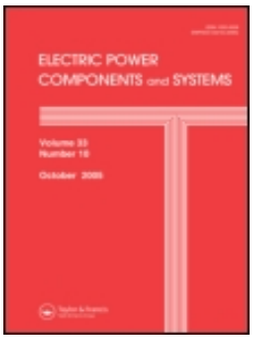

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# Transferring Power Sectors from Aging Utilities into Smart Grids—The Case of Lebanon

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**Abstract**—The substantial increases in the energy consumption during the second half of the last century have amplified the use of fossil fuels in various economic sectors, mainly the power sector. Also, the low-efficient technologies still adopted in many countries have mounted the losses associated with various energy conversion processes to substantial levels. Tasks and challenges associated with transferring power sectors from energy-wasting utilities into advanced smart grid-based utilities are discussed in this article. To transfer the Lebanese dilapidated and aging electrical power sector into a modern economically profitable sector, adopted two major projects have been adopted: the Lebanese Electrical Network Control Center and the Advanced Metering Infrastructure. This article explains the outcomes and impacts of the major components of these two projects; it article also discusses the problems encountered during the implementation process of the Lebanese Electrical Network Control Center, where several original software packages have been modified by the research team to properly integrate the Lebanese Electrical Network Control Center with the aging Lebanese power sector. Finally, the article describes the controlled design project, which also has been implemented as part of the Lebanese Electrical Network Control Center project and highlights problems associated with upgrading the high-voltage transmission lines.

## 1. INTRODUCTION

Activities associated with human development and welfare have provided a clear perturbation of the global environmental balance and resources depletion and have led to local air quality degradation in many regions and communities throughout the globe. In the last decade of the previous century, further to the ozone layer depletion problem and global warming, the air pollution problem and resources depletion have become international concerns of developed as well as developing countries [1–3]. The electric power sector is globally regarded as the major contributor to resources depletion, greenhouse gas (GHG) emissions, and air pollution. The rapid increase in the energy demand and consumption during the last century has amplified the use of fossil fuels in the power sector. Also, the low-efficient technologies have mounted the losses

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associated with various energy conversion processes to substantial levels.

Since the turn of the 21st century, the concept of a smart grid has been developed as a mean for intelligent utility network and has been strongly supported by the innovative trends in the telecommunication, information technologies, and infrastructure markets. This digital innovation is proven to be capable of improving power quality and reliability, reducing costs, incorporating alternative energy sources, reducing carbon emissions, and ensuring that future energy demand is effectively and efficiently met.

In Lebanon, and due to the 30 years of civil unrest, deficiency in the national power generation to meet the demand has been consistently witnessed. Alternative private generation units are currently regarded as the measure to overcome the shortage and interruptions in power supply. Electricité du Liban (EDL) is the national electric power utility of Lebanon, serving the generation, transmission, and distribution needs of the entire country. EDL, an autonomous state-owned power utility, owns roughly 90% of the installed generation capacity in addition to the transmission and distribution networks [4–6].

The power grid of EDL consists of several high-voltage networks (66, 150, and 220 kV) in addition to the interconnection with networks in neighboring countries, namely Egypt, Jordan, Syria, and Turkey, through 400-kV transmission lines and a 400/220-kV substation.

The bulk of EDL's generation units are located along the coastal region. Electric power is produced in Lebanon from thermal and hydroelectric power plants, and a small amount is purchased from Syria and Egypt through regional interconnections. The purchases from Syria and Egypt constituted around 7.5% of the total energy consumed but have been discontinued due to political and security situations in both countries. The installed hydropower capacity is 274 MW, but the actual generation capacity is around 190 MW, *i.e.*, around 10% of the total capacity. The installed capacity of aging thermal power plants is 2038 MW, with the actual capacity being around 1785 MW. Thermal generation capacity is divided into steam turbines units at Zouk, Jieh, and Hraycheh plants, which are old and suffering from a lack of maintenance. Diesel-fired combined cycle gas turbines at Beddawi and Zahrani and diesel-fired open-cycle gas turbines at Sour and Baalbek are more recent but operate with low conversion efficiencies and higher operation and maintenance costs since they are operated using heavy fuel oil and diesel instead of natural gas. A feasibility study for different fuels has revealed that using natural gas in association with combined cycle gas turbine technology offers the most economic and environmentally friendly option [7].

