NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

SPECS Smart Grid + Power Electronics Consortium Singapore

GRID 2.0

CONTENTS

BACKGROUND

Electricity is the most versatile form of energy and is accessed by more than 5 billion people around the world through a series of tried-and-tested technologies. The majority of the world's electricity distribution system, which is called the 'grid', was erected when energy demand was moderately sized. Upgrades have been made to meet increasing demand; however, the grid still operates the way it did almost a century ago. It is unidirectional, where energy flows from the central power plants to end-users, and has a surplus capacity to ensure reliability. The world net electricity generation is forecasted to reach 36.5 trillion kilowatt-hour (kWh) by 2040; representing an increase of 69% from 21.6 trillion kWh in 2012 (ref: www.eia.gov). Electrical energy continues to be the fastest-growing source of end-use energy supply globally, displacing petroleum-based fuels in households, industries, and even transportation.

The grid has been a major consumer of fossil fuels, emitter of greenhouse gases, and often lacks compatibility with distributed or renewable energy sources. As a result, it is a system with a large environmental footprint and therefore has many opportunities for efficiency enhancement. Over time, there has been a significant shift in the method of electricity generation, transmission, distribution and consumption. Power grids are challenged with the need for radical changes promoted by the need to reduce the emissions from electricity supply, to replace and upgrade ageing resources and to reap efficiencies from application of advanced information and communication technologies (ICTs). Moving towards these goals leads us towards the 'Smart Grid.' A Smart Grid does not have any single definition. But a common consensus is that Smart Grids are grids that are transparent, seamless, and allow instantaneous bi-directional flow of the energy information system, which enables the power industry to efficiently manage the delivery of energy and empowers the consumers to have more command over their energy decisions. A Smart Grid incorporates the benefits of advanced communications and information technologies to deliver real-time information and enables the near-instantaneous balance of supply and demand on the electrical grid. In short, a Smart grid is capable of hosting multiple solutions that empower customers, improve the capacity of the transmission lines & distribution systems, provide real-time information as well as pricing between the utility & clients, and integrate reasonable levels of utilisation for renewable energy sources.

Many countries have realised the benefits of deploying smart grid systems. Some have gone further to embark on visualising the next evolution of the grid, i.e. Smart Grid 2.0. This new paradigm in grid systems aims to enable complete decarbonisation of electricity supply while maintaining overall system reliability and resilience. It will leverage the major advances in ICT including data sciences, artificial intelligence, and 5G communications to deliver a fully digital grid. Figure 1 shows the transition of the conventional grid to Smart Grid 2.0.

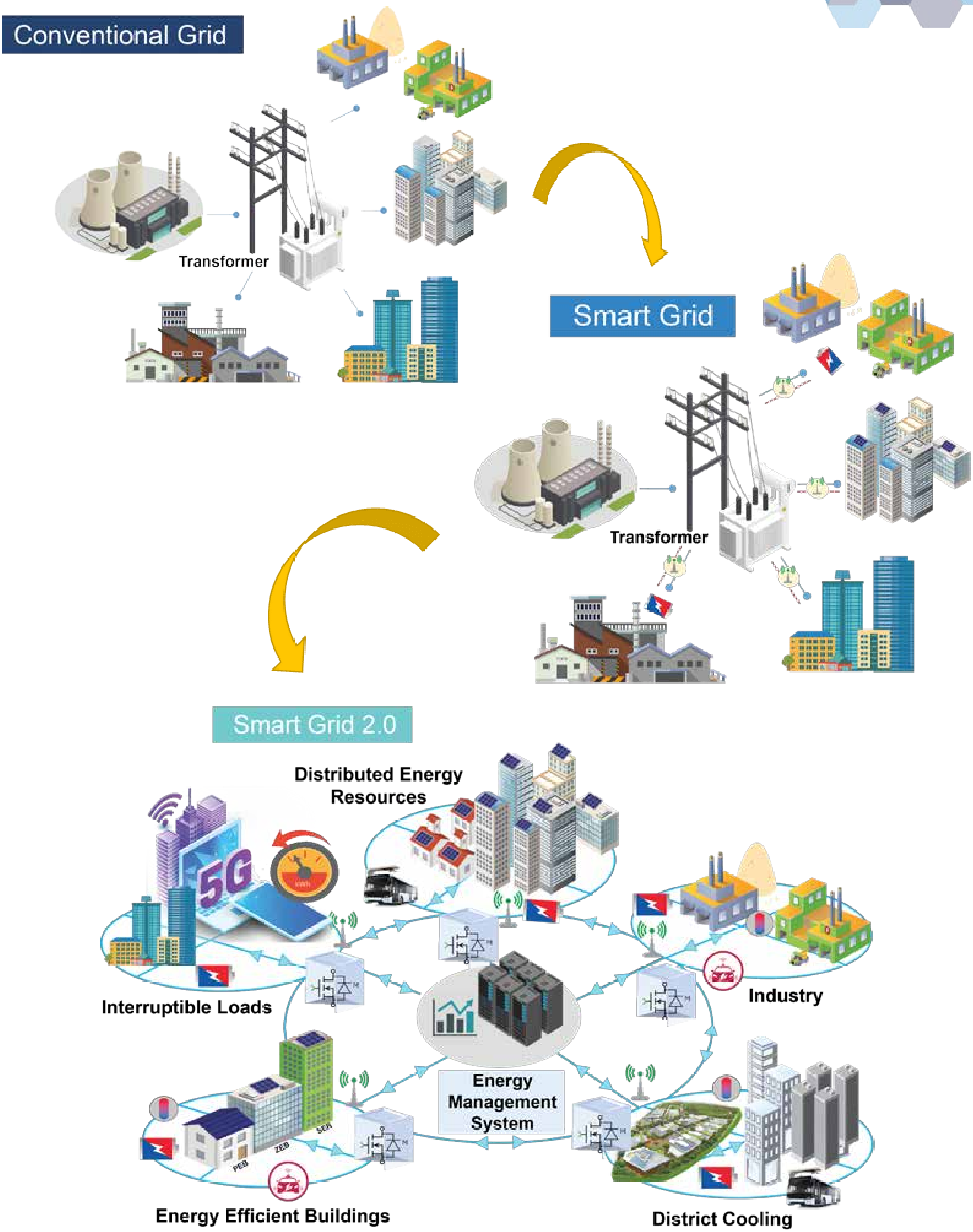

Figure 1. Conventional Grid vs Smart Grid vs Smart Grid 2.0. Smart Grid enables bi-directional information flow (red dotted line), Smart Grid 2.0 enables bi-directional flow of both energy and information (blue arrows)

