Universidad Popular Autónoma del Estado de Puebla

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Maestría en Sistemas Integrados de Manufactura y Estrategias de Calidad

A NETWORK DESIGN FOR POWER LINE CONTROL

Tesis que para obtener el Grado de Maestro
en Sistemas Integrados de Manufactura y Estrategias de Calidad

Presenta
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Se aprueba la Tesis:

A NETWORK DESIGN FOR POWER LINE CONTROL

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A NETWORK DESIGN FOR POWER LINE CONTROL

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ABSTRACT

POWER LINE CONTROL, OVERHEAD LINE, WIRELES NETWORKING, UNMANNED AERIAL VEHICLES, WIRELESS TECHNOLOGIES, CABLEWALKER, 802.11.

The 1st chapter includes the theoretical issues of organization of a network in the business process of a power line control.

In the 2nd chapter analyzes the design of the network for a power line control task.

The third chapter provides testing and the solution for a power line control in Russia and in México.

Master thesis contains 76 pages, 33 figures, 7 tables, 30 sources.

CONTENT

INTRODUCTION

These days development of a country economy necessitates the need to ensure high-quality and reliable energy supply and energy consumption. The electrical sector plays an important role in the technological and industrial progress, Robotic system have a great possibilities of appliance in this sector. According to the data presented in the "Energy strategy of Russia for the period until 2030" [4], not yet realized managerial and technological potential of energy saving reaches up to 40% of the overall volume of internal energy consumption. The efficiency of energy resource, implies an important challenge in the development of wireless communication that integrated between the drone and the terminal. This integration demand for adapting to new requirements, for instance identification and sensing technology.

Electric power; as a resource to now everyday life necessities would need to be distributed one way or another, the media that is common to use nowadays are underground cables or overhead lines each has its own advantages and disadvantages. As we know that electric power can be transmitted or distributed either by means of underground cables or by overhead lines. The underground cables are rarely used for power transmission due to two main reasons. Firstly, power is generally transmitted over long distances to load centers. That being case, the installation costs for underground transmission will be very heavy.

Secondly, it is very difficult to provide proper insulation to the cables to withstand or to be transmitted at high voltages. Therefore, the use of overhead lines is more suitable for long distance power transmission.

With the growth in power demand and consequent rise in voltage levels, power transmission by overhead lines has assumed considerable importance, and in advance schemes are being proposed to the new dimension that could be added to the potential application of established wire line infrastructure.

On the other hand, the overhead lines do have some issues of its own due to the reason that overhead lines are exposed to all kinds of weather conditions and other external interferences. This calls for the use of proper mechanical factors of safety in order to ensure the continuity and security of operation in the line. In general, the strength of the line should be such so as to provide against the worst probable weather conditions. [1].

The operation of an overhead line may rely upon the mechanical design of the line. Accordingly, the construction should be ensured possess the main components towards the probable weather condition any other risk.

To deliver this issue, this paper represented a network design for powerline control; that allows the wireless network to communicate and transfer information between a drone and some mobile station in the

ground. We briefly formulated investigations of the potential design and implementation of powerline control within Russia and Mexico. This includes:

- The system of overhead powerline control in commerce industry.
- The design of the wireless network for the powerline control task.
- How it works in Mexico and Russia.

1 ORGANIZATION OF A NETWORK IN THE BUSINESS PROCESS OF AN OVERHEAD POWER LINE CONTROL

Electric power can be transmitted or distributed either by means of underground cables or by overhead lines. The underground cables are rarely used for power transmission due to two main reasons. Firstly, power is generally transmitted over long distances to load centers. Obviously, the installation costs for underground transmission will be very heavy.

Secondly, electric power has to be transmitted at high voltages for economic reasons. It is very difficult to provide proper insulation to the cables to withstand such higher pressures. Therefore, as a rule, power transmission over long distances is carried out by using overhead lines. With the growth in power demand and consequent rise in voltage levels, power transmission by overhead lines has assumed considerable importance.

The overhead lines are exposed to all kind of weather conditions and other external interferences. This calls for the use of proper mechanical factors of safety in order to ensure the continuity of operation in the line. In general, the strength of the line should be such so as to provide against the worst probable weather conditions. [15]

1.1 Power line control task

Power line is used as a channel for transferring information and control signals. The basic principle in transmitting data through PLC (power line communication) consists in superimposing a high frequency signal that is message signal (1.6 to 30 MHz) at low energy levels over the 50 Hz electrical signal [1]. This second signal is transmitted via the power infrastructure that can be received and decoded remotely. Thus the transmitted signal is received by any PLC receiver located on the same electrical network. In order to transport the PLC signal on electrical wiring, the line frequency (for example, 110 V/60 Hz) of the electrical circuit is supplemented by a modulated signal of low amplitude around a center frequency (carrier frequency).

To transmit electric power from a small number of sources (the generators) to a large number of sinks (consumers) in the frequency range of 50-60 Hz power lines were designed.

Electrical power lines are usually classified into the high (>100kV), medium (1-100kV) and low (<1kV) voltage network.

Systemic effects for the energy system as a whole classified into 3 areas:

- The technological process production, transport and consumption of electricity and power
- The relations of economic entities in the energy sector
- Work of the wholesale electricity and capacity market

Effects in terms of influence on the technological process development and the consumption of electricity and power are as follows:

- Increasing awareness of the power grid of the state electric grid and as a result a more precise analysis of the risks of a particular mode of overhead lines, and the ability to predict more accurately determine the boundaries of the possible weighting regime as an overhead line and power system as a whole;
- Increase the reliability and security of power supply to consumers in terms of reducing the risk of occurrence and development of system failures at failure of the system and intersystem overhead lines and cross-sections.
- Reduction of time eliminates the consequences of outages overhead line, location and reasons for disabling the HV, expert analysis of the possibility of continuing the work of the HV without repairs.
- It's a tool for more information on the progress of an accident.

The effects of the improvement in relations between economic entities in the energy sector are as follows:

- There is a technological basis for more precise (instrumental) and formalized to build relations between the branches of power grid distribution network level companies, interconnected systems, the Federal Grid Company and System Operator in part justify the adoption of certain technological and economic decision-making, including in terms of justification investment programs.
- There is an opportunity to create a more accurate GIS system for the power system as a whole, which may in future be imposed data of heating system, and possibly road and rail transport.
- There is an opportunity to more accurately prepare the terms of reference as a technical service and repair of the HV by contractors, as well as in the calculation of the amount of clearing firebreaks, which will build a transparent relationship with the contractors.

The effects in terms of impact on the operation of the wholesale electricity and capacity market are as follows:

- The work of the network infrastructure has a direct impact on the price of electricity and capacity on the wholesale electricity market, both in the sector of the market day-ahead, balancing market, and in terms of market of bilateral contracts, affecting the price of network constraints specific site electrical network, the project gives the possibility of more accurate accounting of the state power grid infrastructure and forecasting of possible technological risks, operating capacity of individual actors of the market strength of the market, depending on market conditions.

1.2 The main elements of an Overhead Power Line

Overhead power lines are the infrastructure for electrical power transmission and distribution along the large distances, the device is outdoors installation and consists of traverse (brackets), insulators and other supporting structures (bridges, overpasses). Overhead power lines passes from one electrical substation (PC) to another. Figure 1.1 displayed the scheme of the terminal pole and an electric power substation.

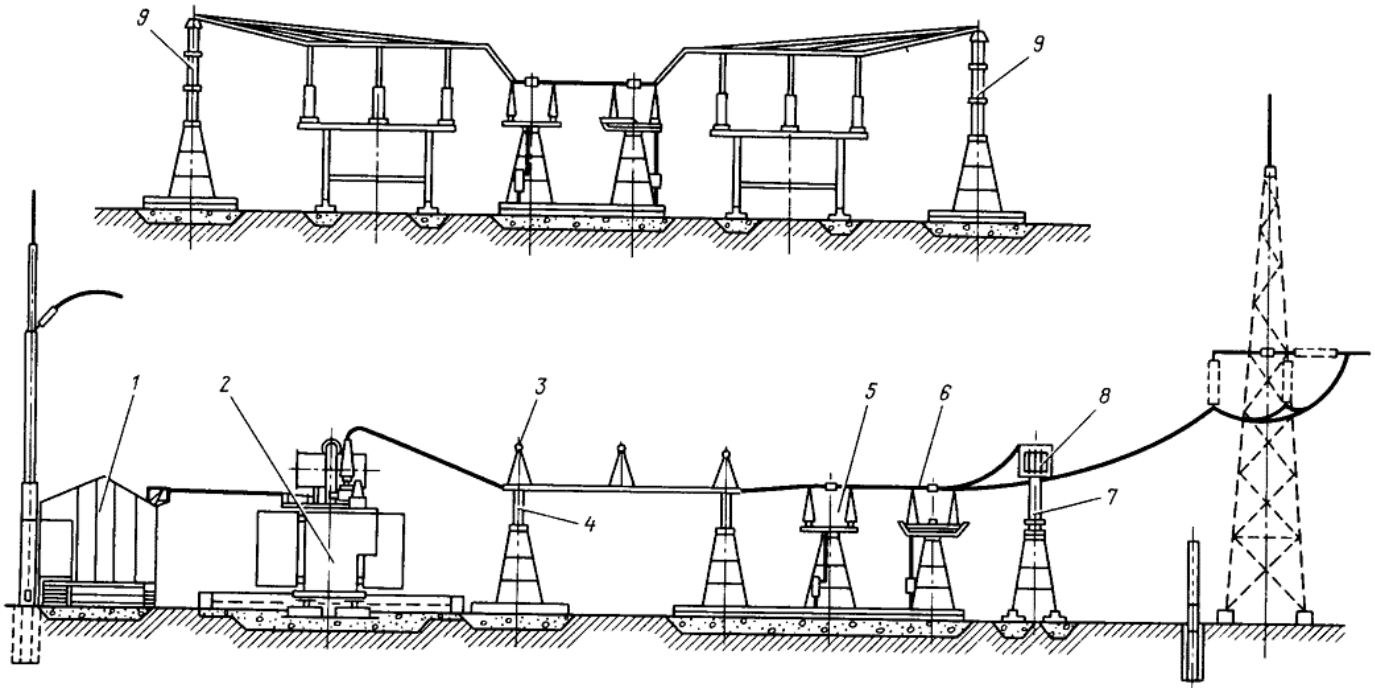

Figure 1.1 – Scheme of the terminal pole and the electrical power substation

In most cases, a good design for a high voltage overhead lines are to consider the positive attributes of the site also the possibility of the overhead lines to be worked upon maximum benefit and to enhanced in the development. To understand the essential components of the electricity equipment that is going to be dealt with and its impact on master planning exercise it is indeed a necessary. Overhead power lines consist of three main components:

- Terminals (also called anchor towers)

  Terminals or anchor towers are the most significant and visually dominant component of overhead power lines. They should be the main object of efforts to decline the visual impacts of the overhead power lines on development land. Though not all pylons are the same, typical overhead line route uses three main types of terminal:

  - Suspension towers which support the conductors on straight stretches of line
  - Deviation towers at points where routes change direction.
  - Terminal towers where lines terminate at large substations or are connected to underground cables at a sealing end compound.

- Lines (also called ‘conductors’ or ‘wires’).

  Lines or wires and terminals ultimately form a composition with a collective visual impact. However, the lines are a finer and less substantial part of that composition. The number of conductors on a circuit will depend on the operating voltage and load carried by a circuit, with up to four conductors forming a phase, with three phases per circuit and typically two circuits per overhead line route at high voltage.

- Transmission route (also called grounding wire).

  Routing practice for new high voltage overhead lines is to route in straight lines and turn corners as few times as possible. Where an overhead power line changes direction, this results in the need for bulkier deviation towers and a potential view of more pylons and more lines. By running in straight lines the overall visual impact of the transmission route is reduced.

Whilst the terminals and overhead lines are often the most distinct and memorable part of the transmission route, the quality of the land through which it passes contributes to its distinctiveness, visual impact and overall perception. The form and layout of development adjacent to the transmission route should

aim to diminish the visual impact of the high voltage overhead lines and promote the highest possible environmental quality. [25]

In figure 1.2 displayed the structure of overhead power lines circuit support. In figures 1.2 а-в displayed single-circuit single intermediate bearing, with and without braces. In figure 1.2.г-е displayed one double-chain, one three-phase system– and double-circuit support. In figure 1.2.ж-к represented the options for the intermediate and anchor supports.

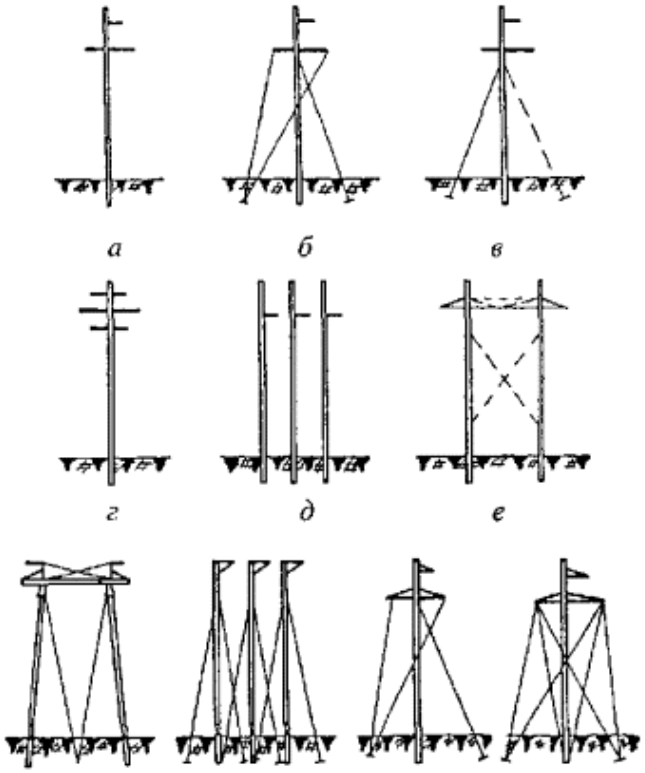

Figure 1.2 – The types of overhead power lines towers

For alignment of overhead power line used three types of supports: Terminal, transitional and anchor. The terminal supports are placed at the ends of the overhead power line and serve for the electric power substation approach. A characteristic feature of the intermediate supports is the lack of the rotation angle of the overhead power line alignment, suspension as a power wire and also as ground wire through the supporting clamp.

The design of anchor towers provides turn route overhead power line at a corner, that leads to additional mechanical loads and strengthen the structure of anchoring the power wire and grounding wire. In the operation of the supports is important to maintain a constant tension of the wires and cables to prevent short circuits.

In the process of the supports operation, it is important to keep the tension of wires and cable to prevent short circuit between the phases and the ground. Figure 1.3 and 1.4 displayed; the respectively clamp grounding wire and power wires' support, the intermediate and anchor support.

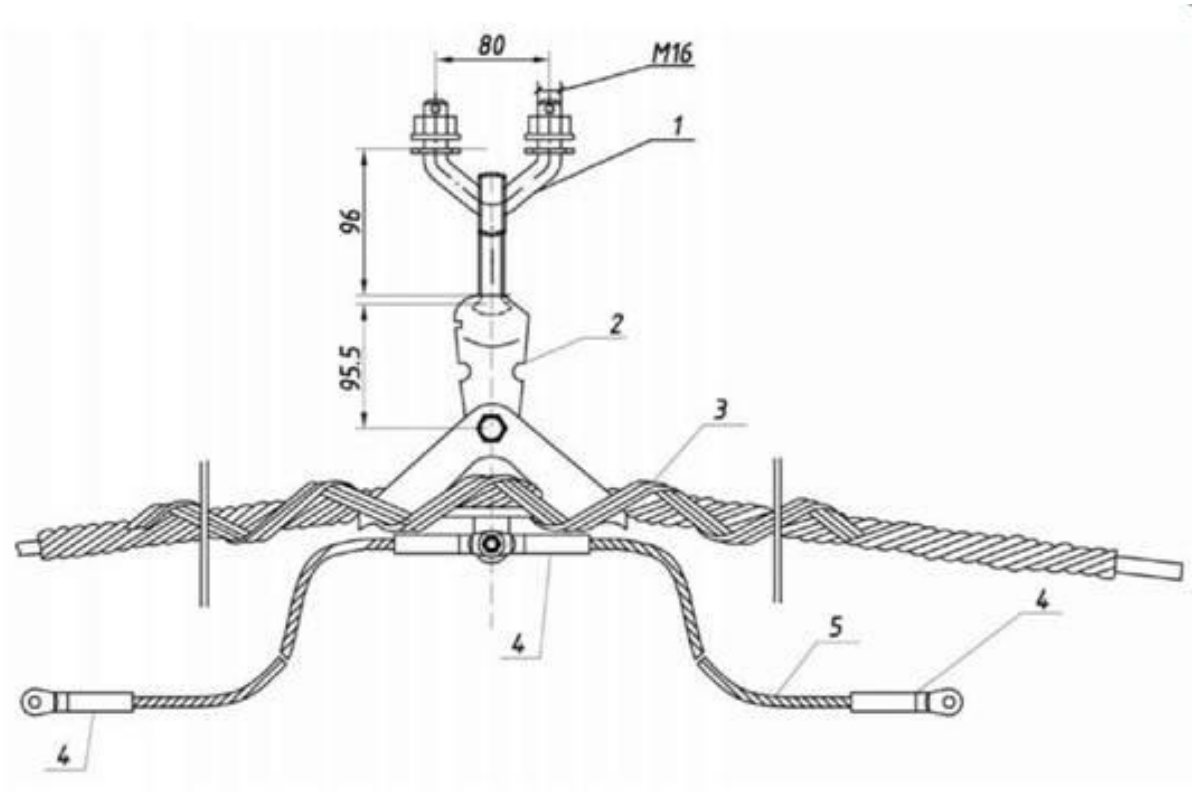

Figure 1.3 – Suspension clamp grounding wire and power wires, the intermediate support