The generation capacity and the imports in 2011 mounted to around 1800 MW, and the instantaneous peak in the summer periods reached around 2450 MW. The supply of electric energy averages 21 hr for the Greater Beirut Area (GBA) and drops to around 15 to 18 hr in the rest of the country. The persistent shortage of power supply has led to having privately owned standby generators installed in most residential areas and in industrial and commercial districts, providing a total supply capacity in excess of 500 MW. According to the country's first and second national communication on climate changes, the share of the power sector in the country's GHG emissions has risen from around 48% in 1994 to 54% in 2004 [8]. These distributed generators are causing excessive air quality degradation in urban regions in addition to high levels of noise pollution.

The non-technical losses along the transmission and distribution networks are not uniform, as they vary between provinces from around 9.6 to 58% and then between regions from 15 to 78% [4, 9]. Non-collected bills constitute a substantial component of these non-technical losses. The transfer of the existing power network to a modern utility infrastructure can be achieved through the implementation of two major projects: the Lebanese Electrical Network Control Center (LENCC) [10] and the Advanced Metering Infrastructure (AMI) [11, 12]. The LENCC project was completed in early 2013, and operators of this modern control center are now able to monitor and control the generation, transmission, and medium voltage (MV) circuit breakers at the distribution level from the EDL headquarters. The AMI project is still in progress and is expected to be operable in 2016. The main advantage of the LENCC project is to help in managing the electric network, economically and technically, to minimize technical losses and keep them in the range of 6–8%, thus saving annually around US$150 million [4].

On the other hand, the AMI project will allow, among other functions, to accurately identify network losses; detect tamper, fraud, and network outages; manage non-technical losses; improve revenue recovery; balance power flow and financial transaction processing; allow the possibility to make multi-tariff structures; provide pre-paid billing functionalities, peak load shaving measures, and load management functionalities; as well as increase operational efficiency and lower operational expenses and increase.

The inefficient electrical grid has left EDL susceptible to security threats, inhibited alternative energy/conservations goals, and contributed to reliability problems, such as power quality disturbances and blackouts. A smart grid is the solution to EDL's conventional electrical system. For example, there will be a large number of sensors that will monitor a variety of critical functions and, consequently, will report the proper information to both EDL and the consumer, thus allowing the latter to better understand his/her consumption patterns.

The concept of a smart or intelligent grid has been around for many years. Many organizations, including the Electric Power Research Institute, Gridwise Architecture Council, and others, have been promoting the concept since the end of the previous century. The big push for using the term smart grid, however, resulted from the enactment of the US Energy Independence and Security Act of 2007, or EISA. In weighing its responsibilities under EISA, the National Electrical Manufacturers Association (NEMA), in its report on "Metrics for Measuring Progress Toward the Implementation of the Smart Grid," stated that standards for the smart grids must incorporate seven major characteristics [13]: to enable active participation by consumers; to accommodate all generation and storage options; to enable new products, services, and markets; to provide power quality for the range of needs in a digital economy; to optimize asset utilization and operating efficiency; to anticipate and respond to system disturbances in a self-healing manner; and finally to operate resiliently against physical and cyber-attack and natural disasters.

Renewable-based smart grid technologies proposed in [14] offered a solution for gathering the distributed energy resources in low population density regions with many natural resources; which proved to largely surpass the fast-growing electricity demand of the geographic conditions of extreme points in Chile. A centralized control system, which is used to optimize the operation of the microgrid during interconnected operation, was presented in [15]. The outcome of this system was to maximize the production of local generators and energy exchanges with the distribution network.