The broad overview of characteristics of conventional grid, Smart Grid and Smart Grid 2.0 are summarised in Table 1 below:

Characteristics	Conventional Grid	Smart Grid	Smart Grid 2.0
Generation	Fossil fuel based generation	Ready to accommodate moderate share of generation from renewable sources - < 5-15%	Capable to accommodate larger share of renewable resources (15%-25%)
Distributed Generation Integration and Storage	Dominated by central generation	Open for distributed generation with additional components	All-in-one components ready for seamless integration of distributed generation and energy storage
Infrastructure	Non interactive, energy inefficient infrastructure	Smart metering systems & advanced controls	All features of Smart Grid + Smart energy routers, advanced power electronics in distribution network to make it energy and space efficient and Integrated
Communication	Manual communication	Two way data flow/ digital communication by using advanced ICT	Two way flow of energy and information, energy internet
Consumer Participation	Nil	Informed, involved and active consumers - demand response and distributed energy resources	All features of Smart Grid + Consumers can generate and route energy through energy internet
Resilience	Vulnerable to natural disasters and malicious acts	Resilient to attacks and natural disasters with rapid restoration	All features of Smart Grid + Can route energy between components to sustain the operation during natural disaster or malicious attacks
Reliability	Breaker trips to prevent further damage	Automated metering anticipates issues and minimizes impact	Fully automated, self-healing and resilient system and adaptively controlled response and management to disturbances

Table 1. Characteristics of a Conventional Grid, Smart Grid & the Future Grid

Electricity Grid in Singapore

The electricity grid in Singapore is one of the most reliable and robust in the world with intelligent components installed in numerous segments of the generation and transmission network. The transmission & distribution network of Singapore comprises of 400kV, 230kV, 66kV, 22kV and 6.6kV systems with cables spanning more than 15,000 kilometres. The uniqueness of Singapore's power system is that it is partially smart, and the transmission & distribution system is underground to a large extent. Network losses are reported to be only around 3%. Figure 2 illustrates the current state of the Singapore electricity grid.

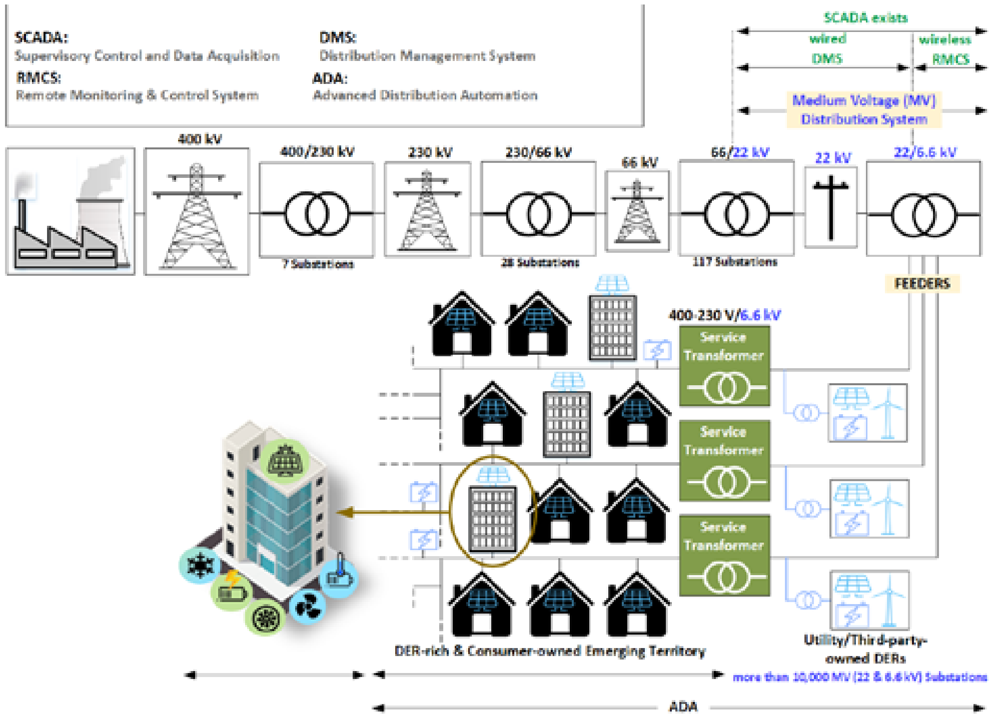

Figure 2. Singapore electricity grid

The grid performance of Singapore in terms of interruption indicators such as System Average Interruption Duration Index1 (SAIDI) and System Average Interruption Frequency Index2 (SAIFI) are one of the lowest, with less than 16 seconds of average disruption time per customer in 2017. Figure 3 shows the 6-year performance of the Singapore grid for these indices.

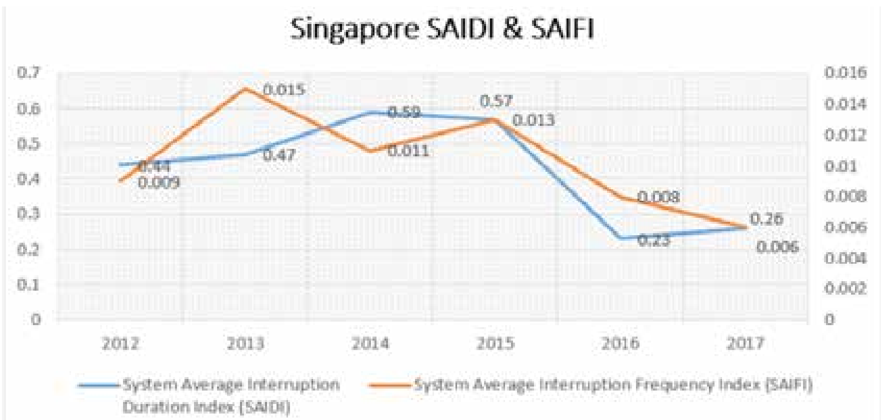

Figure 3. Singapore SAIDI & SAIFI

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[1] SAIDI is the average outage duration for each customer served, and is measured in units of time. SAIDI = (sum of all customer interruption duration)/(total number of customers served)

[2] SAIFI is the average number of times an average customer would experience. SAIFI = (total number of customer interruptions)/(total number of customers served)

Grid Modernisation: Global Status

Singapore has set forth to develop cost-competitive energy solutions to improve energy efficiency, reduce carbon emissions and broaden energy options. Two key strategies in Singapore's Energy Transition include the increased focus on natural gas including LNG and deployment of at least 350 MW of solar energy by 2020. The Energy Market Authority (EMA) has also introduced trials on electrification of transportation, utility-scale energy storage systems (ESS), and has implemented the open electricity market for all customers to buy electricity from a retailer of their choice. The United Kingdom has taken rapid strides in changing its generation mix from fossil fuels to renewables. Electricity capacity from renewables has increased dramatically from less than 6.7% generation in 2009 to 33% in 2018. Renewable electricity capacity (onshore & offshore wind, solar PV, hydro and biomass) was 45 GW in the first quarter of 2019. Regarding smart grids, the UK has made significant progress to-date in deploying smart grids and has made a considerable investment in smart grid research & demonstration projects.

