Assessment and Mitigation of Risks for People Living Under and Near High-Voltage Powerlines in Urban Areas of Egypt

Dr. Ahmed El-Mahdy*

Assistant Professor, Department of Nuclear Engineering, Egyptian Atomic Energy Authority (EAEA), Cairo, Egypt

KEYWORDS: Risk, Reduction, High, Voltage, Egypt.

ABSTRACT

Electricity is very important for modern life, and an important factor for development, and no one could think of living without electricity, but potential hazards to human being should be addressed carefully. Powerlines are part of the national grid that supplies electricity across Egypt. They include high voltage transmission lines, some of these power lines are mounted on and passing through different urban areas, and some of these areas are informal development which were extended unofficially under or very close to these high voltage powerline which can put the people living in these areas in risk.

Electromagnetic radiation from high voltage power lines can affect the health of people in urban and rural communities. According to World Health Organization (WHO), EMF such as those from power lines, may increase the risk of many diseases. Different studies worldwide have shown that living next to high voltage power lines increases the risk of cancer and other health problems especially for children. Although there are different laws for setting the buffer safety zones for the high voltage power lines and they are mandatory, the law is not implemented, not well understood and has been difficult to enforce because of technical, administration and social aspects.

This paper is highlighting the current situation of informal areas under high voltage power lines in Egypt. Also, it is reviewed the previous and current research studies in the field of effects of EMF from powerlines. It described the previous and current activities of the governmental programs towards this problem and highlighting constrains which include legal, administration and financial issues. It is concluded that different new preventive measures are needed to reduce the risk for the people living near and under high voltage cables in urban areas in Egypt.

INTRODUCTION

With the population growth around Egypt, towns are expanding, many buildings construct near and under high voltage overhead power transmission lines. The increase of power demand has increased the need for transmitting huge amount of power over long distances. Large transmission lines configurations with high voltage and current levels generate large values of electric and magnetic fields stresses which affect the human being and the nearby objects located at ground surfaces. Investigation of the effects of electromagnetic fields near the transmission lines on human health had been studied from different years. In 2002, the World Health Organization's and the International Agency for Research on Cancer (IARC) updated its classification of power line radiation to "possibly carcinogenic (cancer-causing) to humans". Most studies show that the association between health effects, such as cancer, and high EMF occurs over many years. Both high-voltage transmission lines and also neighborhoods power lines constitute a radiation hazard. The size of the power line is not the issue. The strength of the electromagnetic field (especially the magnetic component) where people live is what important [1]. To prevent health-relevant interactions with static or LF fields, ICNIRP recommends limiting exposure to such fields so that the threshold at which the interactions between the body and the external electric and magnetic field shows adverse effects is never reached inside the body [2].

METHODOLOGY

The research begins with a descriptive study of health effects of EMF from high voltage power lines, and it is reviews the national legislation. It is showed the current situation of informal settlements near or under high voltage power lines in Egypt and studied the previous and current programs of the government. The results of the research provide a better understanding of constrains which facing the government to solve the problem and provides some preventive measures that can help to tackle the problem.

Health Effects of EMF from High Voltage Power Lines

The electricity system produces extremely low frequency electromagnetic field which comes under non-ionizing radiations which can cause health effects. Long-term effects of low-level exposure stemming from the power distribution system including power lines and their relevance to health have been extensively studied over the last few decades [3].

Electromagnetic fields (EMFs) are produced by power lines. Numerous studies have investigated EMF exposure and health. Although earlier studies did suggest associations between exposure and a variety of health effects including brain cancer, breast cancer, cardio-vascular disease, and reproductive and developmental disorders, most of these associations have not been substantiated by more recent research. One notable exception to this is the association with childhood leukemia, which the International Agency for Research on Cancer regards as sufficiently well established to rate extremely low frequency magnetic fields as a "possible" human carcinogen [4].