A better way to realize the emerging potential of distributed generation that views generation and associated loads as a subsystem or a "microgrid" has been developed [16]. This approach allows for local control of distributed generation, thereby reducing or eliminating the need for central dispatch. During disturbances, the generation and corresponding loads can separate from the distribution system to isolate the microgrid's load from the disturbance (thereby maintaining a high level of service) without harming the transmission grid's integrity. Intentional islanding of generation and loads has the potential to provide a higher local reliability than that provided by the power system as a whole. The size of emerging generation technologies permits generators to be placed optimally in relation to heat loads and allow for use of waste heat. Such applications can more than double the overall efficiencies of the systems [17].

Most current microgrid implementations [18] combine loads with sources, allow for intentional islanding, and try to use the available waste heat. The objective of this work is to provide these features without a complex control system requiring detailed engineering for each application. This approach provides generator-based controls that enable a plug-and-play model without communication or custom engineering for each site.

In [19], an energy management system (EMS)/supervisory control and data acquisition (SCADA) system was presented, where the "open system" concept from the viewpoints of users and suppliers was examined and current technologies for open distributed EMS/SCADAs and their possible future trends were described.

The SCADA system usually consists of the following subsystems [20]:

- a human–machine interface (HMI) is the apparatus or device that presents process data to a human operator, and through this, the human operator monitors and controls the process;
- a supervisory (computer) system gathers (acquires) data on the process and sends commands (control) to the process;
- remote terminal units (RTUs) connect to sensors in the process, convert sensor signals to digital data, and send digital data to the supervisory system;
- programmable logic controllers (PLCs) are used as field devices because they are more economical, versatile, flexible, and configurable than special-purpose RTUs; and
- communication infrastructure connects the supervisory system to the RTUs with various process and analytical instrumentation.

## 2. COMPONENTS OF THE LENCC PROJECT

The implementation of EMS-based control centers has to overcome several obstacles, both technical and political. The execution of the LENCC project has revealed many technical problems due to aging EDL power components, which caused costly delays during the execution process. Several original software packages have been modified by the research team to properly integrate LENCC with the aging sector. Accordingly, this project, which was expected to be commissioned in October 2008, was completed during the first quarter of 2013. Details of these problems and the adopted solutions will be highlighted in this article.

The LENCC project is based on the e-terra platform, an EMS with programs and applications that control and monitor the generation, transmission, and distribution phases of the power network. What follows is a description of this system based on its initial design [21].

