Smart Grid Technology, Vision, Management and Control

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Abstract: **-** Energy supply has become one of the most challenging issues facing the world in the 21st Century. Growing populations, more homes and businesses and a myriad of new appliances have caused energy demand to skyrocket in every part of the country. The fundamental method of operating the nation's power grid has not changed much in the past 100 years. It has remained essentially the same, although the number of customers and their needs have grown exponentially. Utilities across the nation and indeed, around the world are trying to figure out how to bring their networks into the 21st century and the digital age. This effort to make the power grid more intelligent is generally referred to as creating a "smart grid" The industry sees this transformation to a smart grid improving the methods of delivery as well as consumption. In the paper the state of the art of "smart grid" and its applications are introduced. The title is handled starting from the energy problems, growth in Egypt particularly and in the world generally were touched. The smart grid definition, benefits, advantages, problems as well as the smart grid vendors was introduced. A real implementation of smart grid technologies around the world as well as in Egypt is illustrated. In this paper many recent references and technical reports issued from authorized agencies are studied and presented. The international and governmental committees recommend the smart grid as smart solution for energy generation, transmissions, consumption and cost estimation.

Keywords: - Smart grid, renewable energy sources, future energy systems, smart grid technology, vision of smart grid, distributed energy systems,

1 Introduction

In EGYPT, Electricity consumption is expected to nearly double in the Conservative Scenario by 2030, with an average annual increase of 4.8% in the residential sector and 6% per year on average in the High Economic Growth Scenario. In the Proactive Scenario, the same economic performance is assumed, but electricity consumption is expected to be about 15% less than the Conservative Scenario in 2030, benefiting from a strong push for energy efficiency improvements through tariffs that better reflect the cost of service and price signals for peak periods. The challenges faced by the Egyptian energy sector in general, and by electricity supply in particular with recent peaking problems, underscore the need for action. Three key areas have been identified [1]:

- Application of demand-side management techniques and effective implementation of an economy-wide efficiency improvement strategy;
- Activate the energy storage options to mitigate electricity system constraints;
- Polices and measures to enhance market opportunities for private investment in renewable and energy efficiency.

As well from measures in all sectors from energy-intensive industries to street lighting; energy standards for the thousands of air conditioners, refrigerators and laundry appliances that will be purchased by Egyptian households in the next 20 years; better building codes and incentives for sensible approaches such as solar water heating [2].

Demand-side management practices such as the use of smart grids, interactive meters and load shedding incentives can help to curb the peak demand, the most expensive part of the load profile for the provision of electricity service.

New innovative approaches to energy supply need to be employed in order to address reliability concerns and meet our growing energy needs. One approach is the implementation of the smart grid.

The "smart grid" is a term used to describe the rapid infrastructure replacement of the electrical wiring system in the United States. When the advanced system is completely implemented, it will allow for communication features across the grids that are not currently available--hence the term "smart." [3]. A “smart grid” is simply an advanced electrical distribution system that has the capability to balance electrical loads from diverse, and often intermittent, alternative energy generation sources. One key component of the “smart grid” is the capacity to store electrical energy; this allows the demand from consumers to be met.

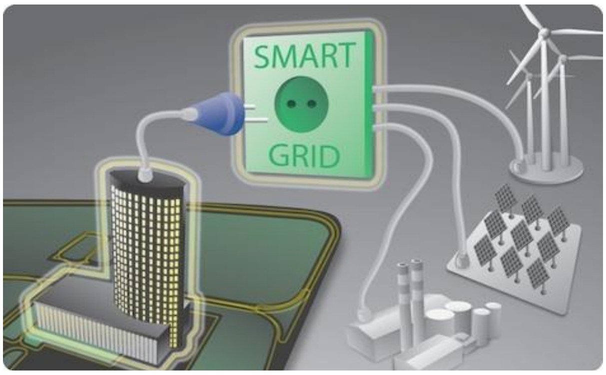

Fig. 1, Smart Grid Definition.

Smart grid uses digital technology to deliver energy to consumers rather than the alternating current technology currently used by our existing grid. Much of the existing energy infrastructure can be used to deliver energy using smart grid technology, but communication between the consumer and provider will be much more efficient and effective and therefore less expensive and more reliable.