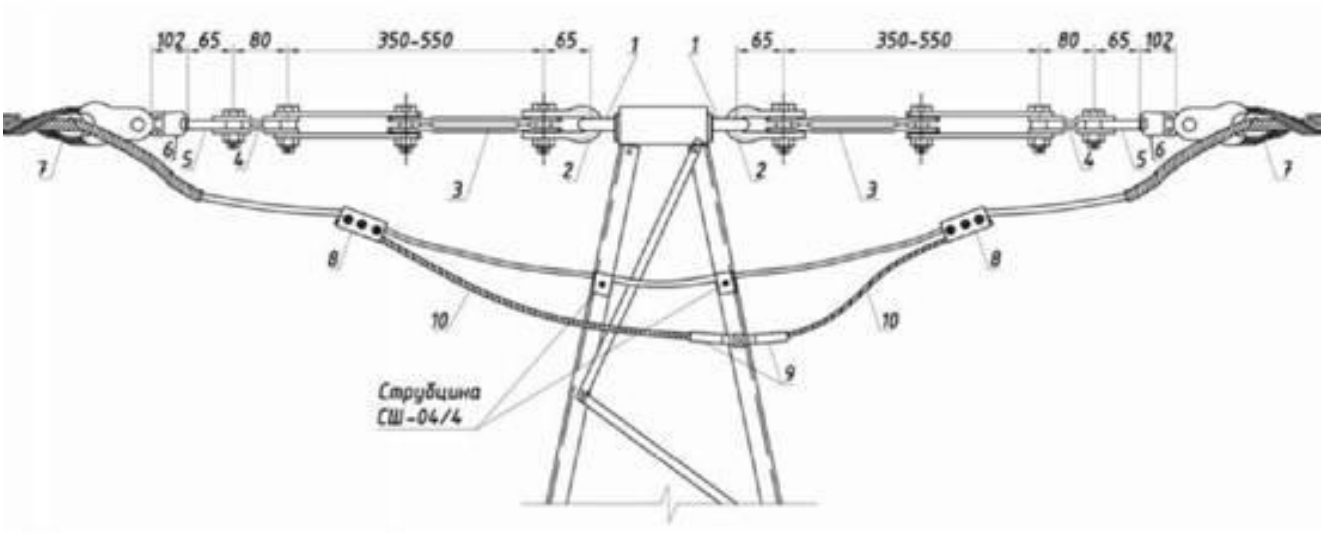

Figure 1.4 – Anchor fasteners grounding wire anchor supports.

The most commonly used conductor material for overhead line is steel-cored aluminum (figure 1.5.). The power wiring lines above 110 kV may have a phase splitting into two or more wires in order to reduce crown losses, associated with the crowding-out effect of charges beyond the conductor due to the high electromagnetic field strength.

Figure 1.5 – Construction ground wire C-35 (top) and the power of AC-120 (bottom)

The anchor support of overhead high-voltage transmission lines, usually it represents a welded metal construction with suspension insulator strings, which are attached to the power wires through a special clamp.

There are several types of insulator but the most commonly used are pin type, which is correlated to a considerable extend upon the proper selection of insulator. Causes of insulator failure. The breakdown of the insulator leads to breakage and short-circuit to the power lines that will disable the overhead power line, triggering automatic reclosing and re-tripping the overhead power line.

Semi-flexible overhead power line tower, are usually a welded metal or reinforced concrete structure with suspension insulator strings, which are attached to the power wires through a special clamp. A guyed tower is designed for overhead grounding wires to support the structure and unbalance tension load from the conductors, which is more safety and saves time. Therefore, monitoring of metal elements in overhead power line cannot be performed to the necessary extent without the use of means and methods of remote and automated control. Remote device is needed in cases of control elements and units of equipment, direct access to which is excluded either due to high voltage electromagnetic fields, either due to design features of

the equipment. In places with limited time of stay of the staff's possible use of automated and mechanized devices to minimize the threat to life and health due to the reduction of execution time control.

1.3 Typical defects on overhead lines

80% of incidents in the work of overhead power lines are caused by mechanical damages or defects of the metal elements of the overhead power lines. The main causes of developing defects and failure of metals can be divided into three groups:

The first design deficiencies are related to errors in calculations, wrong choice of materials that would be used, constructive solutions, short comings of existing calculation methods.

The second is the imperfection of production technologies and installation of equipment, the skipping of invalid defects control at the factory and during installation.

The third performance, associated with deviation from the design parameters of the equipment, fatigue phenomena under the influence of high voltage electromagnetic fields, temperature, corrosion environment, etc.

Currently there is a large amount of data about detected defects of the metal on various items of overhead line, both in Russia and abroad. Research presents data on the defects of metal on the overhead power line of the Ural branch of main power networks of federal grid company specifies that the cable ground cracks formed on the surface and spread into mainly where there was a small damage. In many cases it was possible to establish that the initial causes of the cracks were small defects: tears, nicks, dings, small pores.

The main reason for the damage of lightning-protective cables for overhead lines is its breaks as a result of long use (20-25 years), when it is corrosion and it loses its initial mechanical strength during low temperature (below -5 deg. C) and wind loads – breaks.

The power wires in the overhead power line are damaged mainly in contacts (the connector in the Bay and in the loops of anchor supports) due to the flow on them the limiting current loads and short circuit currents. Have a damaged wire near the stretch and supporting clamps due to vibration of the wires (especially where the project is not provided, the vibration dampers). In this vein aluminum wire gradually break, wire in this place begins to warm up from the load current and, eventually, burnout. Also have the injury individual wires, aluminum wires, for the reasons (direct lightning strikes to the wire, hooking the wires can carry oversized loads, falling trees from the side of the road on the wires, etc.).

Table 1.1 contains a list of the specific damages elements of overhead power line.

Table 1.1 – Specific damages elements of overhead power line

Type of equipment	Types of defects
1	2
Line fittings	Cracks in the valve overlap or deforms the taper on.
	Damage to the protective horns
	Damage to shielding rings
	Invalid wear reinforcement
	Invalid corrosion of reinforcement
	non-project reinforcement
Wire and ground wire	Impingement
	The presence of broken or burned out wires.
	Disajustment of wires phases
	Disajustment of wires in the same cleft of the phases
	Corrosion of wires and cables
	Damage the wires and cable at the terminal
	Damage to wires and cables at the remote recognition
	Damage /employment quenching dance and custom clutch
	The lack of vibration
	The displacement of the vibration
	The absence of quenchers dance
	A crack in the body of the lighter or of a connector
	Improper installation of the clamps or coupling
	Signs of overheating of the contact clip (United)
	The absence of bolts and washers
	The hood wire from the clip or connection

Continuation of the table 1.1

1	2
	The approach of the loop to the elements of the anchor and carbohydrates supports
	Loose wire to pin insulator
	Slippage of wires in the mating
	The availability of custom clips
	Welding defects
	The fault loop of ground wire
	The fault loop wire
	Changing the arrows of SAG
	Changing the distance from wire to the ground of the objects
Ground	Failed control connection of grounding from phone support
	Exceed beyond permissible means resistance
	Missing brackets attached grounding descent
	The destruction by corrosion of grounding device
	Protrusion of the wires above the ground
	Uncomfortable contact in the connection of ground wire to ground later
	The lack of grounding
	Detached grounding beam of the grounding conductor
	The resistance of the grounding device above the permissible
	The correction of the grounding device above the regulatory
Insulators	
	The mechanism of damage to the porcelain or glass isolates
	Traces of ceiling lights and stay insulator

Continuation of the table 1.1

1	2
	The presence of defective (unusable) insulators
	Contamination of insulators
	Incorrect nozzle pin insulators
	Wypalania rod from the head of the insulator
	The presence of bent rods insulators
	No screws, locks or cotter pins
	Corrosion of rebar and caps of insulators
Support	
	The presence of vegetation on the land allotment under a support
	Defects of bolted, riveted joints
	The lack of numbering and posters
	Defects of welds
	The rotting parts of wooden supports
	The lack of supporting elements
	Corrosion wear of the structural element
	Corrosion wear is the main working element
	The weakening of the support braces
	The weakening of the internal bonds
	The weakening of bolt connections
	Corrosive wear braces supports
	The presence of bird nests and other items
	Corrosion wear of steel structures, reinforced concrete pillars
	Damage to the support braces

Continuation of the table 1.1

1	2
	The presence of ice deposits
	Violation of attachment of the braces to the Foundation and support
	Disadvantages length cutting of bolts on wood support
	Faulty mounting of parts of wood support
	Faulty devices adjusting the length of braces
	Substandard mounting brackets to wood support
	The erosion and splitting of parts of wooden poles
	An open, loose wire gang on the wooden poles
	Deviation of support across the axis OL
	Deflection of the support along the axis of the overhead line from the project package
	Deviation of support across or along of the axis OL
	Deflection of the support struts from the vertical axis along the alignment OL
	Deflection of the uprights of the supports from the vertical axis across the course of OL
	The absence of bolts and nuts on wood support
	The lack of fences supports OL
	The lack of alignment stands and footrests support
	The lack of dowels and wedges on wood support
	Damage of the upper end concrete counters
	Damage to fixings concrete counters
	Damage and weakening of the internal connections concrete supports
	Transverse cracks concrete counters

Continuation of the table 1.1

1	2
	The deflection of the strut or brace metal supports
	The deflection of the chord angles of the metal supports
	The deflection yoke metal and concrete poles
	Longitudinal cracks concrete counters
	The destruction of the reinforced Concrete consoles
	Shell and holes on the Concrete counter
	The slope of the traverse on a support
Surge protection	
	The discrepancy between the external value of the spark gap tasks
	Bad consolidation horns arresters
	Improper installation of the arrester
	The ingress of moisture into the arrester
	Wrong location of zones of surge arrestor
	Pollution discharger
	Cracks and damage to the varnish bit
	The removal of the arrester from the design position
	The absence or malfunction of pointers triggering the development
	The presence of reflow on the electrodes of a spark gap
Routing and security zone OL	
	Availability under the wire. in protection zone of high voltage overhead lines for the test sample
	The presence ceased to pay is not canceled in the passport and database
	The presence of trees threatening to fall on wires

Continuation of the table 1.1

1	2
	Insufficient width of the clearing on the track OL
	The vegetation on the land reserved for the support
	Production work in Security zone OL without the agreement with the European Union organizations
	The presence of overlap of objects a violation of the overall
	The lack of access roads, bridges, crossings
	The lack or failure of part of roads, bridges
	The lack of fences supports OL
	The lack of signs at crossings
	Absence of prohibited signs, information symbols
	The presence of fires in the protected area near OL and OL
	Flooding of the plots of OL
	The presence of washouts, gullies near the Foundation
	The lack of protective structures against ice
	The lack of protective structures against erosion.
	The lack of protective structures Pescuitului
	Fire situation on the road OL
	The presence of dry vegetation in Security zone OL
	The presence of flammable materials in Security zone OL
	On the track overhead line (under wires) Monetary control above 4m
	The presence of discordant buildings
Foundations	
	Erosion of the Foundation soil
	Watering ground

Continuation of the table 1.1

1	2
	Insufficient depth of foundations support
	Insufficient penetration of the uprights supports
	Insufficient penetration of reinforced Concrete consoles
	The lack of embankment (stools)
	The lack of improper installation of the crossbars
	Unsatisfactory. compaction of soil during the installation
	Roll and offset of the basement
	Land subsidence
	Swelling of the soil
	Settling of foundations
	Buckling of the Foundation
	Kink pillar of the Foundation
	Cracks in concrete Foundation
	Sinks, cracks, holes in concrete pillars
	Chips, destruction of the foundations
	The state seal concrete pillars
	Loosely fit the heel support to the rotary Foundation
	The discrepancy between the anchor nuts anchor bolts
	Welding of anchors hook bolts instead of nuts
	The lack of nuts on the anchor bolts
	The presence of erosion soil erosion near the Foundation
	Wear anchors

Continuation of the table 1.1

	The lack of U-bolts
	The state of anticorrosive coating of U-shaped bolts
	The condition of the anchor plates
	The lack of protection of the Foundation

Disabling the overhead lines due to insulation failure are mainly taking place in Grosseto. The overlap of garlands when storms arise will generate the destruction and release of insulators. This occurs when there is a bad connection to ground or lack of support.

Figure 1.6 given a sketch diagram of a typical emergency situation on overhead line 110 kV open power line.

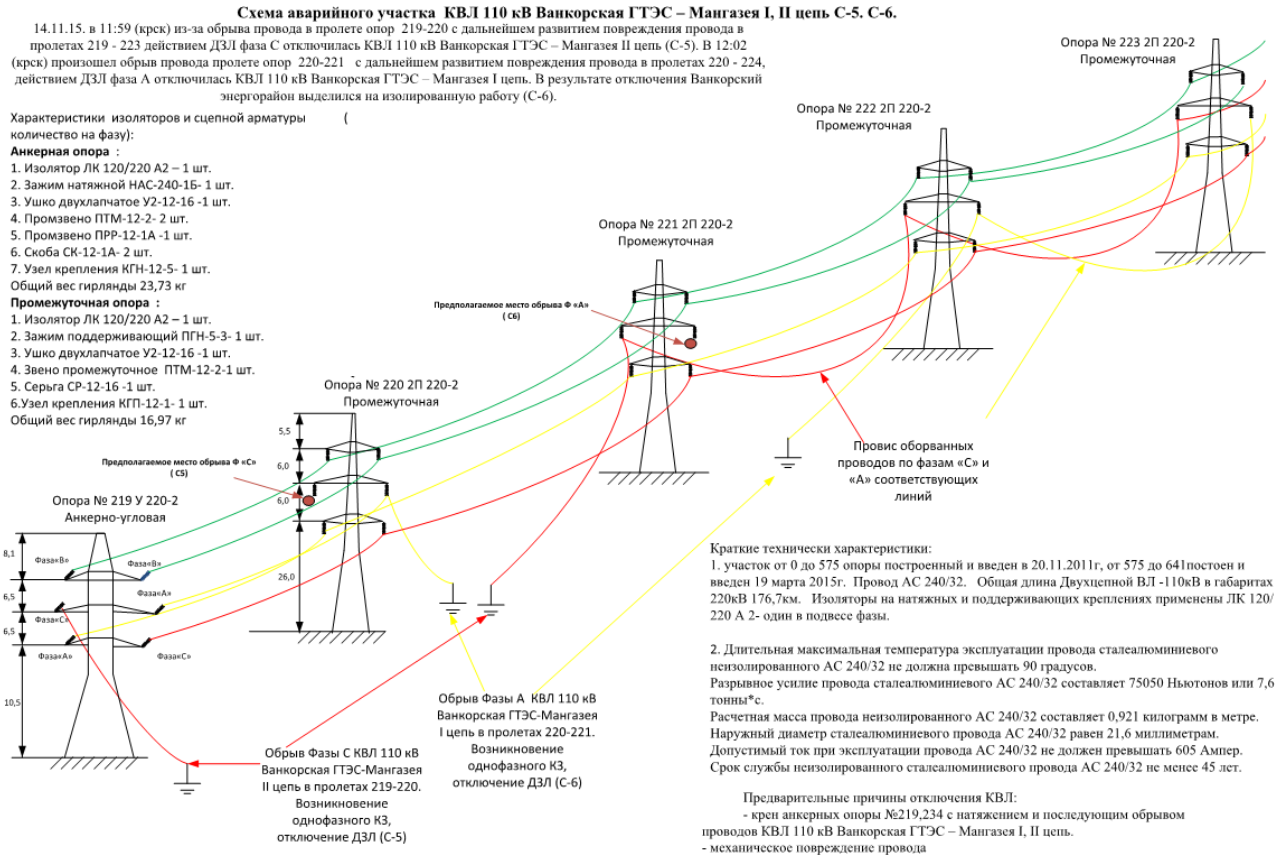

Figure 1.6 – Typical emergency on OL (Public joint stock company "Oil company Rosneft"

Accumulated operating experience overhead line shows that the appearance of defects in the metal elements of the overhead line is an accident, but rather a pattern. These defects (damages) do not arise suddenly, and evolve within a certain time. Therefore, periodic inspection of the metal is effective in preventing unplanned downtime and accidents in electric networks. The greatest concern is the state of metal power wires and grounding wire, because their failure can lead to system crash.

Currently, it has accumulated considerable experience in the use of methods of non-destructive monitoring of metal equipment on high-voltage overhead transmission lines. Apply methods of radiography, ultrasonic testing, infrared thermography, UV scan (to assess crown), eddy current inspection, widely used visual inspection. However, the conditions of performance of works on monitoring of the metal functioning elements of overhead line, as described above, is significantly different from the conditions of carrying out of similar works on the disconnected overhead line.

It is primarily determined by the presence of overhead line in a strong electromagnetic field, whose source is a power wire through which passes an electric charge and other equipment from induced

electromagnetic field. In this regard, the staff being in the vicinity of this equipment without acceptance of special measures of protection or totally excluded or very limited on time. Therefore it is not always possible to use in existing overhead lines of the same methods of control that disabled overhead line, since almost all control is performed manually. The use bulky means of protection from electromagnetic fields are not always justified, and often simply impossible. In the figure 1.7 give the existing scheme of control state elements in overhead line.