The debate of whether there are adverse effects associated with electromagnetic fields from living close to high-voltage power lines has raged for years. While research indicates that large risks are not present, the possibility of a relatively small risk cannot be conclusively excluded specially for children. The first study to link childhood leukemia with residential EMF exposure was published in 1979[5].

Epidemiological studies have suggested that long-term low-level exposure to 50-60 Hz magnetic fields might be associated with an increased risk of childhood leukemia. A totally independent team of Swedish medical scientists, reviewed almost 100 epidemiological papers published up to July 1994, [3]. They concluded that there are possible associations between:

- An increased risk of leukemia for children live near the power lines,
- An increased risk of chronic lymphatic leukemia and occupational exposure to low frequency electromagnetic fields and,
- An increased risk of breast cancer, malignant melanoma of the skin, nervous system tumors, non-Hodgkin lymphoma, acute lymphatic leukemia or acute myeloid leukemia and certain occupations [3].

However, a more recent study in 2005 by Draper G, Vincent T, Kroll ME, et al [6] showed an elevated risk of leukemia among children living in homes with distances much greater than 60 m from high voltage power lines. This study involved close to 30000 matched case-control pairs of children living in the United Kingdom. It was found that children living in homes as far as 600 m from power lines had an elevated risk of leukemia. An increased risk of 69% for leukemia was found for children living within 200 m of power lines while an increased risk of 23% was found for children living within 200 to 600 m of the lines. This study was notable in that it found some elevation of risk at much greater distances than previous studies.

The United Kingdom Childhood Cancer Study reported in 2006 a smaller study of childhood leukemia and other cancers across England, Wales and Scotland, which both measured magnetic fields within the home from all sources and calculated distances to powerlines. It also reported elevated risks for leukemia that were not statistically significant, though they were compatible with the pooled analyses for magnetic fields and with the Draper et al (2005) results for powerline proximity [7]. A study in France by Sermage Faure et al, 2013 [8] found elevated risks within 50 m, confined to the higher-voltage lines and to younger children but not extending beyond 50 m. Figure (1) shows power frequency fields of a 765 KV powerline in relation to observed biological effects, [9].

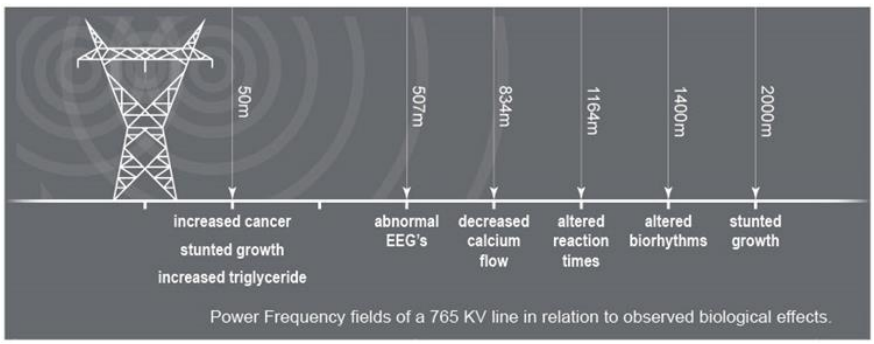

Figure (1): Power Frequency Fields of a 765 KV Powerline to Observed Biological Effects, [9].

National Legislation

There are different legislative forms which subject, regulate and administrate electrical power plants and electrical high voltage powerlines in Egypt and these include:

- ***Environmental Law 4/1994***

  Law 4/1994 and its executive regulations, subject to the Cabinet Decree 338/1995, is the main environmental protection legislation in Egypt. The published Environmental Impact Assessment (EIA) guidelines (January 2009) form the key regulation on environmental protection. According to the law no. 4 of 1994, EIA must be performed for new establishments or projects and for expansions or renovations of existing establishments. The Purpose of EIA is to ensure the protection and conservation of the environment and natural resources including human health aspects against uncontrolled development. All projects should include EIA studies and its divide into three groups which require different levels of EIA according to the severity of possible environmental impacts: oil, cements and chemical companies and electrical power plants are classified in the "Black Projects" category which due to their potentially severe environmental impacts need a full EIA study [10].