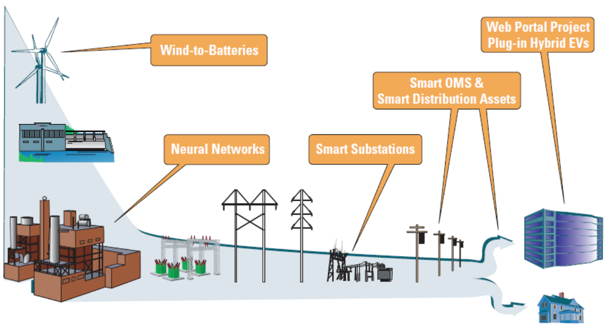

Fig. 2, typical configuration of Smart Grid

In attempt to harmonize the descriptions and goals of smart grid technology, the U.S. Department of Energy’s smart grid Task Force brought together leading research groups in 2008, who agreed upon the seven characteristics of a smart grid [1]:

- Enable active participation by consumers
- Accommodate all generation and storage options
- Enable new products, services, and markets
- Provide power quality for the range of needs in a digital economy
- Optimize asset utilization and operating efficiency
- Anticipate and respond to system disturbances in a self-healing manner
- Operate resiliently against physical and cyber attacks, and natural disasters

The basic idea of Smart grids is about information and control as much as power management. Much of the information is sent over the power lines using broadband over power Lines (BPL), which superimpose information on top of the electrical power. This information can reroute electricity around problem spots until the problem is fixed, and adjust power levels to match demands.

Both power suppliers and power consumers can be accommodated by smart grids. Wind and solar power can add to the grid, and consumers can be charged higher rates during peak consumption hours and lower rates when consumption is low. Smart grids can even adjust for reduced output from solar cells on cloudy days and from wind turbines on still days, in addition to the increased demands from air conditioners on hot days.

Smart grids can also quickly respond to natural failures “Disaster Avoidance” or terrorist attacks by rerouting around problems or closing down the network entirely. They also manage rolling brown outs to save electricity when demand exceeds production.

2 Status of Smart Grid

Up until now smart integration of grid-connected photovoltaic (PV) systems is a concept that has been neglected in part due to the availability of subsidies. These subsidies given under different forms of national incentive schemes have made PV the fastest growing energy source in the last few years.

In the future, as direct financial incentives and other types of subsidies to PV systems are gradually phased out, smarter grid interface will become an essential feature of future PV systems design [4].

3 A Vision for the Smart Grid

The Smart Grid is a necessary enabler for a prosperous society in the future. Modernizing today’s grid will require a unified effort by all stakeholders aligned around a common vision. Throughout the 20th century, the U.S. electric power delivery infrastructure served our nation well, providing adequate, affordable energy to homes, businesses and factories. This once state-of-the-art system brought a level of prosperity to the United States unmatched by any other nation in the world. But a 21st-century U.S. economy cannot be built on a 20th-century electric grid. There is an urgent need for major improvements in the nation's power delivery system and the advances in key technology areas that will make these improvements possible. A vision for the Smart Grid is needed to set the foundation for a transition that focuses on achieving value in the following six areas [5]:

- The grid must be more reliable. A reliable grid provides power, when and where its users need it and of the quality they value. It provides ample warning of growing problems and withstands most disturbances without failing. It takes corrective action before most users are affected.
- The grid must be more secure. A secure grid withstands physical and cyber attacks without suffering massive blackouts or exorbitant recovery costs. It is also less vulnerable to natural disasters and recovers quickly from disturbances.
- The grid must be more economical. An economic grid operates under the basic laws of supply and demand, resulting in fair prices and adequate supplies.
- The grid must be more efficient. An efficient grid employs strategies that lead to cost control, minimal transmission and distribution losses, efficient power production, and optimal asset utilization while providing consumers with options for managing their energy usage.
- The grid must be more environmentally friendly. An environmentally responsible grid reduces environmental impacts thorough improvements in efficiency and by enabling the integration of a larger percentage of intermittent renewable resources than could otherwise be reliably supported.
- The grid must be safer. A safe grid does no harm to the public or to grid workers and is sensitive to users who depend on it for medical necessities.

Modernization of the nation's grid must start with building a vision, followed by the deployment of enabling technology platforms and the integration of smart grid applications that will support that vision.

Table 1 summarizes the seven points and contrasts today's grid with the vision for the Smart Grid.

