equipment to monitor, protect and control the distribution network both in normal operation and in accidents.

Benefits: Distribution automation, as an important part of the development of intelligent distribution network, is an important means to increase the reliability of power supply, the level of quality service, and the lean management of the distribution network, and is an inevitable trend of the modernization and intelligent development of it.

Application: The first batch of distribution automation pilot projects in China started in 2009, and different forms of distribution automation projects, such as centralized master station and feeder automation, have been launched in Beijing, Chengdu, Guangzhou, Foshan and Zhongshan. The first batch of pilot units used the distribution automation system to reduce the power failure by 16,402.15 hours pre household, and the average fault handling time of distribution network was reduced from 68.25 min to 9.5 min, which strengthened the professional and lean management of distribution network production and provided more reliable power supply and better service. With the increasing demand for new energy consumption, China has carried out research work on the active distribution network to improve the consumption capacity of the distribution network to distributed new energy.

Typical case: In 2015, the national 863 program project Research and Application of Intermittent Energy Consumption and Optimization Technology of Active Distribution Network undertaken by China Southern Power Grid passed the acceptance test, which is the first national major project on active distribution network technology in China. This project developed distributed energy network system controller and hierarchical distributed controller of the active distribution network, and an active distribution network energy management and power quality comprehensive monitoring system. The first demonstration project of the active distribution network in China is built with the energy storage access capacity reaching 1.1 MWh and the photovoltaic consumption rate being 100%

7. Smart meter

Definition: Smart meter is an important part of intelligent power consumption, and it is the "end nerve" to realize two-way interactive intelligent power consumption. It supports bidirectional metering, automatic collection, step tariff, time-of-use tariff, freezing, control, monitoring and other functions.

Application: China has started to install smart meters on a large scale since 2010, and the coverage rate has continuously increased. In 2012, the collection coverage rate of smart meters in Smart Grid was about 41%. By 2016, 74.76 million smart meters were newly installed in Smart Grid, and a total of 410 million users were collected, with a collection coverage rate of 95%. Up to now, Smart Grid has installed more than 457 million smart meters, covering 99.57% of users in the service area.

III. Prospects and Outlook for Smart Grid Development

The latest 14th Five-Year Plan for Modern Energy System issued by the National Development and Reform Commission (NDRC) and the National Energy Administration (NEA) puts forward the need to take the power grid as the basic platform, enhance the ability of optimal allocation of power system resources, improve the intelligent level of the power grid, promote the power grid to actively adapt to the development of large-scale centralized new energy and distributed energy with large quantity and wide range. It is important to accelerate the transformation and upgrading of distribution network, promote the construction of intelligent distribution network and active distribution network, improve the bearing capacity and flexibility of distribution network to accept new energy and diversified loads, and prioritize onsite development and utilization of new energy. We need to actively develop smart micro-grids that mainly consume new energy, and realize compatibility and complementarity with large power grids. We need to improve the main grid structure of regional power grids, promote flexible and controllable interconnection between power grids, build a safe and reliable power system with rational scale and hierarchical division, and improve the dynamic stability level of power grids adapting to new energy sources. At the same time, China will focus on promoting the digitization and intelligent upgrading of the energy industry, putting smart grid as a smart energy demonstration project, and carrying out demonstration applications such as the new-generation dispatching automation system, and distribution network transformation and intelligent upgrading.

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[VI]

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I. Understanding of the Smart Grid

An understanding of a more complex interrelated world has now demanded that in the twenty-first century, power should not only be reliable but cleaner, more efficient and addressing diverse customer requirements and a growing digital economy. Into this space steps the concept of a “smart grid” or a more intelligent grid. Many smart grid definitions and explanations have evolved over time. While there is no common definition of a smart grid, there is consensus that the networks/grids of today will not be able to meet the grid intelligence required associated with the energy demands, managing a diverse portfolio of energy sources and the business sustainability challenges of the future. A draft South African Smart Grid vision document, endorsed by the South African Smart Grid Initiative (SASGI) forum in 2014, leveraged the definition of the European Technology Platform Smart Grid (ETPSG) in developing the current South African smart grid vision statement. The ETPSG defines the smart grid as follows:

“A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it – generators, customers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies.”

Based on ETPSG definition, Smart Grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies to:

- Better facilitate and manage the connection and operation of all sources of energy.

- Give customers more choice so they can help to optimise energy use;
- Provide customers with greater information and choice of supply;
- Significantly reduce the environmental impact of the whole electricity supply system;
- Deliver enhanced levels of reliability and security of supply.