- ***Electricity Law No. 87/2015***

  In addition to EIA requirements, Electricity production and generation establishments are subject to the provisions of different legislations and laws but the most related one is electricity Law No. 87 of the Year 2015 which is concerning the electricity sector Installation, the people assembly passes the bill of electricity law that regulates all activities and developments related to the electricity sector. Article 55 of chapter 5 of the law addresses the right of way (ROW) safe distance which should be measured from the axis of the power lines as well as the underground.

Right of Way (R.O.W) of High Voltage Power Lines

An electric transmission line right-of-way (ROW) is a strip of land used by the electrical utilities to construct, operate, maintain and repair the transmission line facilities. The width of a right-of-way depends on the voltage of the line and the height of the structures. The right-of-way generally has to be clear of structures and trees that can interfere with the power line. These ROW land are usually evaluated to decrease the effects of the energized line including magnetic and electric field effects [12]. Public access to ROW is permitted, but building and long-term occupation are not. At the edge of ROW, the EMFs are appreciably lower than they are in the center. The WHO limits should not exceeded anywhere within ROW but the EMFs outside the area are consequently below these limits [13]. The safe clearance distance is measured from the center line of the transmission tower on each side of the power line. According to the electrical law, the safe clearance distance for super high voltage power lines (500 KV and above) is 25 meters, 13 meters for high voltage power lines, 5 meters for medium power lines, and 5 meters for super and high voltage cables.

Informal Areas Near and Under High Voltage Power Lines in Egypt

Sharp escalation in the land prices both in cities and rural areas and also pressure of economic situation have resulted that a lot of people immigrate to urban cities where economic situation is better. Different governmental and private lands had been occupied by informal areas and one of these areas are the vast part of land available in the ROW of the medium and high voltage power transmission lines that spans all through different urban areas in cities. A view at the right-of-way (ROW) corridors of the power transmission lines that pass all along different cities in Egypt indicates illegal structures and buildings that have come up. Residential houses, commercial buildings and even workshops with sometime high rise buildings which can be seen right near or under the power lines and towers, this situation is putting the people live or work in these areas under high risk. According to Informal Settlements Development Facility (ISDF) in 2016, there are 50 areas distributed in 15 governorates classified as slums under health hazardous because they are located under high voltage powerlines. Figures (2) and (3) show high voltage powerlines passing through Ezbet El Hagana Area, Nasr City, Cairo.

Figure (2) High Voltage Powerlines Passing through Ezbet El Hagana Area, Nasr City, Cairo (By the Author)

Figure (3) High Voltage Powerlines passing through houses, Ezbet El Hagana Area, Nasr City, Cairo (By the Author.

Health Hazard in Informal Areas in Egypt

According to a study did by (Hanna Karawia, 2013) [15] in three slum areas in Alexandria. The overhead power lines passing through these areas are belong to Electricity Distribution Company (AEDC) which has about 577 km Medium Voltage (MV) overhead lines. These slums located under the medium overhead power lines and within the right of way, and they are developed in contradiction to building laws and planning regulations, as the residents had built their houses on state-owned land or on private owned agricultural land without getting permission to build or to fit in with land use plans. These three areas are: Borg Al Arab, Abbis, and Abd Elkader areas. The study showed that although the values measured in some of the houses of these areas are lower ICNIRP limits but still there are elevated risk of cancer for children living in high-current-configuration for long period. Also there were many fatal accidents in these areas due to the closeness of OHPL from people. The survey results showed also that one of these slums suffering from high level exposure to ELF-MF reached above 10 μT inside homes which is considered dangerous for long time exposure period especially for children. The study concluded that the AEDC has to study the feasibility of converting the overhead power lines in these slums to underground cables to ensure healthy environment for the inhabitants. Also, it is concluded that the government should reassess

the hazards and re-define the safe zones near the Medium and high voltage power lines. And the authorities must prevent any building to be established within the ROW [14].