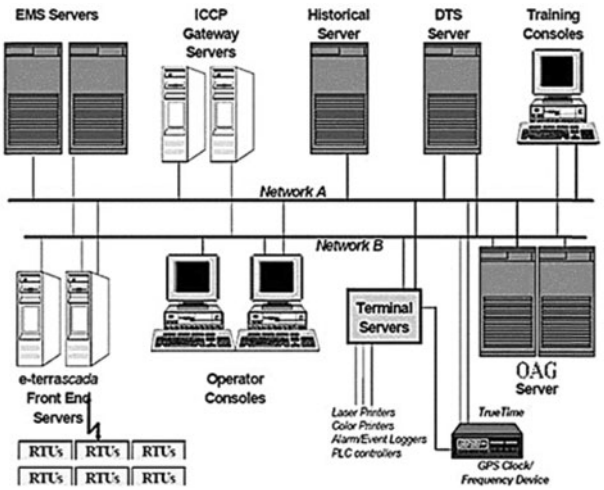


**FIGURE 1.** Typical EMS hardware configuration.

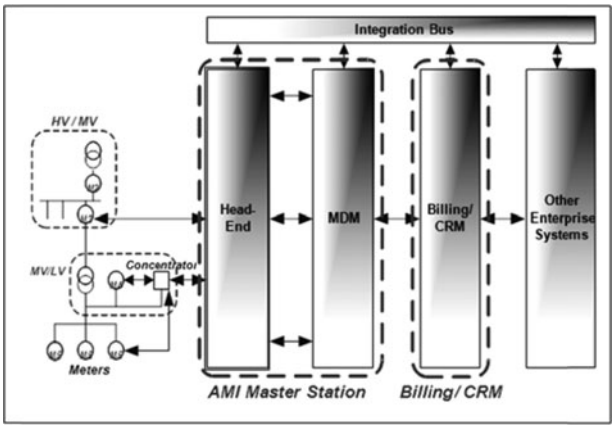


**FIGURE 2.** Central AMI system main components.

### 2.1. The E-terra Platform Hardware Configuration

The total processing power of the e-terra platform is distributed among various computers and servers interconnected through a real-time network. The e-terra platform configuration is designed to ensure that system is available 24 hr/day through the use of redundant EMS servers, e-terra control front ends (FEs), networks, and loggers. The main components of typical EMS hardware, as shown in Figure 1, are EMS host nodes, an FE communication subsystem, a global positioning system (GPS) clock-frequency device, a historical server, an inter-site communication (as an open-access gateway [OAG]) subsystem, a user interface subsystem, inter-company communication protocol (ICCP) gateway servers, a dispatcher training simulator (DTS) server, a wide-area network (WAN) subsystem, and a local area network (LAN) subsystem.

### 2.2. Components of the E-terra Platform

The components of the e-terra platform are e-terra habitat, an e-terra browser, application portable interfaces (API) and utilities, an e-terra SCADA, e-terra automatic generation control (AGC), e-terra transmission, and an e-terra archive [10, 22, 23].

## 3. COMPONENTS OF THE AMI PROJECT

The purpose of the AMI project, shown in Figure 2, is to design and construct meter data management (MDM) billing, customer relationship management (CRM), and the AMI-MDM and billing/CRM monitoring center. In parallel to this project, another ongoing project—the distribution service provider (DSP) [4]—aims at outsourcing the complete distribution network services, including planning, design, expansion, operation and maintenance, metering, and bill collection. The AMI project covers the implementation and replacement of all conventional metering of Lebanon to automatic meters to be controlled remotely through a central AMI system and the procurement and installation of the corresponding concentrators.

### 3.1. AMI Communication Solution

Data exchange and remote metering commands in the AMI system will make use of a communication media, which will bridge the various elements of the AMI between the automatic meter to reach the utilities' central system, allowing a bi-directional flow of data and commands. The communication platform in the AMI supports two-way info interchange ability and a communication protocol that adopts a store-and-forward procedure for retransmitting signals. It is secured with non-intrusive features that ensure no interferences with other communication systems.

The data concentrator creates the necessary infrastructure by linking several meters to the control center system and captures and reports vital data, synchronizing time and data of the meter to the control center and enabling secure data transfer of user-authenticated and encrypted information. The communication to the meters is comprised of a wired (PLC/DLC) connection, enabling data transfers to the control center system via Ethernet, GSM, GPRS, POTS, or UHF/VHF networks.

There will be a concentrator at each of the 18,000 existing substations in the power network. The concentrators will communicate with the meters, which are attached to these substations using a narrowband power line carrier (PLC) technology. For this purpose, the PLC communication module has been installed in both the meters and the concentrators. The concentrators gather data from the meters throughout the day and store them in the concentrator for collection by the

central AMI system. Alarms from smart meters are collected by the concentrators and communicated immediately to the AMI center.

### 3.2. Central AMI System Solution

This section describes the solutions for the main components of the central AMI system.

#### 3.2.1. AMI Master Station—Head End

The Head End system is responsible for data communication with the concentrator/meter and is responsible for translating the meter messages into a common message format for feeding into the MDM. The AMI Head End system provides two-way communication with the data concentrators/meters and with the MDM and receives and sends data as specifically requested or scheduled as well as sending alarms. The Head End system is responsible for getting the data to and from the data concentrators through the mobile data communications. In some cases, the data could be communicated from and to the meters directly for some remote areas. The data exchanged between the Head End and the meters include meter readings, accumulated totals, messages, quality data, and other data.