The United States also aims to fasten the modernisation and revolution of the country's electric transmission and distribution systems under the Smart Grid Investment Grant program. Over $8 billion in investments have been made towards smart grid rollout between 2010 and 2015. Over 50% of the investment was made in advanced metering infrastructure (AMI). As of December 2016, 72 million smart meter units had been installed in the US and by 2020, they are aiming for this number to go up to 90 million. In the US as well as the European Union, smart meters have been deployed in more than 50% of the market. Germany plans to increase investment in smart grid infrastructure to $23.6 billion between 2016 and 2026. It aims for 100% deployment of smart meters by 2032. Besides smart meters, Germany also plans to invest in other advance grid infrastructure segments. Over the next few years, the country intends to invest $14.1 billion in advanced sensors, communications and software for its distribution grid and in battery storage. Investment will be undertaken by the country's four largest utilities – RWE, E.On, EnBW, and Vattenfall – as well as the numerous municipal utilities. France's energy landscape has been changing steadily for decades. Initially, it was dominated by coal and eventually by oil, however, it went through a serious transformation in the 1970s with the large-scale development of nuclear energy, and again in the 1990s with the increasing use of natural gas. Today, it is undergoing a transition with the development of renewable energies and the implementation of policies aimed at reducing greenhouse gas (GHG) emissions. Moreover, France has also continued to invest in future grid technology and by 2016 it rose from 13th position to the 10th position in a world Smart Grid infrastructure market estimated to be worth 65.42 billion USD in 2021.

Smart-meter deployment has advanced significantly in the last few years in several key countries. China is moving towards full deployment and, Spain, Japan and France are ready to accomplish full rollouts in the coming few years. Progress in India and Southeast Asia has been slow, but there are plans on paper to achieve a significant advancement by 2025. These developments are indicative that the global focus has shifted from the traditional electricity model to one where multi-energy and smart energy systems are considered as part of the grid too, affecting the way we view the smart grid.

SMART GRID

Smart Grids are considered to be synonymous with electricity supply networks that use digital communications technology that transforms electricity supply by allowing better energy delivery and enabling consumers to have more say over energy decisions. Smart Grids involve the deployment of "smart hardware" including smart meters (Advanced Metering Infrastructure) and distribution devices such as automatic voltage regulators. The deployment of such Advanced Metering Infrastructure is expected to be accelerated, due to increased affordability of devices. Given their familiar form and functionality, smart meters enable the very first non-threatening step towards migration to a smarter grid. Smart controls and Advanced Metering Infrastructure provide high resolution data regarding flow of power. The Smart Grid makes the grid smarter and would generate efficiencies in electric power distribution. This network will consist of detection, measurement and control devices with two-way information exchange between parties. This gives energy stakeholders real time updates about the network condition, enabling them to take instantaneous action to correct the grid. Ultimately, it aims to empower customers, improve the transmission lines and distribution systems, provide information and accurate pricing for consumers & suppliers, and capitalise on renewable energy sources.

Benefits of a Smart Grid

The main force driving the development of the new power systems is the requirement to feed the rising demand for electricity while reducing carbon emissions, without compromising the reliability of electricity supplies on which economies heavily lean. With developing economies such as ASEAN, China, India, and others embarking on higher levels of economic growth, the Smart Grid has a crucial role to play in offsetting carbon emissions while feeding such economies with the energy needed for continuous growth.

The key benefits of a smart grid can be summarised as:

Meeting our Energy Needs: Global energy consumption in 2018 increased at nearly twice the average rate of growth since 2010, driven by a robust global economy and higher heating and cooling needs in some parts of the world as illustrated in Figure 4 (IEA). This trend is expected to continue into the future as countries demand more energy to power their economies especially the emerging economies.

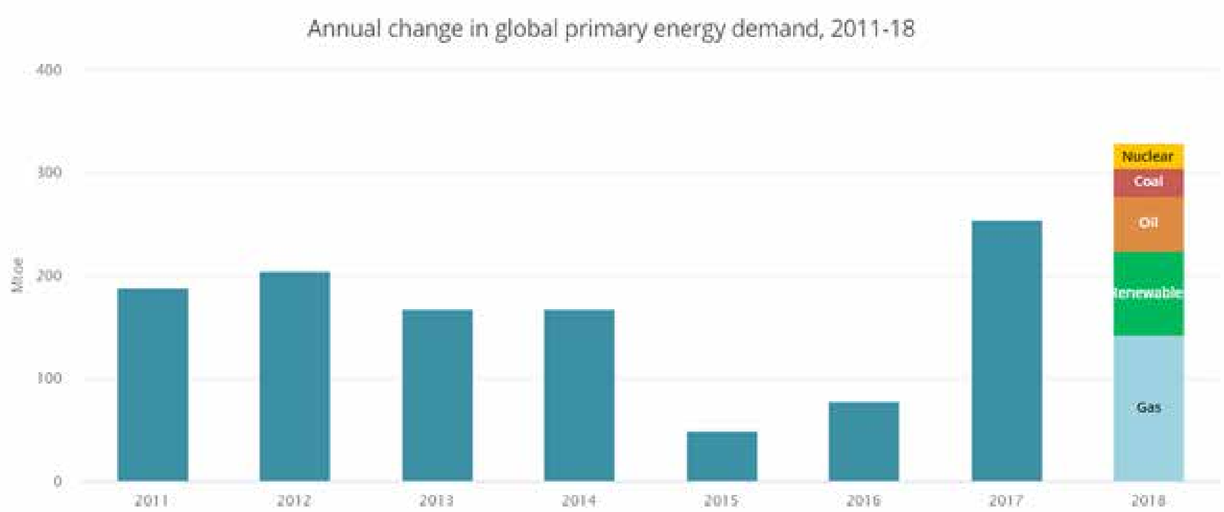

Figure 4. Annual Change in Global Primary Energy Demand, 2011 - 2018
(Adapted from the International Energy Agency)

The increased demand for energy traditionally would result in greater carbon emissions. The major benefit of a Smart Grid is that it will enable us to meet this rising demand for energy while reducing carbon emissions without compromising on the reliability of electricity supply reliability, a major key for all economies.