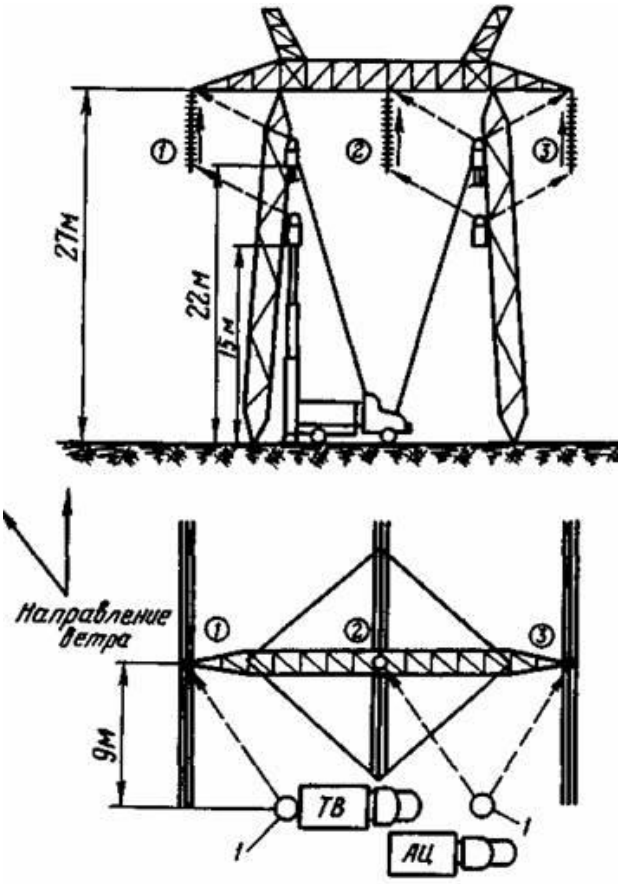

Figure 1.7 – The scheme of control the state of elements of overhead line

Based on the analysis of various non-destructive methods for performing periodic surveys of the condition of the metal elements of overhead line can be formulated as basic requirements for an ideal method of control from the existing overhead line:

- Method to control without breaking.
- Be insensitive to background electromagnetic field.
- Provide remote and automatic control.
- Provide high sensitivity and resolution.
- Ensure the control of all the section elements of overhead lines.

- Provide control in all weather conditions, including rain, hail, snow, ice, wind, and other similar conditions.
- Use different methods of control within a single scanning system.
- To provide the ability to store, quickly locate and reproduction of the results of the inspection.
- Not require careful preparation of the surface under control.
- To ensure the highest efficiency.

1.4 Technologies comparative

It is noted that with the currently available nondestructive methods, the most suitable for performing periodic inspections of metal elements of overhead line are remote visual inspection, magnetic control with remote control, thermal control, and ultraviolet scanning. In most countries, for the automated control the magnetic method was adopted, although the cheapest method is the ultrasonic test

First remote control was applied in 2003 for a survey of the individual elements of overhead line in Canada and in the UK. The scanning device consisted of a cart that was installed on the power wire and move the ultrasonic probe along the power wires overhead line. The first mechanized scanning device for monitoring the condition of elements of overhead line was developed by Hydro-Québec Research Institute (IREQ) for the enterprise of electric networks of UK. It is shown in figure 1.8. Further development of remote monitoring has been in two directions: installations for the movement on the power wire – "crookedy" and install airborne – "helicopters". [11]

Figure 1.8 – Device Line Scout on overhead line

In the control settings for movement on the power wire as a reference plane for installation of the scanning system used on the overhead line plot the power wires close to the support, where with the help of lifting equipment is installed the device. Travel device "trashed" includes three wheels and two movable pinch wheels, engine, drive system, battery, vehicle engine control. For visual control units can be fitted with television cameras. Scanning modules installations contain a large number of transducers for monitoring the wires and elements of overhead line. For example, the Canadian installation consists of 5 inverters. The signals from the transducers are recorded in a memory of the onboard computer, and a ground control station with display and controls.

A method of aero diagnostic set up air-based high-voltage transmission lines, which consists in registration of electric high-frequency pulses near a power transmission line using the electromagnetic sensor and connected to a digital oscilloscope during the flyby overhead lines along the route. The measuring

instrument is moved along the route of the transmission line by means of automatically controlled small unmanned aerial vehicle. During the flight measure magnetic field strength with the help of sensors located at the ends of the wings of the aircraft, calculate the average value of the field strength and use it to automatically maintain the vertical position of the aircraft relative to the wire of the power line. The position of the aircraft along the route automatically support, acting on the keel, on the basis of the difference of the measured intensities of the magnetic field. Measurement information and current coordinates of the aircraft, obtained with the aid of Global Positioning System or Global Navigation Satellite System navigators recorded in the memory of the portable computer located on Unmanned Aerial Vehicle.

Another type of installation to monitor the status of grounding wire overhead line is a Russian plant INTROS (producer by "INTRON). Installations of mechanical stretches along the grounding wire, and scans of his condition through the guidance of the electromagnetic field and remove the residual tension, was designed to check a steel rope but it can be used also for the inspection of Aluminum Conductors Steel Reinforced conductor core. It consists of the portable Basic electronic Unit and the set of Magnetic Heads for various types of ropes/conductors (objects under test) and for the range of diameters. [20]

All of these settings are fairly complex and bulky structures. They are usually designed to control the state of elements of overhead line of the same nominal voltage. Transportation of such installation from one overhead line to another, and from one anchor post to another, since the device does not require the crossing of anchor supports is quite a difficult task.

In domestic practice to control the state of elements of overhead line are used; the examination and horse inspection. ; Inspection involves the movement of the installation crews along route overhead line with fixing visible defects using photo equipment, video equipment, sometimes a thermal imaging camera and the ultraviolet scanner. Overhead inspection of overhead line involves the personnel hoist to a support by visual inspection and fixing materials, using photo equipment, video equipment, sometimes a thermal imaging camera and the ultraviolet scanner.

Separately should be noted the installation, the basis of the mechanism of remote scanning of which is controlled self-propelled transport modules. Attempts to use such devices were made as we have in the country and abroad. Similar devices were developed and applied to the welding technique. However, the uses of self-propelled transport modules are insufficiently developed. Not resolved a number of issues relating to secure movement by a steel rope at a considerable angle, sufficient maneuverability, the possibility of transition as a bushing, and through the anchor supports of overhead line, the ability to install the device on a support and dismantling without involving cumbersome lifting equipment. The creation of such devices is a

highly relevant task, as these modules allow you to create a versatile compact, simple and mobile unit for remote and automated control of the status of the different elements of the overhead line.

Process control in the General case can be divided into 2 stages:

- Search (discovery) of the defect;
- Evaluation of the size and determination of the nature of the defect.

In order for the defect (inconsistent) was discovered, the following conditions are required:

- The defect must fall within the zone of effective action of the scanner;
- The size of the defect must exceed a certain level;
- The defect must create in the direction of the receiver signal is equal to or exceeds a certain level.

In addition to the above, for the detection of defects affects the status of the scan system, the condition and the shape of the surface of the controlled element overhead line, the reliability of electronic equipment etc.

Thus, the search process is to establish energy contact between the test inconsistent, the dimensions of which exceed the minimum allowed, and a signal receiver. To the power contact could be made, the scanning of all items controlled items will be overhead line, which a priori may have defects. The trajectory scanning of the scanning system, consisting of sensors, transducers and controller depends on the surface shape and geometric dimensions of the element of overhead line and other parameters. The most detailed questions on manual scanning of grounding wire.

The transition through the obstacles on the ground cable and support the cable clamp to the overhead line can be implemented on the principle "displacement" of the transport module by controlling the center of gravity of the module and consistent transfer of weight to the device to bypass certain obstacles. The number of positioners included in the system is determined by the number of wires in phase of overhead line, the thickness of the controlled section of the wire. Therefore, the disadvantages of this control method include the complexity and awkwardness of manipulation of the system, the need for special switching devices or a large number of independent clips.

The same weakness has a way of overcoming obstacles in the form of a console, able to move beyond the obstacle and to capture the power wires or grounding wire and pull the remaining part of the self-propelled module, like in the Figure 1.9 are shown. [24]

Figure 1.9 – Expliner Device

Promising is the use of automated control of Unmanned Aerial Vehicle. In this case, one transport module of the Unmanned Aerial Vehicle with the scanning system without transverse displacement can scan the metal cable and other elements of the overhead line. In this case, you do not have to overcome obstacles as it is possible to carry out contactless circled overhead, using the lifting force of the Unmanned Aerial Vehicle.

The rise of the Unmanned Aerial Vehicle is performed with a pneumatic catapult, flight altitude is about 60 meters, cruising speed reaches 100 km/h, and landing by parachute it is made with a shock-absorbing cushion like in the figure 1.10 are shown.

Figure – 1.10 Machine Ptero CM

Consider a helicopter type unmanned aerial vehicle, which is a four propeller helicopter with auto stabilization. It consists of housing with guides that are offset by 90 degrees in the same plane with the length of nearly one meter on each rail, an electric motor, provides power from the battery and electronic control system. The scanning elements of overhead line are carried out by successive flyby and contactless fixing of a scanning system of each object with video cameras, thermal imager and other equipment like in the figure 1.11 are shown.

Figure – 1.11 Aibotix drone

On the basis of the above arguments, it is necessary to achieve high control performance to increase the number of "steps" per unit of time. This can be achieved a sufficiently high scanning frequency plots between the supports and a significant acceleration of time to bring the installation to a working state and operational transition through obstacles, such as support clamps and anchor fasteners. It is important to be able to search on the assessed level of control, as excluding as the pass of unacceptable defects, and the inspection result. [23]

At high wind speeds ensuring the sustainability of remote scanning device helicopters for practical purposes is difficult. For this purpose it would be more convenient to use the remote scanning device of the type "Cable Walker", combined with the unmanned aerial vehicle.

1.5 Unmanned Aerial Vehicles

An unmanned aircraft vehicle is an aircraft with no pilot on board. UAV can fly autonomously based on pre-programmed flight plans or more complex dynamic automation system. The autonomy is related to the control algorithms that these vehicles possess to respond satisfactorily when encountering unexpected or random events, during their reference flight missions in. This certain type of vehicles are able to be built with less expensive fund and also with smaller body due to the reason that they are not expected to carry the

weight of a person, with such size the speed or lifting power concentrated on carrying out a mission is undeniably marvelous. UAV is also commonly known as Drone or flying robot, that can be remotely controlled or fly autonomously based on pre-programmed flight plans using complex control systems. Currently, Drones are rapidly growing in the world and considered as a new technology. [9]

Unmanned Aerial Vehicles were most often associated with the military, where they were used initially for anti-craft target practice, intelligence gathering. They are also used, although to a lesser extent, in civilian applications such as fire inspection, monitoring of political events and recognition of natural disasters, mapping, research, photography and others fields; They are also employed on boring or hostile missions to be commanded by a pilot.

The main advantage of this technology is that it can be used in dangerous places and mission without harm the pilot. Drone currently divided into two categories:

- The fixed wings (unmanned aircraft that uses wings)
- Multi rotor (drone that use more than one motor and without wings – more like a helicopter). [2]

1.5.1 Military applications

The most important quality of unmanned aerial vehicles is unmanned flight. This essential feature makes it possible to avoid any possible risk to the pilot, notably in the military domain as well as in missions in hostile areas, as well as in missions where there is a significant psychological load and damage to the pilot: access to high altitudes or repetitive surveillance.

Technological advances help to extend the range of applications of autonomous systems: military actions, monitoring and tracking enemy positions, creating communication links between ground stations for the exchange of information. Military unmanned aerial vehicles applications can be divided into three main categories:

- Patrol and reconnaissance.
- Support for combat.
- Combat.

1.5.2 Civil applications

Compared to military unmanned aerial vehicles, civilian unmanned aerial vehicles do not have the same development as their military counterparts. However, they have a good potential, due to their versatility

and flexibility of operation. There is a wide range of potential applications for civil unmanned vehicles, especially on missions with dangerous or routine characteristics.

The security in this era is something that we hold on to, to ensure such safety wireless network indeed is a major importance. The ability of the wireless network to help protecting the public from a threat and in successfully identifying crimes. The drones itself could also be a great help for securing the public from natural disaster such as a volcano eruption; to see the activities of the magma of the volcano is a crucial importance to gather the knowledge on whether the readiness for the volcano to erupt, and so the help of a drone is needed. Another examples are to see the eye of the storm, the position of it, monitoring landslides, monitoring catastrophes and so on and so forth. [27]

1.6 The robotic system for diagnosis of power lines "Cable Walker"

Live-power lines maintenance is characterized by three main features:

- Works can be carried out over power elements but in any case being in contact with elements of different power degree, like touching simultaneously two lines or a line and the tower
- The work environment can be previously known but not the elements positions and the relation among them.
- The task execution is conditioned by the tower and lines location, which normally is very complex. A proper vehicle for these tasks is therefore required.

The previous aspects determine the development of any tele robotic system. All proposed systems are based on tele operated robots where the human operator monitors, in different degrees, the task execution. So this progress can be seen as a powerful tool that the sector workers can benefit from. [19]

The use of Unmanned Aerial Vehicles for overhead power line inspections has been identified as a viable alternative to aerial manned inspections due to the use of unmanned vehicles which eliminate the accidental loss of life, and they are easily carried to the starting point and can be picked up at the same point at the end of the inspection flight. The advantages of these systems are: significant cost savings, staff safety is guaranteed and improved, Unmanned Aerial Vehicles can hover as close as even 10 meters away from the medium voltage power line, the inspection is documented by video, images and data, reduce the risk for having to pay compensations to customers.

This inspection method allows us to take advantage of the implementation of inspection systems based on preventive and predictive models [13]

In order for the robot to grit-blast autonomously in each position, an up-to-date geometric map of the surrounding environment is provided to the robot such that a plan for grit-stream trajectory and robot movements can be newly generated. At present, there are well-developed approaches for a robot to explore and build an update geometric map of an environment using a depth sensor mounted on the robot's end-effector

For a robot to be capable of selectively grit-blasting specific surface areas, it must also explore and inspect the surface's condition. One possible approach to this is to mount a vision camera to the robot's end-effector and capture images during [7] pre-grit-blasting for identifying specific surface areas to grit-blast based on rust grading, and [6] post-grit-blasting for assessing whether the required steel cleanliness has been achieved or re-blasting is necessary.

A robot can inspect the surfaces in the captured images by using a classifier trained with surface samples from a visual inspection standard such as the rust grading and steel cleanliness visual metrics.

The “Cable Walker” will solve the following issues:

- Comprehensive efficiency of overhead line through the organization of quality maintenance and accurate repairs planning as with the ability to Refine management regime with a view to establishing automatic control technology to the electric grid - the "Smart network 4.0".
- Maintenance requirements overhead line rising, the number of staff does not increase – a growing risk the actual failure of routine procedures and create conditions for the emergence and development of the system crash;
- Overhead line is a complex, physically extended engineering facility, one flight overhead line contains more than 2,000 components that require inspection;
- Disruption of the normal operation of the power system usually occurs due to problems in the network equipment;
- Evaluation of specific value of the stability margin of the power system mode ((МДП – металл - диэлектрик – полупроводник = MIS – metal - insulator – semiconductor) based on the current values of the arrows of SAG (The difference in level between points of supports and the lowest point on the conductor is called sag) of the wire;
- Staffing problems – poor control over compliance with the technologies of diagnostics, low controllability and large complexity at a low efficiency, shortage of the staff.

Require effective means for carrying out complex engineering control by inspection to diagnose the state of the clearing of items overhead lines without switching off.

The solution will be a robotic system that combines flying and a mobile platform capable of docking in the wire or guestroom the overhead line, in order to do that we need to fulfill these requirements:

- The robotic system must land and move along the overhead line.
- We need to manage comprehensive engineering diagnostics from substation to substation that is in a remote mode without disconnecting the overhead line.
- To draw power from overhead wires, in order to charge the robotic system and continue the diagnostics for longer.
- To evaluate seedlings and to build a map of the route overhead transmission lines.
- To clarify the stability margin's value of the overhead line regime (MIS) at the current boom SAG.

