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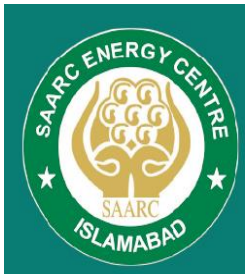

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STUDY ON
DEVELOPMENT OF ROADMAP FOR IMPLEMENTATION OF SMART GRID-CONCEPTS, PRACTICES AND TECHNOLOGIES IN SAARC COUNTRIES

VOLUME 1

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Executive Summary

The South Asian Association for Regional Cooperation (SAARC) comprising of Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka accounts for 21% of world population in a relatively small land area of about 3% of the world. Though, SAARC region is endowed with a fairly large potential of diverse energy resources like hydropower, coal, gas, solar and wind, the exploitation and utilization of these resources could not be effectively achieved so far. Consequently, the average percapita consumption of electricity in the SAARC region is 576 kWh per person per year which about one-sixth of the world average of 3,100 kWh. The SAARC nations also depends excessively on fossil fuels which many of them are importing leaving them exposed to price fluctuations in the volatile international energy markets as well as pose serious threat to nations energy security and increasing levels of GHG emissions. All the SAARC member countries have accorded Paris climate agreement and set limits for their Intended Nationally Determined Contributions (INDC) and are working towards energy transition to cleaner and efficient energy production and usage.

Socioeconomic development, industrial competitiveness and people's well-being and overall efficient functioning of the society is dependent on access and availability of safe, secure, sustainable and affordable energy. Looking forward, it is important that SAARC nations have reasonably priced and environmentally sustainable energy resources to support economic growth and attract investments in the region that will provide jobs and prosperity throughout the SAARC region. The emerging philosophy for low carbon development is to electrify almost all human activities including transport and agriculture to the extent possible and decarbonize the electricity sector through mix of renewable energy and energy efficiency.

Globally, the electric grid which is considered as the greatest invention of the 20th century that made every other invention possible, is today at the threshold of a paradigm shift. The electric grid is being modernized with the overarching goals of Decarbonization, Decentralization, Digitalization and Disintermediation. The visible changes taking place are:

- With the increasing share of generation resources being added at the distribution end, the traditional boundaries between generation, transmission and distribution is fast disappearing
- With consumers becoming "prosumers", the grid that is built for one-way flow of electricity is now experiencing bi-directional flow of electrons
- With decreasing cost of energy storage solutions, there is already a debate on whether to invest in transmission or in storage – the choice between "Generation + Transmission + Distribution" and "Distributed Generation + Storage + Distribution" is becoming real. This is even more relevant in regions where T&D losses are very high as with distributed generation there are fewer network losses
- Loads have changed – Incandescent lamps and induction motors that could accommodate frequency and voltage excursions comprised majority of the load on the grid in the past. The present-day digital loads require quality power at constant frequency and voltage real time basis with predictive forecasting
- Power purchase is moving from Volumetric Tariffs to Transactive Tariffs as Inflexible Demand has become Price Responsive Demand

- The "Merit Order Dispatch" has graduated towards an "Energy Efficient and Environmentally Responsible Dispatch" regime
- Solar PV has already achieved grid parity in many parts of the globe which is about to unleash a rooftop PV revolution and with quantum wind power implementation, Hybrid Renewables Solar +Wind will add to the Power Generation in a big way
- Large fleets of Electric Vehicles that can be aggregated as virtual power plants which could support short term supply-demand balancing will make the grid even more dynamic and complex

In the traditional electric grid, the ability to monitor power flows and control it in real-time is limited to high voltage networks which are equipped with automation systems. In the low voltage network, the power system operator has no visibility on who is consuming how much electricity when and where. In a smart grid equipped with sensors and smart meters which are connected to computers in the control room, it is possible to remotely monitor and control the flow of electricity in real time to every customer or even to every smart appliance inside a customer's premise. So, the evolving smart grid of the 21st century will be drastically different – the grid will soon emerge as the **"grid of things"** like how the internet is evolving as **"internet of everything".**

Smart Grid:

Smart grid is the electric power system with advanced automation, control, information technology (IT) and operational technology (OT) systems that enables real-time monitoring and control of power flows from sources of generation to sources of consumption. Smart grid solutions comprise of a set of technologies to enable these functionalities and help manage electricity demand in a sustainable, reliable and economic manner. Smart grids can provide consumers with real-time information on their energy use, support pricing that reflects changes in supply and demand, and enable smart appliances and devices to help consumers exercise choices in terms of energy usage.