Energy Efficiency: Energy efficiency may be viewed as the most amenable, sustainable and cost-efficient way of reducing greenhouse gas emissions. Energy efficiency improvements do not usually require a large overhaul of existing infrastructure which can be very expensive. Smart Grids have the potential to be a cheap yet significant source of cost savings for energy stakeholders, making it more palatable for stakeholders to embark on these projects. The Smart Grid enhanced with network monitoring and control features will enable transmission and distribution grids to run more smoothly, enhancing capacity and improving reliability leading to energy efficiency.

Integrating Renewable Energy: Incorporating renewable energy into the grid will help offset carbon emissions. By introducing renewable energy sources such as solar and wind energy, the world opens itself to the opportunities of limitless clean energy. Once fully deployed, economies would receive unlimited power at almost zero cost to the environment, which is a win-win situation for these economies and the world. The current grid however faces a major difficulty in the form of renewable intermittency. The amount of renewable energy available changes with changes in the weather. When a cloud covers the sun, solar panels are rendered useless. When the wind stops blowing, wind turbines fail to turn. A smart grid with energy storage elements helps to alleviate these problems and achieve an ideal scenario of uninterrupted power supply.

Enable the Adoption of Electric Vehicles: The advent of environmental challenges has caused car manufacturers to rethink their car models & design. It's a well-known fact that cars are a major source of environmental pollutants. In response to global environmental awareness, car manufacturers are turning to electric cars as a solution. If not planned properly, the proliferation of charging stations has the potential to overload the distribution network, thus destabilising the grid. The smart grid can streamline the EV charging by providing sophisticated control systems and communication networks, which not only prevents a sudden increased demand for electricity in the grid but also help to shape the total grid demand profile.

Figure 5. Electric Vehicles Charging in Singapore
(Image credit: The Straits Times Online, Singapore Press Holdings, 28-Sep-2017
ST Photo: Joyce Fang)

Enable better Energy Management, Outage Management & Grid Reliability: The smart grid will facilitate the rapid growth of smart meters, which can track user's electricity usage over time. These meters are important precursors in smoothening peak demand and achieving energy efficiency, which are crucial for energy management stakeholders. Current meters are not able to provide information on the same level as smart meters and hence unable to achieve the aforementioned outcomes. Smart Grids can enable better energy management, better tracking and monitoring of devices, predictive maintenance and cost savings with lifetime extension of existing grid infrastructure.

Smart Grid Index

In 2019, the SP Group conducted a comprehensive survey to develop a Smart Grid Index (SGI). The study covered 75 major utilities over 35 countries globally. This index served as a useful reference guide to benchmark the SP Group against other utilities worldwide. It also highlighted the best practices of each utility and provided recommendations on possible areas of improvement.

Based on the definitions of smart grid by a European Union Commission Task Force and a U.S. Department of Energy Smart Grid Task Force commissioned for the subject, SP Power Grid identified key dimensions of a Smart Grid, and developed a framework that guides Smart Grid development to deliver value to customers. The key dimensions are illustrated in Figure 6:

