FLEXIBILITY IN TECHNOLOGY – ENHANCED USE OF POWER ELECTRONICS IN GROWING FLEXIBILITY OF POWER SYSTEMS & ENERGY TECHNOLOGY IN A SMART GRID ENVIRONMENT

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Abstract: *Flexibility of technological systems is increasingly required because of uncertainties and fast developments. Environmental & sustainability issues linked with electrical power systems should make energy & power technologies take flexibility into account in the development and implementation of new technologies. Power Electronics technology is holding the key in the present situation of electrical power systems & energy. PE technology is based on need for flexibility in generation & utilization of electrical power. Sooner or later almost all forms of electrical power small or mega size & important energy conversions like vehicle transport will be passing through one or any other form of power electronics technology conversions. Flexible power electronics topology is also the key to distributed energy generation promoting alternative & renewable energy sources like wind & solar which will be soon addressing the issue of energy security and environmental subjects. The boon of power electronics technology is transforming our present electrical power network grid which needs urgent attention into smart grid which is not only a solution to our future overall energy security but also a very apt example of flexibility strategies for technology where a strategy for robust options, flexible options & flexibility by variety is demonstrated.*

Keywords: Flexibility, technology, strategy, power electronics, smart grid, sustainability, energy, distributed generation.

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Need for Flexibility

Enhancing the flexibility in technological systems is very important. In fact the flexibility of technological systems is now being increasingly required because of very fast technological developments and uncertainties like environmental & sustainability issues. Those technological systems which are deeply societal in nature like energy & power technologies should take flexibility into account in the development and implementation of new technologies.

Electrical Power Networks are important element for every individual as well as any industry or business making it highly societal in nature. Efficient operation of an electric power network requires excellence of producing and distributing this power. Not only the technical aspects of producing & distributing but there are also other broader organizational excellence required in the areas of marketing, pricing, servicing and regulatory process in the system. So the strategy for the development and implementation of technological systems will require integration of engineering and of the applied societal requirements. [1] Flexibility in technology development is important in order to enable timely and adequate responses to new criteria or demands, or new technological possibilities.

Power Electronics

Power Electronics (PE) is the process of using semiconductor switching devices to control and convert electrical power flow from one form to another to meet specific needs. Power electronics enables the control of the power flow as well as its form i.e.
ac or dc and the magnitude of currents and voltages. Figure 1 illustrates a basic block diagram of a power electronic system.

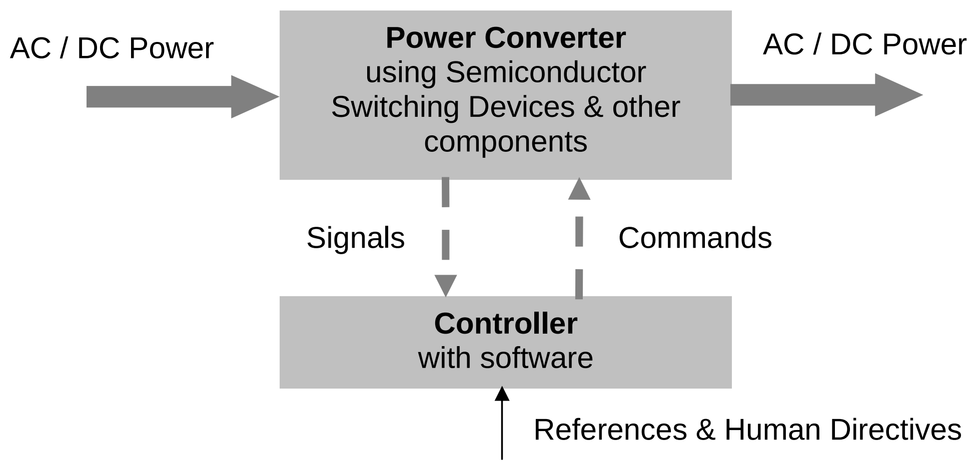

Figure 1 Power Electronics System

The hardware that performs the power processing is called a “Power Converter.” Power Converters can perform the function of rectifying (ac to dc), inverting (dc to ac), “bucking” or “boosting” (dc to dc), and frequency conversion (ac to ac). It basically constitutes semiconductor switches, passive components (such as capacitors, inductors, and transformers), thermal management systems, packaging, protection devices, dc and ac disconnects, and enclosures The conversion process requires some essential control system with software to the work of controller. This complete system represents Power Electronics