"Smart grid is an electricity grid with communication, automation and IT systems that enable real time monitoring and control of bi-directional power flows and information flows from points of generation to points of consumption at the appliances level."

Smart Grid Roadmap for SAARC Nations:

While these transformational shifts are taking place in most regions, the countries in SAARC region are yet to achieve the goal of universal access to electricity to their citizens. The focus therefore should be to expand electricity generation, grid extension and modernization leveraging emerging smart technologies which will transform the power systems of SAARC nations to smart grids at marginal cost. Since most of the infrastructure that will support the economy in 2050 are being built today, SAARC nations have the enviable opportunity to build the new infrastructure as smart infrastructure which are grid interactive and energy efficient. Transition to a cleaner power system will insulate the SAARC countries from price spikes of fossil fuels and will be cheaper in the long run. For example, cost of electricity from solar and wind resources will be stable for 25+ years. In this transitional stage there may be disruptions and requirement for large investments. However, this transition could be managed efficiently through long-term planning and regional cooperation. A large SAARC grid with diverse mix of energy resources could address the region's needs more effectively and efficiently rather than each country fighting their battles separately. In the planning process it is imperative to include all stakeholders and sufficient care may be taken to protect the interests of low-to-medium income

groups and other vulnerable sections of the society. The long-term pursuit would be to boost productivity and quality of life of future generations by helping ensure reliable supply of electricity at affordable cost which is increasingly clean and sustainable.

It is a very pertinent and timely step that SAARC Energy Centre has taken to prepare Smart Grid Roadmap Study for SAARC countries and India Smart Grid Forum has prepared this report considering the diversity amongst the SAARC nations in terms of size, economy, geography, state of development of the electric power systems and the market structure as well as the national priorities. The smart grid roadmap recommended in this report is based on the analysis of data gathered from secondary sources which are though old, but from reputed sources. We have used approach of Smart Grid Maturity Model (SGMM) to suggest a systematic framework for utilities in the SAARC nations to navigate their smart grid journey. Due to lack of power grid in Maldives, ISGF has given basic recommendations for the country. SGMM can only be suggested where a proper grid infrastructure is present.

Smart Grid Maturity Model:

SGMM is a decision-making framework tool developed by a set of forward-looking electric utilities from USA, Europe and Asia during 2006-08. The tool was handed over to the Software Engineering Institute (SEI) of Carnegie Mellon University, USA in 2009 which is the custodian of the tool now. The model describes eight domains, which contain logical groupings of incremental smart grid characteristics and capabilities that represent key elements of smart grid strategy, organization, implementation, and operation. Utilities use the SGMM to assess their current state of smart grid implementation, define their goals for a future state, and generate inputs into their road-mapping, planning, and implementation processes. Hundreds of utilities around the world have used SGMM for their smart grid journey.

Overview of the Model:

The SGMM describes 8 domains containing logical groupings of incremental smart grid characteristics, which represent key elements of smart grid strategy, organization, operation, and capability.

SMR	**Strategy, Management and Regulatory** Vision, Planning, Governance, Stakeholder, Collaboration	**TECH**	**Technology** IT Architecture, Standards, Infrastructure, Integration, Tools
OS	**Organization and Structure** Culture, Structure, Training, Communications, Knowledge Management	**CUST**	**Customer** Pricing, Customer Participation & Experience, Advanced Services
GO	**Grid Operations** Reliability, Efficiency, security, Safety, Observability, Control	**VCI**	**Value Chain Integration** Demand and supply Management, Leveraging market opportunities
WAM	**Work and Asset Management** Asset monitoring, Tracking 7 Maintenance, Mobile workforce	**SE**	**Societal and Environment** Responsibility, Sustainability, Critical Infrastructure, Efficiency

Figure 1: Domains of SGMM

SGMM navigation process is a five-phase, expert-led process as illustrated below:

