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STRIDE Smart grid workshop

Lecture 1

Energy transition and smart grid

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Energy transition (1)

- Energy transition has always existed, only much slower
  - Coal - oil - nuclear energy - gas - renewable sources
- Today, the **transition is much faster**: the market and encouraged renewables
  - **The main question is what dynamics** (costs)
- The main drivers of the transition:
  - energy security - market - global warming and decarbonisation (Kyoto - Paris Agreement)
- Main directions:
  - energy efficiency - carbon-free technologies - energy market integration - electrification of other sectors - connection of different energy sectors
- Method: **smart grid** - digitization

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Energy transition (1)

- **Energy transition** is a radical shift in the energy system from an existing model to a new paradigm.
- It is complex and goes beyond only the replacement of one source of fuel with another.
- In essence, energy transition **involves changes in three interrelated dimensions**:
  i. the tangible elements of the energy system, which include technology, infrastructure, market, production equipment, consumption patterns and distribution chains;
  ii. actors and their conduct, which comprise new strategies and investment patterns, as well as changing coalitions and capabilities of actors; and
  iii. socio-technical regimes that contain formal regulations and policies, institutions as well as mindset and belief systems, discourse and views about normality and social practices.
- Therefore, **transition is multidimensional**, complex, non-linear, non-deterministic, and highly uncertain.
- As the transition outcome is the result of an interaction of technology, institutions, society and agents, in practice, it is difficult to predict accurately the behaviour of such a process.

Energy transition (2)

- While the precise scope and pace of the energy transformation cannot be predicted, its impact on countries, communities and companies will be profound
- The **transition will generate considerable benefits and opportunities**.
- It will s**trengthen the energy security and energy independence** of most countries; promote prosperity and job creation; improve food and water security; and enhance sustainability and equity.
- The energy transformation is also **driven** by the **policies and actions of governments, businesses, cities and civil society**, as well as the world-wide movement to combat climate change and dangerous air pollution.

Energy transition (3)

- This ongoing transition to renewables is not just a shift from one set of fuels to another.
- It involves a much deeper transformation of the world's energy systems that will have major social, economic and political implications which go well beyond the energy sector.
- The term 'energy transformation' captures these broader implications.

Energy transition (4)

- Rapidly growing renewables have unquestionably started to transform the global energy landscape in an irreversible way.
- At the same time, considerable uncertainty still surrounds the energy transition that is taking place.
- As the rapid uptake in renewables shows, we live in an age of exponential change and disruption.
- Which technological innovations will accelerate the transformation cannot yet be foreseen.
- Political choices will affect the course and pace of the energy transformation, which is likely to progress at different speeds in each country and in each sector.
- However, three primary aspects characterize and underpin the transition:
  - energy efficiency,
  - the growth of renewables, and
  - electrification.

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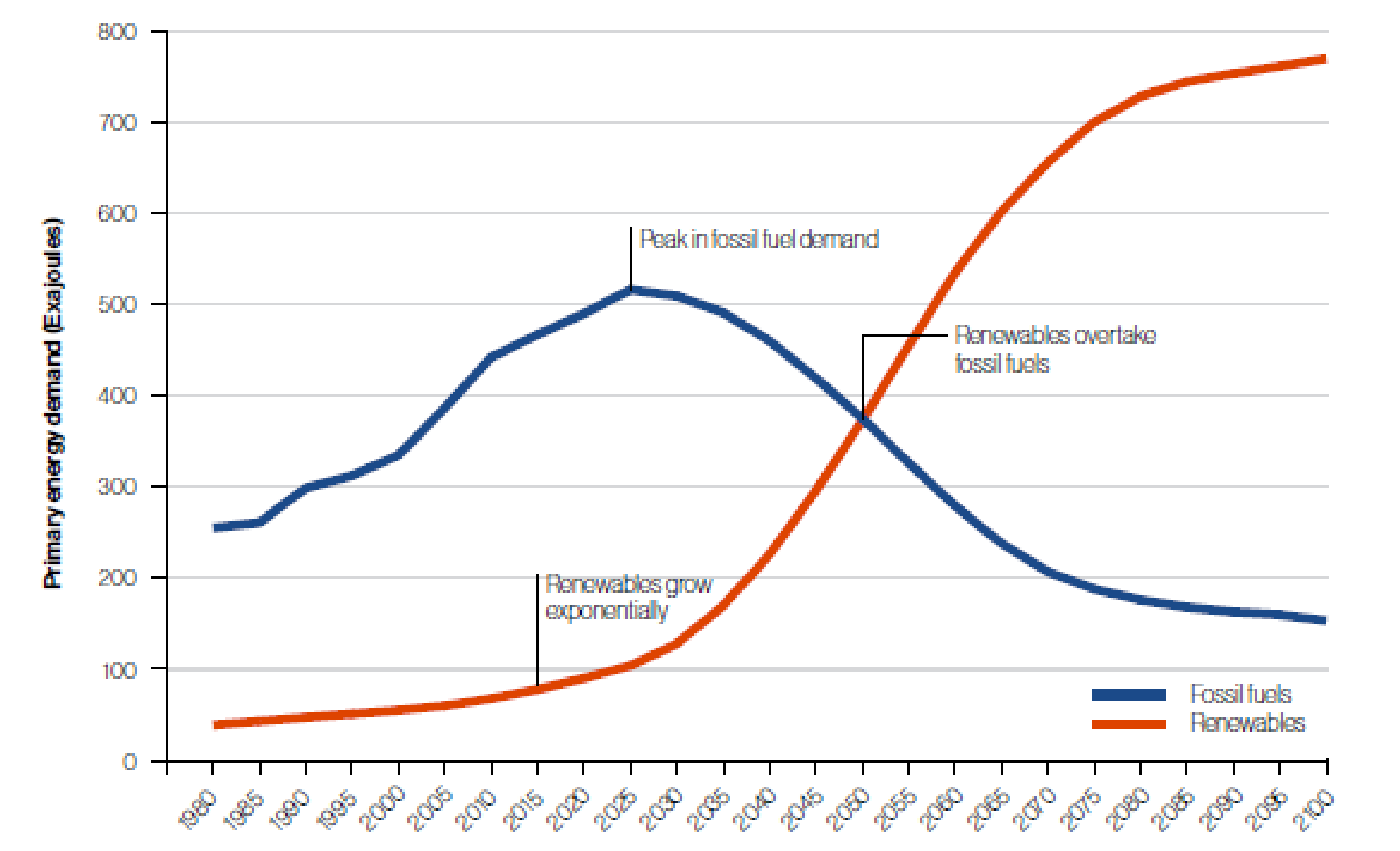
Energy transition (5)