As shown in Figure 2 PE have already found an important place in modern technology and are now used in a great variety of power product, including heat controls, light controls, electric motor control, variable-speed drives for motors that drive fans, pumps, and compressors power supplies, switching power supplies found throughout most consumer products like mobile phone or television or a computer, Uninterrupted Power Supply with battery back-up, vehicle propulsion system, hybrid & complete electric vehicles, High voltage direct current (HVDC) systems transmission etc.

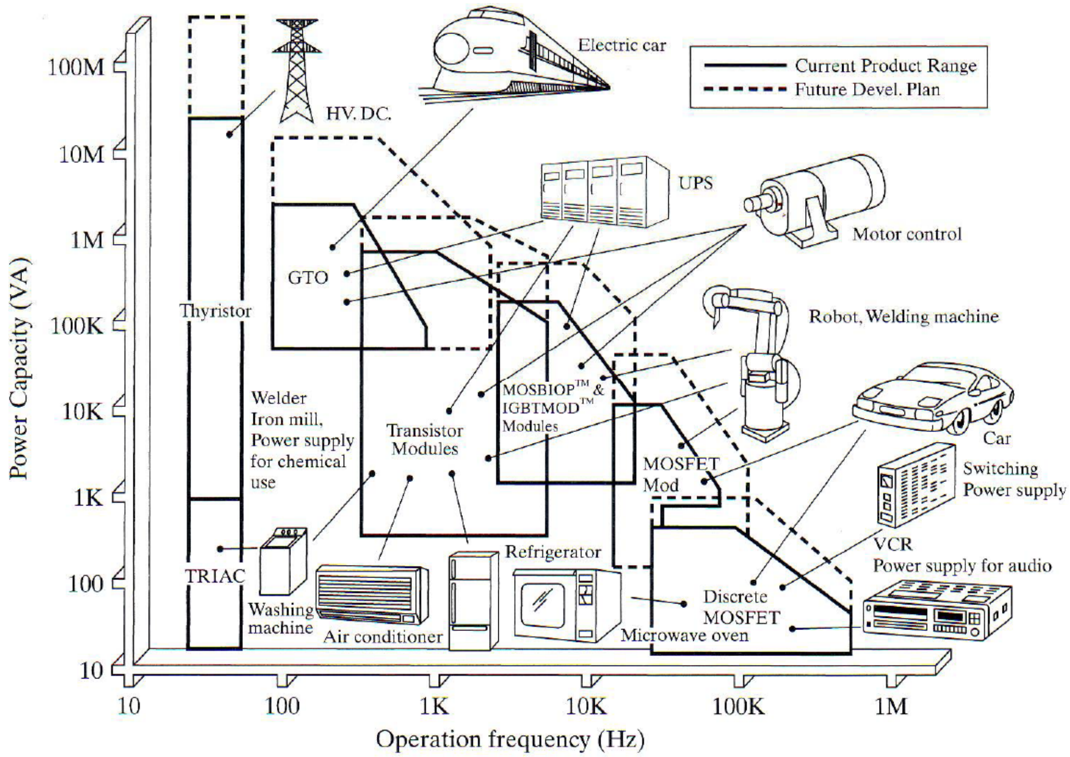

Figure 2 Power Electronic Devices & Applications [2]

Presently, approximately one third of all electric power generated in the world utilizes power electronics somewhere directly or indirectly between the point of generation and its end use. In next ten years it is expected that perhaps two third of all electric power will use power electronics.