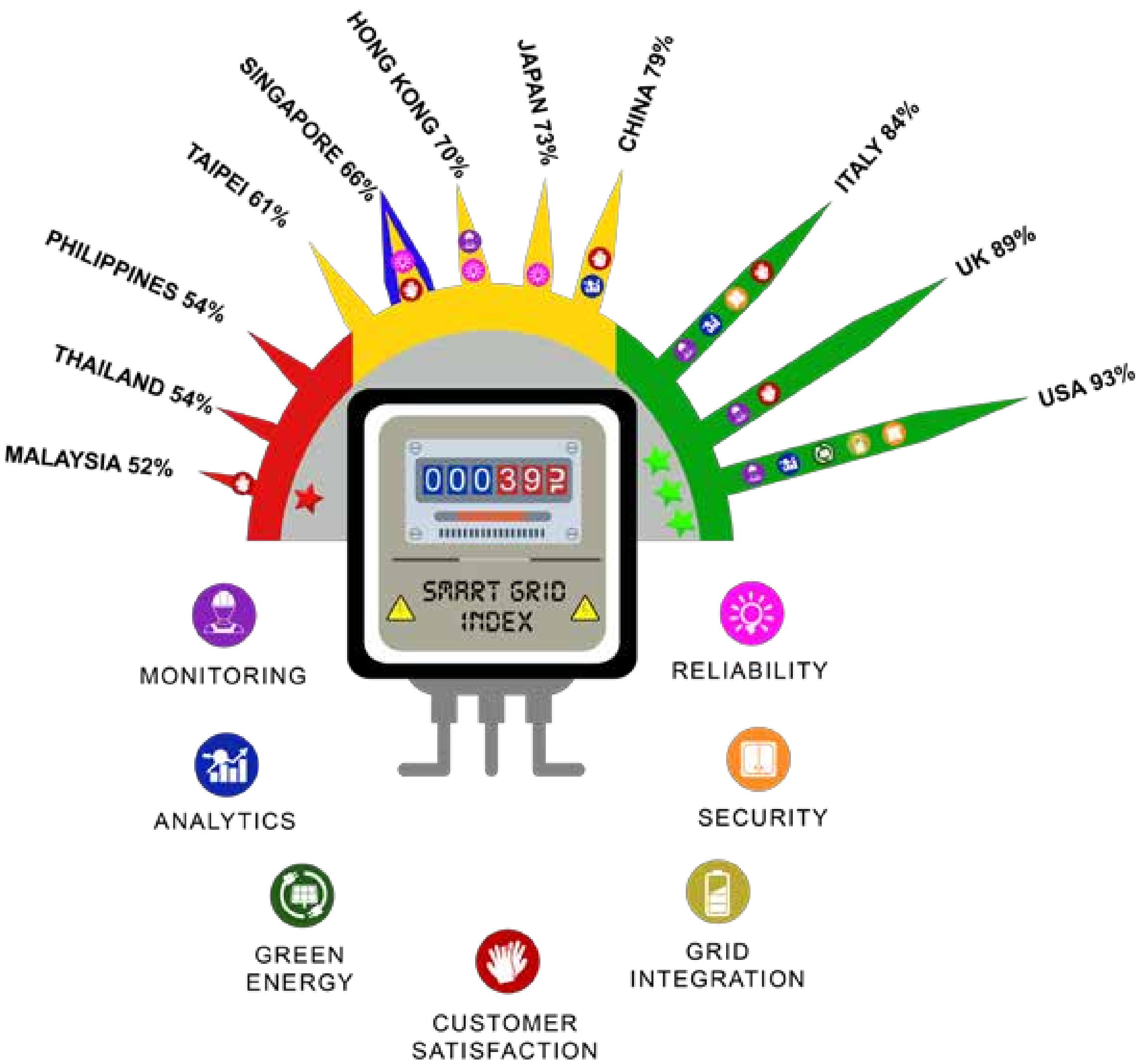

Figure 6. Seven Dimensions of a Smart Grid

Using this SGI framework, utilities can track development progress, and set targets for further improvement to align with the future energy landscape and customers' expectations. The SGI is constructed to not only measure the systems & processes implemented but also the outcomes that deliver sustainability, reliability and satisfaction to the customers. By benchmarking these results, best practices from individual utilities can be identified, shared and acted upon in working towards a smarter grid. The results of this benchmarking are presented in Table 2.

Benchmarking Results 2019				
Rank	**Country**	**Utility**	**Score (%)**	**Best Practices**
1	**United States of America (USA)**	Pacific Gas & Electric Company (PG&E)	93	• Data Analytics • DER Integration • Green Energy • Security • Monitoring & Control
2	**United Kingdom (U.K.)**	United Kingdom Power Networks (UKPN)	89	• Monitoring & Control • Data Analytics • Green Energy • Security
3	**United States of America (USA)**	Southern California Edison (SCE)	88	• DER Integration • Data Analytics • Green Energy • Security
34	**Singapore (SG)**	SP Group (SP)	66	• Supply Reliability • Customer Empowerment & Satisfaction
52	**Thailand (THA)**	Metropolitan Energy Authority (MEA)	54	• N/A
57	**Malaysia (MY)**	Tenaga Nasional Berhad (TNB)	52	• Customer Empowerment & Satisfaction

Table 2. The Singapore Grid Benchmarked Against Grids Worldwide

In general, US utilities fare better than European utilities and both are ahead of Asian utilities. This could possibly be attributed to the fact that US and European utilities have been facing disruption in their industry and regulatory intervention earlier than Asian utilities. PG&E of US for example, is strong in areas of (i) Monitoring & Control, (ii) Data Analytics, (iii) DER Integration, (iv) Green Energy, and (v) Security. In comparison, the SP Group is strong in supply reliability and customer empowerment & satisfaction with room for improvements in other areas. Not far behind Singapore are its neighbours such as Malaysia and Thailand. Singapore was ranked 34th (score: 66%) amongst 75 utilities surveyed. Thailand was ranked 52nd (score: 54%), while Malaysia ranked the lowest with a score of 52%. This indicates that Singapore has the opportunity to review its strategy and investments in the Smart Grid to support its objectives of sustainability, affordability, and reliability of its power supply network.

GRID OF THE FUTURE: SMART GRID 2.0

While the Smart Grid injects intelligence into the current power grid, the Smart Grid 2.0 is envisioned to be a technology leap that will usher in the Internet of Energy, realising bi-directional energy and information flows, and leveraging upon breakthroughs made in power electronics to enable active network management. Replacement of the analog power-line transformers of today with power electronics components will greatly facilitate intelligent and remote network management and will create opportunities for miniaturisation of the power grid components (e.g. substations) supporting initiatives of greater land utilisation and potentially housing some of the components of the power grid at remote underground locations. The next generation power grid is being explored globally, with the US allocating US$3.4 billion to develop “Power Grid 2.0”. The research efforts are mainly focused on advanced power electronics technology, installation of smart meters, and broad band technology across grid systems to enable the use of renewable integration, intelligent bi-directional power flow and ensure a secure and stable grid under disasters like hurricanes. In Europe, large industrial corporations are partnering with the government to enable utilities move beyond the Smart Grid which is comprised of automated metering infrastructure (AMI), and towards Grid 2.0. The focus of Grid 2.0 is on Distribution Automation (DA) and AMI. The objective of DA here is to make a self-healing, digitally controlled network for reliable electric power delivery.

The United States Department of Energy (DOE) states that a future grid would be a facile, cost-effective electricity system at every point that can match the demand for renewable energy with:

- Vast improvements in clean energy capacity
- All consumers being able to access the electricity market
- Solutions that fit all imaginable scenarios
- Energy & Information Exchange
- Reliability, Resiliency & Security (Cyber & Physical)