This data is taken from the Shell Sky Scenario (2018),

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Energy transition: accelerated use of RES

- The forces of change
- Six enabling trends drive the rapid deployment of renewables.
  I. Declining cost
  II. Pollution and climate change
  III. Renewable energy targets
  IV. Technological innovation
  V. Corporate and investor action
  VI. Public opinion

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Geopolitics of energy transformation (1)

- At the same time, the energy transformation will g**enerate new challenges.**
- **Fossil fuel-exporting countries may face instability** if they do not reinvent themselves for a new energy age; a rapid shift away from fossil fuels could create a financial shock with significant consequences for the global economy; workers and communities who depend on fossil fuels may be hit adversely; and risks may emerge with regard to cybersecurity and new dependencies on certain minerals.
- **The main story of the energy transition is the rise of renewables, particularly solar and wind, and the future decline of fossil fuels.**

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Geopolitics of energy transformation (2)

- Renewables differ in many respects from fossil fuels, and these differences will have geopolitical consequences.
- Fundamental changes are taking place in the global energy system which will affect **almost all countries** and will have wide-ranging geopolitical consequences.
- **These trends are creating an irreversible momentum for a global energy transformation.**
- Renewables enable countries to **strengthen their energy security** and achieve greater energy independence by harnessing the vast indigenous renewable energy sources that can be found across the planet.
- The rapid development of renewable technologies and their widespread deployment is certain to have significant long-term effects on geopolitical dynamics

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Energy security

- The supply of energy will no longer be the domain of a small number of states, since the majority of countries will have the potential to achieve energy independence, enhancing their development and security as a result.

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Energy planning

- The **speed of the energy transformation** is uncertain.
- Because of the complexity of energy systems, there are as many scenarios on the future of energy as there are forecasters.
- Nevertheless, scenarios that model an energy future compatible with the goals of the Paris Agreement have a similar structure:
  - a near-term peak in fossil fuel demand,
  - a rapid uptake of renewables, and
  - a long decline in fossil fuel demand.

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Digitization and new platforms in energy (1)

- **Innovations in digitalization and energy storage** are expanding the potential for renewables to flourish in ways that were unimaginable just a decade ago.
  - *The energy sector has not yet been conquered by a platform giant like Amazon, Spotify or Facebook, But there are reasons why this will happen soon. The only question is, who is going to be there first?*
  - What platforms like Amazon, WhatsApp, Spotify and Facebook have taught us over the last few years is that size matters. Once such a business reaches a certain scale, it produces customer benefits that cannot be matched by smaller platforms. This is often described as “network effects”.
  - These businesses then have almost monopoly power. Their access to huge amounts of data about their customers and their value chain enables them to continuously improve the user experience and/or extract more revenue from those users which, in turn, increases their market penetration and competitive advantage.

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Digitization and new platforms in energy (2)

- To date, we have not seen any platform businesses in energy, but that we will see them soon.
- All that is needed is two things: **a trusted customer-facing platform and a back-office platform that combines the purchasing and trading of energy together with the management of customer demand**.
- What there are, are companies like Google and Facebook which use that equipment to deliver services to their customers.
- They may have some hardware but that is not their core competence. What they do is control the customer relationship.
- And this may be the real opportunity for a platform business in energy as the utilities who currently hold the customer relationship see them more as a 'number', or a metering point than a customer.

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Digitization and new platforms in energy (3)

- ***That it is only a matter of time before global household names such as BMW, Daimler, Amazon or Google begin making the necessary acquisitions to enable them to offer such energy services to their customers***
- Obstacles will soon be a thing of the past.
- With regards to the lack of competition amongst suppliers of energy, we are seeing the increasing liberalization of energy markets across the world as well as increasing pressure from regulators and legislators.
- The other big change is renewable generation, most of which is not owned by the utilities, which in turn is creating more competition in the power market.
- Add to that the growing use of wholesale power markets for trading electricity, not to mention the possibilities of **blockchain,** which will make it easier and more transparent to buy and sell electricity.
- This in turn makes it possible for a whole range of new players to enter the world of electricity as well as enabling a new range of business models

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Digitization and new platforms in energy (4)

Global platform

- What does this all mean if you want to build a platform business in energy?
- You need two parts; one, a trusted brand name and cost-effective platform with an ability to treat the electricity user as a customer.
- The second part is the back-office platform that links the purchasing, trading and management of decentralised generation assets together with the low-cost management of customer demand.
- Such a platform is known as a virtual power business and it enables not only generators to optimize their assets but also end customers to lower their energy bills.
- Bring the two together and you have the chance to build a global platform in electricity.
- It is only a matter of time before global household names such as BMW, Daimler, Amazon or Google begin making the necessary acquisitions to enable them to offer such energy services to their customers.

Sector Coupling

- **Sector coupling** involves the increased integration of **energy** end-use and supply **sectors** with one another.
- This can improve the efficiency and flexibility of the **energy** system as well as its reliability and adequacy.
- Additionally, **sector coupling** can reduce the costs of decarbonisation.
- To foster the full potential of sector coupling in several end-use and supply applications, it is important that existing techno-economic, policy and regulatory barriers are removed.
- Furthermore, a more integrated approach to energy systems planning is needed.
- Sector coupling can contribute to the cost-efficient decarbonisation of the energy system, by valuing synergy potentials and interlinkages between different parts of the energy system.
- Electrification of energy demand and end-use sector coupling is one of the core strategies in the decarbonisation of the energy sector.
- Electric devices are often more efficient than fossil fuel based alternatives, and the cost to produce electricity from renewable sources has recently become increasingly competitive with other electricity sources.