The architecture of the cable walker includes transport platform, Diagnostic module, base station, Software

- Transport platform, include flying and wheeled module. Ensures the delivery of the measuring module overhead transmission line
- Diagnostic module Consists of diagnostic devices, an integrated information and management system
- The base station The control communication module, take off platform stabilization
- Software expert system, Software collection and backup, Autonomous management *expert system

Following is presented a schematic diagram of the robotic "Cable Walker"

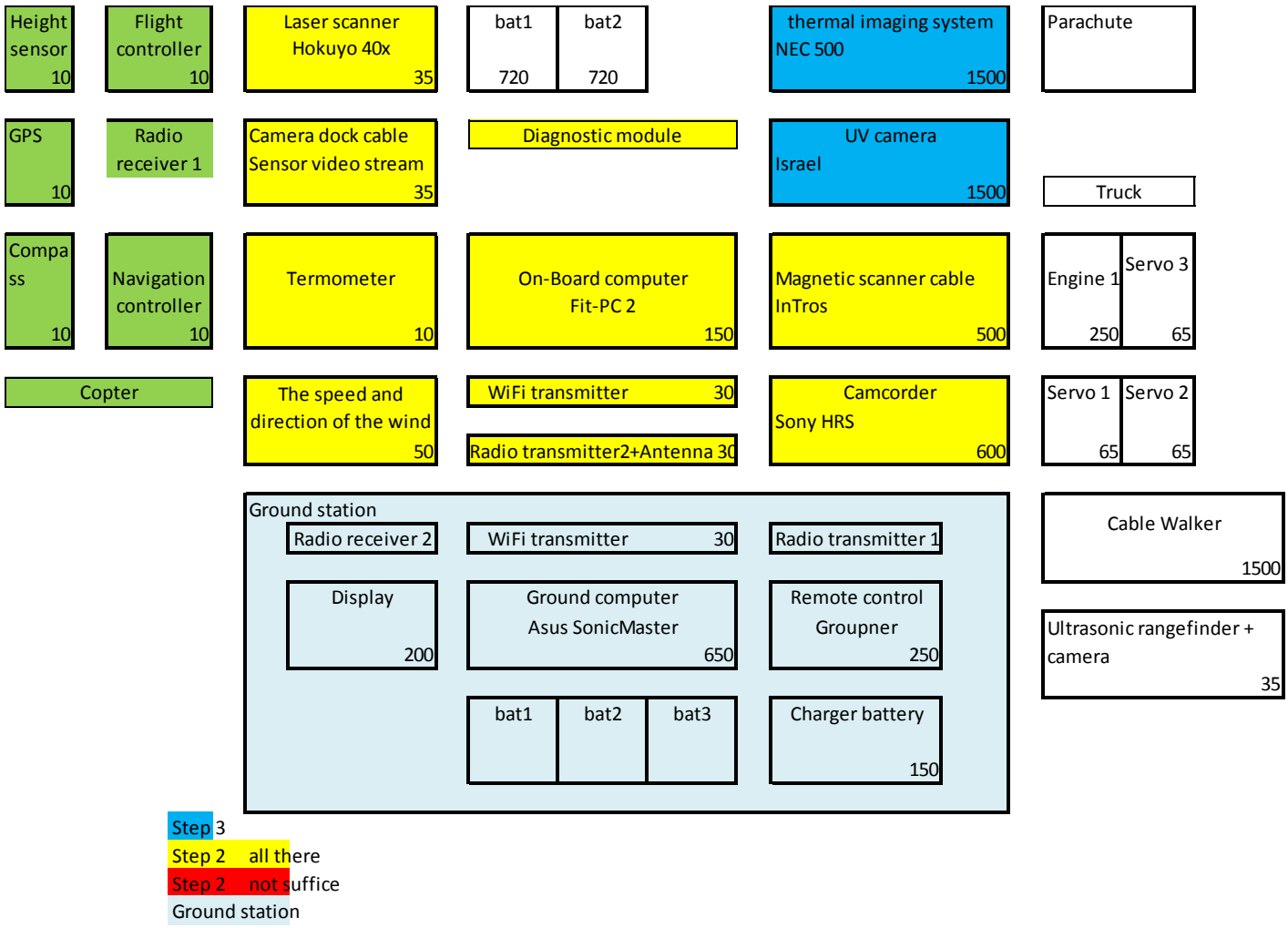

Figure 1.12 – Schematic diagram of the robotic complex

The principal benefits that we will obtain of the creation of the robotic system are the followings:

- The advantage of flying platforms will give us the spatial delivery of the diagnostic equipment without disconnecting overhead line; the figure 1.13 will give us an overview of the flying platform.
- The advantages of wheeled platforms:
    - Low energy loss when moving through the ground wire or the wire of overhead transmission lines.
    - Detailed and quality inspection.
    - No vibration – effective use of the thermal imager, video camera, UV camera.
    - Ability to use contact devices (scanning of ground wire, power wire).

Figure 1.13 – Unmanned air vehicle prototype (patent number 2558002)

The Table 1.2 shows the wires and Groseclose diagnostics task and the table 1.3 shows the routing and security overhead line zone diagnostics task of the cable walker.

Table 1.2 – Cable walker wires and groseclose tasks diagnostics

Wires and groseclose	**Line fittings**
1	2
Impingement	Cracks in the fittings, chafing or deformation
Dysfunctional wires in the same cleft of the phases	Damage to the protective horns
Dysfunctional wires in the same cleft of the phases	Damage shield rings
Dysfunctional wires in the same cleft of the phases	Unacceptable wear of the valves
Corrosion of wires and cables	Unacceptable corrosion of reinforcement
Wires and cables damage at the terminals	Non-design reinforcement
Wires and cables damage from remote schedule	**Support**

Continuation of the table 1.2

1	2
Damaged transfer - the requirement to put out dance and custom clutch	The presence of vegetation on the ground, try under support
Connections contact Control	Defects of bolted, riveted joints
The Vibration is absence or displacement	The lack of numbering and posters
The absence of quenchers dance	Defects of weld seams (visual)
A crack in the lighter or connector's body.	The lack of supporting elements
Improper installation of the clamps or coupling	Corrosion wear of the structural element
Signs of overheating of the contact clip (United)	Corrosion wear is the main working element
The absence of bolts and washers	The weakening of the support braces (visual)
The hood wire from the clip or connection	Weakening internal linkages (visual)
The approach of the loop to the elements of the anchor and carbohydrates supports	The weakening of bolt connections (visually)
Loose wire to pin insulator	Corrosive wear braces supports (visual)
Slippage of wires in the mating	The presence of bird nests and other items
The availability of custom clips	Corrosion wear of steel structures reinforced concrete pillars
Welding defects (visual)	Damage to the support braces
The fault loop of ground wire	The presence of ice deposits
The fault loop wire	Violation of attachment of the braces to the Foundation and support
Changing the arrows of SAG	Disadvantages length cutting of bolts on wooden poles
Change of the distance from wires to the ground, objects	Faulty mounting of parts of wooden poles
Insulators	Faulty devices adjusting the length of braces
The mechanism of damage to the porcelain or glass isolates	Substandard mounting brackets to wooden poles
Traces of ceiling lights and stay insulator	The erosion and splitting of the tree parts support
The presence of defective (unusable) insulators	An open, loose retaining wire on wood pole
Contamination of insulators	Deviation of support across the axis overhead line
Incorrect nozzle pin insulators	The deviation of the support along the axis of the overhead line from the project picket
Wypasanie rod from the head of the insulator	Disability to support across or along of the overhead line axis
The presence of bent rods insulators	To disconnect the support struts from the vertical axis along the overhead line requirements

Continuation of the table 1.2

1	2
No screws, locks or cotter pins	Disability of the uprights supports from the vertical axis across the requirements overhead line
Corrosion of rebar and caps of insulators	The absence of bolts and nuts on wooden poles

Table 1.3 – Cable walker routing and security overhead line zone diagnostics task

Routing and security overhead line zone	**Support**
1	2
The presence of wiring and overhead line in land object perhaps about the experience.	The lack of alignment of the uprights and the foot-support
The presence ceased to pay is not canceled in the passport and database	The lack of dowels and wedges on wooden poles
The presence of trees threatening to fall on wires	Damage of the upper end concrete counters
Insufficient width of the clearing on the track overhead line	Damage to fixings concrete counters
The vegetation on the land reserved for the support	Damage and weakening of the internal connections concrete supports
overhead line production work in Land Object (LO) without consent from EHS organization	Transverse cracks concrete counters
The presence of overlap of objects a violation of the overall distance	The deflection of the strut or brace metal supports
The lack of access roads, bridges, crossings	The deflection of the chord angles of the metal supports
The lack or failure of condition of roads, bridges	The deflection yoke metal and concrete poles
The lack of fences supports overhead line	Longitudinal cracks concrete pillar
The lack of signs at crossings	The destruction of concrete consoles
Absence of prohibited signs, information symbols	Shell and holes on the concrete pillar

Continuation of the table 1.3

1	2
The presence of fires in overhead line Land Object and around the overhead line	The slope of the traverse on a support
Flooding of the overhead line plots	**Overvoltage protection**
The presence of washouts, erosion near the Foundation	The discrepancy means external of the spark gap tasks
The lack of protective structures against ice	Bad consolidation horns arresters
The lack of protective structures against erosion.	Improper installation of the arrester
The lack of protective structures Pescuitului	The ingress of moisture into the gap (visually)
Fire situation on the road overhead line	Wrong location of surge arrestor zones
The presence of dry vegetation in unit overhead line	Pollution discharger
The presence of flammable materials in Land Object of overhead line	Cracks and damage to the varnish bit
On the track overhead line (under wires) LSC (x-ray Dosimeter Control) above 4m	The removal of the arrester from the design position
The presence of dissenters of buildings/structures	The lack or failure pointers of surge arrestor

Operating parameters: The current and voltage phase wire, temperature, humidity, wind speed, boom SAG wire are measured by specific sensors, and example of the measurements are shown in the Figure 1.14 , and in the table 1.4 are show the technical characteristics of the cable walker.

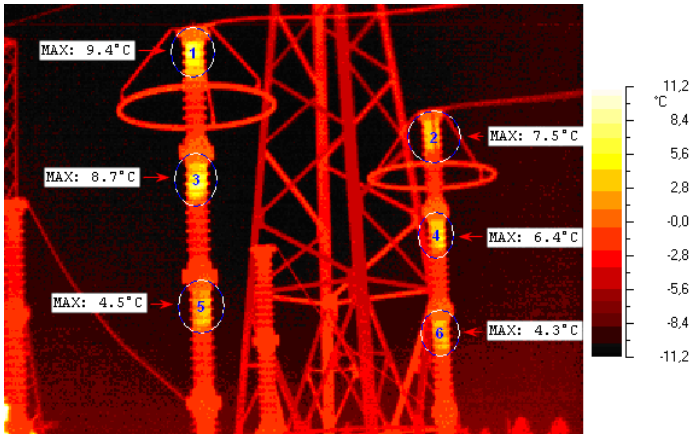

Figure 1.14 – Results of the measurements.

Table 1.4 – cable walker technical characteristics

The type of platform	**№**	**Parameters**	**Value**
1	2	3	4
Average	1	Dimensions, m	0,75x0,75x0,75
	2	Weight	3
	3	Load capacity, kg	3
	4	Sensors	K, T, V, L, I, U, Te
	5	Flight time, min.	30
	6	Range for overhead transmission line	Up to 5 km
	7	Communication interfaces	Radio, GPS, Wi-Fi
	8	The range of communication	According to customer's requirement
	9	On-Board computer	According to customer's requirement
	10	Offline	According to customer's requirement
	11	A rescue mechanism	According to customer's requirement
	12	The charge from overhead transmission line	no
Heavy	1	Dimensions, m	1x1x0,75
	2	Weight	4
	3	Load capacity, kg	7
	4	Sensors	K, T, V, L, Te, U, I, D
	5	Flight time, min.	30

Continuation of the table 1.4

1	2	3	4
	6	Range for overhead transmission line	More than 10 km
	7	Communication interfaces	Radio, GPS, Wi-Fi, GSM
	8	The range of communication	According to customer's requirement
	9	On-Board computer	there
	10	Offline	there
	11	A rescue mechanism	there
	12	The charge from overhead transmission line	there

While: high-definition Camera – K, Imager – T, Laser scanner – L, the Magnetic scanner of Intros – I, And temperature Sensor – Te, The Sensor direction and wind speed – B, In a Device of inspection of the rope (360), Scan the bar – D.

The mayor planned features of the cable walker are shown in the table 1.5.

Table 1.5 – Major planned features of cable walker

№	**Function complex "Kanatoko"**	**Main**	**Auxiliary**
1	2	3	4
1	Shipping measuring module on a running overhead transmission line (energized)	×	
2	Visual (;) inspection	×	
3	Riding inspection	×	
4	Movement on the power wire/ground wire	×	
5	Thermal control	×	
6	UV control	×	
7	Magnetic control of ground wire, core wire of power		×
8	Mobile lab (vehicle diagnostic)		×
9	Takeoff platform stabilization by car (airport)		×
10	The collection of data in a database (library)		×
11	Autonomous management of the complex		
12	Expert system for analysis and classification of defects		×
13	A rescue mechanism in case of failure (an emergency withdrawal with wire, parachute)		×

Continuation of the table 1.5

1	2	3	4
14	*Spot repair (compression of veins, tightening/loosening of bolts, relocation of vibration dampers, spot welding)	×	
15	*Coating (of ice, corrosion, etc.)	×	
16	*Work in extreme conditions (squally winds, high elevation, substantial length, a high risk to personnel, chemical contamination, radioactive contamination)		×
17	Charging from overhead lines	×	

Between the necessity for a Smart Robotic system for diagnosis of high-voltage transmission line "Cable Crawler" are the design of a quadcopter with diagnostic equipment that can dock with the cable and to move it electrically, the figure 1.15 shows the quadcopter making the diagnosis.

This method greatly simplifies the diagnosis process (no longer need to walk several miles through the swamp with binoculars), a much cheaper process, and reduces the risk of mortality almost to zero.

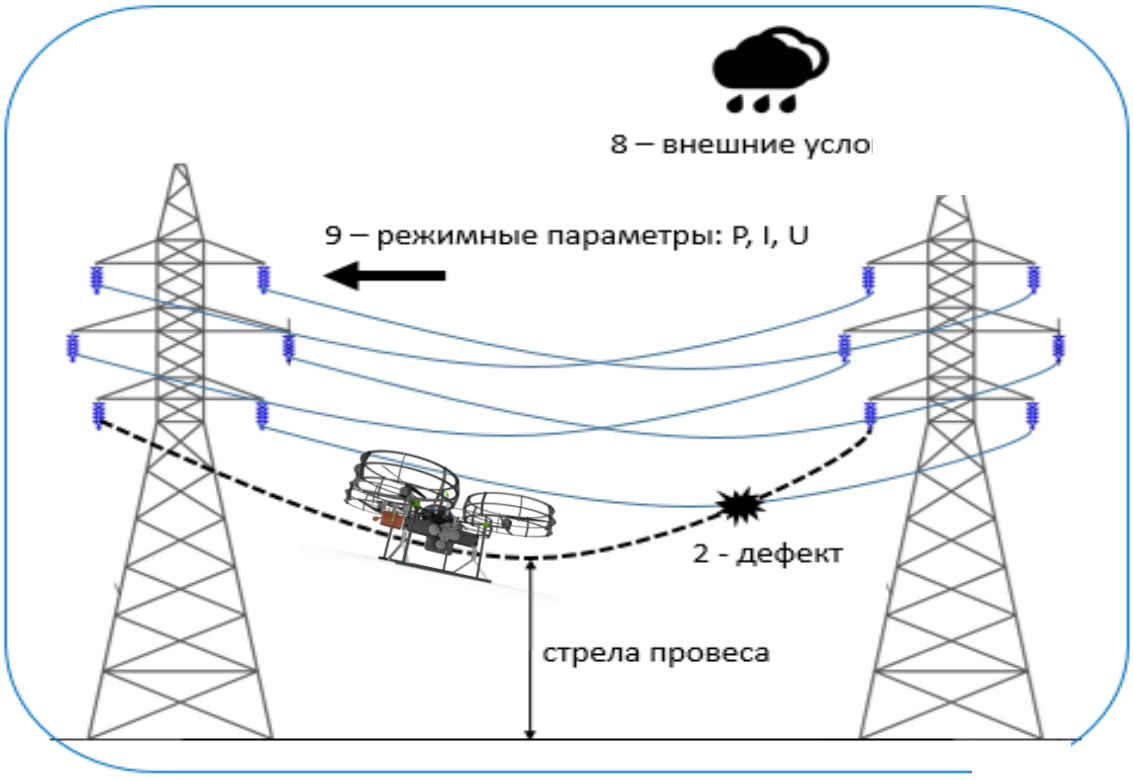

Figure 1.15 – Robotic system for diagnosis of high-voltage transmission line.

The construction relying on the advantages of competitors has developed this design with variable geometry. When boarding the cable wings fall down under its own weight. For take-off on the screws served a certain attraction and they take the wings back as it is shown in the figure 1.16.