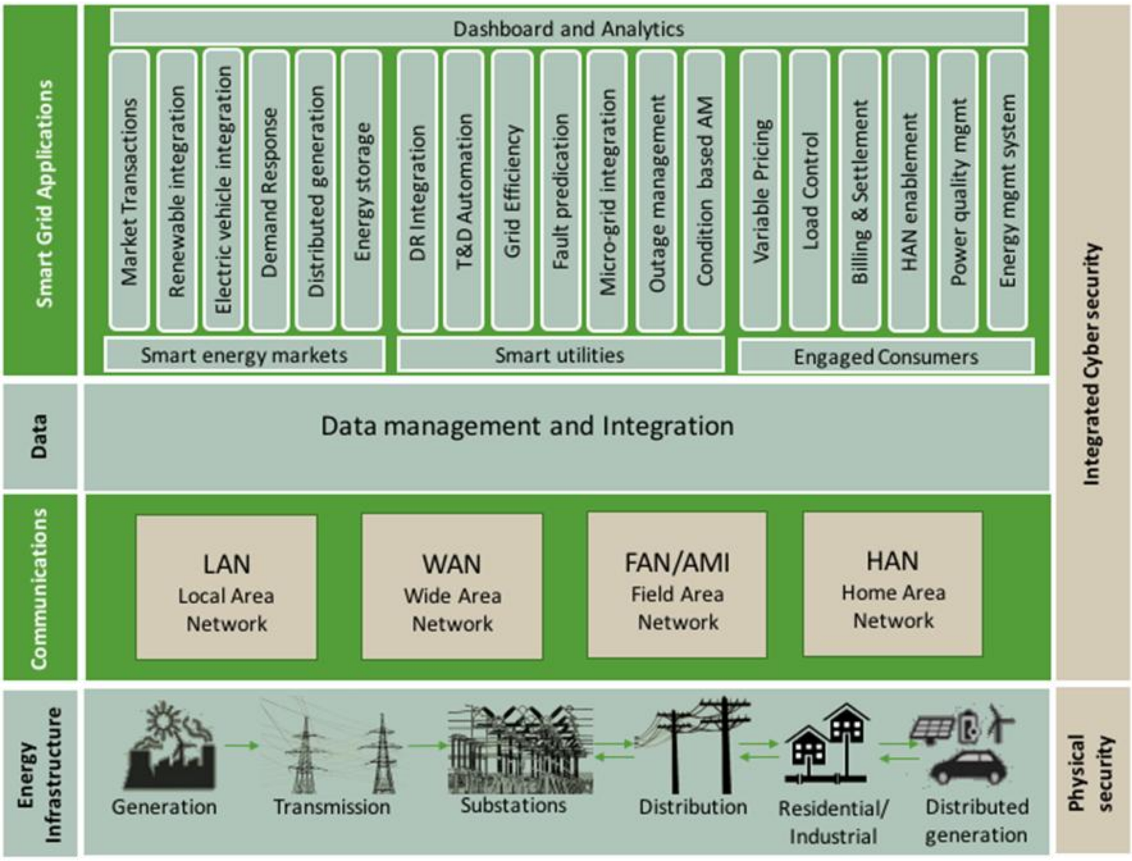
The South African smart grid vision statement is as follows:

"An economical evolved, technology enabled, electricity system that is intelligent, interactive, flexible and efficient and will enable South Africa's energy use to be sustainable for future generations".

Smart Grid implementation must therefore take cognisance of and include technology, commercial considerations, business model, skills requirements, environmental impact, regulatory framework, standardization, usage, integrated resources plan (IRP), integrated development plan (IDP), societal requirements and government mandates. The smart grid is a complex infrastructure arrangement, depending on a number of interconnected elements/capabilities such as monitoring, control, protection and telecommunications. The four major layers can be defined as; energy infrastructure, communications, data management and smart grid applications. These layers and the importance of integrated cyber security and physical security are depicted in Figure5.1-1 below:

Figure5.1-1: Source: Adapted from Magal & Uluski, (2015). [11]

11 Magal & Uluski, (2015)



For the purpose of this report, energy infrastructure includes generation, transmission and distribution of assets that produce, transport, and deliver energy to customers. Communications services enable applications to monitor, protect, and control the grid. The smart grid has given rise to collections of data sets so large and complex (also known as "big data") that it becomes difficult to process this information using classic available database management tools. Newly developed data-processing tools (grid analytics) permit utilities to analyse large volumes of information that will help improve the performance of the electric transmission and distribution system. To this end the correct specification of the distribution management system (DMS), the customer system and the metering data management system plays a key role. Smart Grid Applications (SGA) enable the electricity distribution utility to optimize the performance of the electric system and derive significant benefits, including real time access to grid related management information which facilitates the provision of solutions to core business problems. Two key aims are to promote more efficient energy use among customers and to make more efficient use of grid infrastructure. Deciding which specific application is required to achieve the smart grid vision is an important part of the planning process.

It is acknowledged that the deployment of smart grid related applications takes place in an environment where other policies, Acts and regulations are incumbent and applicable. To this end the some relevant policies have been considered in the identification of specific policy requirements to facilitate smart grid deployment in South Africa:

The National Energy Act, 2008 (Act No. 34 of 2008): The premises of the National Energy Act are to ensure that diverse energy resources are available, in sustainable quantities and at affordable prices, to the South African economy in support of economic growth and poverty alleviation, taking into account environmental management requirements and interactions amongst economic sectors; to provide for energy planning, increased generation and consumption of renewable energies, contingency energy supply, holding of strategic energy feedstocks and carriers, adequate investment in, appropriate upkeep and access to energy infrastructure; to provide measures for the furnishing of certain data and information regarding energy demand, supply and generation; to establish an institution to be responsible for promotion of efficient generation and consumption of energy and energy research; and to provide for all matters connected therewith. Provides for energy research and development as well as measures to promote energy efficiency throughout the economy.

Regulation 773 - Gazette 18 July 2008 - Electricity Regulation Act, 2006 (Act No. 4 of 2006): Electricity Regulations for Compulsory norms and standards for reticulation services. The objectives of the actions reflected in Regulation 773 were, among others, to address specific aspects to improve the efficient use of energy, and to hedge against load shedding and blackouts. In essence this announcement acknowledged the need to improve the efficient use of energy and effective grid/network control through appropriate technology deployment. Regulation 773 made specific provision for the introduction of smart systems for all customers consuming 1000kWh or more per month, with effect from 01 January 2012. Within certain quarters of the electricity distribution industry, Regulation 773 was narrowly interpreted to specifically mean the rollout of Smart Meters to installations supplying the targeted customer groupings.

The effective deployment of smart grids in the ESI is recognised as a critical business enabler. The implementation of an appropriate[12] technology contributes amongst others to improved customer service, improved business efficiency and business sustainability.

12 D.M.R.E, “Integrated Resource Plan (IRP2019),” Department of Mineral Resources and Energy , South Africa, 2019.

Thus, the positive outcomes that are observed from the deployment of smart grids provide an effective solution to address some of the challenges that South Africa is faced with. The investment into smart grids takes a value inclusive approach to test solutions that transition a utility into becoming more efficient and competent in managing their systems and processes. The desirability of smart grids concepts and technologies has gained noticeable interest in South Africa, with more utilities looking for ways to improve the effectiveness and efficiency of their performance and the long-term outlook of fulfilling their strategic objectives, whilst ensuring sustainable operations. Smart Grid is an essential transformative vision and a system of systems that facilitates the efficiency of energy provision and integration of renewable energy to meet the energy demand of various consumers.