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The Energy System of the Future Is Electricity-based (1)

- Sector coupling aims at **decarbonizing the national economy** by converting the energy supply as completely as possible to electricity, finally reaching an "All Electric Society".
- A prerequisite for this is the use of the complete flexibility potential of producers and consumers as well as the storage of energy in its various forms.
- Sector coupling says goodbye to the energy industry as a separate field of economic research and **instead focuses on the entire economy** as a flexible interplay of processes of electricity generation, consumption and storage with the aim of climate neutrality.
- However, this goal can only be achieved **if all the required energy is generated from renewable energy sources**.
- The previous primary energy sources of oil, coal and gas must therefore be replaced not only in the current electricity system, but also in all other consumption processes - i.e. in transport, heat generation, agriculture, heavy industry, and other sectors.

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The Energy System of the Future Is Electricity-based (2)

- The approach is based on the fact that when coupled to a power grid, technologies at this interface effectively also become components of the power system and thus can be modelled as such.
- Electric vehicles (EVs), electric boilers, heat pumps and electrolysers for hydrogen production provide additional flexibility to the power system by
  - 1) adjusting their demand profile based on price signals and
  - 2) making any integrated electricity, gas or heat storage a source of energy storage for the power system, thereby decoupling the timing of demand for final energy from electricity demand.
- With a high share of VRE, the production of carbon-free electrofuels such as hydrogen from renewable electricity could have a significant role in the context of the decarbonisation of the energy sector beyond electricity generation.
- The production of hydrogen can provide significant flexibility for the power system (depending on the type of electrolyser), as well as – most importantly – seasonal storage of renewable electricity by blending hydrogen into natural gas grids.

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Coupling different energy sectors - options for the next phase of the energy transition

- Direct use of electricity should be the method of choice as it comes from more efficient conversion chains.
- This applies in particular to heat pumps for heating buildings, the direct use of electricity for industrial processes and, in the transport sector, electric vehicles with battery storage units.
- Once a certain level of expansion of renewable energy use is reached, hydrogen production by electrolysis with energy from renewable sources is a desirable means of utilizing excess electricity that would otherwise have to be lost.
- Despite the expansion of renewable energy sources for energy production, the construction of short-term storage systems and the use of intelligent load management, it is necessary to ensure a secure supply at all times, including during dark and windless periods.

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Sector Coupling Conclusions

- Climate targets can only be achieved through explicit strategic change in energy policy.
- In order to be able to integrate more renewable energies into the overall system and lead the energy transition to its ultimate success, the energy system has to be optimised holistically throughout all sectors, and the individual sectors must be more thoroughly interwoven with one another.
  - Electricity from renewable sources will become the prevailing energy source within the energy system.
  - Technologies such as electric vehicles and heat pumps, which use electricity directly and efficiently, will become increasingly important in the future.
  - But synthetic combustibles and fuels are also presumably indispensable.
  - Short- and long-term storage as well as flexible power consumption models must aid in compensating for the volatile production of electricity in the future.
- The energy transition leads to systemic additional costs every year
- Investments in the transformation of energy supply at all levels and in all consumption sectors account for a significant share of additional costs.

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Smart grids: enabler for the energy transition

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Smart grids: enabler for the energy transition

- Smart grids have to 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

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Smart Grid

- **The Smart Grid** is the integration of Electrical & Digital Technologies, Information and communication which facilitates integration of business processes and systems to yield real measurable value across the power delivery chain.
- It is an i**ntelligent future electricity system** that connects all supply, grid and demand elements through a communication system.
- Smart grid delivers electricity to consumers **using two-way digital technology** that enable the efficient management of consumers, efficient use of the grid to identify and correct supply- demand imbalances.
- Smart Grid solutions **enable utilities to increase energy productivity** and **power reliability** while allowing the customers to manage the usage and costs through real time information exchange.

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Smart grid: drivers

- The European Union in 2007 has started a comprehensive plan to increase the environmental sustainability, the security of supply and the competitiveness of its energy system.
- This strategy was translated into **binding targets for greenhouse gases reduction, renewable energy sources (RESs) and energy efficiency**
- In most EU countries, these goals have required a major contribution from electrical final uses in order to compensate lower efforts achievable in transports and thermal usages.
- In the past decade, the exploitation of **renewable sources** has been realized by means of s**mall-size generators especially, with a leading role of photovoltaic plants** and wind farms and a more limited growth of biomass and run-of-river (without basin) hydro plants. Medium and small generators connected to the distribution grid are referred to as “distributed generation”; some definitions include a power threshold but the typology of the hosting network represents the focus for the scope of this discussion

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Smart grid: drivers

- The presence of a large number of plants connected to the distribution networks has caused the entire system to undergo a deep evolution, towards the so-called "smart grid" concept.
- According to the EU definition, a smart grid is a "grid 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"

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Perspectives (1)

- Transitions in the power system last about 50 years, the time necessary to replace generators and upgrade infrastructures.
- The shift towards renewable resources (RES) observed in these years shows a quicker pace of change than past experiences: **smart grids are one of the pillars to enable this transition**.
- Exploitation of renewable energy resources has led to the diffusion of a large number of small-size generators, connected to distribution grids.
  - Not only farms and factories, but even citizens can now install their own generator, and have “smart” controllers to combine consumption with generation.
  - These small generators could be aggregated to bid their flexibility on the market, competing with conventional large plants for providing ancillary services.
  - This participation, currently limited to few activities, will turn into a necessity within the next decades, when RES penetration will reach higher percentage and fewer thermal plants may remain into service.
  - Integrating variable generation entails additional costs for monitoring and control of distribution networks, and also for balancing the power system, with an increased coordination between the TSO and the DSO.