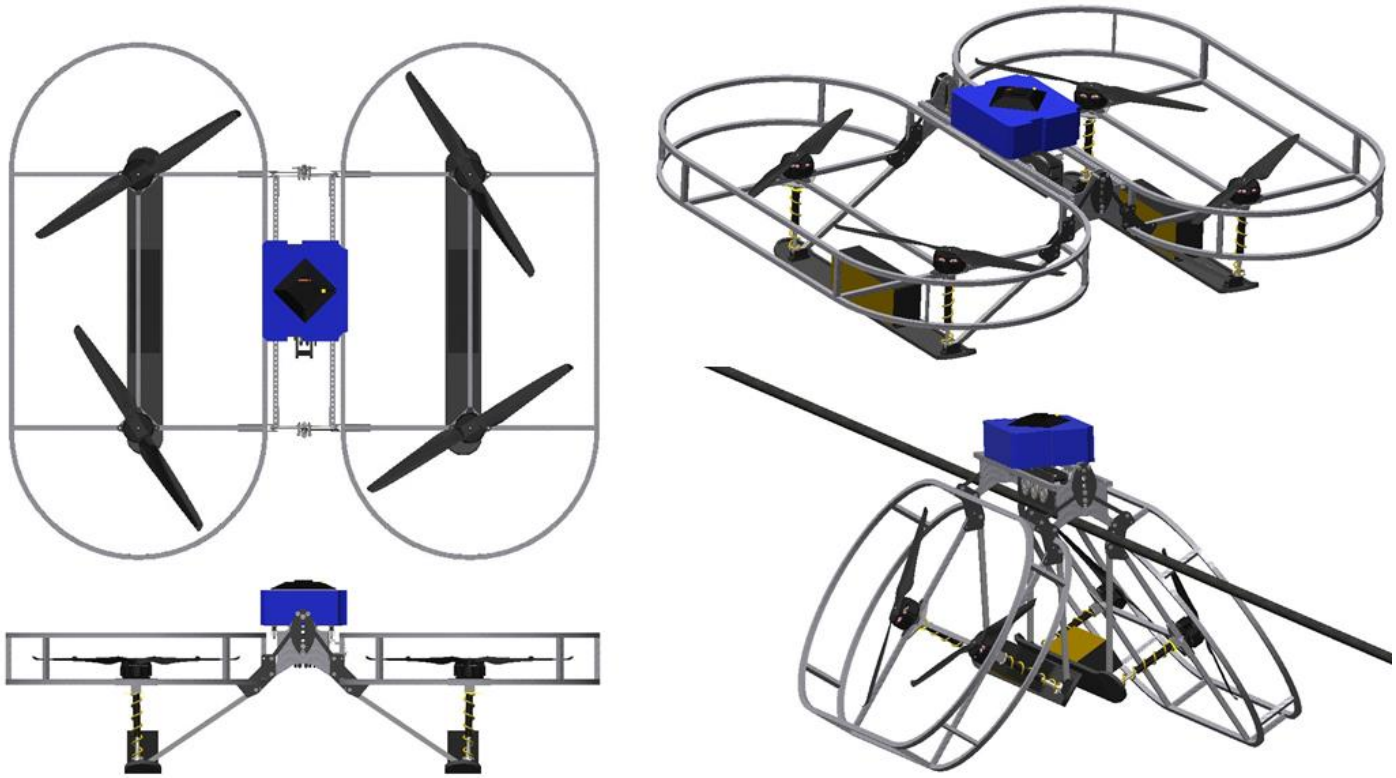

Figure 1.16 – Schematics for the construction of the cable walker

The sustainability stabilization allows to shift the center of gravity and to ensure stability in the air and on cable that is show in the Figure 1.17. In addition, the power cable and ground wire transmission lines are wrapped. There is a problem of twisting the contact diagnostic systems for the cable axis. In this case, start vibrations that make error in the operation of the equipment. To this end, it provides a special roller design. And with a strong crosswind relevant electronic stabilization using quadcopters screws.

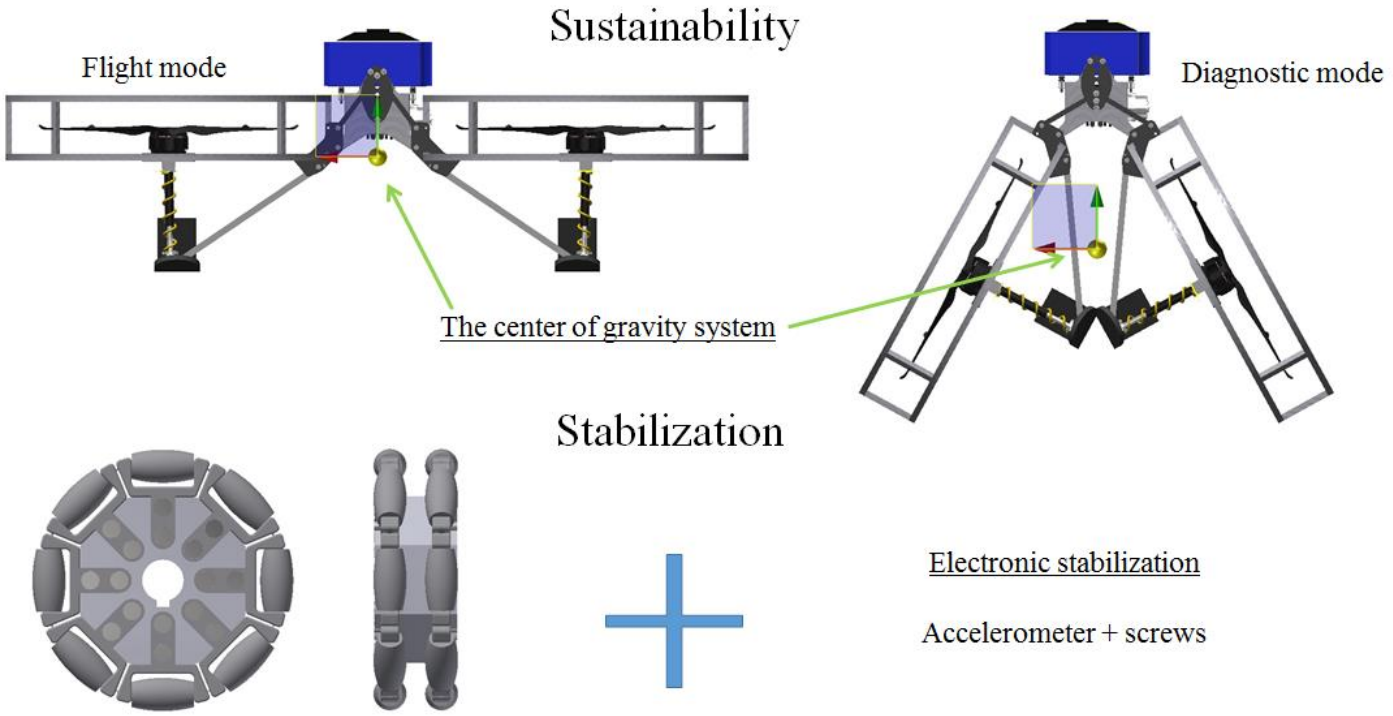

Figure 1.17 – Sustainability and Stabilization for the cable walker

The advantages of the concept are:

- Spatial delivery of diagnostic equipment in the line without shutting down the overhead line.
- Rechargeable from the overhead line provides unlimited term of operation.
- The thermal and UV camera is very sensitive to vibration. In this complex they can be installed.
- The use of contact devices: Magnetic flaw detector, load control, applying lubricant against the ice.
- The payload capacity of 6 – 8 kg equipment.

The system will be able to identify faulty poles, wires, ground wire, suspension insulators, and grounding devices plus violations on the road of the overhead line, representing 95% of all possible defects.

2 DESIGN OF THE WIRELESS NETWORK FOR A POWER LINE CONTROL TASK

2.1 Network communications

The word “network” makes reference to a set of entities (An entity is an electronic and/or computer system) which could be objects, people and so on, that are connected between each other. Therefore, a network allows material or immaterial elements to flow between these entities, according to well-defined rules. In data communications, a network is a configuration in which two or more locations are physically connected for the purpose of exchanging data

A network must have a:

- Means of communication which transfer the information between devices.
- A language or set of rules in order to communicate between devices (Like protocols TCP/IP, IPX, X.25).

The world has not always been so easy. In the past there was no communication of systems through the network, the big companies devised network protocols. Protocols are used to engage in two way communication entities located on different machines, which in combination with the other entities forms a whole (a distributed system). [10]

With the small disadvantage that each company designed its own network protocol and the details of those protocols were not public, so that the computers could only communicate between them if they belonged to the same brand, with the passage of time around The 1970s and 1980s there was a formal association between computer manufacturers and communications.

For example, IBM released its Systems Network Architecture (SNA) model in 1974. After SNA was released, other computer companies developed products that allowed their computers to communicate with IBM computers using Systems Network Architecture. This measure worked, but it was not the best solution, as this meant that big computer companies like IBM would monopolize the market. [26]

A better solution was to create an open standardized network model that all vendors would support. The International Organization for Standardization (ISO) took on this task in the late 1970s, beginning work on what would be known as the Open Systems Interconnection (OSI) model. International Organization for Standardization had a noble objective for the Open Systems Interconnection model: to standardize protocols

of data networks to allow communication between all the computers of the whole planet. Organization for Standardization worked towards this ambitious and noble goal, with participants from most of the technologically developed nations on Earth participating in the process. [16]

Around the 1970s and 1980s, there was an association between the fields of computers and communications that brought about a drastic change in technologies, products and in the companies themselves, which since then have been working together in the computer sectors And communications. In the figure 2.1 shows a comparative between the IBM "Systems Network Architecture" model and the Organization for Standardization "Open Systems Interconnection" model

<table>
<tr><th>OSI Model</th><th>SNA</th></tr>
<tr><td>Application</td><td>Transaction Services</td></tr>
<tr><td>Presentation</td><td rowspan="2">Presentation Services</td></tr>
<tr><td>Session</td></tr>
<tr><td>Transport</td><td>Data Flow Control</td></tr>
<tr><td>Network</td><td>Transmission Control</td></tr>
<tr><td>Data Link</td><td>Path Control</td></tr>
<tr><td></td><td>Data Link Control</td></tr>
<tr><td>Physical</td><td>Physical</td></tr>
</table>

Figure 2.1 – Comparative between OSI and SNA model.

To create a working network, the devices in that network need to follow the details referenced by a particular networking model. When multiple computers and other networking devices implement these protocols, physical specifications, and rules, and the devices are then connected correctly, the computers can successfully communicate.

You can think of a networking model as you think of a set of architectural plans for building a house. Sure, you can build a house without the architectural plans, but it will work better if you follow the plans. And because you probably have a lot of different people working on building your house, such as framers, electricians, bricklayers, painters, and so on, it helps if they can all reference the same plan. Similarly, you could build your own network, write your own software, build your own networking cards, and create a network without using any existing networking model. However, it is much easier to simply buy and use

products that already conform to some well-known networking model. And because the networking product vendors use the same networking model, their products should work well together. [21]

We can observe the parts that integrate a system of communication in Figure 2.2, in which a block diagram is proposed.

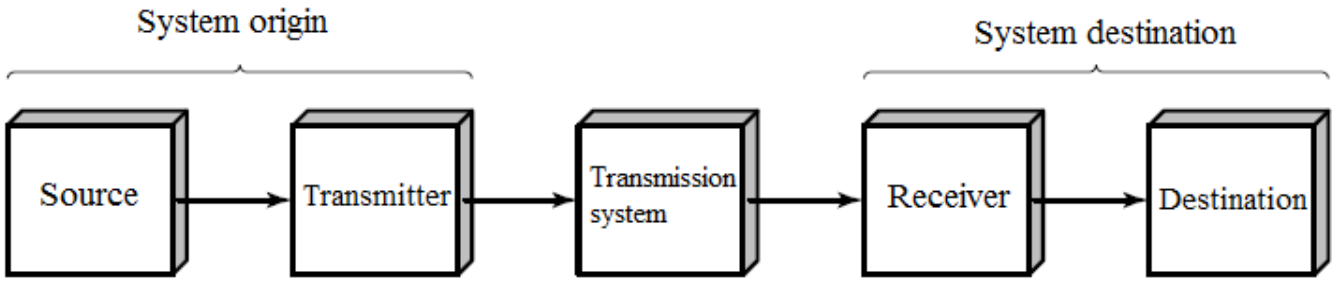

Figure 2.2 – Communication system

- The source. This device generates the data to be transmitted. Examples of sources may be a telephone or a personal computer.
- The transmitter. Normally the data generated by the source is not transmitted directly as it is generated. On the contrary, the transmitter transforms and encodes the information, generating electromagnetic signals susceptible of being transmitted through some system of transmission. For example, a modem converts bit strings generated by a personal computer and transforms them into analog signals that can be transmitted over the telephone network.
- The transmission system. It can be from a simple transmission line to a complex network that connects the source to the destination.
- The receiver. The receiver accepts the signal from the transmission system and transforms it so that it can be handled by the destination device. For example, a modem will pick up the analog signal from the network or transmission line and convert it to a bit string.
- Destination. Take the data from the receiver. [22]

  The reasons why a network needs to be implemented are:

  - Sharing: Networks allow sharing of information, databases and media.
  - Communication: Networks are critical for email, instant messaging.

- Organization: networks centralize information and make it accessible, which increases the efficiency and speed with which this information can be accessed.
- Money: A network can save the company money by helping in the budget process and / or increasing productivity. [5]

For a network to be functional it has to meet the following characteristics:

- A network covers a limited area. It is confined to a limited area.
- It shares one or several common media.
- High transfer speed. This is increasing every day, by the use of increasingly sophisticated technologies.
- Flexibility. An increasingly important concept, and must be understood, by the ability of networks to adapt to the needs of users.
- Reliability. Term discussed that raises the degree of data security, expressed by the facilities and means available to the networks.
- Security. In the network infrastructure and its components within the environments and facilities.
- Operability. Supported on principle of easy installation and manipulation of the components of the computer network.

2.1.1 IEEE Standards

IEEE is the acronym for The Institute of Electrical and Electronics Engineers, the Institute of Electrical and Electronic Engineers, a worldwide technical-professional association dedicated to standardization, among other things. It is the largest non-profit international association of new technology professionals, such as electrical engineers, electronics engineers, systems engineers and telecommunication engineers.

Its creation goes back to the year 1884, counting among its founders to personalities of the stature of Thomas Alva Edison, Alexander Graham Bell and Franklin Leonard Pope. In 1963, it was renamed IEEE by merging associations such as the American Institute of Electrical Engineers (AIEE) and the Institute of Radio Engineers (IRE).

Through its members, more than 360,000 volunteers in 175 countries, the IEEE is a leading authority and of maximum prestige in the technical areas derived from the original electric: from computational

engineering, biomedical and aerospace technologies to electrical energy, Telecommunications and consumer electronics, among others.

According to the IEEE, its work is to promote creativity, development and integration, share and apply advances in information technologies, electronics and science in general for the benefit of humanity and the professionals themselves. Some of its standards are shown in the Figure 2.2.

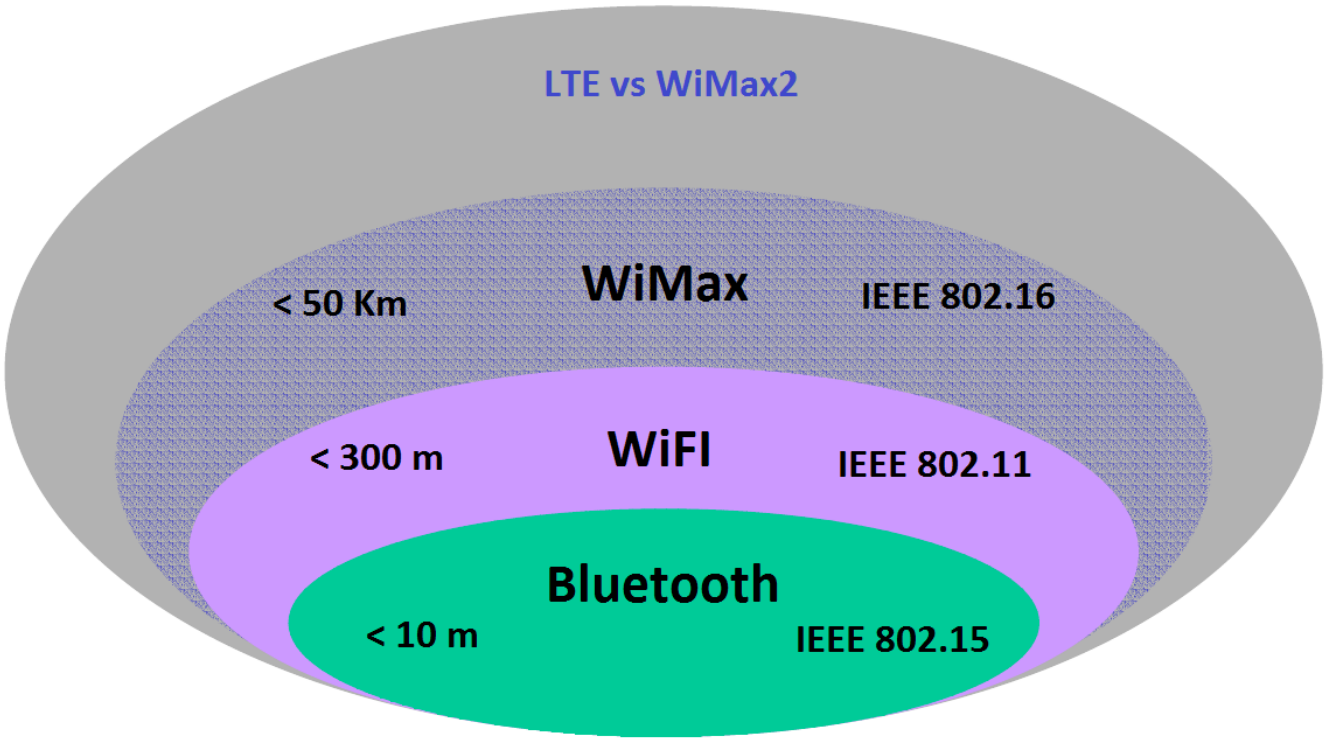

Figure 2.3 – IEEE Wireless standards

2.1.2 802.11a

It was standardized by the IEEE in July 1999 but was not commercialized until mid-2002, reaching 54Mbps in the 5 GHz band called Unlicensed National Information Infrastructure with Orthogonal Frequency Division Multiplexing modulation that helps to minimize Interference and increases the number of channels without overlap. A disadvantage is that it limits the radius of reach to 50 m due to a higher absorption rate, which means installing more access points to cover the same surface as if using 802.11b.

This standard is not compatible with 802.11b products, as they do not use the same frequency range.

2.1.3 802.11.b

It is the main wireless network standard approved by IEEE in September 1999 and known as Wi-Fi. Using a Direct Sequence Spread Spectrum modulation, it reaches a speed of 11 Mbps operating within the Industrial, Scientific and Medical band 2.4 GHz that does not need a license either. With a maximum power of 100 mW can support up to 32 users per Access Point.

In addition to presenting the disadvantages of 802.11a, such as the lack of "Quality of Service", there are several drawbacks when working in the 2.4 GHz band, because it has several sources of interference due to the use of the same band by several Electronic equipment such as wireless, keyboards and mouse, telephones, and so on.