1. Overview of the Electricity Supply Industry in South Africa

The energy sector in South Africa is at the centre of the economy due to the country's high energy intensity. Despite its recent electricity struggles, South Africa has a well-developed electricity network and one of the highest rates of electricity access in sub-Saharan Africa[13]. In both urban and rural areas, electricity is the favourite option for cooking, and the country also relies on oil and gas for its energy needs[14].

The Department of Mineral Resources and Energy (DMRE) is mandated to ensure that energy resources are available, and that there`s access to energy services in an affordable, reliable, and sustainable manner, while minimising the associated adverse environmental impacts. The electricity industry is regulated by the National Energy Regulator of South Africa (NERSA) and historically the delivery of electricity has been approached on a least-cost basis.

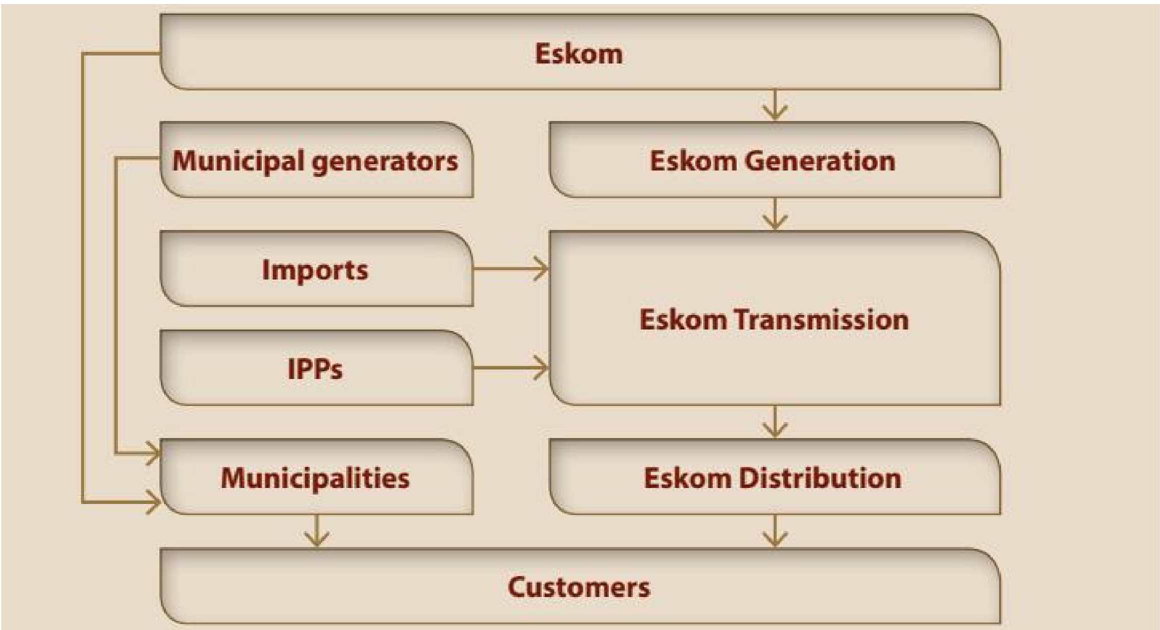
In South Africa, Electricity infrastructure comprises of three sub-sectors, namely: - generation, transmission, and distribution. The electricity supply infrastructure was designed in a vastly different political, societal and technology context, to respond to relatively 'simplistic' supply needs. In terms of generation, Eskom dominates the production of electricity. Eskom generates, transmits, and distributes electricity to industrial, mining, commercial, agricultural, and residential customers in South Africa, and

13 I.E.A, International Energy Agency, 2020

14 D.M.R.E, "The South African Energy Sector Report," Department of Mineral Resources and Energy, 2021

to municipalities, who in turn redistributes electricity to businesses and households within their areas. The utility also purchases electricity from Independent Power Producers (IPPs) in terms of various agreement schemes as well as electricity generating facilities beyond the country's borders. All utilities (municipal, metro and Eskom) are subject to annual assessments and reporting commitments with respect to service delivery objectives and performance. At present, utilities are confronted with severe maintenance and investment backlogs, impacting negatively on service delivery. They will therefore have to take focused action to create sustainable and effective electricity distribution networks[15].

Figure5.1-2: Electricity Generation, Transmission and Distribution.



2. Challenges of the Electricity Supply Industry

South Africa has installed capacity to of approximately 46,000 MW of electricity, and at peak times we use about 32,000 MW of electricity. However, only 60% of this installed capacity is available at any given time due to some generation units going through planned maintenance and others having unplanned maintenance. The average age of Eskom's power stations is 35 years, as power stations get older, their performance deteriorates. As a result of this, Eskom deferred essential maintenance to keep the lights on, which is causing breakdowns and failures now.

15 D.M.R.E, S.A.N.E.D.I and S.A.S.G.I. , "Strategic National Smart Grid Vision for the South African Electrcity Supply Industry," Department of Mineral Resources and Energy , 2017.

The focus of the current smart grid plan as stated within the South Africa Smart Grids Vision document is on the distribution segment of the electricity supply network. The South African electricity distribution segment is confronted by numerous and significant challenges that impact directly on the sustainability of the industry and the ability to provide reliable service to electricity customers. While the distribution grid has previously served South Africa well in many aspects, the electricity grid is aging, outmoded, and stressed.

All indications are that the electricity distribution operating environment will change significantly over the next couple of years. There are various indications, amongst others, such as the introduction of electric vehicles, a drive to enhance the use of renewable energy options, interest in distributed generation and customer involvement, which reinforce the observation in respect of the predicted changes in the industry. Most of the existing distribution grid is not designed to accommodate, for example, distributed generation, renewable solutions, or electric vehicles.