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Perspectives (2)

- Besides, the **electrification of transports and thermal applications** may bring a **higher RES penetration** in the final uses and overall a greater energy efficiency.
- Liberalization of retail market allows customers to choose their preferred tariff among a large variety of offers, but this freedom converts into an advantage only if users are aware of their actual consumption habits.
- Smart meters, delivering consumption data close to real time, support this awareness and allow designing tariff schemes with variable prices, for example depending on the actual RES production in the power system
- Buildings are responsible for about 40% of energy consumption in Europe, and **automation is now required in new large buildings** together with insulation to reduce the energy wastage

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Smart Grid

- Basically, **smart grids are composed of the superimposition of the power grid and the ICT layer**: development of successful and cost effective solutions needs the close collaboration of experts from both sectors, and even the support of social sciences to actually enable customers' participation apart from pure economic reward.
- Last but not least, regulation authorities have the duty of proposing shared methodologies to assess benefits and costs of smart grid development, and fairly allocate these costs to the different actors. In any case, "smart technologies" are the way to develop a sustainable energy system, not the goal
- The Smart Grid is a compilation of concepts, technologies, and operating practices intended to bring the electric grid into the 21st century.

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Impacts of Smart grid

- While the scope of **smart grid covers the entire utility system from generation to how customers use energy**
- Smart Grid impacts all the components of the power system like Generation, Transmission and Distribution.
- All elements of smart grid include important engineering, economic , and policy issues.
- However, with the exception of alternative generation options, the generation and transmission segments are less uncertain and more dominated by engineering economics than the distribution and customer segments.
- **The Smart Grid focuses in four key areas:**
  - **Generation**
  - **Transmission**
  - **Distribution**
  - **Consumer**

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Historical viewpoints (1)

- Earlier in the power industry (20th century), the main aim of electricity was:
  - To **provide sufficient electricity wherever and whenever the demand** is there
  - But it changed (Mid 20th century)
  - To provide cleaner and more efficient power having diversified demands due to expansion of electrical networks and increase in the variety of appliances.
  - Then it evolved (Early 21st century to now)
  - Increased number of appliances and electronic revolution
  - Sudden increase in the demand

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Historical viewpoints (2)

- The world electrical system has operated successfully over the past century depending upon historical data and good estimates.
    - So, real time data was not required to run such widespread and delicate system until now.
- But,
    - With innovations such as Evs (Electric Vehicles), Communication apparatuses, HVACs etc., the demand will be increasing more than ever,
    - Rather than only “Load sharing” & “Load shedding”, “Load shaving” is also required
- Load shaving can be done efficiently by only getting “Real Time Data” and accurate operation of available and to be included appliances in the system i.e.

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Defining the smart grid

- Defining the smart grid is difficult for several reasons.
  - First, there is no single template that defines exactly what the smart grid will look like or how it will operate in any given service area.
  - Without a consensus template people tend to construct their own mental vision of how the technologies, systems ,and customers will interact.
  - There is also the reality that customer mix, geography, weather and other factors will almost certainly make the smart grid in each service area a little unique.
- The second factor contributing to the uncertain definition is the fact that the smart grid does not yet exist.
- Many of the systems and technologies expected to become a part of smart grid either haven’t been developed yet or are in prototype or early stages of testing and implementation.
- It is difficult to define something that does not exist.
- While these factors attach a degree of uncertainty to smart grid, there are several foundational concepts, technologies, and regulatory practices that define smart grid expectations.

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Defining the smart grid

- To define smart grid we have to answer three basic questions.

1. What is a smart grid?
2. How is a smart grid different from the existing utility grid?
3. Why do we need it?

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What is smart grid? (1)

- Fundamentally, smart grid is a **combination of information and communication applications that link together generation, transmission, distribution, and customer end-use technologies.**
- The need to integrate all of the systems that generate and supply energy with customer usage is one of the very certain design principles of smart grid.
- System integration will be accomplished using information and communication systems .
- Smart grid is not necessarily a specific combination of parts as much as it is a process for using information and communications to integrate all the components that make up each electric system.
- Smart grid is system integration.

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What is smart grid? (2)

- In a laymen language we can say that….
  - Including the digital layer in the analogue structure of electrical system which can react to wide spectrum of abnormalities in the most efficient way.
- According to “EU Smart Grids Technology Platform”,
  - A smart grid is called “electricity network which intelligently integrates the actions of generators and consumers connected to it in order to efficiently deliver sustainable, economic and secure electricity supplies”
- According to “US Department of Energy”,
  - “A smart grid is self healing, enables active participation of consumers, operates resiliently against attack and natural disasters, accommodates all generation and storage options, enables introduction of new products, services and markets, optimizes asset utilization and operates efficiently, provides power quality for the digital economy”

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What is smart grid? (3)

- The Smart Grid comprises everything related to the electric system in between any point of generation and any point of consumption. Through the addition of Smart Grid technologies the grid becomes more flexible, interactive and is able to provide real time feedback. (**International Electrotechnical Commission IEC**)
- A “Smart Grid” is an evolved grid system that manages electricity demand in a sustainable, reliable and economic manner, built on advanced infrastructure and tuned to facilitate the integration of all involved. (**ABB**)

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What is smart grid? (4)

- Keywords from such definitions:
  - Remote control and automation.
  - Comprises everything from generation to consumption.
  - The grid becomes
    - more flexible,
    - interactive
  - • Advanced management of the grid
    - sustainable, reliable and economic manner,
    - built on advanced infrastructure
  - • DER integration

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What is smart grid? (5)

- From a regulatory perspective, a clear definition of smart grid is important for two reasons.
  - First, it helps if consumers, utilities, vendors and regulators all start from a common understanding of smart grid.
  - Second, how smart grid is defined establishes the framework to guide expectations, resource allocation decisions, and implementation priorities.
- However, coming up with a simple, universally accepted definition of the smart grid is not an easy task.
- While everyone generally agrees that the term “smart grid” implies a modernization of the existing electric system, there are divergent opinions on how modernization translates into specific policy actions or resource decisions.