Most PE used today is basically meant for flexibility. It won't be wrong to say that the sole reason for PE technology is based on need for flexibility in generation & utilization of electrical power

Power Electronics contributing Flexible Power Systems

Electric power production in the 21st century will see dramatic changes in both the physical infrastructure and the control and information architecture. A shift will take place from a relatively few large, concentrated generation centers and the transmission of electricity over mostly a high-voltage AC grid to a more diverse and dispersed generation infrastructure –

Distributed Generation (DG). The advent of high-power electronic modules will continue to encourage the use of more AC / DC convertible transmission and make the prospects for interfacing various power sources. An advantage in using DG is convenient local positioning avoiding transmission and distribution losses [3]. The most striking advantage of distributed generation is of alternative and renewable energy sources like Photo-Voltaic, Wind Turbines, Micro-Turbines, Fuel Cells. This type of concept is gaining popularity day by day as shown in Figure 3.

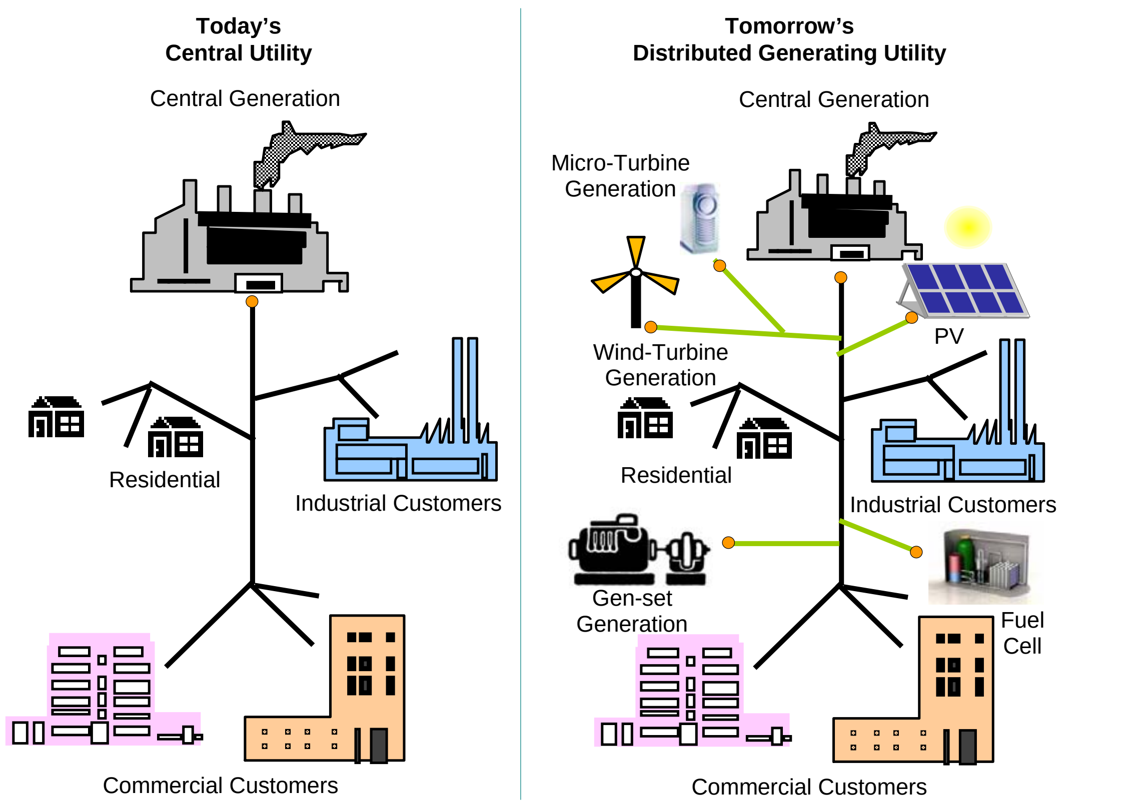

Figure 3 Power Distribution System with Distributed Generating Energy Sources connected easily by means of Power Electronics Converter Systems

The market dynamics for DG differ from region to region. In North America, DG helps to relieve the pressure from volatile power prices and ensure power reliability. In Europe, DG is being promoted because it provides an environment-friendly energy source, which helps reduce greenhouse gas emissions. In Asia, DG contributes to the alleviation of power shortages and helps both mature and developing nations manage their energy needs.