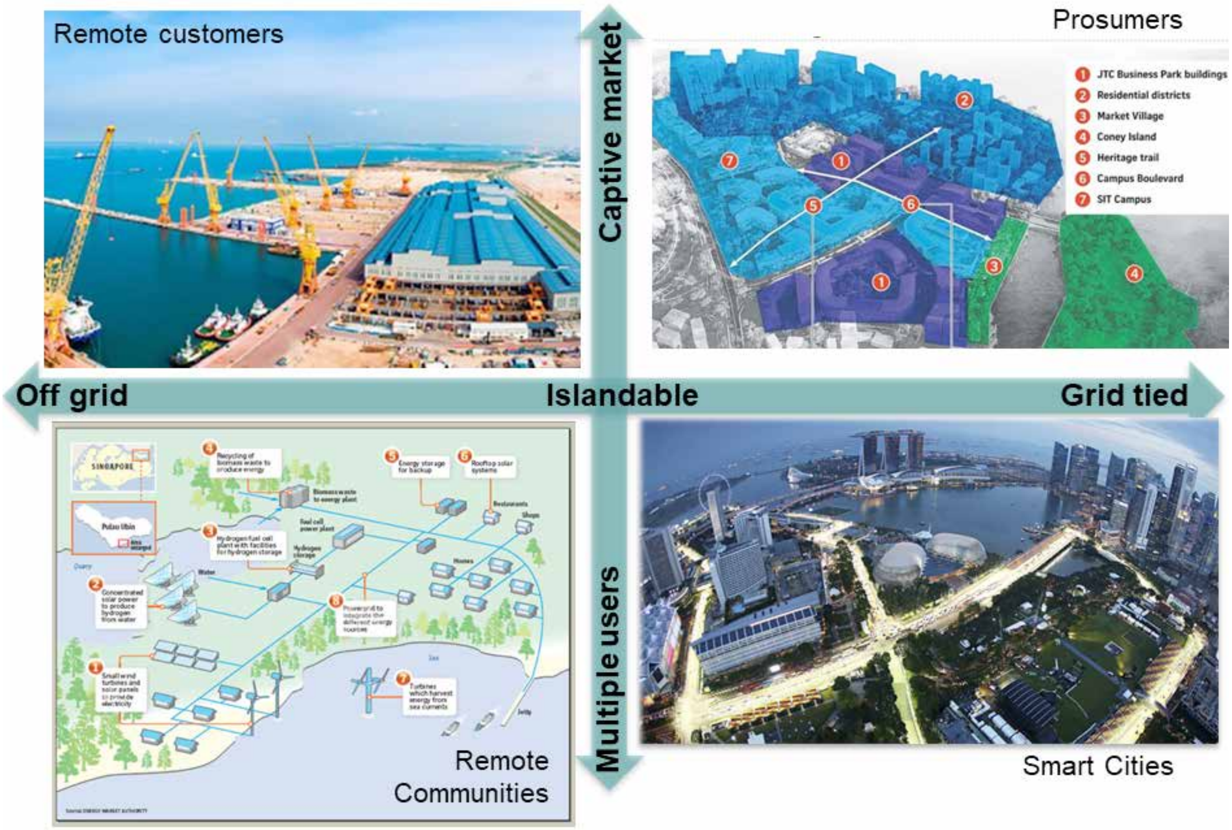

Figure 7. Smart Grid 2.0 Application Domains
(Figure is adapted and reproduced from Schneider Electric)

The grid of the future should be designed to adapt to a variety of operating environments and Use Cases (Figure 7). For example, in environments where users are not (or cannot) be connected to the central grid, the local microgrid would not have a cushion to absorb massive swings in supply and demand. Thus, its design needs to have an added buffer of storage and sinks that can ensure the necessary frequency and voltage modulation, together with AI capabilities for self-healing. The Use Cases themselves can be divided into two broad categories: those involving a single transacting entity such as resort islands, military bases, ports, etc. and those involving multiple transacting entities, e.g. a rural community. The latter would also require the grid to accommodate transactional capabilities. In central grid-tied environments, the challenge first and foremost is that of grid architecture, i.e. whether its centralised or decentralised. A traditional network would be more centralised in its design, with a few large discrete power stations as supply points, and a multitude of demand points, i.e. customers. This set-up relies on a very strong high voltage transmission grid that connects large power stations with the distribution areas. However with the increasing prevalence of distributed generation (e.g. solar photovoltaics) and energy storage options, it creates opportunities for supply and demand points to be co-located, thus reducing the reliance on the central grid. This would lead to increased emphasis on the low and medium voltage distribution network, as opposed to the high-voltage transmission network. This need will be further exacerbated by the rapid penetration of electric vehicles and the associated charging infrastructure.

All the above Use Cases would require grid bidirectionality in order to accommodate rapid intra-day changes in flow patterns, an updated grid architecture to allow multiple agents to transact with each other on a level playing field, and platforms to facilitate these transactions. Bidirectionality can be introduced by replacing the analog transformers in smart grids with power electronics based solid state transformers (SST). Additionally, software and communication platforms such as advanced distribution systems and solutions such as Distributed Energy Resource Management Systems (DERMS) would also be required. In developing countries, the implementation of the Smart Grid would be different from that in developed countries. Countries without an established grid can build a Smart Grid from the get go instead of making modifications to existing infrastructure. The efficiencies that the Smart Grid would create can solve a variety of problems such as insufficient supply to meet demand and electricity theft management. Given that several developing countries are reliant on coal for power, the smart grid would also offer many opportunities in the form of carbon savings. Smart Grid 2.0 is hence a complete shift from both the previous generation of hard and soft grid components to its modernised digital version for enabling better integration of renewable energy resources, facilitating two-way power and information flow, more active consumer participation, improving quality of service and resilience of grids in a varied and challenging environment. It will be smarter, detecting excessive amounts of energy and redirecting it to prevent the grid from shutting down. It can freely receive energy from anywhere and offer improved resilience in the event of disruptions. It allows two-way communication between the consumer and the utility, creating more options & possibilities for consumers. Furthermore, it will leverage upon advancement of power electronics to make distribution networks more efficient in terms of both energy and space occupied, and explore the possibilities for housing some of the components of the power grid at remote underground locations.

The modernization of soft components involves advanced digital information and telecommunication technologies: from last-generation business intelligence (BI) reporting solutions (analytics) of utilities to the real-time and predictive analytics. The advanced IT offerings include consumer behaviour analytics, time-of-use-pricing analytics, cloud-based solutions and most importantly the Internet of Energy. The Internet of Energy intends to link the distributed generation, energy storage and loads to build a grid with seamless information & power exchange. The disruptive change in hard components involves the grid infrastructure itself on the distribution transformer and the introduction of new control and communication technologies.

Benefits of Smart Grid 2.0 to Singapore

Singapore's challenges being markedly different from those in the USA and Europe would require a different approach. Feed-in-tariffs, microgrids, natural disasters and transmission over hundreds of kilometres do not feature as top challenges to the Singapore power grid. Singapore would however face a challenge of deploying and integrating renewables into its power system – mainly in a distributed form. Besides renewables, the two other levers of decarbonisation involve a transition to electric mobility and a focus on energy efficiency solutions. Ensuring operational stability and reliability will however require a data-centric approach – an ability to capture utilization patterns via sensors, to analyse disparate data streams with Artificial Intelligence algorithms, and to engender corrective action for system stability and reliability. The key drivers for Singapore's transition to Smart Grid 2.0 are thus decarbonisation, decentralisation, and digitalisation.

Singapore's Smart Grid 2.0 focus would naturally concentrate on the distribution network and address challenges that are unique to this City-State, a metropolis situated in the tropics. Besides the cooling load, more than 60% of Singapore's emissions emanate from its industrial activities with significant contributions from petrochemical industries.

Although the possible architectures of future grids are still emerging, Singapore's priorities include clean energy generation, energy efficiency, and grid resilience. Initiatives to support these include power generation from natural gas and potentially hydrogen in the future, deployment of solar cells coupled with energy storage, building and industrial energy efficiency, and electrification of transport. In keeping with the Smart Nation vision, Smart Grid 2.0 offers an unparalleled opportunity to leverage digital technologies, artificial intelligence, and data analytics to leverage the full potential of digitalization to deliver the outcomes of sustainable growth, with energy security and affordability.