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What is smart grid? (6)

- In definition, Smart Grid is a form of electricity network utilizing digital technology.
- Its connects between suppliers, distributors and consumers.
- Its delivers electricity from suppliers to consumers using two- way digital communications to control appliances at consumers' homes; which in deed will saving the energy, reduce costs and increase reliability.
- A key feature of the smart grid is automation technology that lets the utility adjust and control each individual device or millions of devices from a central location.

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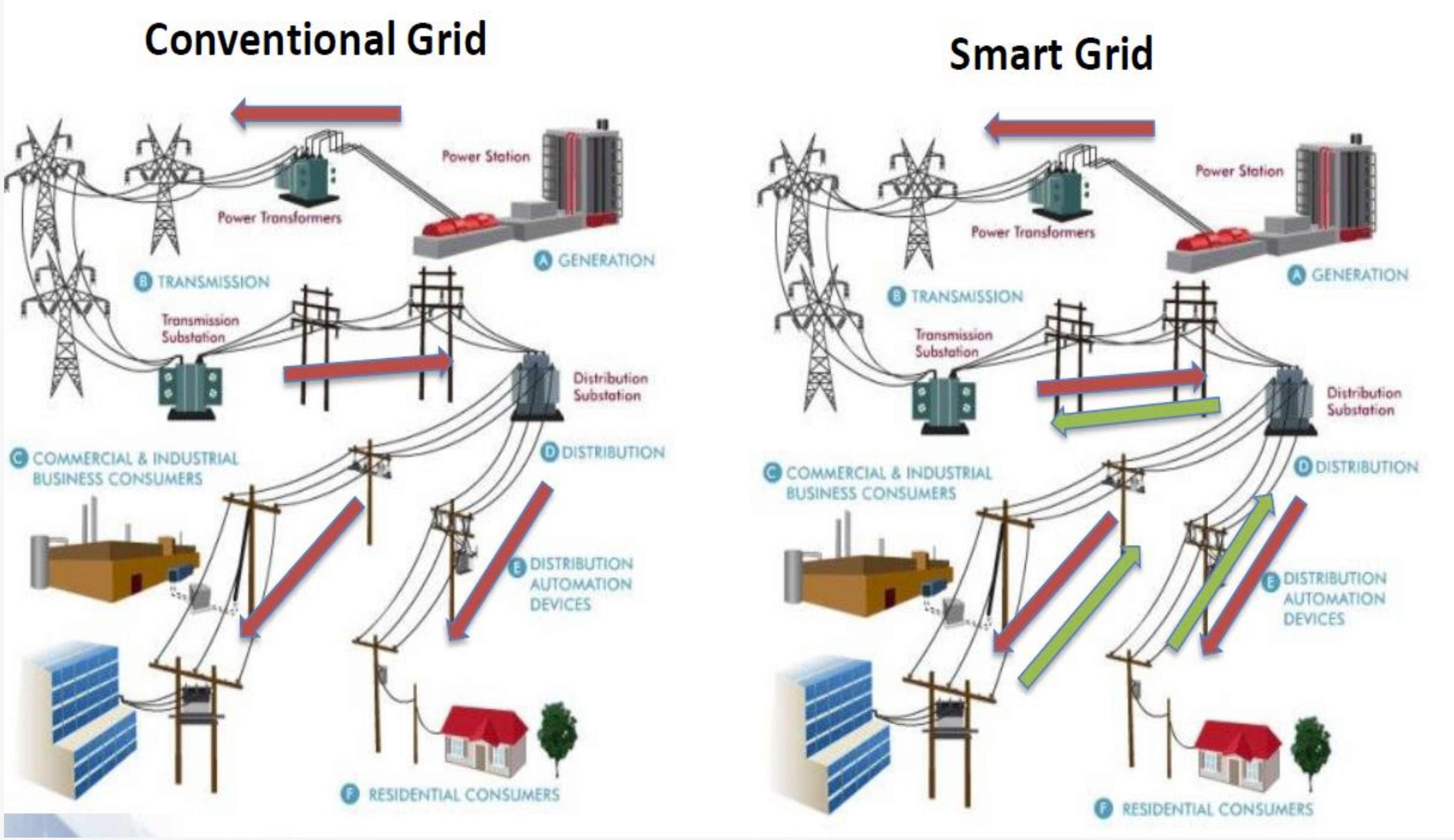
New electrical grid paradigm