In the future, using hybrid electric vehicles along with the utility grid in the form of plug-in hybrid electric vehicles (PHEV) and vehicle-to-grid systems (V2G) will be a very promising option to be included in the DG classification

The PE requirement varies significantly on which DG technology serve. Wind turbines are the biggest market for power electronics, while Photo Voltaic, Micro-turbines and Fuel Cells are the emerging areas. In year 2010 Photovoltaic systems saw more then 100% growth worldwide which use extensively PE systems to interface solar modules converting sunlight to DC power to the AC grid. Such individual PV system varies from few hundred Watts of power to Multi-MWs of power based on specific usage all using flexible PE Converter technology of different power ratings. PV inverters have evolved from modified sine wave to true sine wave, from stand-alone to grid-inter-tie. A multifunction inverter even combines battery storage with grid-tie function to ensure power reliability. Technology development in PE plays a very important role in improving various DG system performances, which will further drive the DG penetration into the electricity market. A growing percentage of DG systems are using PE to improve power efficiency. Just a few years ago, only about 30% of wind turbines used PE. This percentage has increased to over 80% in recently installed wind turbines. Gen-set developers are exploring the use of variable speed operation to increase system efficiency.

All of these DG technologies require specific power electronics capabilities to convert the power generated into useful power that can be directly interconnected with the utility grid and/or can be used for consumer applications. Because of similar functions of these power electronics interfaces, the development of scalable, modular, low cost, highly reliable power electronic interfaces will improve the overall cost and durability of distributed and renewable energy systems – or in short Flexibility of Power Electronics Technologies is required.

Furthermore the present power network we have which is AC Transmission network is no more conventional in nature. In recent times due to PE technology applications AC Transmission network or the Grid has become Flexible AC Transmission Systems (FACTS). FACTS increases flexibility in power transmission and distribution, improving capacity and dynamic quality of transmission corridors to integrate renewable power production. The term “FACTS” covers several power electronics based systems utilized in AC power transmission and distribution. So the grid is no more a conventional grid but becoming Smart Grid

Smart Grid & Flexibility

Grid referred here is basically the complete detailed infrastructure of conventional Electrical AC Power Network at a regional or country level to transmit and distribute power from generation to consumers with various interconnections. Conventional grid is centralized, one directional, historical & limited accessibility. Smart grid is a type of electrical grid which attempts to predict and intelligently respond to the behavior and actions of all electric power users connected to it - suppliers, consumers and those that do both – in order to efficiently deliver reliable, economic, and sustainable electricity services [4].

To meet the growing demand for power, an intelligent and flexible grid infrastructure is essential. Smart Grids basically enables additional System Flexibility by offering:

- Optimize generation based on real time data
- Multi-directional power flow
- Consumer also become producer
- Enhancing Renewable energy interface
- Activate demand side
- Optimize complete transmission & distribution asset use
- Accommodate all generation and storage options
- Enable new products, services and markets (e.g. PEVs)
- Increase resilience / security (contingencies, congestion, attacks, natural disasters)
- Safeguard & enhance power quality