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Today's Grid	Principal Characteristic	Smart Grid
Consumers are uninformed and do not participate with the power system	Enables Consumer Participation	Full price information available, choose from many plans, prices, and options to buy and sell
Dominated by central generation, very limited distributed generation and storage	Accommodates All Generation & Storage Options	Many "plug and play". distributed energy resources complement central generation
Limited wholesale markets, not well integrated	Enables New Markets	Mature, well-integrated wholesale markets, growth of new electricity markets
Focus on outages rather than power quality	Meets PQ Needs	PQ a priority with a variety of quality and price options according to needs
Limited grid intelligence is integrated with asset management processes	Optimizes Assets & Operates Efficiently	Deep integration of grid intelligence with asset management applications
Focus on protection of assets following fault	Self Heals	Prevents disruptions, minimizes impact, and restores rapidly
Vulnerable to terrorists and natural disasters	Resists Attack	Deters, detects, mitigates, and restores rapidly and efficiently

4 Smart Grid Benefits

Several quantifiable benefits the smart grid will bring today as many other significant benefits exist that will not become apparent until the smart grid begins to be implemented. There is compelling evidence that supports the following long-term benefit assumptions [1]:

- Significant reductions in residential peak demand energy consumption achieved by providing real-time price and environmental signals in conjunction with advanced in-home technologies
- Additional reductions in residential peak demand by fully integrating the utility system with distributed generation technologies (scalable for mass penetration)

- Up to 30% reduction in distribution losses from optimal power factor performance and system balancing
- Potential carbon footprint reduction as a result of lowered residential peak demand and energy consumption, improved distribution losses and increased conservation options
- Possible reductions in the number of customer minutes out as a result of improved abilities to predict and/or prevent potential outages, and more effective responses to outages and restoration
- Expected deferral of capital spends for distribution and transmission projects based on improved load estimates and reduction in peak load from enhanced demand management
- Potential utility cost savings from remote and automated disconnects and reconnects, elimination of unneeded field trips and reduced customer outage and high-bill calls through home automation

The utility industry today is faced with not only supplying resources to accommodate the projected growth in demand for energy, but also minimizing and reducing the impact we have on the environment from producing that energy. The smart grid provides a solution to this challenge. The benefits and payoffs are numerous.

5 Smart-Grid Technologies

Renewable energy systems (RESs) cannot directly replace the existing electric energy grid technologies. The latter are far too well established to abandon, while the new technologies are not sufficiently developed to meet the total energy demand. Therefore, it is sensible to gradually infuse renewable energy sources into existing grids and transform the system over time [7].

A smart grid is modelled by two concentric circles the outer circle represents energy flow and the inner circle models information flow over communication networks. Different approaches to the management of energy flow in active grids integrating distributed power generation have been proposed. One of the most interesting ideas employs energy hubs to manage multiple energy carriers (e.g., electricity, natural gas, and district heating). Within each hub are energy converters that transform part of the energy flow into another form of energy. Fig. 3 is a possible scenario of the future power system based on smart-grid technologies, with power electronic building blocks (PEBBs) and mechanical building blocks (MEBBs) as intelligent energy conversion nodes.

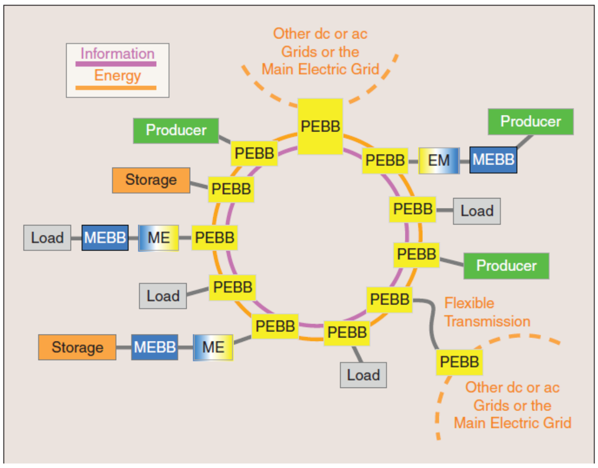

Fig. 3, intelligent energy conversion nodes.

With the development of smart grid technology, the intelligent meters will be likely to control home appliances, when users can adopt more sensible strategies to reduce the cost of electricity during the high electricity price. So peak load shifting can be achieved, and the system will tend to be more economic, intelligent and environmental friendly[8].

6 Smart Grid Platform

Shahram Javadi and Shahriar Javadi have reported in [9] that, in principle, the smart grid is a simple upgrade of 20th century power grids which generally "broadcast" power from a few central power generators to a large number of users to instead be capable of routing power in more optimal ways to respond to a very wide range of conditions.