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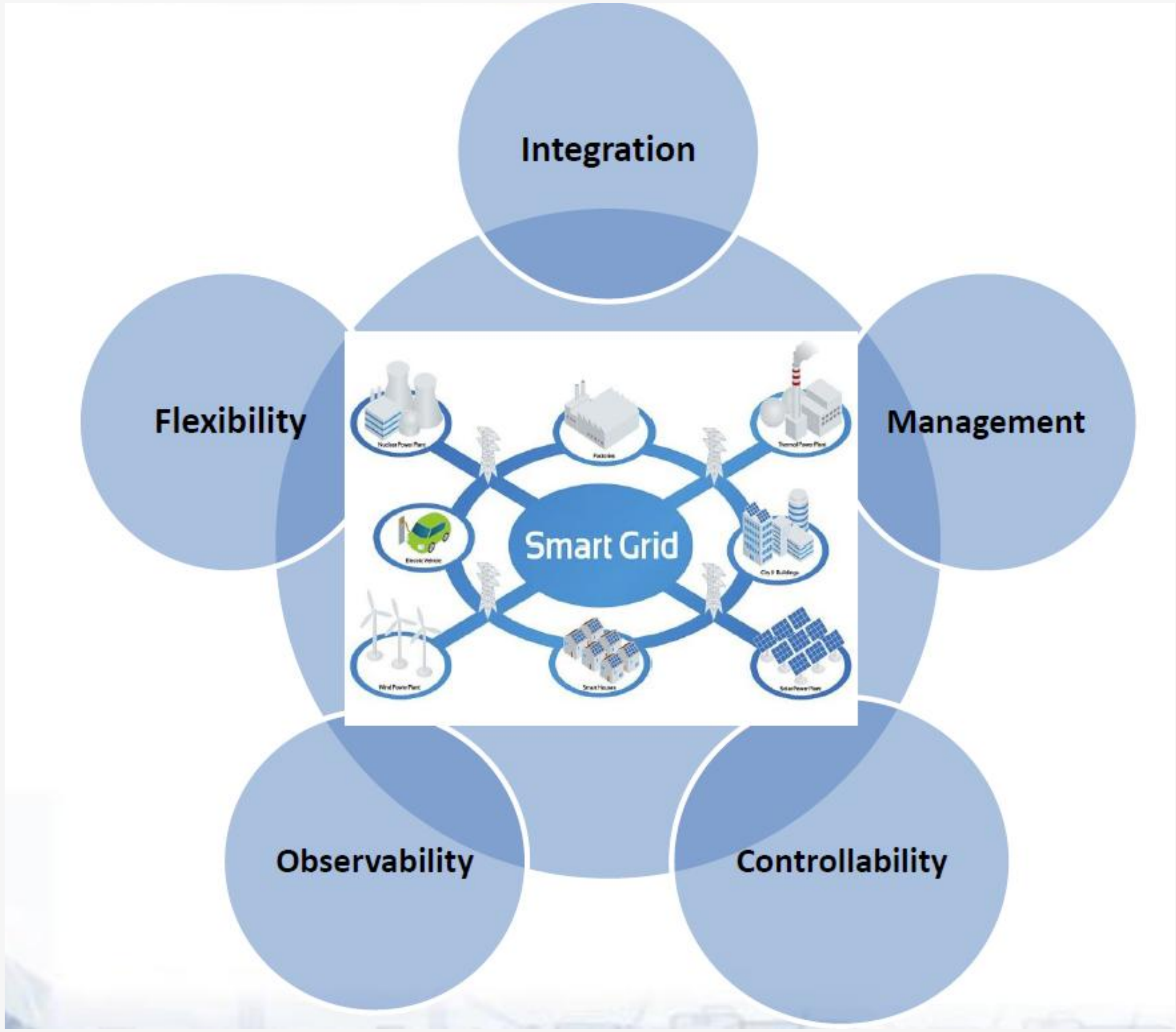
New capabilities



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Key challenge for creating a smart grid

- Designing a system from scratch, starting with no legacy systems and no rules, allows you to identify how best to incorporate new technologies and designs and to achieve the objectives most important to you.
- Your neighbors design and objectives may not exactly match yours, which is exactly the problem we encounter today in defining smart grid.
- Everyone has slightly different perspectives, which results in different designs and objectives.
- Once your new smart grid is designed, you have established the vision or where you "want to be", which makes it possible to compare your future grid, with "where you are", the current grid.

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CONCEPT OF SMART GRID

- The basic concept of Smart Grid is to add monitoring, analysis, control, and communication capabilities to the national electricity delivery system.

- This in turn can maximize the output of equipment, help utilities lower costs, improve reliability, decrease interruptions, and reduce energy consumption

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- The smart grid system integration process shares **three common objectives:**

1. **Promote customer choice** – provide customers with information, rates and pricing, and technologies that will allow them to make better usage decisions;

2. **Improve reliability** – use automation on the grid and in customer premises as well as alternative generation options to improve system reliability and stability, and

3. **Integrate renewables** – support alternative generation and storage options that minimize or reduce environmental impacts, improve overall system efficiency, and reduce carbon-based fuel usage.

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Summary of Components of Smart Grid

Main components	Centralized generation	Transmission / distribution	End-user location
Physical power assets	Power plants (including storage)	• Power lines, substations, transformers, etc • Sensors, security (networked cameras etc) • Storage	• Smart meter / wireless devices • Microgeneration • Storage
Physical communications assets	Power station communications network	• Access and transport network (fibre, powerline or wireless), • switches and routers	Home area network (powerline, fixed or wireless)
Software and applications	Distributed data processing - on-site, off-site and virtualised		
	Grid management / load balancing / power routing; end-user usage and billing; IT security; grid and communication network operation and management systems (including protection and control)		Business and consumer energy management

Functions of Smart Grid

- Smart device interface
- Digital Data Storage
- Transmission subsystem
- Monitoring and Control Technology
- Intelligent grid distribution subsystem
- Demand side Management

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Features of Smart Grid

- Reliability
- Flexibility in network topology
- Efficiency
  - Load adjustment
  - Peak shifting/shaving
- Sustainability
- Market enabling
  - Demand response support
  - Platform for advance service
  - Communication network setup for control and operation

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Opportunities of smart grid

- Real time analysis can be done which can further help in better forecasting and operation of the grid
- Conventional system can be upgraded to the advanced system
- Increased load sharing by using more penetrated Photovoltaic system
- Energy storage can be increased by using fuel cells
- Beneficial usage of appliances for the end user
- Evs (Electric Vehicles) integration projects
- Smart metering infrastructure

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Barriers

- **Economic barriers**
  1. Higher investment
  2. Higher running cost
- **Social barriers**
  1. Lack of awareness
  2. Violation of privacy
  3. Illiteracy in terms of technical knowledge •
- **Technical barriers**
  1. Malfunctioning of appliances
  2. Difficulties of integration of various type of energies
- **Regulatory barriers**
  1. Data handling difficulties
  2. Limited multitasking difficulties

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How is a Smart Grid different from the existing grid? (1)

- The existing utility grid is a centralized system where power flows in one direction, from generation resources through the transmission-distribution system to the customer.
- Generation may or may not be located in the same geographic area as the load being served, which can often require transmission from distant locations.
- Existing utility grids may or may not include Supervisory Control and Data Acquisition (SCADA) sensors, computing, and communications to monitor grid performance.
- Utility systems may depend instead on separate reporting systems, periodic studies, and stand- alone outage management applications.
- Information to the customer is generally limited to a periodic bill for services consumed in a prior time period or billing cycle.
- Utility web sites may or may not provide customers will access to their usage data. Energy usage is usually presented as an aggregate kWh value for a specific billing cycle, which may or may not align with monthly calendar boundaries.