Contrary to the previous specification, 802.11b has gained market acceptance despite its disadvantages. This is due to its low cost, its acceptable speed and the compatibility gained when being certified by the Wi-Fi Alliance.

2.1.4 802.11g

Compatible with 802.11b products using the same working frequency, it can reach speeds of up to 54 Mbps supporting Direct Sequence Spread Spectrum and Orthogonal Frequency Division Multiplexing modulations, achieving the same propagation characteristics as the 802.11b standard and maintaining transmission reliability with the reduction of the transmission rate.

Devices that adopt the 802.11g specification hit the market before the official release of the standard. This was in part due to the fact that equipment already manufactured for the 802.11b standard could be adapted to work on the new 802.11g. As of 2005, most of the equipment marketed in the wireless network market follows the 802.11g revision providing 802.11b compatibility.

2.1.5 802.11n

The formation of this group of the IEEE was announced in January of 2004, in order to develop improvements in the guidelines of the previous standards, due to the great demand that the wireless networks have, but has not yet been approved.

A theoretical maximum transmission speed of 600 Mbps or more is expected to obtain a throughput rate of around 74 Mbps, extending the range of coverage to about 70m in enclosures and 250m in outdoor environment. Other important components of the draft or pre-standard 802.11n specifications are the implementation of a new technology in the physical layer called Multiple Input Multiple Output, as can be seen in Figure 2.3 as well as compatibility With all standards previously ratified, doubling the bandwidth channel from 20 MHz to 40 MHz, which can achieve transfer rates of 144 Mbps up to 300 Mbps.

As for the modulation can be by Orthogonal Frequency Division Multiplexing or Direct Sequence Spread Spectrum according to the case in a 2.4GHz or 5GHz band. [1]

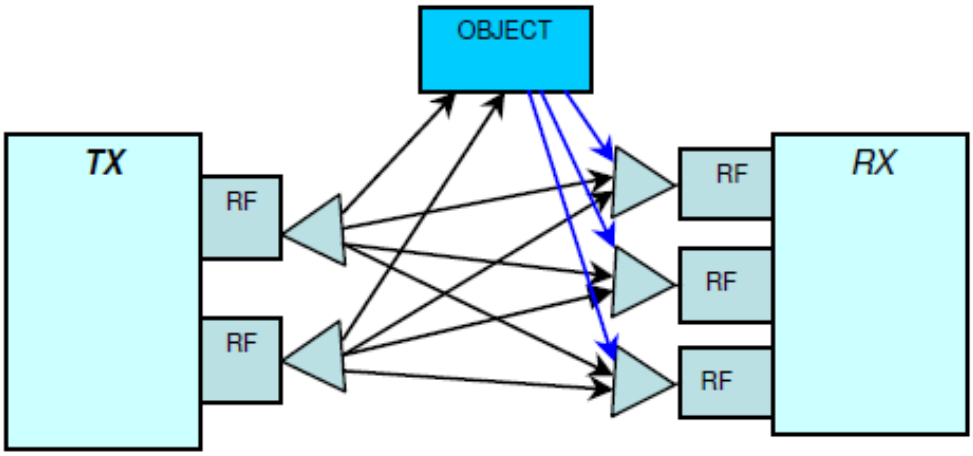

Figure 2.4 – MIMO uses Multiple Transmitters, Receivers and Antennas

2.2 Wireless networks

To send data across a wired link, an electrical signal is applied at one end and is carried to the other end. The wire itself is continuous and conductive, so the signal can propagate rather easily. A wireless link has no physical strands of anything to carry the signal along, how then can an electrical signal be sent across the air, or free space?

The transmitter can send an alternating current into a section of wire (an antenna), which sets up moving electric and magnetic fields that propagate out and away as traveling waves. The electric and magnetic fields travel along together and are always at right angles to each other, as shown in Figure 2.2.1. The signal must keep changing, or alternating, by cycling up and down, to keep the electric and magnetic fields cycling and pushing ever outward. [3]

Electromagnetic waves do not travel in a straight line. Instead, they travel by expanding in all directions away from the antenna. [3]

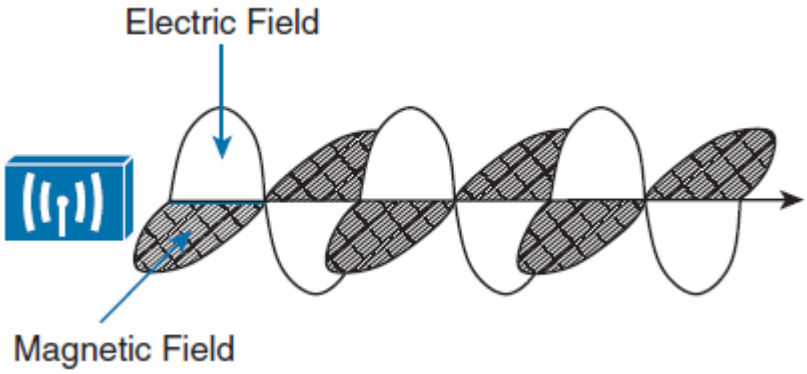

Figure 2.5 – Traveling electric and magnetic waves

The waves involved in a wireless link can be measured and described in several ways. One fundamental property is the frequency of the wave, or the number of times the signal makes one complete up and down cycle in 1 second. Figure 2.5 shows how a cycle of a wave can be identified. A cycle can begin as the signal rises from the center line, falls through the center line, and rises again to meet the center line. A cycle can also be measured from the center of one peak to the center of the next peak. No matter where you start measuring a cycle, the signal must make a complete sequence back to its starting position where it is ready to repeat the same cyclic pattern again. [3]

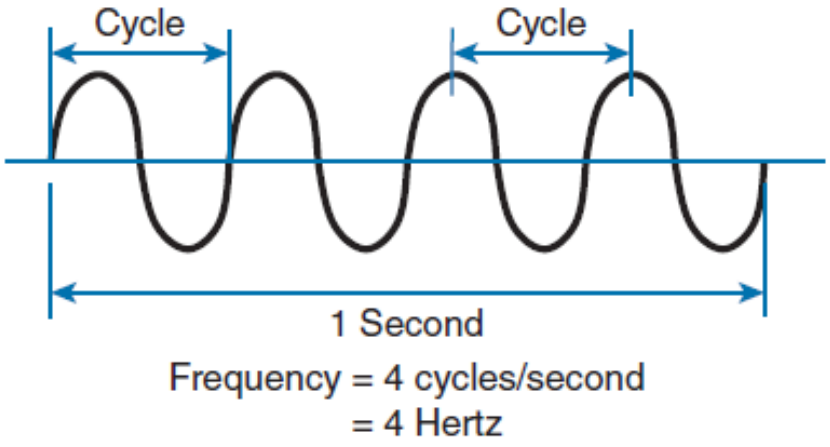

Figure 2.6 – Cycles within a wave

Wireless networks consist of a number of nodes which communicate with each other over a wireless channel. Some wireless networks have a wired backbone with only the last hop being wireless. Examples are cellular voice and data networks and mobile IP. In others, all links are wireless. One example of such networks is multihop radio networks. [17]

Digital wireless communication is not a new idea. In early 1901, the Italian physicist Guglielmo Marconi demonstrated a wireless telegraph from a ship to land using the Morse code (after all, the dots and dashes are binary). Today's digital wireless systems perform better, but the basic idea is the same to be communicated without having to be physically connected. These wireless networks have many uses, for example a portable office or military communications. [12]

As a first approximation, wireless networks can be classified into four main categories:

1. Wireless personal-area network.
   WPAN is a network that is used in transmitting data among devices or gadgets. Such networks could be useful for communication among the personal devices or to be able to connect onto an upper tier level of connection such as the internet itself.
2. Wireless LANs. Wireless local-area network
   Designed to cover areas of a few hundred meters, they are the ones that have had the most impulse thanks to the IEEE 802.11 (Wi-Fi) standard and its numerous variants.
3. Wireless metropolitan-area network
   They have an average range of action of about 20 km, and the most outstanding standard in this field is 802.16 (WiMAX).
4. Wireless WANs. Wireless wide-area network
   They are the type of networks that have a broader coverage. The family of standards
   IEEE 802.20 or UMTS are the most representative of this type of networks.

Figure 2.5 gives a general idea of the network types and their scopes

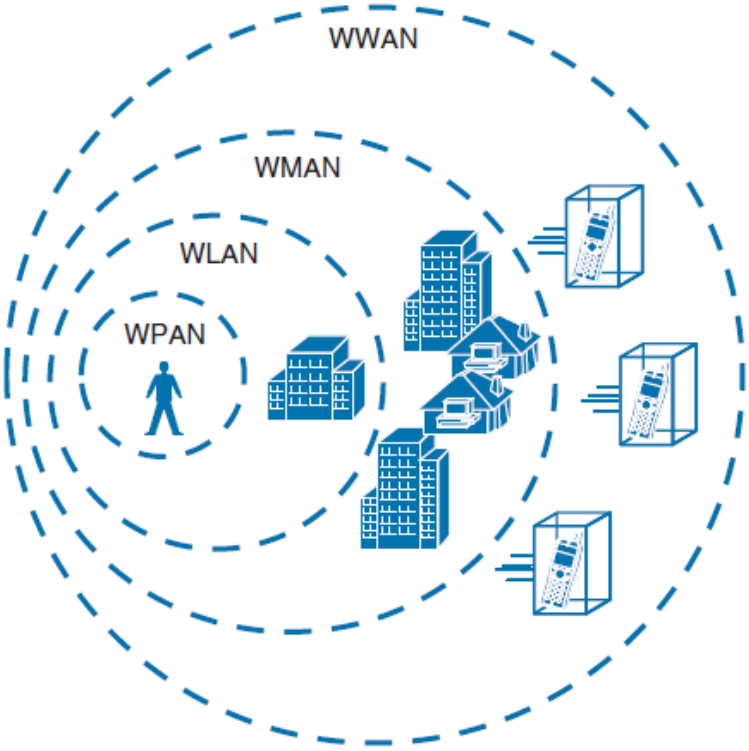

Figure 2.7 – Wireless network types and scopes

As its name implies, a Wireless personal area network uses low powered transmitters to create a network with a very short range, usually 20 to 30 feet (7 to 10 meters). Wireless personal area network refers to the interconnection of components of a computer using short-range radio and are based on the IEEE 802.15 standard and include technologies like Bluetooth and ZigBee, although ZigBee can have a greater range. Unlicensed ISM frequencies are used, including the 2.4-GHz band. [3]

In the simplest form, systems interconnect networks use the master and slave paradigm. The teacher tells the slaves what directions to use, when they can broadcast, how long they can transmit, what frequencies they can use, and so on.

The next step in wireless connectivity is wireless local-area network. A wireless service that connects multiple devices using the IEEE 802.11 standard over a medium-sized range, usually up to 300 feet (100 meters). Unlicensed frequencies in the 2.4- and 5-GHz band are used. They are systems in which each computer has a radio modem and an antenna through which it can communicate with other systems. Sometimes an antenna is placed on the ceiling with which the machines communicate. However, if the systems are close enough, they can communicate directly with each other in a peer-to-peer configuration.

Wireless local area network is becoming increasingly common in small homes and offices, where installing Ethernet is considered very problematic.

Wireless metropolitan area network it's a wireless service over a large geographic area, such as all or a portion of a city. One common example, WiMAX, is based on the IEEE 802.16 standard. Licensed frequencies are commonly used.

Wireless wide area network it's a wireless data service used for mobile phones that is offered over a very large geographic area (regional, national, and even global) by telecommunications carriers. Licensed frequencies are used. Is an example of low bandwidth wireless systems. This system has gone through three generations. The first was analog and only for voice. The second was digital and voice only. The third generation is digital and is for both voice and data. In a sense, cellular wireless networks are like wireless local area network, except that the distances involved are much larger and the bit rates are much lower. Wireless local area network can operate at rates of up to 50 Mbps over distances of tens of meters.

Cellular systems operate below 1 Mbps, but the distance between the base station and the computer or phone is measured in kilometers rather than meters.

Wireless networks have a number of advantages, among which we can highlight:

- Flexibility: They are flexible because they allow us to interconnect complicated locations, and can also easily adjust to the requirements imposed.

- Scalability: This quality refers to the possibility of adapting and rapidly expanding the qualities of the network in terms of coverage and bandwidth.

- Deployment speed: The deployment of a wireless network is usually quite fast, especially if there is already a previous infrastructure or infrastructure (communication towers, street lamps, water tanks located at high altitudes) that can be used to carry out the installation.

- Reduced costs: It will depend on the case, but in general it is less expensive to deploy a wireless network than a wired one, especially if the conditions mentioned in the previous section are again given that there are previous infrastructures that can be exploited.

It should also be noted that not all are advantages in wireless networks. The problems that arise with the wireless networks are the following:

- Interference: the propagation of electromagnetic waves through the air interface implies the risk that they may interfere with one another. The solution to this problem passes through the legislation of the use of radio electric spectrum in terms of frequencies used and powers allowed in each of those frequencies.

- Instability of the physical environment: electromagnetic propagation through the air interface is highly complex phenomenon's that are affected by elements such as atmospheric conditions, presence of background noise, uncontrolled interference and other modifications of the physical environment that make conditions Of the radio links generally have great variability.

- Transmission speed and delays: the factors described in the two previous points are those that cause the transmission speeds are smaller and the delays are greater than in the transmissions carried out by wired means.

- Security: data transmitted by the air interface are susceptible to being heard by anyone with the proper means. Thanks to the development of mechanisms of authentication and encryption, this problem is solved, as long as these mechanisms are properly implemented.

2.3 Network services

One way to define a network technology is to define the services it offers and allow equipment vendors to implement those services in whatever way they see fit. 802.11 provide nine services. Only three of the services are used for moving data; the remaining six are management operations that allow the network to keep track of the mobile nodes and deliver frames accordingly

- Distribution:
- Integration:

- Association
- Reassociation
- Disassosiation
- Authentication
- Deauthentication
- Privacy
- MAC Service Data Unit

The Distribution service is used by mobile stations in an infrastructure network every time they send data. Once a frame has been accepted by an access point, it uses the distribution service to deliver the frame to its destination. Any communication that uses an access point travels through the distribution service, including communications between two mobile stations associated with the same access point.

Integration is a service provided by the distribution system; it allows the connection of the distribution system to a non IEEE 802.11 network. The integration function is specific to the distribution system used and therefore is not specified by 802.11, except in terms of the services it must offer.

Association is responsible for Delivery of frames to mobile stations is made possible because mobile stations register, or associate, with access points. The distribution system can then use the registration information to determine which access point to use for any mobile station. Unassociated stations are not "on the network," much like workstation’s with unplugged Ethernet cables. 802.11 specify the function that must be provided by the distribution system using the association data, but it does not mandate any particular implementation.

Reassociation, when a mobile station moves between basic service areas within a single extended service area, it must evaluate signal strength and perhaps switch the access point with which it is associated. Reassociations are initiated by mobile stations when signal conditions indicate that a different association would be beneficial; they are never initiated by the access point. After the reassociation is complete, the distribution system updates its location records to reflect the reachability of the mobile station through a different access point.

Disassosiation, to terminate an existing association, stations may use the disassociation service. When stations invoke the disassociation service, any mobility data stored in the distribution system is removed. Once disassociation is complete, it is as if the station is no longer attached to the network. Disassociation is a polite task to do during the station shutdown process. The MAC is, however, designed to accommodate stations that leave the network without formally disassociating.

Authentication, physical security is a major component of a wired LAN security solution. Network attachment points are limited, often to areas in offices behind perimeter access control devices. Network equipment can be secured in locked wiring closets, and data jacks in offices and cubicles can be connected to the network only when needed. Wireless networks cannot offer the same level of physical security, however, and therefore must depend on additional authentication routines to ensure that users accessing the network are authorized to do so. Authentication is a necessary prerequisite to association because only authenticated users are authorized to use the network. (In practice, though, many access points are configured for "open-system" authentication and will authenticate any station.)

Deauthentication, terminates an authenticated relationship. Because authentication is needed before network use is authorized, a side effect of deauthentication is termination of any current association.

Privacy, strong physical controls can prevent a great number of attacks on the privacy of data in a wired LAN. Attackers must obtain physical access to the network medium before attempting to eavesdrop on traffic. On a wired network, physical access to the network cabling is a subset of physical access to other computing resources. By design, physical access to wireless networks is a comparatively simpler matter of using the correct antenna and modulation methods. To offer a similar level of privacy, 802.11 provide an optional privacy service called Wired Equivalent Privacy. Wired Equivalent Privacy is not ironclad security in fact, it has been proven recently that breaking Wired Equivalent Privacy is easily within the capabilities of any laptop. Its purpose is to provide roughly equivalent privacy to a wired network by encrypting frames as they travel across the 802.11 air interface. Depending on your level of cynicism, you may or may not think that Wired Equivalent Privacy achieves its goal; after all, it's not that hard to access the Ethernet cabling in a traditional network. In any case, do not assume that Wired Equivalent Privacy provides more than minimal security. It prevents other users from casually appearing on your network, but that's about all.

MAC Service Data Unit, networks are not much use without the ability to get the data to the recipient. Stations provide the MAC Service Data Unit (MSDU) delivery service, which is responsible for getting the data to the actual endpoint. [14]

2.4 How to build a wireless network

Wireless technology is a communications system that has gained the confidence of a large number of users by freeing them from the limitations of cable connection and its flexibility in implementing it as an extension or as an alternative to a network by cable.

In addition to minimizing the need for cable connections, the use of the electromagnetic spectrum combines data communication with the mobility of users with access to information in real time. This mobility supports productivity and service opportunities that are impossible with wired networks.