Key Technological Building Blocks of Smart Grid 2.0

Each step for an escalation in grid maturity is facilitated by the deployment of key enhancements in the hardware, software and communications layers. The key technologies needed from each layer are illustrated in Figure 8.

Hardware Layer:

The main change inherent in the transition from a conventional grid to the Smart Grid is the overlay of Information & Communications Technology (ICT) on the power grid, coupled with progressive introduction of multi-energy distributed resources and stationary storage assets. The greater transformation of the hardware layer however would be in the shift to Smart Grid 2.0 via Solid State Transformers (SSTs). An SST is a gathering of high-powered semiconductors, conventional high-frequency transformers and control circuitry which provides advanced flexible control for power distribution and is capable of rerouting power from point to point via the best route.

Some of the several significant advantages of SSTs over conventional transformers are as follows:

- Massively deduct from the size and weight of each individual transformer, thus reducing the overall land footprint of distribution sub stations and making it possible to house key components in underground remote locations
- Improve power quality
- Provide efficient electricity routing via communication between grid components
- Allow two-way power flow
- Facilitate active and easier change in voltage and frequency levels, when required
- Support early identification of system problems momentarily and sustained power restoration and routing
- Facilitate full digital control, thereby enabling power grid digitalisation

Software Layer:

There are various aspects of transformation in the software layer (see Figure 9):

- Radical shift in software architecture from server to cloud based computing, with the capacity to support system-wide energy transaction optimisation algorithms

- Capacity to manage optimal dispatch in multi-energy systems at a local or neighbourhood level, via SMES (Smart Multi-Energy Systems) software. This software, which integrates multiple energy vectors of electricity, gas, and heat, determines an optimal fusion of energy choices comprising distributed generation (e.g. Roof-installed PV panels), power storage kits, demand response options & meeting residual demand via the grid

- Managing grid stability and reliability at the overall network level, using DERMS software. It comprises several layers of energy management resource solutions. Firstly, it includes models and algorithms that facilitate outage management, granting self-healing capabilities to the grid. Secondly, it facilitates a fundamental shift from a hierarchical grid architecture to one that is heterarchical, thereby allowing a multitude of distributed "agents" (e.g. solar plants, storage kits, electric vehicles, large equipment, etc.) to transact with one another. Finally, it incorporates platforms to facilitate transactions between these "agents".

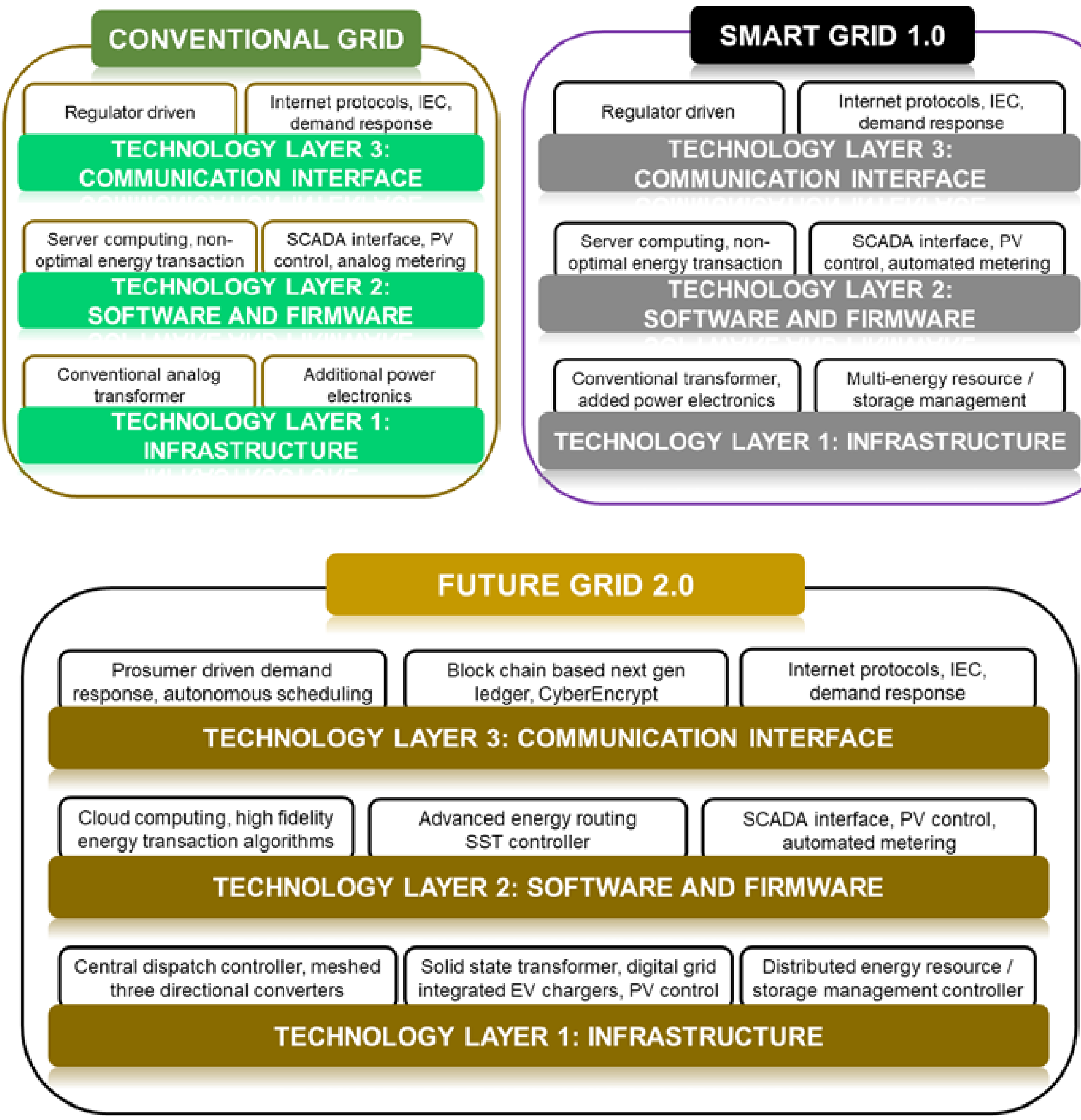

Figure 8. Key Technologies Needed to Drive Singapore Future Grid

In short, DERMS enables grid operators to manage distributed energy resources in front of and behind the meter. The complete view of grid conditions facilitates better coordination between system operators, aggregators and owners, thereby transforming a conventional grid into an Advanced Distribution Management System (ADMS). The complete view of grid conditions facilitates better coordination between system operators, aggregators and owners, thereby transforming a conventional grid into an Advanced Distribution Management System (ADMS).