CURRENT ACTIVITIES OF GOVORNMENT TOWARDS PROTECT PEOPLE LIVING NEAR AND UNDER HIGH VOLTAGE POWER LINES

Different initiations had been approached by the government from 2010 when Informal Settlements Development Facility (ISDF) had issued its national plan for slum development which include projects for category (3) slum areas which are located under high voltage power lines. In 2010, ISDF had surveyed about 55 areas in governorates and it calculated the cost for changing of power lines to underground cables and the cost was about 550 Million Egyptian Pounds on that time. ISDF had implemented some pilot projects and succeeded with some governorates to remove power lines in 5 areas and change it to underground cables.

In 2011, the board of ISDF had suggested and agreed about an approach to solve the high cost of changing the powerlines to underground cables by differentiate the cost as follows: 25% to be covered by electrical utilities, 25% to be covered by Ministry of Local Development and 50% to be covered by governorates. In fact, this approach did not implemented in any governorates.

In 2014, ISDF had asked the ministry of electricity and energy to make a feasibility study and action plan to change the power lines which passing through 11 slum areas in Shoubra El-Khaimah which affects and increase the health risks of thousands of people living in these areas and the cost was about 1 Billion Egyptian Pounds. This study and action plan did not implemented. Besides that, there are different laws and they are mandatory but the law is not well understood by different local people and has been difficult to implement and enforce. Also the law does not address a number of issues including the effects of development underneath transmission lines. So, a different measures should be approached by the government to protect the people live near or under high voltage power lines.

After review of previous and current approaches and plans of the government, the study had highlighted different constrains which delay the implementation of these plans and it can be summarized as follows:

- **Cost**
  All of Egyptian national Grid's overhead lines have been given consent under the electricity law and have agreement and compensation payed to the landowners. Any re-routing of the overhead line would invariably require new consents and new landowner agreements and compensation fees. These new consents for overhead line routes are not easily obtained and need different procedures and cost. Also, change the powerlines to underground cables is very expansive and no one need to pay for.
- **Land**
  In most areas the existing overhead power lines had been routed taken into account of all siting, technical and environmental factors. In seeking to change these routes, it is not easy to obtain or found land to reroute or transfer the power lines to underground cables because of lack of governmental lands or very small roads to pass the cables.
- **Sustainability**
  National power lines and electrical power plants equipment are built to have a lifespan of about 40-60 years and they are big and bulky, so it is difficult and costly to move it. Relocation of a line is also unlikely to solve the problem long term anyway - once the overhead power lines had been moved in one place, in 20 years' time the grid may be asked to move the relocated line once again to accommodate additional growth.
- **Legal, Administration and Social Concerns**
  As stated in the electrical law, "the land under the power lines is under the responsibility of the owners and it is not allowed to construct any buildings if it is empty land or to increase the height of the building if it is constructed" this legal concern give the electrical companies the right to pass the high voltage power lines over existing houses which in all legal laws and regulations all over the world not allowed. Also the ROW which stated in the law is not fenced or guarded by any means and the law stated "if any occupation will happen to the land it will be removed by administration measures". In fact, in real life all these legal penalties are not implemented and different ROW's are occupied and different informal areas were built near or under these power lines, this situation put the government in pressure because it cannot remove the people living in these areas before it will found another safe houses which should be close to reduce the social resistant.
- **Political Will**
  Different initiations had been approached by the government starting from 2010 till now but there is no real political will to face the problem seriously which affecting the health of thousands people living

near and under high voltage power lines and also to implement the plans which developed and to allocate the needed fund.