While the availability of a more intelligent grid would not have removed all the challenges, it would have enabled the electricity supply industry to better respond to situations such where generation capacity constraints are experienced.

Without investment in the infrastructure and the introduction of intelligence in the grid, the unreliability of the electricity supply will continue. Therefore, without the desired interventions, the cost to the economy as well as the end customers because of distribution-related outages will continue. Furthermore, the current grid is vulnerable to attack (predominantly physical, but potentially also cyber where intelligence is introduced) and natural disaster with limited “self-healing” capability.

The demand for electricity is projected to increase substantially towards 2030 and the cost to build new generation is increasing dramatically. Electricity prices have increased drastically over the past couple of years and the approved tariff plan suggests that above inflation increases will continue into the foreseeable future. Without addressing the grid intelligence i.e. making it smarter, the projected economic growth targets are at risk. The current grid and technology deployed cannot support the projected economic growth or respond effectively to the broader dynamics affecting the grid. The most important benefits offered by the Smart Grid would be improved service delivery, revenue protection, improved reliability and improved efficiency of operations and utilisation of resources.

II. Relevant Policies to Promote Smart Grid Development

A smart grid is a key enabler towards the 21st century of South African Economy. The South African National Energy Development Institute (SANEDI) in collaboration with Department of Mineral Resources and Energy (DMRE), developed a Smart Grid Vision 2030 Document in 2017. The vision document expresses the long-term aspirations and development objectives for the electricity supply industry in South Africa. South Africa has energy policies and legislations which are aligned and promote the development of smart grids in South Africa, the policies are briefly outlines below:

1. White Paper on Renewable Energy

White Paper on renewable energy policy was published in 2003 to ensure that renewable energy resources are used optimally in South Africa. The white paper policy encourages the introduction of decentralized mini-grids and hybrid systems in rural areas that will also promote the development of small medium and micro enterprises (SMMEs)[16].

2. National Energy Act

The National Energy Act was gazetted in 2008. The act aim is to ensure that diverse energy resources are available in sustainable quantities and at affordable prices, to the South African economy in support of the economic growth, and poverty alleviation; provide energy planning, increased generation and consumption of renewable energies, contingency energy supply, holding of strategic energy feedstocks and carriers, adequate investment in, appropriate upkeep and access to energy infrastructure; to provide measure for the furnishing of certain data and information regarding energy demand, supply and generation; to establish an institution to be responsible for promotion of efficient generation and consumption of energy and energy research; and to provide for all matters connected therewith [17].

16 D.M.R.E, " White Paper on Renewable Energy" Department of Resources and Energy, South Africa, 2003

17 The Presidency Department " National Energy Act", South Africa, Cape Town, 2008

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3. Electricity Regulation Act

The electricity regulation act 4 of 2006, is to establish the national regulatory framework for the electricity supply industry, and for National Energy Regulator of South Africa (NERSA) to be the custodian and the enforcer of the framework. The NERSA is given the authority to provide for licences and registration within the generation, transmission, distribution, reticulation, trading and import and export of electricity. NERSA regulates the reticulation of the municipality's electricity.

4. Electricity Pricing Policy

South Africa has gazetted Electricity Pricing Policy (EPP) in 2008 and its purpose is to obtain a balance between several competing objectives, inter alia: affordable electricity tariffs for the low-income consumers and cost reflective electricity tariffs for all the other consumers. In this regard, electricity prices should reflect efficient market signals, accurate cost of supply and concomitant price levels that would ensure financial viability of the electricity sector in its entirety. In order to place the EPP document into perspective, and to ensure that electrification targets are met, it is imperative to summarise the electricity sector objectives as detailed in the White Paper (WP) of 1998 as follows[18]:

- Improved social equity by addressing the requirements of the low income;
- Enhanced efficiency and competitiveness to provide low-cost and high quality inputs to all sectors;
- environmentally sustainable short and long-term usage of our natural resources;
- The right of choice of electricity supplier;
- Competition in especially the generation sector;
- Open non-discriminatory access to the transmission system; and
- Private sector participation in the industry.

18 "Electricity Pricing Policy of the South African Electricity Supply Industry," Department of Mineral Resources and Energy , 2008.

5. National Development Plan

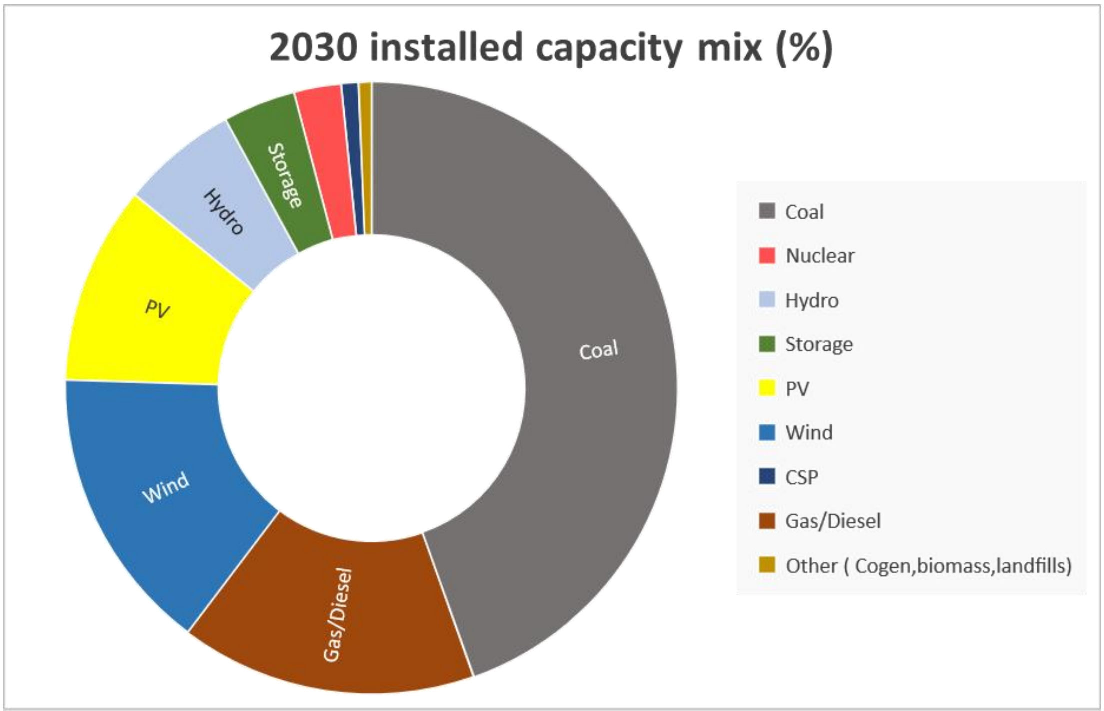
The National Development Plan 2030 (NDP) envisage that by the year 2030, South Africa will have an energy sector that promotes economic growth and development through adequate investment in energy infrastructure; to have social equity through expanded access to energy at affordable tariffs and through targeted; sustainable subsidies for needy households and environmental sustainability through efforts to reduce pollution and mitigate the effects of climate change[19].