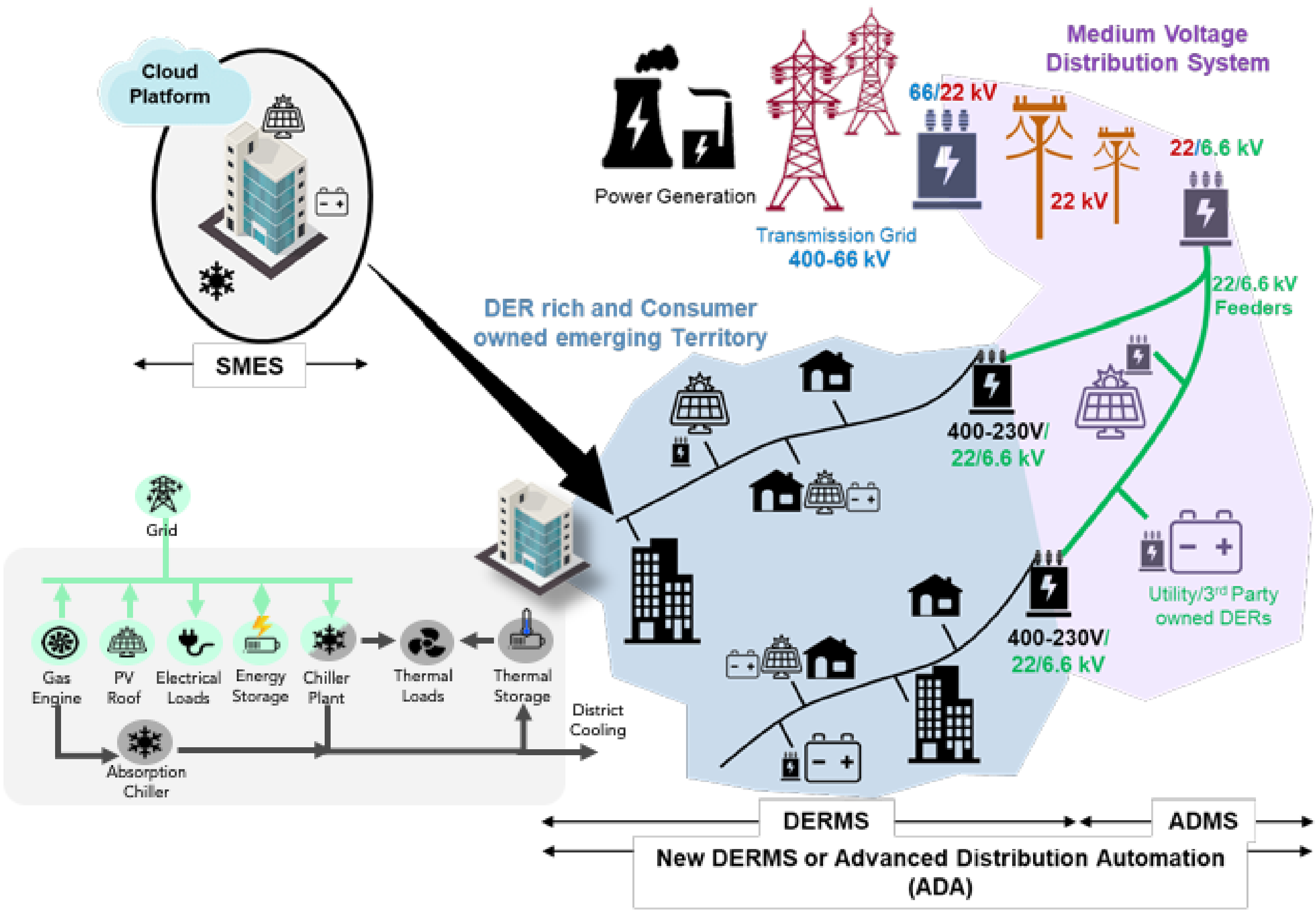

Figure 9. Distributed Energy Resource Management System (DERMS)

Communications Layer:

Secure, reliable & fast wireless communication has to be embedded within the hardware and software layers to enable the future grid. The coordination of work between these layers is reliant on this layer. The advanced network techniques and controls under the Internet of Energy would be capable of anticipating the future state of power systems and make relevant intelligent decisions on their own. Anticipation of future states, health of power system and intelligent decision making could result in a grid with lower maintenance cost and higher reliability.

The Internet-of-Things (IoT) enables meters, sensors, appliances, home control systems to be interconnected using ethernet or wireless technologies. IoT devices connected to the Internet enabling them to send and receive data, are an important technological platform of the future grid. Advances in connectivity such as 5G, would enable rapid transmission of data between these elements to perform grid operations and optimise functions in transmission, distribution, and integration of renewables and the charging of electric vehicles. Block-chain technology would then add a layer of security in energy trading and related transactions facilitated by the internet. Cyber physical systems including IoTs coupled with networked communications are integral parts of the future grid and will usher in a new opportunities for an empowered consumer + producer; or “prosumer” who may participate directly in electricity generation (i.e. with solar panels), electricity supply to the grid, electricity trading and consumption.

CONCLUDING REMARKS

Smart Grid 2.0 is the future of power grids. The functional performance of the Smart Grid 2.0 offers significant benefits over the Smart Grid technologies under deployment in many parts of the world. It interconnects electricity and IT infrastructure to bring together all users, i.e. producers, operators, marketers, consumers, etc. so that there is an efficient balance between demand and supply over a progressively complicated yet comprehensive network. Building the Internet of Energy will be the solution to numerous energy challenges related to the implementation of the infrastructure for the full deployment of the renewable energy production, while the progress in power electronics, energy storage, communications, control, data centres and internet technology are the enablers which will implement the concept successfully in the near future.

Over the years, Singapore has piloted smart grid technologies and has focused extensively in making Singapore's grids one of the most stable in the world. Singapore has set forth to develop cost-competitive energy solutions to improve its energy efficiency, reduce its carbon emissions and broaden its energy options. This Energy Transition will need a transition to a new generation of electricity distribution, Smart Grid 2.0 that will transform the electric power grid into an interoperable network integrating information and communication technologies with the power-delivery infrastructure, enabling two-way flows of energy and communications.

For smart grids to develop and be implemented, we need to plan and establish strategic R&D in key focus areas ahead of discussing its methodology. The goals of R&D should be to develop commercially viable microgrids, developing a self-healing electric distribution grid, and enabling high penetration of distributed energy resources (DERs).

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