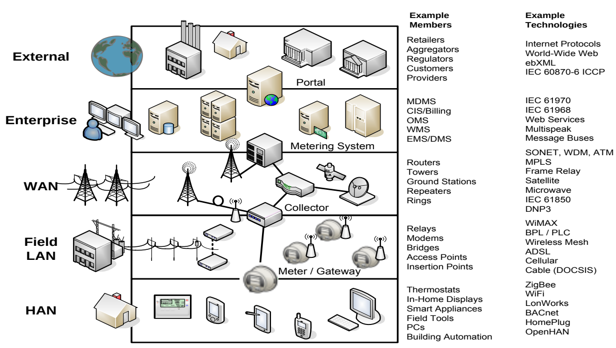

Fig. 4, Smart Grid Standards

A realization is emerging that a new view of energy, beyond oil, coal and other fossil based fuels, will result in decentralized components of the electricity grid, a far cry from the central generation and structured system of the past.

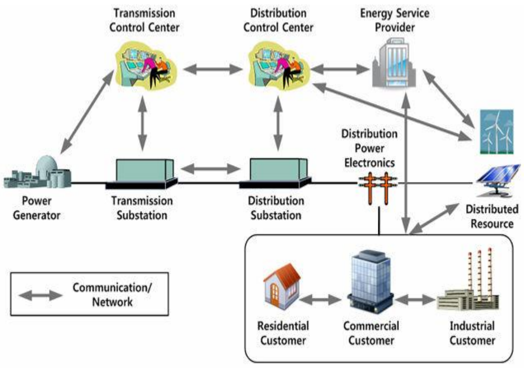

Fig. 5, Control Center in all parts of grid

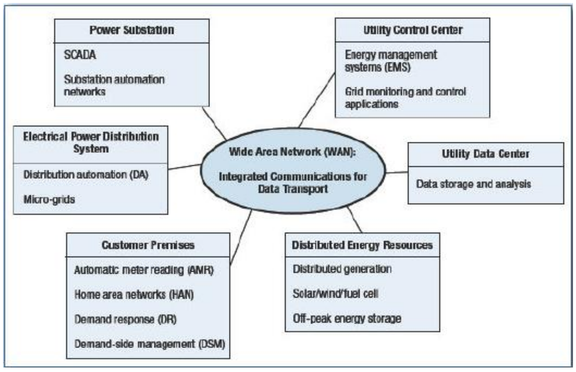

Fig. 6, an Integrated Communication System

7 Smart Cities and Smart Grids

The Smart City concept reflects the growing importance of Information and Communication Technologies (ICT) – in addition to social and environmental factors – in defining the competitiveness of cities and improving the quality of life of their citizens. Smart City projects frequently utilize a networked infrastructure to enable economic and political efficiencies and social, cultural and urban development. They may focus on social and environmental sustainability through the participation of citizens in processes and the balancing of growth initiatives with the protection of valuable natural resources. Smart City projects often look to tap into collective community intelligence, based on effective planning for urban and regional development, and innovation management [8].

A smart information network the energy internet for the electric grid is seen as necessary to manage and automate this new world. The integration of communications networks with the power grid in order to create an electricity communications superhighway capable of monitoring its own health at all times, alerting officials immediately when problems arise and automatically taking corrective actions that enable the grid to fail gracefully and prevent a local failure from cascading out of control, as happened in 2003 Blackout in US. Increased reliability and efficiency in the low voltage power grid is an essential part of future energy efficiency efforts. However, the Smart Grid makes many customers wonder what it actually is, what it will cost to implement and within what time frame.

It is supposed to implement the Smart Grid from the ground up, starting with LV substations, smart meters and streetlights. Once we have full control of these components in the grid, we can detect leakages, provide streetlight dimming, enable smart households, and perform load balancing and a number of other Smart Grid features [9].

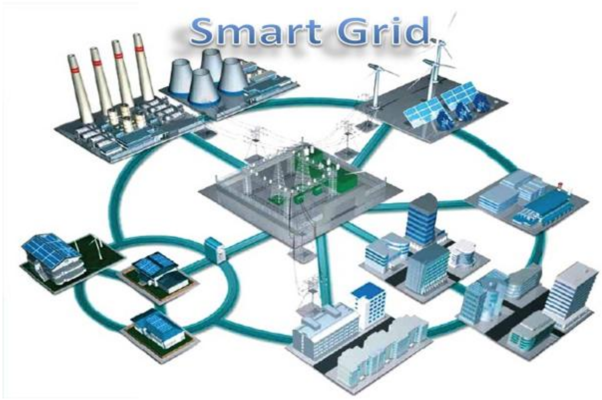

Fig. 7, Smart City Planning

7.1 Smart meter of smart grids

Key benefits of the point to point smart meter solution to utility companies include:

- Improved speed of deployment over traditional meshed networks
- Simplicity of an open standard, IP-based network
- Ability to communicate directly with each meter.