6. Integrated Resource Plan

South Africa has developed the Integrated Resource Plan (IRP) in 2019, which is the update of the previous IRP 2010. IRP is defined as an electricity infrastructure development plan based on least-cost electricity supply and demand balance, considering security of supply and the environment. The IRP identifies the preferred generation technologies required to meet expected demand growth up to 2030 while reducing the carbon emissions and water usage. South Africa is committed to procure 18 000MW of new capacity generators from various technologies.

Figure 5.2-1: South Africa IRP 2019 Installed capacity mix .

19 National Planning Commision (Department of the Presidency of South Africa), "National Development Plan 2030," Republic of South Africa.



The capacity mix of installed, committed and new additional capacity generators indicted in Figure 3 into the South African grid, increases the opportunity of the smart grid technologies such as the advanced metering infrastructure.

To reach the targeted renewable energy capacity mix in the IRP 2019, South Africa has developed the Renewable Energy Independent Power Procurement Programme (REIPPP). The REIPPP aim is bringing additional megawatts onto the country's electricity system through private sector investment in wind, biomass, and small hydro, etc. The REIPPP has released the Request for Proposal (RFP) to Independent Power Producers (IPPs) to develop new generation capacity of 2 600 MW, including 1 600 MW from onshore wind energy and 1 000 MW from Solar Photovoltaic (Solar PV) power plants. The REIPP can trading electricity through the Power Purchase Agreement (PPA) and wheeling agreement.

7. National Energy Efficiency Strategy of South Africa

South Africa has developed the National Energy Efficiency Strategy (NEES) in 2005, which sets the long-term energy intensity reduction target of 12% by 2015. The 12% target was not reached, and government implemented post-2015 NEES, to stimulate energy efficiency improvements through a combination of fiscal and financial incentives, a robust legal and regulatory framework, and enabling measures. To achieve the post-

NEES target, the department of DMRE and other partners has launched programmes such as Industrial Energy Efficiency Programme (IEEP), Commercial Buildings Programme (CBP), Public Buildings Programme (PBP), Income Tax Allowance (ITA) and Monitoring, Evaluation and Enforcement Programme (MEEP) [20].

The IEEP focus on promotion of energy management systems and standards to provide companies with a platform to sustain energy-efficient practices, promote energy systems optimisation to unlock the industry's energy savings potential, train energy experts and practitioners to transfer skills to the broader industrial sector and provision of pilot projects to demonstrate the impact of energy efficiency practices on industries. The IEEP has two targets. The first target is the manufacturing target: a 16% reduction in weighted mean specific energy consumption in manufacturing by 2030. The second target is the minimum target, which is the cumulative total annual energy saving of 40 petajoules arising from specific energy saving interventions undertaken by mining companies.

The CBP target is 37% reduction in energy consumption by 2030. The government has rolled out mandatory display of Energy Performance Certificates (EPC) in all properties rented and owned by the commercial sector. The deadline for the EPC is the 8th of December 2022. The PBP aim is to accelerate the current rate of improvement in energy consumption per square metre in buildings occupied by the public sector at the national, provincial, and municipal levels. The public buildings target is the reduction of 50% reduction in the specific energy consumption by 2030, which is relative to a baseline projected from 2015. The department of energy has rolled out the roadmap to energy efficiency within the public buildings.

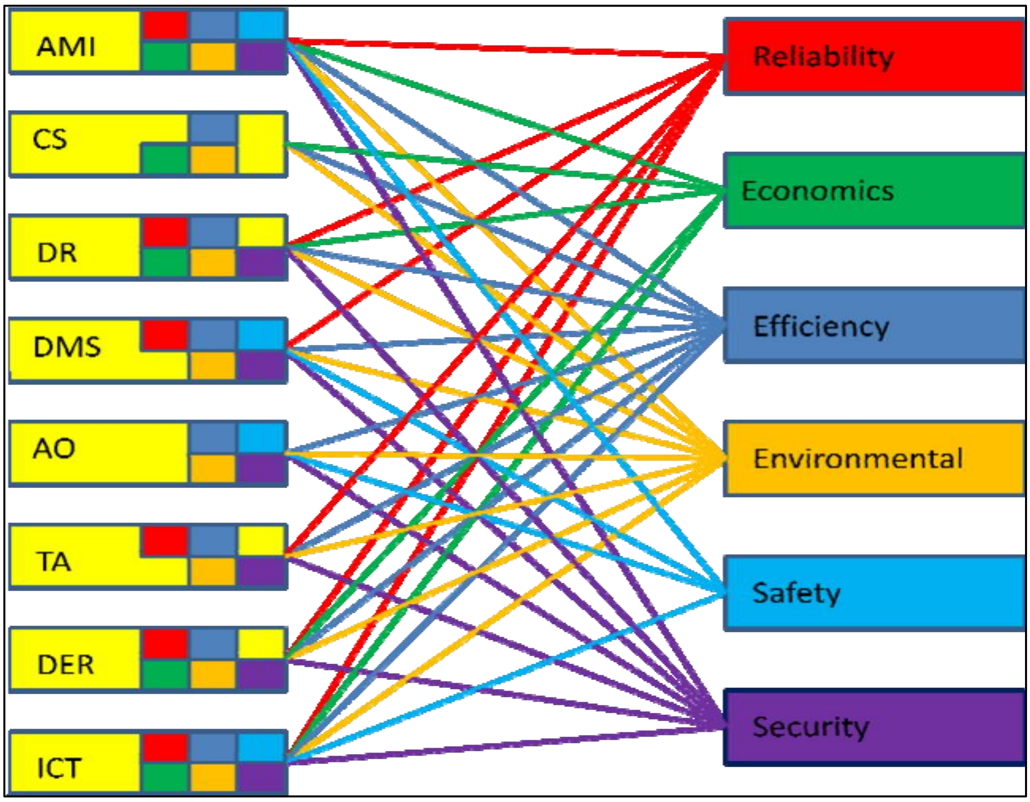
III. Smart Grid Technology and Application