PROPOSED MEASURES TO PROTECT PEOPLE LIVING NEAR AND UNDER HIGH VOILTAGE POWER LINES

After review of different articles some measures had been suggested and it include the followings:

- **Increase the ROW**
  Contact by people or objects with high voltage equipment must be avoided. For overhead power lines a statutory minimum clearance must be maintained between conductors and the ground. The higher the voltage of the line, the greater the safety clearance that is required. Safety clearances must be maintained from buildings constructed under or adjacent to overhead power lines. A study done by Ray Copes and Prabjit Barn (2008) suggested that to eliminate the risk of leukemia for the population live near high voltage powerlines, one would need to achieve a separation distance of 600 m between every high voltage power line and the nearest residence. While this could be done, it would require substantial changes to existing land use patterns and would require significant resources and change in legislation of the electrical and environmental laws [4].
- **Rearranging the Conductors**
  Salameh and Hassouna (2010) published a paper which had introduces a numerical solution based on Particle Swarm Optimization (PSO) technique, to reduce both magnetic and electric fields of high voltage overhead transmission line by rearranging the conductors. The horizontal, vertical, and triangular configurations of both single circuit and double circuit transmission lines were investigated. The examples presented in this paper show that the rearranged line configurations can introduce up to 81% reduction in magnetic field and up to 84% in Electric field when the effects of ice and wind are considered, and up to 97% reduction in both magnetic and electric fields when these effects are neglected. A comparison is made between the costs of reducing EMFs of a line segment in a suburban area in Amman in Jordan, and the cost of not-reducing EMFs, where it is found that the cost of reducing the fields is outweighed by the possible health costs otherwise. Figure (4) shows conductor arrangements for 230kV overhead double circuit delta transmission line with 740 A in each phase [15].

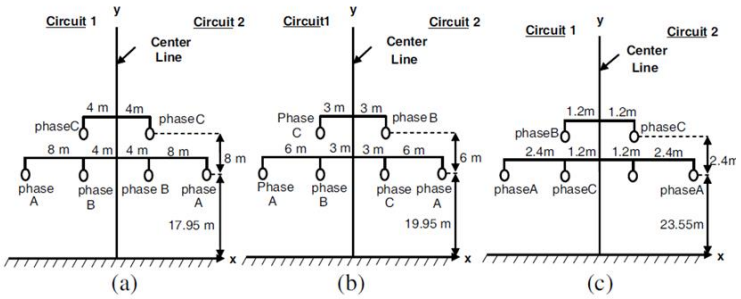

Figure (4): Conductor arrangements for 230kV Overhead Double Circuit Transmission Line with 740 A in each phase, (a) Existing line. (b) Optimized line with considering ice and wind effects. (c) Optimized line without considering ice and wind effects [15].

- **Protecting the Right of Way**
  Some countries put some regulations and guidelines to use the ROW for landscape, open spaces and parking area. The high voltage powerline right of way within the city landscape should be properly fenced using special trees and walls as applicable in order to prevent further encroachment.
  In UK, a study had identified over 40 locations across England and Wales in order to examine positive and negative environmental aspects evident in the relationship between pylons and overhead power lines and the built form and landscape. The case study locations cover a wide geographical spread and include a variety of land uses in urban and urban edge settings. One example of the study is Fairford Leys which is a new residential development situated on the edge of Aylesbury. This is a medium density development based upon a deformed grid layout. The development has a suburban character and is rapidly becoming well established despite some areas still being under construction. The transmission route is accommodated in a number of ways including as part of a riverine corridor running through the development. The various forms of circulation define the character of the corridor. The space is compartment by the low road bridges running across the area. There are wide footpaths in front of the houses on both sides of the corridor and other footpaths meander through the space with timber footbridges crossing the stream. The residential cul-de-sacs perpendicular to the transmission route open up views into the area. There are good pedestrian links weaving throughout the built form. There is also

street lighting to the residential footpaths on either side of the corridor. Figure (5) shows Fairford Leys which is a new residential development and an example of successful integration between development and overhead power lines [16].

Figure (5): Fairford Leys., An Example of Successful Integration between Development and Overhead Powerlines [16].