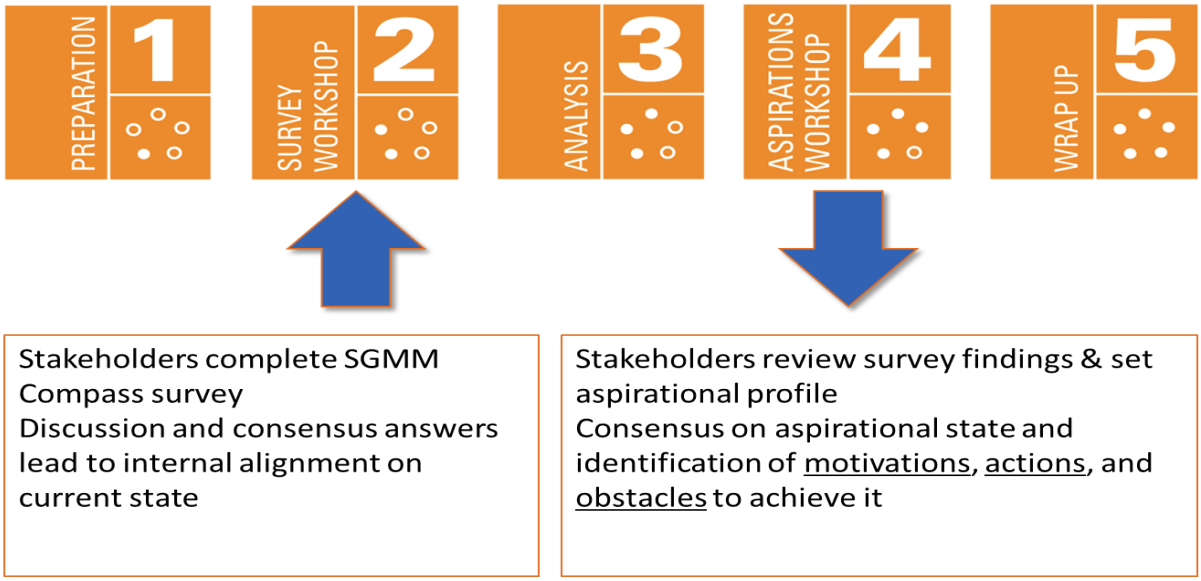

Figure 2: Five Phases of SGMM Navigation

SGMM Levels:

Figure 3: Smart Grid Maturity Model – levels

The compass survey results will determine the AS-IS state of the utility in each of the 8 domains. Thereafter, the key stakeholders of the utility can brainstorm to decide which levels in each of the domains they wish to take the utility in five, ten- or fifteen-year horizon. Once that TO-BE state is decided, different pathways to ascend to higher levels of maturity and technology options and its cost-benefit analysis can be undertaken in a systematic manner. That is the advantage of the SGMM tool.

Benefits to the Utility:

Many utilities have reported that the SGMM comparison yields additional insights about their smart grid progress and plans. Major investor-owned utilities and small public power utilities alike, in the US and around the world, have reported finding the model a valuable tool to help them:

- Identify where they are on the smart grid journey
- Develop a shared smart grid vision and roadmap
- Plan for technological, regulatory and organizational readiness
- Assess resource needs to move from one level to another
- Create alignment and improved execution
- Communicate with internal and external stakeholders using a common language
- Prioritize options and support decision making
- Compare against themselves over time and to the rest of the community

Some of the SAARC nations have just one electric utility and few of them have over dozens of them. Within the country itself, the regions and utilities are in different levels of maturity. In the case of India, the private utilities serving metropolitan cities are at par with utilities in developed countries whereas some of the state government owned utilities are in primitive stages. Hence the recommendations in this report are generic in nature for each country. We have assumed that at least some of the utilities are at initial stages (level-0 in SGMM) in each country and made the recommendations how they can ascend higher levels of maturity. If a utility is already at level 1 or 2 in a particular domain, they can ignore the steps to be taken to reach those levels and rest of the recommendations can be followed.

In general, it is recommended that each country may advise the utilities to undertake SGMM survey and prepare the utility specific roadmap depending on their present levels of maturity and business priorities.

Brief Description of the Contents in this Report:

Chapter 1 provides the broad objective, scope and approach of the study. Smart Grid Maturity Model (SGMM) is also explained in detail here.

Chapter 2 is an introduction to Smart Grid, its components and the various smart grid applications such as SCADA, DMS, GIS, Advance Metering Infrastructure, Distribution Transformer Monitoring System, Outage Management System, Enterprise IT Systems etc. In addition, some select case studies that portray the usage of these smart grid applications in different utilities are also included in this section.

Chapter 3 presents country-wise details of the existing power systems, demand-supply scenario, planned transmission and distribution projects, development and integration of renewable energy, smart grid drivers and policy landscape; and recommendations for smart grid developments by utilities in each of the SAARC countries. Cost benefit analysis of one relevant project for each country has been included in this section.

Chapter 4 discusses the way forward for each member states in terms of policy and regulations, standardization, capacity building, customer engagement, organisational structure and investment facilitation in a phased manner needed for the smooth transformation of the existing grids to smart grids.