The smart grid vision document has defined a smart grid as "An electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies". South Africa has lagged the world in the adoption of smart grid technologies. As a result of this, the country now has the opportunity, at a convenient time in our investment cycle, to leapfrog several technology development cycles and

20 D.M.R.E, "Post-2015 National Energy Efficiency Strategy", Department of Mineral Resources and Energy, 2016

lessons learned by the front-runners in implementation. South Africa should capitalise on the improvement of global understanding of smart grids and to adopt applicable best practices to achieve full and relevant benefits for the country. Smart grid applications are Advanced Metering Infrastructure (AMI), Customer Side Systems (CS), Demand Response (DR), Distribution Management System/Distribution Automation (DMS), Transmission Enhancement Applications (TA), Asset/System Optimization (AO), Distributed Energy Resources (DER) and Information and Communications Integration (ICT).

Figure 5.3-1: Illustrating the Correlation between Applications and Key Success Factors[21]



The application shown in figure 3 above are aligned to four functional areas of the Smart Grid, namely; Customer Enablement (CE), Advanced Distribution Operations (ADO), Advanced Transmission Operations (ATO), and Advanced Asset Management (AAM). The table below briefly outlines the principle characteristics of all principles

21 D.M.R.E, S.A.N.E.D.I and S.A.S.G.I. , "Strategic National Smart Grid Vision for the South African Electrcity Supply Industry," Department of Mineral Resources and Energy , 2017.

Table 5.3-1: Principle Characteristics of Functional Smart Grid Areas[22]

Principle characteristic	CE	ADO	ATO	AAM
Enables informed and greater participation by customers	X	X		
Accommodates all generation and storage options	X	X	X	
Enables new products, services, and markets	X	X	X	
Provides power quality for the range of needs in the 21st century	X	X	X	X
Optimizes assets and operates efficiently	X	X	X	X
Addresses disturbances – automated prevention, containment, and restoration	X	X	X	X
Operates resiliently against physical and cyber-attacks and natural disasters	X	X	X	

1. Advanced Metering Infrastructure (AMI)

AMI includes smart meters for advanced measurement, an integrated two-way communications infrastructure, and an active interface to give customers and their home area networks access to information, and a meter data management system to process the vast amount of new data. South Africa has not deployed Advanced Metering Infrastructure (AMI) as a whole, however South Africa has focussed more on the installation of smart meters as key enablers towards AMI. Most of the smart meters in South Africa are mainly used for revenue enhancement (billing) and does not active interface to give customers and their home area networks access to information.

ESKOM has conducted a pilot study of AMI technology, which consisted of Installation and testing of 10,000 AMI Meters within small power users, Customer Interface Units (CIUs) and Appliance Control Devices (ACDs), Analyse the process and technology

22 D.M.R.E, S.A.N.E.D.I and S.A.S.G.I. , “Strategic National Smart Grid Vision for the South African Electrcity Supply Industry,” Department of Mineral Resources and Energy , 2017.

impacts to embed the changes into the business, Integrate AMI head-ends with Eskom's billing system (CC&B), Implement automated meter readings (AMR), Pilot and test the residential time of use (TOU) tariff – Home flex, Target conventionally metered customer's consuming 500 kWh and above per month.

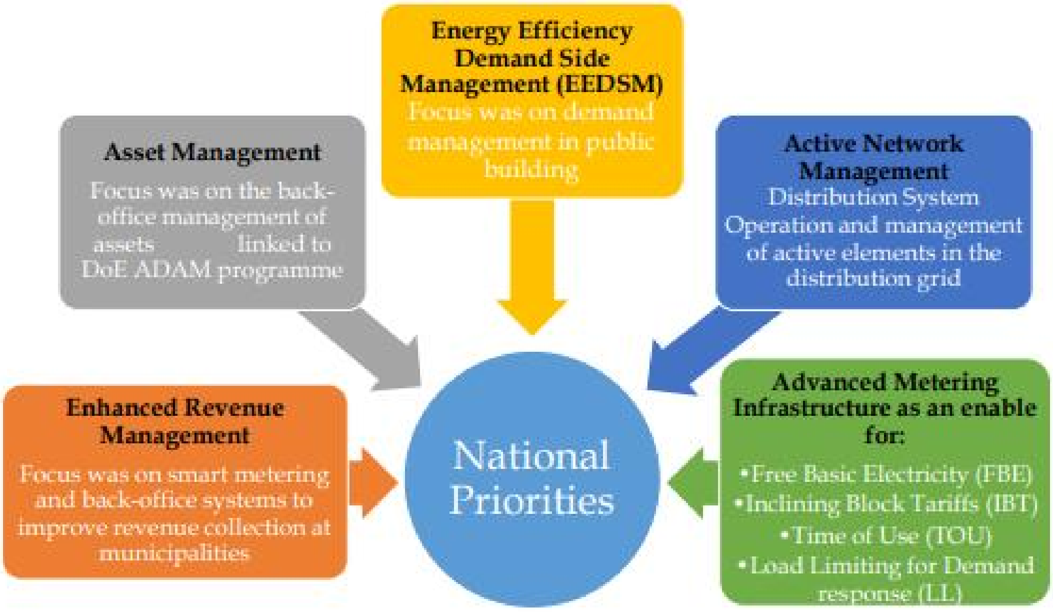
Through the EU Donor Funded Smart Grids Programme completed in 2018, SANEDI implemented 10 pilot projects, aimed at improving business sustainability within the operations of 10 municipal electricity departments. The projects focused on 4 priority areas: asset management, revenue enhancement, Advanced Metering Infrastructure, and active network management. Through these pilot projects, SANEDI has implemented 12,200 smart meters across 10 municipalities. The AMI was implemented at City Power municipality to support the implementation of Free Basic Electricity (FBE), implementation of tariff structure such as inclining Block Tariff (IBT) and Time of Use (ToU) and load limiting for demand response within the network.