- **Re- routing of High Voltage Power Lines**
  Re-routing of high voltage power lines is one option to protect the people living near and under these power lines. Any re-routing of the overhead line would invariably require new consents and new landowner agreements and compensation fees. These new consents for overhead line routes are not easily obtained because the different administration procedures and also because of the cost.

- **Transfer the High Voltage Power Lines to Under Ground Cables**
  One of the technical options to protect people living near and under high voltage power lines is transferring them into underground cables. In a densely populated urban area, particularly in the center of large cities direct burial of cable is preferable in order to protect people and also to make available room to accommodate other services. The main difference between overhead lines and underground cables arises from the different ways in which they are insulated. Overhead lines use air whereas underground cable conductors are wrapped in layers of insulating material. Air is the simplest and cheapest insulation because it removes the heat produced by the electricity flowing through the bare overhead conductors naturally and efficiently [17]. From the cost point of view undergrounding of electricity lines is, however, more expensive than overhead lines, because of: additional insulation is required; extra land is needed; access to the cables is essential for repairs and maintenance purpose, therefore the land above the cables cannot be used for farming or other purposes; with Alternating Current, it is necessary to provide for reactive power; at 400kV, this requires compensation/substations every 15 to 20 km;
  In case of Egypt, change the high voltage powerlines to underground cables can be considered as a realistic solution in some high population density informal areas in spite of the higher construction costs involved. Figure (6) shows the proposed route for re-routing of power line in Ezbet El-Hagana, Cairo and it is noticed that the total existing length of the power lines is 7.8 KM and the new proposed route length is 13.3 KM which can cost approximately 350 million LE.

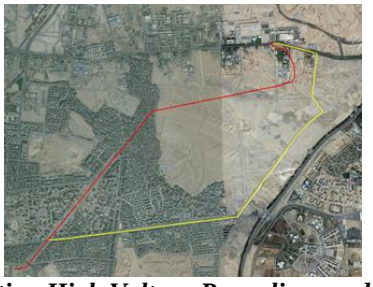

Figure (6): Map Showing the Existing High Voltage Powerlines and the Proposed Route for the Under Ground Cables in Ezbet El Hagana Informal Area, Nasr City, Cairo (By the Author).

- **Underground Cable Tunnels**
  In recent years technology has allowed for the development of high voltage electricity cables to be placed in dedicated deep-bore tunnels. Though the installation of a deep-bore tunnel is extremely costly but it is an alternative to direct-burial undergrounding in high density urban areas, or in circumstances where the restrictions resulting from a direct-burial cable are not acceptable. Also, the tunnels can be used for other

infrastructures routes [18]. Figure (7) shows the cross section of high voltage underground tunnel in China.

Figure (7): Cross Section of High Voltage Underground Tunnel, China [18].

CONCLUSION

The study assessed and evaluated the problem of high voltage power lines which passing through different informal areas in Egypt policy and the current programs which had initiated by the Egyptian government and it is showed that the government needs to have different approach and measures towards protect the people living near and under high voltage power lines. It is concluded with the followings:

- There are no doubt that the high voltage power lines produce extremely low frequency electromagnetic field which comes under non ionizing radiations which can cause different health effects especially for children.
- The government has to study the feasibility of converting the high voltage overhead powerlines in informal slums to underground cables or reroute them to ensure healthy environment for the inhabitants living in these areas.
- The government had to give priority of plans and allocate the appropriate funds to remove high voltage power lines passing through different informal areas.
- Different legal aspects should be readdressed in the electrical and environmental laws to deal with the occupation of the ROW, its protection and the enforcement and penalties.
- Different technical options are available to deal with high voltage power lines such as rearranging of the conductors, transferring the power lines to underground cables, using underground tunnels but these options should be studied carefully taken into consideration technical, administration and financial aspects in each area.