Wireless networks are designed to operate in frequency ranges of character free, which gives rise to some costs use much less than the networks based on cellular systems. The use of a space-frequency character free also represents an increase in potential security risks of the network and the occurrence of interference. These can be configured in a variety of topologies easily changed from networks point-to-point appropriate for a small number of users, networks of infrastructures for whole-of-thousands of users that allow Roaming over a large area.

2.5 Design of the network for a power line

The design of the network consists of the synthesis of the needs identified in a network architecture that meets the established performance requirements. This is accomplished by performing the following steps.

- Identify customer capabilities and performance requirements of the application.
- Determine the Access Points and the radio capabilities needed to support the needs of the identified customers and applications.
- Determine the appropriate type and quantity of Access Points, as well as the accessories you need and your location on the site to get optimum coverage based on the features of the facility.

The main objective of this network is to provide wireless coverage to achieve the intercommunication of the drone "Cable Walker" with the mobile monitoring station for data transmission. This will happen concretely in outdoor environments where the drone performs diagnostic tasks for electrical towers and power lines.

First, the types of client devices to be used in the medium, their quantities, and their wireless radio capabilities must be identified, so at the beginning, at least 1 client must be able to connect to the mobile station, taking into account It should be easy to expand the network to support more users should it be required.

The greatest possible coverage will be provided around the structure where the tasks to be performed by the drone are carried out, the wireless network must serve all the devices simultaneously. Because Wi-Fi leverages a shared radio frequency medium, the design and configuration of the network must balance the requirements of all customers. Identifying the radio type on each device and its IEEE certificates

(802.11b/g/a/n) will help determine data speeds, compatible frequency bands, and application performance capabilities.

When working with wireless networks, it is important to pay sufficient attention to the planning and design of the network. It is also important to ensure that the network equipment that is installed is capable of delivering both high performance and optimization functions for a limited spectrum. The power output of the equipment will be adjusted taking into account the gain of the antenna.

The minimum technical characteristics required for the equipment of the wireless access network in each of the access points (drone and mobile station) are the following:

- Devices must support 802.11b and / or 802.11g standards.
- The equipment must be manageable through SNMP, which will allow monitoring and remote management of these.
- Must support WEP and WPA security.
- The equipment must have an Ethernet port 10/100 Base T that allows to connect it with other equipment of network.
- The equipment must have an external antenna connector, so that it is possible to use the most appropriate antennas in each situation.
- The minimum aggregate traffic to be distributed among the connected users will be 5 Mbps in each of the points, allocating this capacity in an equitable way among the users that are associated to the access points.

One of the access points will be installed in the mobile station and connected to an outdoor directional antenna, choosing the right type of antenna to minimize interference and maximize coverage.

The other access point will be installed in the drone and connected to an omnidirectional antenna, choosing the type of antenna most suitable to guarantee the communication.

The equipment used in each of the links and that meet all the requirements of functionality and bandwidth described above are the following:

AS the Figure 2.6 shows we are going to use an Access Point called “Bullet M”.

- The Bullet M delivers up to 100+ Mbps real TCP/IP throughput.
- The robust, weatherproof case withstands harsh outdoor conditions.
- The Bullet M features up to 600 mW of power and an enhanced receiver design for point to point or point to multi point deployment.
- The Bullet M provides high performance at a range of up to 50+ km, depending on its antenna.

Figure 2.8 – Bullet M, model BM2HP

As the Figure 2.7 shows we are going to use an 24dBi 2.4GHz Outdoor Parabolic Grid antenna, and this are the specifications:

- Frequency Range 2.40-2.49GHz
- Gain 24dBi Rated, 23dBi Actual confirmed
- Voltage Standing Wave Ratio 1.2:1 average (AC voltage due to standing waves along the transmission line reaching a peak value 1.2 times that of the minimum AC voltage along that line).
- Beam width, -3dB point Azimuth 7.8 degrees
- Beam width, -3dB point Elevation 7.0 degrees
- Cable Length, Type 10" RG-8
- Connector N-Type Female
- Mounting Bracket, U-Bolts fro 1" - 2" mast
- Wind Rating 120 MPH
- Dimensions 39" x 24" rectangle grid
- Weight 8 lbs.

Figure 2.9 – Outdoor Parabolic Grid antenna

2.6 Architecture of the system

In wireless communications there is always, as a basic structure, a communication manager and a series of clients. The clients will always listen for the presence of one or more managers, which will indicate, among other things, the name of the network they manage, the channel to use, the security and authentication algorithms available, etc. Based on this Information and configuration of the device in question, the customer will be able to join the appropriate network.

Depending on who implements the network management function, we will be faced with an "ad-hoc" network, in which the manager is a computer that is part of the network itself, or an "infrastructure" type network in which the manager In an access point, router or similar.

Ad hoc network is often local area network or other small area network formed by wireless devices. In Latin, ad hoc literally means "for this," further meaning "for this purpose only," and thus usually temporary,

and do not require a centralized access point. Instead, the devices in the wireless network connect directly to each other.[18]

Usually a wireless network leverages APs for organization, control, and scalability. Sometimes that is not possible or convenient in an impromptu situation. For example, two people might want to exchange electronic documents at a meeting, but they are unable to find a BSS available. In addition, many personal printers have the capability to print documents wirelessly, without relying on a regular basic service set or access point.

The 802.11 standard allows two or more wireless clients to communicate directly with each other, with no other means of network connectivity. This is known as an ad hoc wireless network, or an independent basic service set (IBSS), as shown in Figure 2.10

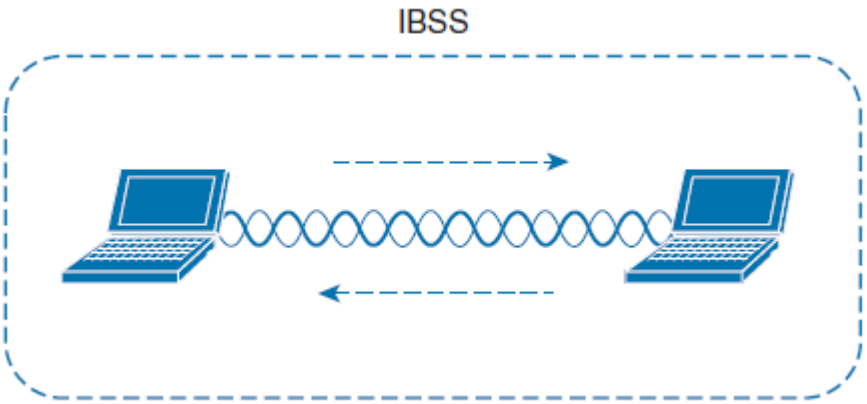

Figure 2.10 – Independent Basic Service Set

For the purpose of this work we will implement an ad hoc network that will be used to create a working group where we can share any type of files that are derived from the diagnostics made by the drone "cable walker".

The equipment's that we want to communicate in our network must be in a radius of less than twelve kilometers to our access point in the mobile station that will perform a server function. This type of network is very useful in these situations, because it require basic and cheap equipment as we can see in the figure 2.11 we just need a couple of access points with their respective antennas.

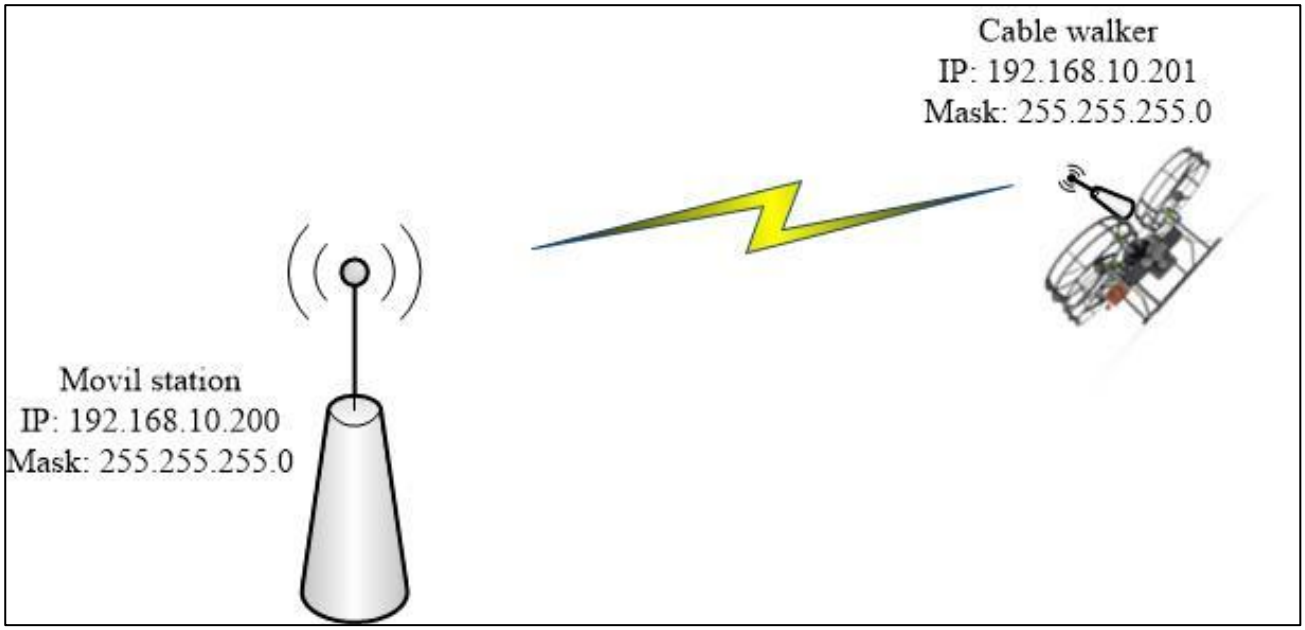

Figure 2.11 – Wireless schematic

3 TESTING A POWER LINE CONTROL IN MÉXICO AND RUSSIA

3.1 The way that México works

An electrical power system is a set of elements whose purpose is to generate, transform, transmit, distribute and consume electric power. These electrical systems are also referred to as high voltage or extra high voltage, or electrical transmission systems.

In other words it can say that the Power Electrical System is constituted by three main parts:

- Generation.
- Transmission.
- Distribution.

An electrical power system grows due to the demand that exists and has the population.

The generation of electrical energy consists of transforming some kind of chemical, mechanical, thermal or luminous energy, among others, into electrical energy. For the industrial generation it is used to installations called power plants, which execute some of the mentioned transformations.

These constitute the first step of the power supply system. The electrical generation is carried out, basically, by means of a generator; although these do not differ in respect to their principle of operation, vary depending on the way in which they are operated.

Generation is where the electric energy is produced, through the generating plants, which represent the production center. [8]

From the need to transport the electric power of the generation centers to the centers of consumption, the transmission lines originate, which continue in parallel growth to the urban development; therefore, require maintenance, which represents a more complex problem as they continually add to the interconnection system. In order for the lines to operate correctly and provide a high degree of reliability, timely maintenance is required.

There are some activities that can be done with the line de-energized and some with energized lines. When working with energized lines, the safety distances must be respected when performing the activity, which can be calculated on the basis of the minimum air insulation distance for the line voltage, plus a factor for inadvertent movement, which are shown continuation:

Table 3.1 – Minimum distance to work in an energized line

VOLTAGE FROM PHASE TO PHASE (Kv)	DISTANCE TO BE USED (m)
0.05 to 0.30	Avoid contact
2.44 to 13.75	0.6
15.1 to 36	0.75
115	1.5
161 to 169	1.75
230	2.5
400	4.4

The distance between the lineman and the energized line shown in the Figure 3.1, plus the distance between the structure and the lineman must not be less than the minimum permitted distance.

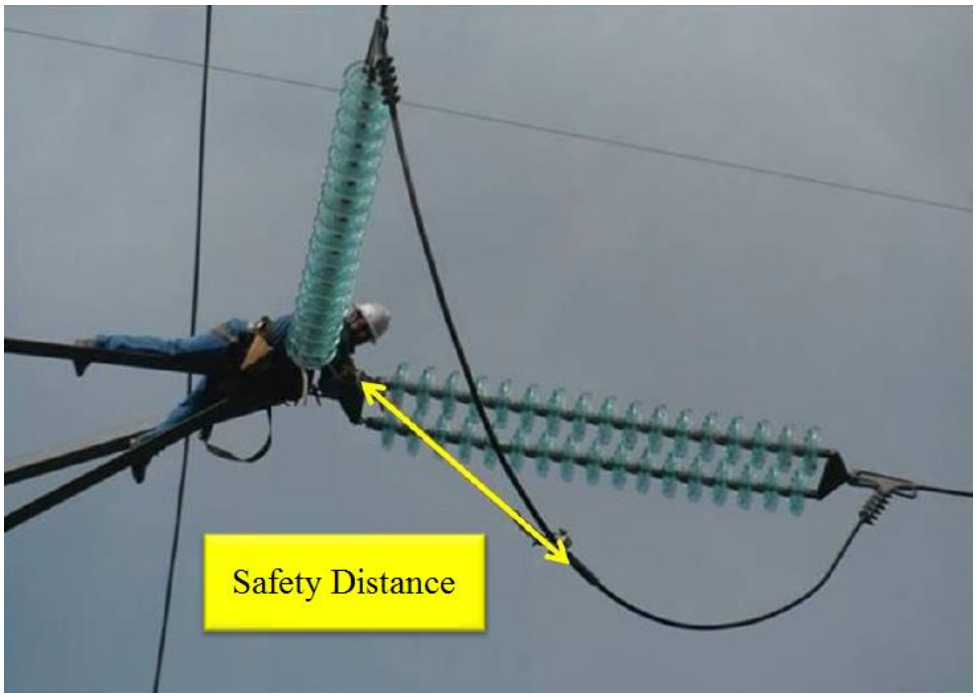

Figure 3.1 – Safety distance

The inspections are the first step to plan the maintenance work to the transmission lines, since in doing so, it throws us the anomalies presented in the lines, besides avoiding possible shots that cause the interruption of electrical energy supplied to a great amount of Users in the area of the Metropolitan Transmission Zone.

A mayor inspection must be carried out at least once a year along the entire transmission line. During the development of this work, a detailed review is performed on each element of the structures, conductive cables, guard cables, as well as factors external to the transmission line as a gap, against profiles, floor to conductor levers, crossings with rivers areas of contamination, vandalism and fire zones.

A minor inspection can be done with a frequency of 2 times a year, since it is not necessary that the personnel ascend to the structures, however, it is an indispensable activity since in the Metropolitan Zone frequently they are anomalies occasioned by thirds like temporary markets, kites, Cranes and vandalism.

An aerial inspection is carried out with helicopter or airplane support, in which the lines can be traversed in a shorter time and detect notorious faults in guard cables, conductor cables, structures, gap, rat tails, foundations, invasions to the right of way, Isolation and construction near the right of way by new roads; Since on several occasions the delegations and municipalities execute projects without consulting the risks that they face when constructing near transmission lines.

The route that takes place in the Metropolitan Transmission Zone is divided into two:

- Rings of 400 kV
- Rings of 230 kV

In this aerial inspection and with the help of the helicopter, thermography is also done to transmission lines, a thermographic equipment is used to find critical points with a high degree of temperature while the line is crossed, which indicates that they have to be taken care of, as the figure 3.2 shows.

Once located, proceed to correct the hot spot, some of these points can be found in the following elements:

- Broken wire in conductor
- In conductor end fittings (mechanical or compression guns)
- Driver suspension hardware
- Splices of conductor

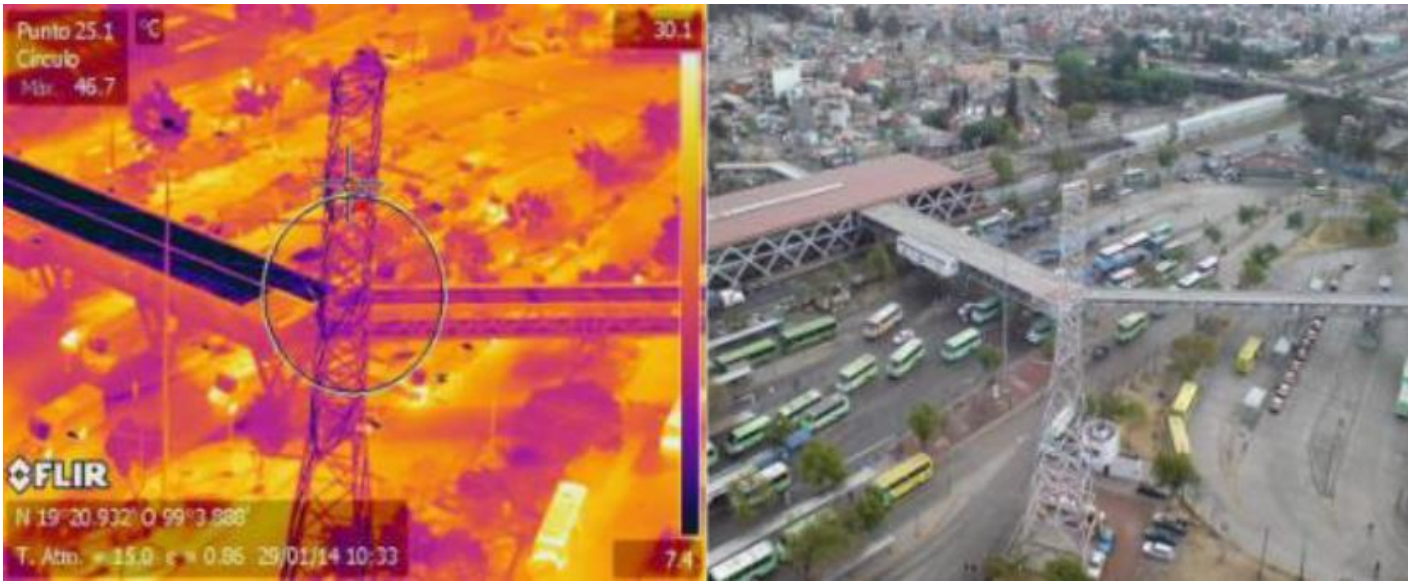

Figure 3.2 – Panoramic view of thermography on the overhead line Xochimilco-93C20-Santa Cruz

Another very important activity of the maintenance to overhead lines is to preserve clean the right-of-way (We will define the right-of-way as the strip of land that is located along the trajectory of the transmission lines, which must remain clean as it is shown in the figure 3.3) of the lines to avoid exit of lines by burning of cane, grasslands, fall of trees or branches near, as sometimes the owners of the farms realize Burning and provoke line outputs.