The concept of electrical power is basically in a real time consumption should be equal to generation. Storage of electricity is practically not very efficient engineering-wise; hence the challenge of introduction of more renewable energy sources into the energy mix actually increases the mismatch between supply and demand of electricity within the grid. A smart grid tries to adjust the electricity demand to match the available supply at that moment and vice versa. This so called supply and demand matching is realized by a constant communication between the producer and costumer of electricity through an advanced metering infrastructure & hence the concept of a 'smart grid' was developed. The extent to which a 'smart grid' cluster is able to deal with unbalance in the electricity grid is its flexibility. Knowledge about flexibility will improve the performance of the ‘smart grid’ cluster when it is combined with supply and demand forecasting. Flexibility is defined as 'the rate at which a ‘smart grid’ can take up or deliver electricity to the main electricity grid using this shift-able loads and flexible production' [5]. This definition already implies that flexibility consists of two parameters: the flexibility to produce electricity and the flexibility to consume electricity. Smart grids can optimize the operation of a range of flexibility mechanisms in three contexts: the power market, system operation and the use of grid hardware. So smart grid actually applies the flexibility theory in practice. More PE technologies at all levels increase flexibility & controllability in the grid.

Taking the case of India, only around 50 per cent of the power produced is billed, the rest being lost due to theft, technical losses, and un-metered power connections to farmers. Transmission & Distribution losses in India are very high, almost around 25 percent compared to international norms of around 10 percent. India has average deficiency of around 15 percent power; however peak deficiency in some place is over 50 percent. Technical losses which are the energy losses in transmission & distribution apparatus cannot be reduced to zero but can substantially lowered by technological efficiency improvements. However looking at the gross power infrastructure in India the scenario of smart grid which will add flexibility in the system giving power where it is most needed and also augmenting power by adding more distributed generation like alternative energy sources is highly needed. Also in India Flexibility strategies could be enhanced by government policies. Governments should quickly become aware of the problems and dangers of entrenched technologies, and try to foster flexibility by stimulating flexible technologies creating more options. It is important that government have to be conscious that an optimum has to be sought between on the one hand flexibility and on the other hand maintaining economies of scale and entrenchment. Another possible approach is the creation of alternatives by multi-stakeholder alliances. Multi-stakeholder alliances are required when changing preferences in society (i.e. sustainability) create challenges that cannot be met by single companies. Multi-stakeholder alliances could create new options and thus increase variety and flexibility for choice. Neither the government organization alone, nor the private sector organization alone, can accomplish the goal of sustainability in energy supply system. Collaboration of policy & technology will be important

The concept of smart grid has picked up in last five years & has massive plans and markets in US & Europe already under execution. In Asia these are being done at pilot levels

As described in [1] three general flexibility strategies for technology development can be presented.

1. Robust options
2. Flexible options
3. Flexibility by variety

Robust options - This strategy involves the formulation of a set of alternative future scenarios and the determination of the technological options that suit most of these scenarios. Smart Grid takes care of alternative energy technology foremost based on robust sources like wind & solar.

Flexible options - are technologies or systems that are adaptable to changing circumstances, for instance changing demands, issues, or concerns. Smart grid takes care of decision making and planning under uncertainty to keep open the various alternative futures or options for which there are various contingentry options.

Flexibility by variety - is obtained by developing or maintaining different technologies that can serve the same function. Smart grid also considers conventional thermal & nuclear energy plants. Variety not necessarily concerns technologies only, but also non-technology alternatives can fulfill a particular function. For example in the field of energy efficiency by smart grid not only technological solutions are developed, but non technical things like policy to do energy metering for all can also imply measures that aim at waste reduction by changes in the behavior of consumers.

The concept of Flexibility in Smart grid encompass the concept all three.

Conclusions

Current trends in energy supply and use are definitely unsustainable – economically, environmentally and socially. Immediate actions are under process worldwide to take up energy revolution where technologies related to low-carbon, energy efficiency & optimal utilization, renewable energy & new transport technologies are being sought – which is encompassed as Smart. One of the enabler of these technologies is Power Electronics. PE technologies must be able to change both incrementally and dramatically to keep up with requirements of Smart Grid. Overall Technological Strategic flexibility has the potential to strengthen sustainability in energy supply.

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Vitae

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