Fig. 8, Smart Meter

Table 2, Modern Hardware and control for Smart Grids

Modern Hardware for Smart Grids	Modern Control Methods for Smart Grids
1 Power Electronic Devices • Unified Power Flow Controller (UPFC) • DVAR or DSTATCOM • Static Voltage Regulator (SVR) • Static VAR Compensator (SVC) • Solid State Transfer Switch • Dynamic Brake • AC/DC inverter 2 Superconductivity • First Generation wire • HTS cable • Second Generation wire 3 Distributed Generation • Microturbine • Fuel Cell • PV • Wind Turbine 4 Distributed Storage • Nas battery • Vanadium Redox Battery (VRB) • Ultra capacitors • Superconducting Magnetic Energy Storage (SMES) 5 Composite Conductors • Aluminium Conductor Composite Core Cable (ACCC Cable) • Aluminium Conductor Composite Reinforced Cable (ACCR Cable) • Annealed aluminium, steel supported (ACSS)	1 Distributed Intelligent Agents • Digital Relays • Intelligent tap changer • Energy management system • Grid friendly appliance controller • Dynamic distributed power control 2 Analytic Tools • System performance monitoring and control • Phasor measurement analysis • Weather prediction • Fast load flow analysis • Market system simulation • Distribution fault location • High speed commutating 3 Operational Application • SCADA • Substation Automation • Transmission Automation • Distribution Automation • Demand Response • Outage management • Asset optimization

Fig. 9 presents an application of smart grid on a small residential or commercial building. The smart meter is used to collect the power and market information and update the customer with real time energy price.

8 Management and Control SG

In the application technologies for SG, an Intelligent Universal Transformer (IUT) has been introduced by [14]. It is a power electronic base transformer introducing for Advanced Distribution Automation (ADA) in future. ADA is the state of art employing the new architecture based on both the flexible electrical network and open communication construction comprise the Future Distribution System. IUT is a basic resource enrolling a key point in ADA conceptual construction which is fundamental part in smart grid network. In [15] and [16], a distributed and integrated power systems, it is vital to ensure that each power source (generator, wind turbine, etc) is working within its allowed parameters. These parameters are normally based on the current power load that are sometimes have been forecasted within regular intervals (weekly, monthly or yearly). Anyway, these non real-time forecasts have their drawbacks and may not supplying correct information when any of these events occurred:

- Sudden failure of any of the power sources
- Unexpected increase or decrease of power demand within a short timeframe.

The future electrical grids will consist of large small-scale generation units of renewable energy sources and other disparate energy sources. Highly scalable and decentralized integrated communication, computing and power networks will be necessary to monitor these smart grids of the future.

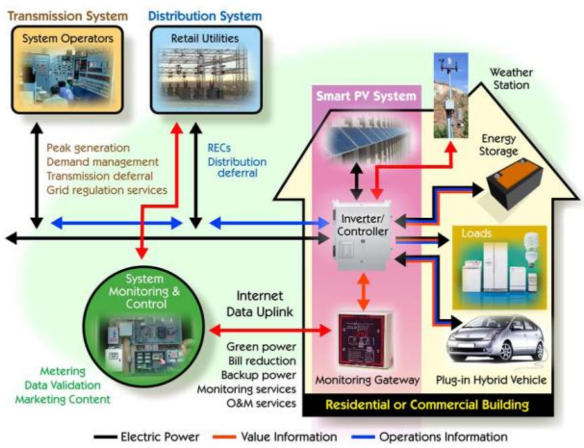

Fig. 9, the solar energy grid integration system integrated with advanced distribution systems

9 SCADA and Smart Grid

Central & distributed generation Virtual aggregation of generators and loads for system management Grid components connected by both electrical and data networks Bi-directional power flows. The following figure shows how Smart Grid will look like [17].

These technical solutions can be very useful for the new electrical system. A smart grid, which aggregates LV consumers, DG plants, controllable loads and energy storage systems, has the possibility to disconnect itself form a faulted distribution system to assure the energy supply inside the isle (intentional islanding operation) [18-19].