The Head End ensures the completeness and timeliness of data according to standard schedules or for specific tasks where confirmations will be notified and logged. The messages sent from the Head End system to the meters include disconnect/reconnect, change tariff parameters, clock synchronization, register reset (status, maximum, tampering, etc.), and faults, such as modem breakdown. The Head End system will have a schedule for routine communications, such as collecting data from all meters every night, and ad hoc communications, such as disconnecting customers. The scheduled communications will be automatic, unattended tasks with call-out alarms for excessive error rates. Alarms for such issues as meter tampering will produce an immediate warning to the operators and will be logged.

#### 3.2.2. AMI Master Station—MDM

The MDM unit serves as the main communication point between the AMI Master Station and enterprise systems, such as billing, CRM, asset management, and outage management systems. The key functions within the MDM are the validation, cleansing, and estimation of missing data before they is analyzed or passed on for use. One of the key applications for EDL is the identification of the losses between concentrators and meter consumption. The main functionality of MDM involves the validation of the data received from the meters to ensure their conformity with various algorithms, the editing of data to correct errors, and the estimation of missing data to produce a complete set of data. Whenever the missing data is received again to the MDM, the restoration of this data is performed to correct the estimates of the edits.

### 3.3. Implementation and Transition Solution

The implementation of the new system and transition from the current situation at EDL to the full operation of the new central AMI systems has provided many challenges, knowing that considerable support and guidance have been provided throughout the implementation phase. The relevant implementation plan and transition scenario is described next. The approach is to keep the legacy systems operational and to move customers' meters and associated activities onto the new systems when the new meter is installed. The central AMI system will be in place before the new automatic meters are installed. The concentrators also needed to be implemented before the automatic meters so that the communications from the meter through the concentrator to the AMI center are tested as part of the installation process. The implementation, integration, and transition plan requirements are critical factors for having a robust and reliable AMI center.

## 4. INTEGRATING LENCC INTO THE UTILITY

Due to the aging of the major power components of EDL's systems, the LENCC installation has encountered a number of technical problems. Several original software packages had to be modified by the research team to properly integrate LENCC with the sector. The major encountered problems and the perspective solutions can be highlighted as follows.

- At the 150/66-kV high-voltage substations, a number of interposing relays, both existing and newly installed under the SCADA adaptation works, had burned out due to earthing problems because the surge arrester was not working properly. Although tests relevant to the installation of another substation were successfully performed, accidents were reported at later dates. These accidents were initiated by an overload on an MV line supplying a control circuit. Connections and wires that were part of the adaptation units were damaged due to EDL's old DC breaker, which energized the corresponding relay panel. The breaker did not function properly, and thus, a short circuit occurred. As a result, the interconnected MV cells were shut down, raising the need for remedial work to be performed.
- The EDL utility has claimed that there are differences in link attenuation values (4.7 versus 14.2 dB) recorded during tests on completion for power line carrier (PLC) link between other two local substations, which was

considered as unreasonable. The highly transmitted power from one of the substations to the other (19 dB) will shorten the lifetime of the corresponding amplifier unit. Necessary actions were performed to correct these differences.

- The most critical problem was encountered at the major Zouk thermal power plant, commissioned in 1984. The AGC test upon completion showed that the initial attempt to send a command from the LENCC simulator as defined within the procedure was accepted and initiated by the software, but Unit 1 in the power plant did not respond. The size of the output change attributed to each pulse was not large enough in comparison to the size of the machine being controlled. Consequently, the corresponding signal would not be seen within the reaction time required by the throttle valves that adjust the speed and, therefore, the load output of the generator. This control method was considered unacceptable and rendered the rest of the procedure to be invalid, leading to postponing the testing. To solve the problem, improvements were formulated to make the control system compatible with the existing aging components of the plant. Although several software upgrades were loaded to the RTUs during the installation period of the EMS, an additional and more upgraded RTU software version had to be loaded to all RTUs of the system after its commercial operation had been started.