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HOW IS A SMART GRID DIFFERENT FROM THE EXISTING GRID? (2)

- The first step to transform the existing grid into a smart grid requires the addition of generation options throughout the grid at bulk power transfer points, substations, other distribution locations and on the customer side of the meter.
- Adding generation throughout the grid allows power sources to be located closer to their point of use, reducing investment in transmission and distribution, and in many cases reducing energy losses. Implementation of widespread, smaller generation resources diversifies supply, reduces risks of major outages, and improves overall reliability.
- Sensors, remote monitoring, automated switches, reclosers, upgraded capacitor banks, and other equipment may be integrated into the grid to provide end-to-end monitoring and control of the transmission and distribution network.
- Equivalent additions on the customer side of the meter would include automated control systems and smart appliances with embedded price and event-sensing and energy management capability.

➢ Sensors provide the information to better understand grid operation, while control devices provide options to better manage system operation.

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Why do we need a Smart Grid? (1)

- The last stage necessary to transform and create a smart grid is the addition of communication systems to support information flows that fully link both the utility and customer sides of the grid.

- **On the utility side** of the grid, sensors will be integrated with high speed switches and expert systems to automatically balance power flows, isolate and re-route power around disturbances , report outages, and continuously update system operators with weather, demand, and performance data from throughout the system.

- **On the customer side** of the grid, near real-time meter data will be available so customers can better understand how individual appliances and behavior impact their energy usage and costs. Broadcast price, reliability and event signals may be monitored directly by smart appliances or through home automation gateways , responding automatically to customer preferences to defer or reduce usage during high-priced or constrained reliability periods. Third-party service providers may also provide customers with a range of information and energy management services.

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Why do we need a Smart Grid? (2)

- Attributes that further distinguish specific differences between the existing grid and a smart grid.
- Distinguishing specific differences between the existing grid and a smart grid helps frame the technological and operational differences that help answer ‘WHY do we need a smart grid’.
- Some of the advantages include:

1. **Utility Business Model:** In a smart grid, ownership and operation is distributed between the utility, third-party providers and the customer. Distributing asset ownership could work to reduce overall long-run costs and spur innovation in generation sources.
2. **Obligation to Serve**: For the current electric grid, the traditional regulatory compact provides utilities with exclusive, sole-provider operating rights and in return obligates them to provide safe reliable service to all customers. With a smart grid, the regulatory compact is broadened to now allow third-party retail service providers and customers to provide additional energy information and management services. Reliability services may become more customized and tailored to each customer’s specific needs and prferences. Under this new compact the customer is expected to have more choice regarding the services received and what they pay.
3. **Generation Resources**: Under a smart grid, more generation resources are expected to become distributed throughout the grid. Distributing generation throughout the grid is expected to improve reliability, reduce the need for transmission expansion, reduce major siting issues, and encourage applications of alternative renewable options.

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Why do we need a Smart Grid? (3)

- Some of the advantages include:

4. **Transmission / Distribution**: Systems designed to transport power from centralized locations will under smart grid migrate to self-contained micro-grids and localized generation sources.

5. **Metering-Measurement**: Advanced metering is expected to provide the interface between the utility and customer, to provide CUSTOMER access to more detailed usage data, and a foundation for more relevant action-oriented customer education.

- Advanced metering will also provide capability to provide a much wider range of pricing options including pre-payment and innovative dynamic rates.
- Finally, advanced metering infrastructure (and near real-time communications) supports expanded demand response opportunities including enabling customer participation in ancillary services markets.

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Why do we need a Smart Grid? (4)

- Some of the advantages include:

6. **Rates (Pricing):** Under the existing conventional grid, rates are reasonably static, changing infrequently, where their primary purpose is to compute a periodic bill. In a smart grid environment, rates will take on an active day-to-day operational role to facilitate not only expanded demand response but also facilitate integration of large- scale intermittent renewable generation, electric vehicles, and other localized options.

7. **Customer Role:** Under smart grid, customers are expected to become more active participants in how they obtain and use energy. That doesn't mean that customers will have to stand around and monitor energy prices in real time, however it does mean that customers will be provided with more information to better inform them regarding how they use energy, what it costs, and options for changing and automating their energy usage habits to better control their costs.

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Smart Grid vision

- In general the Smart Grid vision and expectations are driven by three different perspectives:

1. Regulatory Perspective: Regulatory decisions must balance the new investment necessary to provide reliable service at reasonable cost (which may translate into limiting cost increases), promote economic efficiency and development, and ensure fairness to all customer classes.

2. **Utility Perspective:** Smart Grid will require significant capital investment (in AMI and other T&D assets) which is consistent with the IOU business model. However Smart Grid may also constrain traditional IOU investment by encouraging demand response (DR) and dynamic pricing, energy efficiency (EE), and increased customer or third-party ownership of renewable resources. While Smart Grid creates opportunity consistent with the IOU business model it also creates a risk that successful DR, EE and non-utility ownership will reduce corporate earnings and shareholder value. The conflict between potential rewards and risks definitely influences IOU Smart Grid investment and implementation perspectives.. Municipal utilities don’t contend with the IOU profit or shareholder objectives, however they have to be much more cognizant of balancing new investment with potential rate increases.

3. **Customer Perspective:** Customers want to see service and value for the dollars spent. The expectations or vision for Smart Grid can vary substantially depending upon which perspective you take. While the four bullet points on this slide don’t fully capture all of the Smart Grid vision, they provide at least one example that bounds many of the general expectations.

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Benefit of Smart Grid

- Among the benefits as the followings:
  - Enabling active participation by consumers.
  - Enabling new products, services and markets.
  - Providing power quality for the digital economy.
  - Optimizing asset utilization and efficient operation.
  - Anticipating and responding to system disturbances.