9.1 SCADA Advantages in SG

- The Tolerant of attack – mitigates and stands resilient to physical and cyber attacks
- Provides power quality needed by 21st century users
- Fully enables competitive energy markets – real-time information, lower transaction costs, available to everyone
- Optimizes assets – uses IT and monitoring to continually optimize its capital assets while minimizing operations and maintenance costs – more throughput per $ invested.
- Accommodates a wide variety of generation options central and distributed, intermittent and dispatchable.
- Empowers the consumer – interconnects with energy management systems in smart buildings to enable customers to manage their energy use and reduce their energy costs.
- Self-healing – anticipates and instantly responds to system problems in order to avoid or mitigate power outages and power quality problems.

10 Implemented SCADA System for Smart Grid Monitoring and Control

A new generation of Remote Terminal Unit (RTU) for SCADA system based on microcontroller for customer side distribution automation system is designed and implemented.

Fig. 10, Two RTU's with Air Station Wireless High Power Module.

We have a common trend of attempting to lower SCADA costs on RTU side. Our system goals are to go to deep in lowering the cost of RTU unit, freeing the software so lowering system cost, and to expand the open source technology culture away from the restricted one of the large companies. The presented microcontroller-based SCADA system with an open source software and graphical user interface is introduced in this paper. The implemented system is modular where the main terminal unit (MTU) with a human machine interface (HMI) can access many RTUs that can plug and play. The system is designed, implemented and gave excellent results in collecting data, transmitting, monitoring, and applying system control as well.

One of the most appropriate applications for SCADA is the remote area photovoltaic standalone systems. The SCADA is used as monitoring, control and management system. The system is tested in three mode; wired, wireless "local network" and broadcasting over network application. The following two figures show the images of the implemented new SCADA MTU and RTU's while test working [10] as shown in Fig. 11.

RTU is composed of microcontroller Ethernet units (AT328 microcontroller board and Ethernet controller) serves as system server. The communication protocol software is open source SCADA software with multiple communication capability. The system is attached to an emulator board with analog and digital input and output capability as shown in Fig. 12

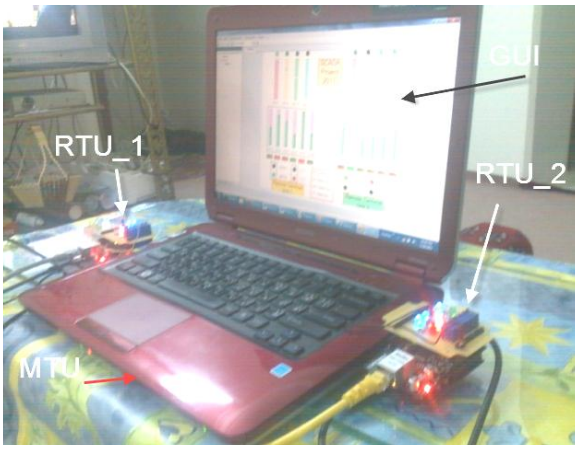

Fig. 11, Two RTU's with MTU in operation mode.

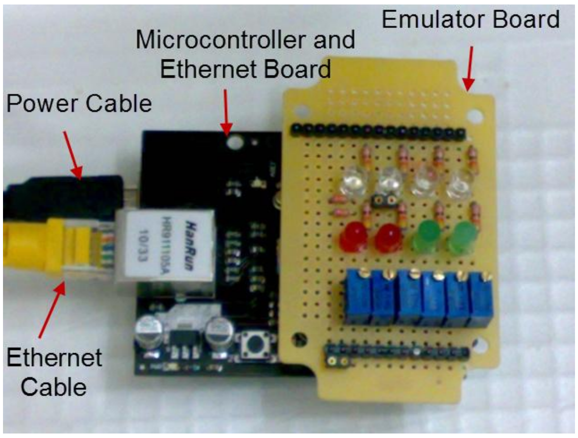

Fig. 12, RTU Emulator Board.

In the GUI HMI window; Fig. 13, left group shows the status and control signals of RTU_1 while right group shows the status and control signals of RTU_2. The upper four bars show the values of the output analog signals, matching could be found between the white LED's brightness and the high of each bar slider. Slider bar is used to control of the value of each output analog signal.

The six bars in the middle represent the analog input signals, the high of each bar changes according to the change of each analog input signal. Each analog signal value is changing from 0 to 1023 decimal as 10-bit resolution A/D is used. This reading is displaying in a text box under the displayed bar taking a color varying from green to red according the strength of the signal as shown clearly in Fig. 13. The check boxes down shows the status of two digital output signals that controls the operation of green LED's. Each LED is illuminating according the related signal. The right two signals of each RTU block shows the status of digital input signal.