The built-in functions were useful for producing information by processing original SCADA data in a simple manner, but other factors had to be taken into consideration, such as the weight of the turbine shaft and the difference in the inertia compared to the small turbine sizes. Also, each turbine operated in the power plant had to be tailored to give a reaction in loading within a common reaction time for each individual machine. The new software properly rearranged the above priorities and the relevant malfunction was resolved.

The SCADA systems have been gradually modified by researchers to be integrated for different industrial sectors. The various practical considerations in applying data acquisition systems and advanced applications were investigated in [24]. Java-enabled mobile is used as a client in a sample SCADA application to display and supervise the position of a sample prototype crane. A SCADA system that allows communication with various input/output (I/O) devices in the renewable energy systems was presented in [25]. It differs from traditional SCADA systems in that it supports a continuously changing operating environment based on the intended test. The SCADA system is based on the concept of having one master I/O server and multiple–client computer systems. The structure and installation of a flexible and low-cost SCADA system were discussed in [26]. The system has reduced the labor cost and has increased the labor productivity of the operation due to the remote supervision of the process.

## 5. CONTROLLED NETWORK DESIGN

The controlled network design includes, among other functions, the calculations of total generation, total demand, frequency, load allocation, losses, and power flows in the controlled network. The controlled network in this case consisted of two thermal power plants (Jieh and Zouk) along with their busbars and four strategic substations (Jamhour, Bsalim, Jeita, and Beitdeen). Figure 3 shows the design of the network, which represents two loads directly fed from the busbar of each thermal plant, two loads directly fed from each busbar of the four substations, and one load directly fed from the busbar of the Jeita substation.

The total power provided by the thermal plants (Jieh and Zouk) and the total demand that represents the sum of the power consumed by the entire network are illustrated in Figure 4. The total generation and the total demand vary instantly depending on the load variations.

The network of Figure 4 represents five major lines linking the power plants to the substations and the loads. The power losses in all the lines are dependent on the loads of the network and are considered constant, such that

- the power loss on the line linking Jieh power plant with Beitdeen substation is 1 MW,
- the power loss on the line linking Jieh power plant with Jamhour substation is 2 MW,