SANEDI have proposed a pilot study on two municipalities to deploy the entire AMI to all the municipal customers (residential. Commercial and industrial), for municipalities to have a full benefit of the technology. The implementation of the AMI will allow municipalities to provide information about conditions on the grid and interfaces with other utility enterprise systems that can benefit from AMI functionality. The deployment of AMI technology will follow NRE 049:2016 standard which is recommended utility specification for South Africa.

2.Demand Response (DR)

ESKOM Integrated Demand Management (IDM) to assist the system operator to maintain a healthy demand-supply balance by changing customer usage profiles to support an optimal system load profile. ESKOM has developed energy efficiency and load shifting programmes to support optimisation of system load profile to minimise future generation cost in line with IRP.

Figure 5.3-2: **National Priorities as Specified by the then Department of Energy, not Department of Mineral Resources and Energy.**



IV. Prospects and Outlook for Smart Grid Development

Electricity availability is a fundamental requirement for supporting South Africa's economic growth and development targets. South Africa's electricity infrastructure countrywide is urgently in need of renewal and enlargement to meet growing electricity demands whilst integrating new, sustainable energy options. This presents significant industry challenges but also opportunities for modernisation and new development.

Appropriate national grid development solutions with a balanced leverage of proven and new technologies are an important part of the response to these challenges. An electricity network with greater intelligence will facilitate the integration of renewable energy, supporting national energy objectives and the transition towards a low-carbon economy. The development and application of smart grid solutions will enable the electricity network to bring considerable additional benefits to customers through improved quality of power supply, more accurate billing and better management of energy consumption. At the same time, it can also be a real source of employment and economic growth.

The South African smart grids vision document developed by SANEDI and DMRE describes the aspirational future state of the ESI in South Africa. The Vision document provides an accelerated journey with progress and goals towards continuously achieving the benefits of a smart grid as defined now and with any changes the future may bring.

SOUTH AFRICA

The document also provides a common picture of a Smart Grid that is relevant to South Africa and the challenges the industry faces. Having an agreed definition or collective understanding of the Smart Grid Vision in South Africa is imperative for alignment of effort and integration into a coherent national system. This document is kept live and will be reviewed and updated to align it with the latest policies and regulations and to integrate the smart grids roadmap elements.

Increasing the intelligence of the grid will enable the ESI to better respond to situations such as when generation capacity constraints are experienced, to better leverage technology to compliment other energy resource availability, to support the growing demand, projected economic growth and climate change commitments and to dampen the impact of electricity price increases through efficiency and reduction of system losses.

In evaluation of a Smart Grid, it is essential to move from a utility-centric evaluation of costs and benefits to a broader societal value proposition. The Smart Grid is expected to set the foundation and be a key enabler to deliver on the anticipated electrical networks resilience, business sustainability, efficiency and environmental benefits. It requires a collective call to action and the support from various stakeholders contributing in their own unique way to the shared vision of Smart Grids in South Africa.

Chapter 3

BRICS Cooperation on Smart Grid Development

[VII]

KEY AREAS OF COOPERATION

I. Brazil

Brazil monitors the progress of new technologies that can be applied in Smart Grids, and has developed projects in partnership with other countries, as was the case with the Ultra-High Voltage Direct Current (UHVDC) transmission technology of +-800 kV, with an extension of 2,076 km and designed to transmit up to 4GW of electricity. This technology was used to discharge part of the energy generated by the Belo Monte Hydroelectric Power Plant, in northern Brazil, to the Estreito substation in the southeast region, and was built in partnership with the Chinese company State Grid. The Brazilian company “Belo Monte Transmissora de Energia” (BMTE) was created in the form of a Special Purpose Company (SPE) composed of State Grid Brazil Holding and subsidiaries of Eletrobras (Furnas and Eletronorte).

Brazil has an emerging economy with great possibilities. There is potential for the development of smart networks considering the various devices that make these networks viable. 5G technology is being implemented in the country and will allow greater speed and quality in data transmission, enabling a multitude of applications. It is also interesting to establish partnerships with foreign companies that have the know-how in implementing solutions for Smart Grids, such as, for example, battery suppliers, which would allow cost reduction for the use of storage systems in Smart Grids.

II. Russia

The key project of cooperation could be the development and implementation of joint research program for the development of smart grids in BRICS countries.

Promising areas of cooperation in the field of smart grids in the framework of the BRICS could include:

- joint research and development of a smart model to prevent the development of large-scale accidents in power grids and power pools;
- smart prediction of mode parameters and characteristics of power grids;
- development of a methodology for the formation and management of local smart microgrids based on renewable energy sources, and management of their communities.