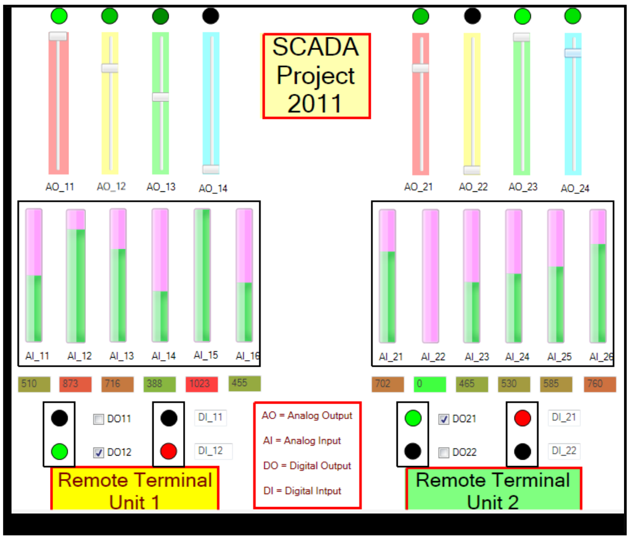

Fig. 13, MTU GUI Menu.

11 What If the Smart Grid Isn't So Smart?

The idea is simple: supply people with smart meters that give real-time information on electricity use and price. Armed with the new information, consumers might opt to plug in their laptop in the middle of the night instead of, say, the middle of the day. As a bonus, the system would lead to more use of renewable energy sources like the wind and sun.

But there's a hitch. If everybody aims to use cheap electricity, the slow time in the middle of the night becomes the high demand time. In the worst case, everybody's laptops start recharging, refrigerator compressors kick on, dishwashers start up and so on, at the exact same moment. At least so say M.I.T. researchers in a paper presented at a recent meeting of the Institute of Electrical and Electronics Engineers.

Instead of charging on the cheap, you get a huge spike in demand and, potentially, a blackout. That's because electricity must be produced at the same second it is consumed and utilities must precisely match supply and demand.

One solution would be to give consumers imperfect or non-instantaneous price information, though that kind of defeats the original purpose. But it does keep the smart grid from outsmarting itself.

12 Problems with Smart Grid

Smart grid power systems use digital technology to deliver electricity. They are being rolled out in the U.S. Though they are promoted as a means to create energy savings, some problems exist with this technology. Some of the problems inherent in smart grid power systems include customer privacy problems, security problems, grid volatility and inflexibility. Implementing a smart grid power system has considerable implications for personal privacy because the grid has the ability to control power access. Security experts believe that this technology may allow someone other than the customer to control the power supply.

12.1 Privacy Problems

The infrastructure supporting the smart grid will have the ability to inform consumers of their day-to-day energy consumption. It will reduce greenhouse emissions and consumer's bills by monitoring and managing power usage. However, the process required to implement the smart grid may sacrifice consumer privacy. U.S. consumers should be allowed to protection the information that flows from their power usage to government agencies. However, if data does not travel back to the power supplier due to privacy regulations, the lack of data, in turn, may inhibit the development of the smart grid.

12.2 Security Problems

Security experts believe that smart grid technology may enable some people to get control of the power supply. The security risks are similar to those related to the Internet. Hackers can get control of innocent people's computers by exploiting the weaknesses in Internet communication. Likewise, communication between utilities and the meters at residential homes and businesses increases the chance of someone gaining control over the power supply of a single building or an entire neighbourhood.

12.3 Grid Volatility

Smart grid network has much intelligence at its edges; that is, at the entry point and at the end user's meter. But the grid has insufficient intelligence in the middle, governing the switching functions. This lack of integrated development makes the grid a volatile network. Engineering resources have been poured into power generation and consumer energy consumption, which are the edges of the network. However, if too many nodes are added to the network before developing the software intelligence to control it, the conditions will lead to a volatile smart grid.

12.4 Flexibility Questions

Smart grid networks need to have the capacity to connect innumerable devices and must maintain reliability and stability. However, growing environmental concerns are placing more demands on the grid's performance. While automation within the network can help generate the information needed to operate the system, utilities are still reluctant to take the risk and are hesitant to adopt this new, untested technology.