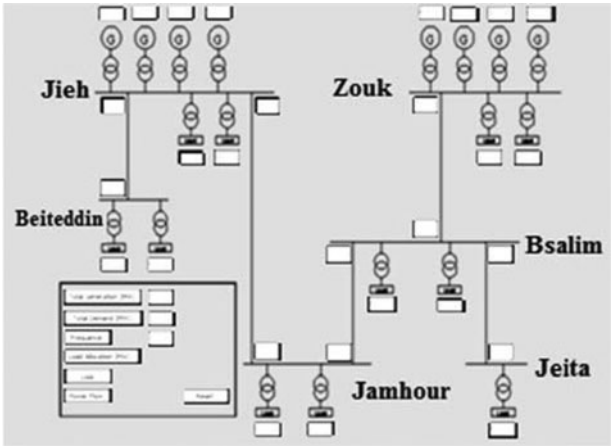


**FIGURE 3.** Design of the network.

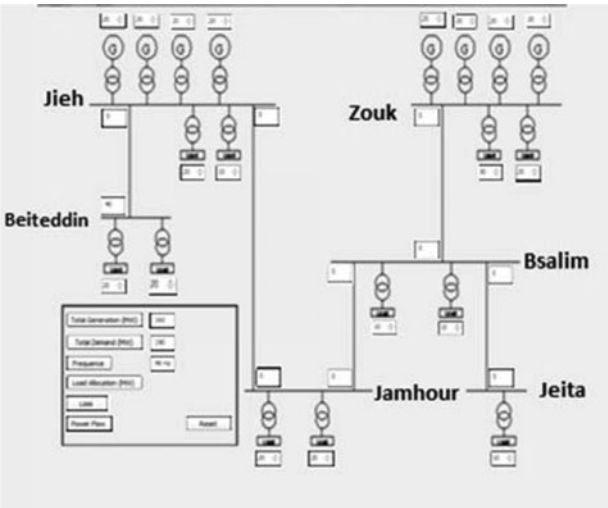


**FIGURE 4.** Total supply and demand network.

- the power loss on the line linking Zouk power plant with Bsalim substation is 1 MW,
- the power loss on the line linking Bsalim substation with Jeita substation is 1 MW, and
- the power loss on the line linking Bsalim and Jamhour substations is 1 MW.

The total loss of 6 MW constitutes around 10% of the transmitted power, and the normal case for the network is to generate a power equivalent to the power demanded by all loads added to the 6-MW losses.

Another problem encountered in the network was the frequency variation with the load by around 2%, such that it drops with overload conditions to around 49 Hz and increases with underload to 51 Hz. Figures 3 and 4 provide information about the power figures at the extremities of each line, direction of power flow in each line, power flow in each line, (where the maximum power flow is labeled), and appropriate messages for user information.

### 5.1. Normal Operating Condition

The normal case is when the supplied power is sufficient to cover the load and the 6-MW losses. The objective is to quantify the electric power passing through each line to supply the loads in the network. The following approach is adopted.

If the Jieh power plant has an excess power after supplying all the connected loads, the remaining power will be used to supply additional zones (Beitdeen loads).

If there is an excess of power, the remaining power is passed through the line Jieh–Jamhour, then to the Jamhour–Bsalim and Bsalim–Jeita. If this power exceeds the demand in the Bsalim station, the remaining power passes through the Bsalim–Jeita and Bsalim–Zouk lines. Hence, the power generated from one plant (Jieh plant) could be connected to loads normally supplied by another plant (Zouk plant).

### 5.2. Excessive Demand Condition

When the total demand with the line losses of 6 MW is greater than the total generation, there will be a shortage of power in the network. The system calculates this shortage, and a signal demanding an increase in generation is sent to all generation units. As a result, the network returns to the normal case.

### 5.3. Excessive Supply Condition

When the total generation is greater than the total demand and the 6-MW losses, there will be an excess of power in the network. A signal is sent from the controller to the generating units having the excess, demanding a decrease in the generation. After decreasing the generation, the network returns to the normal condition. Three cases are further examined:

#### 5.3.1. Excessive Power in the Jieh Power Plant

When the generation in the Jieh power plant is greater than its three loads, there will be an excess of generated power. To determine the value of this excess power, the following process is adopted.

i. If the generation in the Zouk power plant is equal to its three loads, then no power is needed from Jieh to supply these loads, and the excess power in Jieh (EPJ) power plant becomes:

$$\text{EPJ} = \text{generation Jieh} - (\text{Jieh's}\, loads + \text{3-MW loss})\,.$$

ii. If the generation in the Zouk power plant is less than its three loads, then the lack of power to supply these loads is covered by the excess power in the Jieh power plant. The remaining excess power in Jieh becomes

$$\text{EPJ} = \text{generation Jieh} - (\text{Jieh's loads} + \text{3-MW loss}) - \text{lack Zouk} - \text{1-MW loss}.$$

With lack Zouk = (Zouk's loads + 2-MW loss) – generation Zouk, the 1-MW loss is for the line Jamhour–Bsalim.