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Benefits of smart grid over conventional grid

- Active consumer participation
- Plug and play convenience
- More focus on Power Quality as well as a win-win situation
- Optimization of available resources
- Better anticipation of future load for self healing feature
- Modernisation of security consciousness

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Driven factors for Smart Grid (2)

- INTRODUCTION
  - Many countries and electricity markets are looking at Smart Grid as advanced solutions in delivering mix of enhanced values ranging from higher security, reliability and power quality, lower cost of delivery, demand optimization and energy efficiency.
  - Its advanced capabilities - demand optimization, delivery efficiency and renewable energy optimization will lead to lower carbon footprint and overall lower energy cost and investment in energy related infrastructure.
  - It is to ensure sustainable development in the electricity sector and many benefits of the all stakeholders.

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Driven factors for Smart Grid (2)

- Increasing reliability, efficiency and safety of the power grid.
- Enabling decentralized power generation so homes can be both an energy client and supplier (provide consumers with an interactive tool to manage energy usage, as net metering).
- Flexibility of power consumption at the clients side to allow supplier selection (enables distributed generation, solar, wind, biomass).

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Issue on smart grid

- Among the issues as the followings:
  - Lack of recognition or rewards on operational efficiency
  - Customer concerns over privacy and transfer of data without their knowledge,
  - Fair distribution of electricity demand
  - Social concerns over information abuses
  - People are concerns on extra control of electricity that government have
  - Customers are concerns on computer security
  - Malware and hacker threat
  - Utilities hard to justify for investment on smart grid
  - Problem over intermittent RE source – e.g. weather
  - Outdate and old existing electrical facilities

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Reliability

- When customers “flip the switch” they expect their lights to go on and stay on. Local storm or accident caused outages can be disruptive and costly, however customers are generally accepting that certain acts of nature are inevitable and must be tolerated.
- Forced outages or rotating blackouts, generate very different adverse customer reactions because they are considered avoidable, they can create significant financial hardships for all customers (and the utility if it results in inappropriate policy or legislative intervention).
- While improved reliability is considered one of the major benefits of Smart Grid, there are emerging concerns regarding the real value of claimed benefits versus the investment required.
- First consider that reliability improvements are not a unique function of Smart Grid.
- Improvements to the transmission and distribution grid are continuous, normal activities necessary to maintain and operate the grid.
- Adding automation, SCADA, and outage management capability have also been common to utility systems for at least 30 years.
- However, under Smart Grid potential reliability improvements expand beyond the normal distribution grid to include the integration of distributed generation, renewables, and micro grids on a large scale.

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Reliability

- The accepted **industry definition of reliability** is limited to total electric interruptions or a complete loss of voltage.
- The value of reliability then becomes a function of the scope of the outage defined by the bulleted list of factors such as number of customers, their connected load, and the duration of the interruption.
- Customer outage cost is a key factor missing.
- An outage on a feeder serving 1000 small residential customers with 5MW of load will probably experience different losses (damage function) than a children's hospital, chicken farm, or public safety complex with the same load.
- Customer outage costs are important because they 'calibrate' the value of an outage, however customer outage costs are usually excluded from utility and regulatory outage measures because they are considered difficult to measure and somewhat subjective.
- Can you measure reliability without including customer outage costs?

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Reliability metrics

Reliability Metrics

System Average Interruption Duration Index [SAIDI]

$$\text{SAIDI} = \frac{\Sigma \text{ Customer Interruption Durations}}{\text{Total Number of Customers Served}}$$

System Average Interruption Frequency Index [SAIFI]

$$\text{SAIFI} = \frac{\Sigma \text{ Number of Customer Interrupted}}{\text{Total Number of Customers Served}}$$

Customer Average Interruption Duration Index [CAIDI]

$$\text{CAIDI} = \frac{\text{SAIDI}}{\text{SAIFI}}$$

Momentary Average Interruption Frequency Index [MAIFI]

$$\text{MAIFI} = \frac{\Sigma \text{ Total Number of Customers Momentary Interruptions}}{\text{Total Number of Customers Served}}$$

- The four formulas on this slide represent the common metrics used to evaluate utility reliability performance, however none of these metrics include factors to reflect the value of service or customer outage cost.
- While these metrics may reflect real improvements to utility system operating and maintenance practices, what still needs to be determined is whether reductions in the average duration of outages (SAIDI) or the average customer interruption duration (CAIDI) and any of the other measures adequately reflect material customer impacts.

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Conclusions on defining and valuing reliability

- Key observations and conclusions on defining and valuing **reliability in the context of Smart Grid**.
  - There is no consistent industry definition for defining system reliability, particularly under a smart grid structure that considers alternative grid designs and distributed generation resources.
  - Existing industry definitions of reliability only report a portion of the events that impact customer service delivery.
  - The value component of reliability is customer outage costs, which is a function of many variables, may be difficult to estimate, and is not considered in current reliability metrics.
  - It is not clear which specific Smart Grid measures will contribute the most to system reliability improvements.
- What is clear is that not all Smart Grid investments will produce equivalent benefits.
- Regulators should be aware that they may have to consider and address the inadequate and incomplete definitions and the difficulty in establishing 'customer value' for reliability as part of their assessment of Smart Grid benefits.

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CONCLUSION

- Smart Grid technology provides opportunity to enhance the existing grid and preventing reoccurrences of major incidents.
- Smart Grid technologies can improve the reliability, security, and efficiency of current electrical grid.
- Intelligent devices can automatically adjust to changing conditions to prevent blackouts and increase capacity.
- Before the implementation, country has to study and do proper planning to ensure Smart Grid is executes smoothly and comprehensively.

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Conclusion and Future work

- The smart grid has been conceived as an evolution of electric power systems due to the increasing diffusion of distributed generation by renewable sources.
- This makes cost-effective remote sensing technologies vital for safe, seamless and efficient power delivery.
- Future Work
  - **Security**
  - **Up front consumer expenses**
  - **Standardization**

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