REFERENCES

1. World Health Origination (WHO), “Electromagnetic Fields and Public Health Exposure to Extremely Low Frequency Fields”, Backgrounder, June 2007, http://www.who.int/peh-emf/publications/facts/fs322/en/.
2. International Commission for Non Ionizing Radiation Protection (ICNIRP), “Power Lines Low Frequency”, http://www.icnirp.org/en/applications/power-lines/index.html.
3. Hardell, L., Holmberg, B., Malker, H., and Paulsson, L.E., "Exposure to Extremely Low Frequency Electromagnetic Fields and the Risk of Malignant Diseases- An Evaluation of Epidemiological and Experimental Findings". Eur. J. Cancer Prevention, September 1995.
4. Ray Copes, Prabjit Barn, “Is Living Near Power Llines Bad for Our Health?” Issue: BCMJ, Vol. 50, No. 9, Centre for Disease Control November 2008.
5. Wertheimer N, Leeper E. , “Electrical Wiring Configurations and Childhood Cancer, Am J Epidemiol, 1979.
6. Draper G, Vincent T, Kroll ME, et al., “Childhood Cancer in Relation to Distance from High Voltage Power Lines in England and Wales: A Case Control Study”. BMJ, 2005.
7. K J Bunch,1, T J Keegan, J Swanson, T J Vincent,1 and M F G Murphy, “ Residential Distance at Birth from Overhead High Voltage Powerlines: Childhood Cancer Risk in Britain 1962–2008, Feburary 2014.
8. C Sermage-Faure, C Demoury, J Rudant, S Goujon Bellec, A Guyot Goubin, F Deschamps, D Hemon and J Clavel1 , “Childhood Leukemia Close to High Voltage Power Lines – The Geocap Study”, 2002–2007 , British Journal of Cancer (2013, Published online 4 April 2013), www.bjcancer.com.
9. EM-watch, “Electromagnetic Radiation Health and Safety”, EMW, Internet Information Platform EMF-Portal of the RWTH Aachen University, Germany, http://emwatch.com/about-us.

10. G. A. Mousa1, “Environmental Laws with Application: A Review”, International Journal of Business and Statistical Analysis, No. 1, January 2016.
11. Official Newspaper, “Law No. 87 for Electricity”, No. 27 (c), July, 8, 2015.
12. Jignesh Parmar, “Effects of High Voltage Transmission Lines on Humans and Plants, February 2012, https://electricalnotes.wordpress.com/2012/02/17/effects-of-high-voltage-transmission-lines-on-humans-and-plants/.
13. Radiation Health Branch, “Environmental Health Directorate”, Nederland, http://www.health.wa.gov.au.
14. Hanaa Karawia, “Extremely Low Frequency Magnetic Field Measurements near Overhead Power Lines”, 22nd International Conference on Electricity Distribution Stockholm, 10-13 June 2013.
15. M. S. H. Al Salameh and M. A. S. Hassouna, “Arranging Overhead Power Line Conductors Using Swarm Intelligence, Technique to Minimize Electromagnetic Fields”, Progress In Electromagnetics Research B, Vol. 26, 2010.
16. National Grid and David Lock Associates, “Sense of Place’ Design Guidelines, Development near Overhead Lines, Planning and Amenity Aspects of High Voltage Electricity Transmission Lines and Substations”, July 2008. www.nationalgrid.com.uk.
17. ICF Consulting Ltd, “Overview of the Potential for Undergrounding the Electricity Networks in Europe”, United Kingdom, Final Report 28 February 2003.
18. Hebei New Baofeng Wire & Cable Co. Ltd, China, (http://www.nbf-powercable.com/contactus.html).
19. Xue Li, , Vasu D. Chakravarthy, , Bin Wang, and Zhiqiang Wu, “Spreading Code Design of Adaptive Non-Contiguous SOFDM for Dynamic Spectrum Access” in IEEE JOURNAL OF SELECTED TOPICS IN SIGNAL PROCESSING, VOL. 5, NO. 1, FEBRUARY 2011