#### 5.3.2. Excessive Power in Zouk Power Plant

Similarly, when the generation in the Zouk power plant is greater than its three loads, then there is excess power in Zouk. To determine the value of this excess power, the following conditions must be examined:

i. if the generation in the Jieh power plant is equal to its three loads, no power is needed from the Zouk power plant; the excess power in Zouk (EPZ) then becomes

$$\text{EPZ} = \text{generation Zouk} - \big(\text{Zouk}'\text{s loads} + 2\text{MW loss}\big);$$

ii. if the generation in the Jieh power plant is less than its three loads, then the lack of power to supply these loads is covered by the excess power of the Zouk power plant; then,

$$\begin{aligned}\text{EPZ} = {} & \text{generation Zouk} \\ & - \big(\text{Zouk}'\text{s loads} + \text{2-MW loss}\big) \\ & - \text{lack Jieh} - \text{1-MW loss.}\end{aligned}$$

With lack Jieh = (Jieh's loads + 3-MW loss) – generation Jieh, the 1-MW loss is for the line Bsalim–Jamhour.

#### 5.3.3. Excess Power in Both Power Plants

When the generation in both the Jieh and Zouk power plants is greater than the six connected loads, then there will be excess power in both plants. The line Jamhour–Bsalim is not used in this case, and the total loss in the network becomes 5 MW. The excess of power in the Jieh and Zouk power plants are determined as follows:

i. EPJ = generation Jieh – (Jieh's loads + 3-MW loss);

ii. EPZ = generation Zouk – (Zouk's loads + 2-MW loss).

## 6. TRANSMISSION LINES UPGRADING

The rehabilitation program of EDL also included adopting the 220-kV level for the entire high voltage (HV) transmission line network. This measure would lead to a 1–2% increase in system efficiency, resulting in annual savings in the range of 150 to 300 GWh. It would also allow the network to be connected to the 400-kV regional network spanning from Egypt to Turkey through Jordan and Syria. The problem encountered during the HV transmission line upgrading, which is still impeding the implementation, is the public rejection of having 220-kV aerial lines installed over residential zones in mountainous regions close to the capital city of Beirut. Locals protested that HV lines will induce harmful magnetic fields that may cause health hazards. Measurements were carried out by a team lead by the authors, and the magnetic field level recorded under the existing lines were around 3.8 $\mu$T, which is within the WHO limit of 100 $\mu$T but much higher than the limit of 0.3 $\mu$T suggested by numerous health studies for continuous exposure [27, 28]. To solve the problem, the power utility has installed high towers reaching heights around 60 m (see Figure 5), but this did not stop the protests that were organized by the locals and even politicians, who succeeded in preventing the technical teams from conducting the work. Solutions suggested by local as well as international experts are being currently investigated and include redirecting the power lines over unpopulated or less-populated areas or using underground cables. Both solutions, however, will impose additional cost on the power utility. Another suggested solution was for the utility to buy all the houses, allowing residents to relocate to other places, but this was also rejected.

**FIGURE 5.** Transmission lines upgrade and electro magnetic field (EMF) concerns.

## 7. CONCLUSIONS

Despite many difficulties facing the implementation of the LENCC and the AMI projects due to the aging Lebanese power sector infrastructure, these systems remain the most optimum solution for this sector. Extra efforts were needed to integrate the LENCC and make it compatible with the existing power network and with the current power plants conditions. Several original software packages have been modified to properly integrate the LENCC within the utility. The implementation of the LENCC and the AMI (planned to be completed in 2016) projects will transfer the Lebanese electric utility from an aging utility into a modern one. The controlled network design project that was developed and implemented proved its effectiveness in the upgraded LENCC project.

The anticipated the integration of smart grid-based power utilities with other smart grid-based projects, such as Home Automation systems, could be developed, allowing the control of lighting, appliances, and other domestics appliances.

This large transformation process provides a good opportunity to promote the development of the smart grid as an integral part of sector reforms and promotes the country to become a potential adopter of a realizable smart grid national action plan. Solutions to avoid exposing local populations to magnetic fields from HV transmission lines are being considered prior to upgrading the transmission line voltage of the whole network up to 220 kV.

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