13 Smart Grid in Egypt

Electricity energy demand growing rapidly in Egypt with an annual average growth of around 7%, which requires huge investment in expansion of electrical power generation, transmission and distribution. The electricity sector in Egypt act to support the legislation policies, making laws and also provide fund to encourage research and development of existing and new technologies in the areas of the most efficient equipment and processes, and specifically by:

- Enhance the consumer awareness about energy efficiency improvement economic benefits.
- Announce the minimum standards requirements for equipment efficiency.
- Provide incentives for investments in energy efficiency technologies in all residential, commercial and industrial sectors.
- Improve and develop utility systems to reduce energy consumption.
- Use communications systems and information technology.
- Activate energy demand management programs to reduce the maximum load.

Energy efficiency improvement programs considered as planning to implement policies and advanced developed technologies for the various activities (industrial, commercial, facilities, etc.) in order to conserve energy and fuel without any prejudice to the quantity and the quality of energy production [11].

13.1 Vision of Smart Grid in Egypt

Due to the dramatically increasing if energy demand in Egypt, the application of “smart grid” is not an optional solution for current grid configurations but it is a must. This idea confirms the opinion of [5] which reports that, “The Smart Grid is a necessary enabler for a prosperous society in the future. Modernizing today’s grid will require a unified effort by all stakeholders aligned around a common vision”.

We are agreed with [4] in that, “Up until now smart integration of grid-connected photovoltaic (PV) systems is a concept that has been neglected in part due to the availability of subsidies. These subsidies given under different forms of national incentive schemes have made PV the fastest growing energy source in the last few years. In the future, as direct financial incentives and other types of subsidies to PV systems are gradually phased out, smarter grid interface will become an essential feature of future PV systems design. Many countries start stopping of supporting their population with subsides and the price of electricity, fuel and foods are doubled or tripled the previous values; you can notice that in the economic news of the European committee as well as in the Egyptian market. So, a problem solution must be found.

To do that, we are agree with [3] in that, “both power suppliers and power consumers can be accommodated by smart grids. Wind and solar power can add to the grid, and consumers can be charged higher rates during peak consumption hours and lower rates when consumption is low. Smart grids can even adjust for reduced output from solar cells on cloudy days and from wind turbines on still days, in addition to the increased demands from air conditioners on hot days”. In Egypt as stated in [1, 11], renewable energy sources are present in Egypt with high rates of solar insolation and enough levels of wind speeds in many sites. So the application of smart grid by incorporating the renewable energy sources with traditional one to handle the peak demand and reduce the pollution emission is necessary in Egypt.

Many references [2, 5, 12, 13] confirm that, the smart grid has a positive impact on the electric grid during the peak times, environment friendly and customer economics. In Egypt, the infrastructure of the electric network is quite different from site to site. It could be clearly depicted that the power generation, distribution and protection in the capital and large cities are much better than those stated in Delta or Upper Egypt. Also, the life style and houses of the people live in large cities is quite different.

This means that "smart grid" could be fully applied on both the customer and the electric network infrastructure by adding smart devices and replacement of conventional meters with other smarter one's that has the ability for power and information exchange between the electric energy provider and the customer. In large cities; most of the customers has enough culture and finance capabilities for revolution from classical apparatus to smarter one's. This modernization leads to have economic and reliable use of electricity, enhance the performance of the installed power utilities, and eliminate or prevent the blackouts.

On the other hand in Delta and Upper Egypt, the "smart grid" technology could be applied only on the level of energy generation and distribution substations.

14 Conclusions

Smart Grids are most comprehensive technology during recent years and it has been grown rapidly because of its benefits. The Smart Grid has many features and could be summarized in the following paragraphs:

For consumers, a smart grid means they can use electricity more wisely and save money by setting "smart" appliances that slow down or shut down on a hot, sunny day when demand for power and its corresponding cost are high. It means having many different options for using energy, and it means having a much better understanding of their overall energy use.

For environmentalists, a smart grid means using technology to help solve climate change by conserving energy and using it more wisely. It also means better integration of renewable resources into standard operations, avoiding the creation of more carbon gases that have been linked to global warming.

For investors, it provides additional revenue opportunities, will lead to the deferral of significant capital infrastructure investments, and will provide the ability to dramatically upgrade systems. It also means significantly improving reliability and increasing customer satisfaction. "Smart grid" enabled distribution could reduce electrical energy consumption by 5-10%, carbon dioxide emissions by 13-25%, and the cost of power-related disturbances to business by 87%. (Source: The Electric Power Research Institute). Smart grid enabled energy management systems have proven in pilots to be able to reduce electricity usage by 10–15%, and up to 43% of critical peak loads. (Source: The Brattle Group, SMUD and PNNL.) The Smart Grid vision generally describes a power system that is more intelligent, more decentralized and resilient, more controllable, and better protected than today's grid.

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