III. India

The infrastructure of Electrical grids needs to be developed to address the issues of power transmission and distribution losses, improving the reliability and quality of power supply. These key priorities are achievable through developing and transforming the existing electrical grid system into the Smart Grid (SG). The increased visibility, predictability, and even control of generation and demand bring flexibility to both generation and consumption and enable the utility to integrate intermittent renewable generation better, making it cost-effective and responsive. Smart grids are engineered for reliability and self-healing operations.

Unlike conventional energy sources, renewable generations are highly unpredictable, intermittent, and variable types and thus require exceptional control and balancing architecture to deal with the uncertainty and variability to maintain grid stability and security. Key factors driving smart grid in developed countries include Demand Side Management (TOU tariff, automated demand response, etc.) and environmental concerns for renewable integration. New taxonomy regarding clean energy technologies to be declared as renewable is a matter of deliberations. Interoperability aspects with due regard to safety and security be considered for deliberations.

IV. China

Smart grid can help realize the smooth transmission of renewable energy and promote the optimal allocation of renewable energy in a wider range, which is an effective way and necessary guarantee to promote the sustainable development of energy. After years of exploration and practice, China's smart grid industry has made fruitful achievements in planning and design, standard systems, engineering equipment and technical services. However, energy transformation also brings multiple challenges to the development of the power system, and it is necessary to further explore new technologies and new formats. BRICS countries have great potential for smart grid development, and their experience in technology research and development, engineering application and market mechanism is worth learning from each other. Key cooperation directions and areas include:

- Promoting micro-grid technology in areas without electricity and some small islands to solve the problem of electricity consumption in remote areas. In some areas without electricity among BRICS countries, wind power and photovoltaic resources are developed based on micro-grid technology to solve the power consumption problem. Equipment and technology such as micro-grid integration technology, micro-grid control system and equipment, and energy storage should be applied to improve people's livelihood.

- Intelligent upgrading of distribution network. In areas with serious aged power equipment, high line loss, backward electric energy metering system, and low level of distribution automation, attention must be paid to promoting cooperation of secondary distribution equipment, upgrading tele-meter reading system, improving its distribution automation level, and helping the upgrading and transformation of the power grid.

- Cooperation of power grid energy management system (EMS). Power grid engineering construction and investment in existing assets should be taken as a breakthrough to explore the application of China's EMS system in BRICS countries, and at the same time bring along the cooperation of other power grid automation systems and equipment, optimize the tie-line power flow distribution, improve the economy of local power grid operation, and enhance the automation level of system dispatching.

- Capacity cooperation of smart grid equipment. Power grid equipment manufacturing enterprises should be encouraged to establish smart grid manufacturing bases in BRICS countries.

V. South Africa

When reviewing international experiences, countries with similar challenges and drivers as South Africa, but whom might be further with their implementation, must be considered. South Africa's top 6 drivers for smart grid implementation are:

- Generation adequacy
- Revenue collection from customer base and assurance improvements
- Aging infrastructure concerns
- Economic advantages of a smarter grid
- Reducing operating and maintenance costs and
- System efficiency improvements

The shortage of electricity is a huge constraint on economic growth and job creation. It deters investment and reduces our economy's competitiveness. Over 2,000 MW of solar and wind power has been connected to the grid through Bid Window 4 a further 2,600 MW of capacity has been procured through Bid Window 5, which will begin to add capacity from early 2024. In June last year, the licensing threshold for new embedded generation projects was raised from 1 MW to 100 MW. This removed the licensing requirement for generation projects of up to 100 MW that are connected to the grid. Regulations has also been changed to allow municipalities procure power independently.

Deployment of appropriate technology applications is the key to achieving the stated success factors, performance requirements and principle characteristics of the Smart Grid. Identifying the relevant applications will influence and improve how the Smart Grid is planned, designed, operated, and maintained throughout the value chain. The focus here is therefore on which technology applications to implement and at what pace to achieve a cost-effective, sustainable and beneficial Smart Grid solution for South Africa.

1. Envisaged Smart Grid Initiative and Interfaces for South Africa

These applications should incorporate and prioritise those technology solutions that will provide a positive return on the investment over the deployed asset life cycle. This is achieved through energy demand reductions, savings in overall system operation costs, delayed capital investment, requiring smaller generation reserve margins, lower maintenance and servicing costs (e.g. reduced manual inspection of meters), reduced grid losses, new customer service offerings and improved customer service levels.

2. Prospective areas for cooperation include:

(1)Policy and regulatory requirements

Policy and regulation is required to provide strategic direction for the industry in respect of testing smart grid concepts, development and deployment. Leveraging upon the international experience of other BRICS country can support South Africa with the forward thinking it requires for the development of smart grids.

(2)Embedded generation technologies

Facilitate the integration of alternative energy options harvesting clean energy sources and move from “unidirectional” to “bi- directional” energy flow is critical. Technologies like roof-top PV system, fuel cells & storage systems, and more are required.

(3)Strategic grid studies

Studies focused on improving the ability to monitor plant/equipment, to effectively deploy resources and real time optimisation of network switches and voltage control thereby reducing line losses and energy consumption. Study for both decision makers and technical managers within the Distribution network.

(4)Investments and funding

Funding smart grid projects requires careful consideration of the regulatory aspects related to recovering investments. Smart Grid implementation should be an integral part of the capital expenditure programme of utilities and linked to their business performance and sustainability objectives. The major capital financing instruments available to local governments in South Africa for capital expenditure are: municipal taxes and tariffs; intergovernmental fiscal transfers; and municipal borrowing. It would help to have international Development Finance institutions support with funding either as grants or subsidies for smart grids implementations projects.

(5)Skills and capacity building

There is an inability to attract the right skills, the inability to establish the desired pool of expertise to support the smart grids within distribution utilities (municipalities). A skills and capacity building programme either through Universities, the South African National

Development Institute (SANEDI) etc. to train and employee the required skilled personnel is required in South Africa.

BRICS
2022 CHINA