Figure 3.3 – Panoramic view of right-of-way in a 400kV overhead line

3.2 Russia

Cable lines that were built the first time in Russia (In the late 70-ies of the XIX century); they were built underground at (range - 1 km, power - 2 kW). The cable lines were mainly used for transmitting electricity for private residence. Even though the cable lines are commonly used for the last half century, only within this age that modern design and manufacturing technologies allow them to be an effective alternative to overhead lines.

Underground lines mostly used for laying electrical networks in urban areas and industrial plans. In developed cities where the building of overhead transmission lines are in fact challenging; due to the dense building, power transmission mainly used the underground high-voltage cable line at 220kV and above, causing the cable lines to be the foundation of the modern city grid, although the cost of the cable lines development itself could cost 2 to 3 times higher than the cost for overhead power lines. Although the lightness of building such lines they sure take a massive lot of space, under that reason the installation of it are banned in the buffer zone which is commonly up to 25 meters. Therefor the authorities and construction companies are searching for new technologies articulation cable sections and buried them underground. It is impossible to dig a cable trench or channel cables installed in tunnels. In some cases, the use of already existing tunnels reduces the cost of operation. [29]

Perm is one of Russian city that rapidly growing and providing electricity demand by vigorously researching and evaluating for new technologies, and so does Ural. One of the companies responsible for the operation for the operation of 360 substations is Permergo; they are currently having a voltage range from 35 kV to 110 kV, and some 12,784 distribution substations. The total installed transformer capacity is more than 11,000 MVA, and the transmission system and distribution network extends to 45,800 km (28,460 miles) operating voltage levels up to 110 kV. The company supplies electricity to the production enterprises and households in a territory of 160,000 km^2 (61,776 mi^2), which has a population of 2.82 million people. The main reason to why they are a major manufacturing hub for many of the nation's most critical industries are because of their location that is located on the deep and easily navigable Kama River. They have been manufacturing oil refining, metallurgy, machine building, chemicals, aerospace, wood processing and foods. Additionally, several branches of the Russian Academy of Science and seven universities conduct research in and around this city.

Due to thoughtful consideration of all the engineering variables and the restriction on the increased land use required by taller towers, the overhead line engineers sought an alternative solution. Following table 3.2 is comparison of Overhead line conductor characteristics. Such conductors has been built in other Russian cities where overhead line upgrades involved challenges similar to those in Perm; for instance, in Moscow [30]

Table 3.2 – Comparison of overhead line conductor in Russia

Comparison of Overhead Line Conductor Characteristics		
Overhead Line Conductor Characteristics	**Ostrich-300 ACCR-297-T16**	**AC-150/24**
Stranding	26/7	26/7
Diameters		
Core wire, mm (inches)	2.111 (0.0831)	2.1 (0.0394)
Layer wire, mm (inches)	2.714 (0.1068)	2.7 (0.1063)
Core, mm (inches)	6.332 (0.2493)	6.3 (0.2481)
Conductor, mm (inches)	17.187 (0.6767)	17.1 (0.6732)
Cross-section		
Aluminum, mm^2 (in^2)	150 (0.2325)	149 (0.2310)
Conductor, mm^2 (in^2)	175 (0.2713)	173.2 (0.2685)
Weight		
Core, kg/m (lb/ft)	0.085 (0.0117)	0.190 (0.0263)
Aluminum, kg/m (lb/ft)	0.416 (0.0575)	0.409 (0.0565)
Conductor, kg/m (lb/ft)	0.501 (0.0693)	0.599 (0.0828)
Tensile strength, N	54,890	52,279
Coefficient of elasticity, GPa	78	82.8
Thermal expansion coefficient		
Conductor, 10^{-6} mm/°C	16.7	18.9
Maximum permissible temperature, modes		
Long-admissible, °C	210	70
Overload, °C	240	70
Current capacity at 210°C, amperes	896	
Current capacity at 240°C, amperes	954	
Current capacity at 70°C, amperes		450

Though such efforts have been done, there are still some regions in Russia are still faced with the problem of limited capacity power lines. According to the FGC, the list of "peak load" region includes 16 regions, including Moscow, Leningrad, Novgorod, Arkhangelsk, Volgograd, Krasnodar and Perm Region, the Komi Republic, Dagestan and others. Even until today, the needs of energy from these regions are several times higher than the values laid down in the Energy Strategy of Russia until 2020, and electricity consumption are constantly growing

The average lifetime of the overhead line (overhead lines) 750-1150 kW is 20 years, HVL 330-500 kV is 24 years old, with more than 30% of the overhead line 500 kV in operation for over 30 years

Wear transmission towers is 36%. Accordingly, they need to be replaced. Just a reduced version for the period 2004-2013 gg. planned entry 30024 km of 330 kV. The implementation of this option would require

the development of electric power industry investment in power grid construction in the amount of 324 260 million rubles. A particular example was the preparation of Sochi for the Olympics 2014 infrastructure.

3.3 Test the components

In order to demonstrate that our network works properly, there is a very practical utility called "PING" that works on IP-level connectivity on another TCP/IP computer when sending ICMP (Internet Control Message Protocol) echo request messages to another device in the same network, the corresponding echo request messages are displayed along with their round trip times and help to evaluate the response time, that utility is provided as a standard feature with most operating systems. Ping is the main TCP / IP command used to troubleshoot connectivity, accessibility, and name resolution problems.

The output of the ping command lets you know:

- The IP address that corresponds to the name of the remote machine.
  The ICMP sequence number.
- Package life Time to Live. The time to live allows you to know the number of routers the packet passed through while traveling from one machine to another. Each IP packet has a time to live field with a relatively high value. Each time it passes through a router, the value is reduced. If ever this number is zero, the router will interpret that the packet is traveling in circles; therefore, it ends the process.
- The lap delay field corresponds to the time lapse in milliseconds needed to cycle between the source and destination machines. As a general rule, the delay of a packet should not be greater than 200 milliseconds.
- The amount of packets lost.

So we are going to proceed with this test knowing that bought of our access points are already configured, first step will be open a command line and write "ping 192.168.10.200" this command will send echo request/replies to the main access point located in the mobile station, as we can see in the figure 3.6 the ping shows 0% loss of packets.

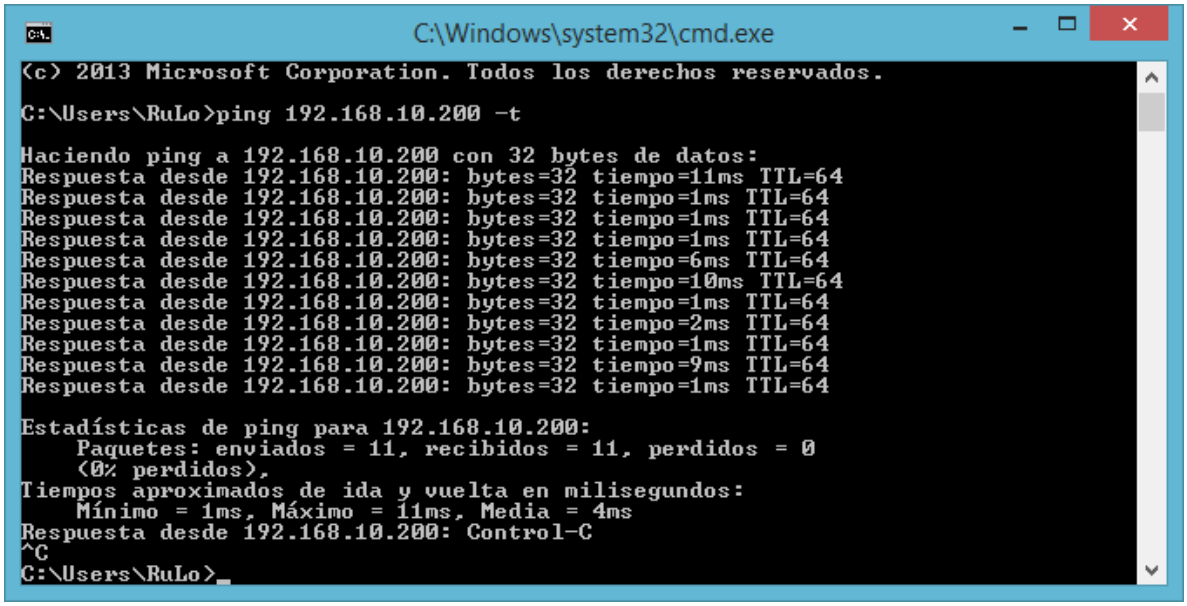

Figure 3.6 – Ping command send it to the access point located in the mobile station

Once we got the result of the ping we can see that it shows 0% of loss packets that's how we are sure that there is successful communication between our computer and the access point located in the mobile station.

The second step will be to do the same for the second access point located in the drone, so we are going to write in the command line "ping 192.168.10.201" and press enter, as we can see in the figure 3.7.

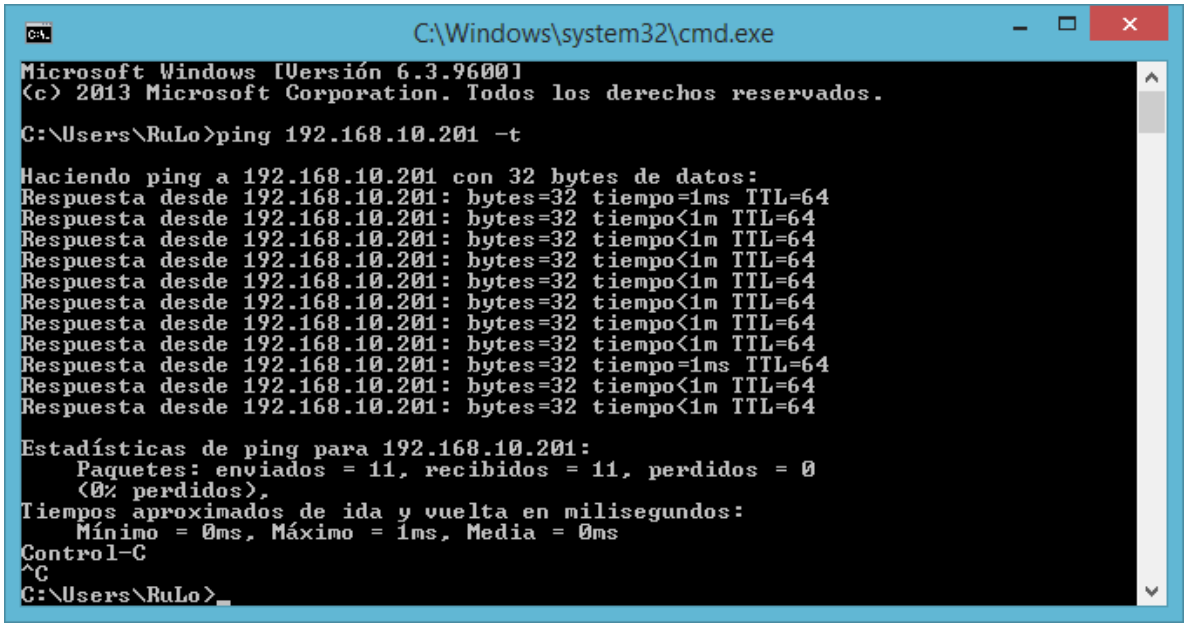

Figure 3.7 – Ping command send it to the access point located in the drone

The next test that we need to do is be sure that there are communication between the two access points, in order to do that, we are going to use the AirOs of the Bullet M2 in order to be able to ping from one access point to another as it is shown in the figure 3.8 we are going to send a ping from the access point located in the drone with the IP address 192.168.10.201 in order to reach the access point in the mobile station with the IP address 192.168.10.200.

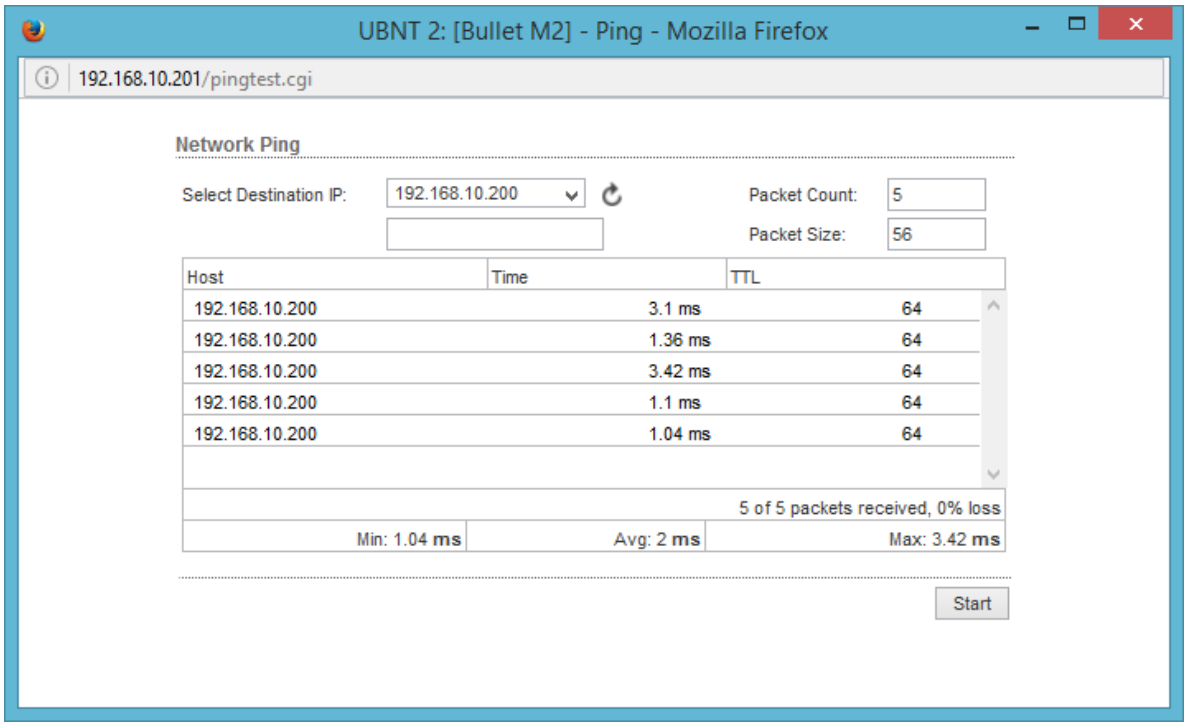

Figure 3.8 – Ping command send it between access points

Another test we can do is: using the device discovery of the bullets, we can verify that our two access points are online and functional as shown in Figure 3.9, as we can see the software detects our two devices without problems.

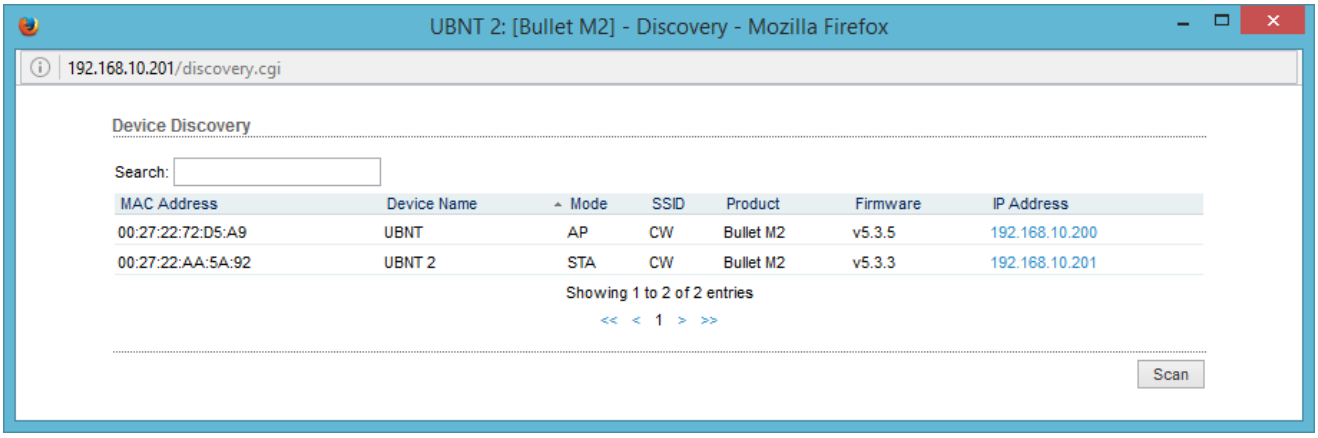

Figure 3.9 – Device Discovery

Finally, we will review the status of our antennas and the signal strength they manage to have optimal communication, as the figure 3.10 shows in the right side we have a strong signal. That means that we will have optimal communication and data transfer between the drone and the mobile station.

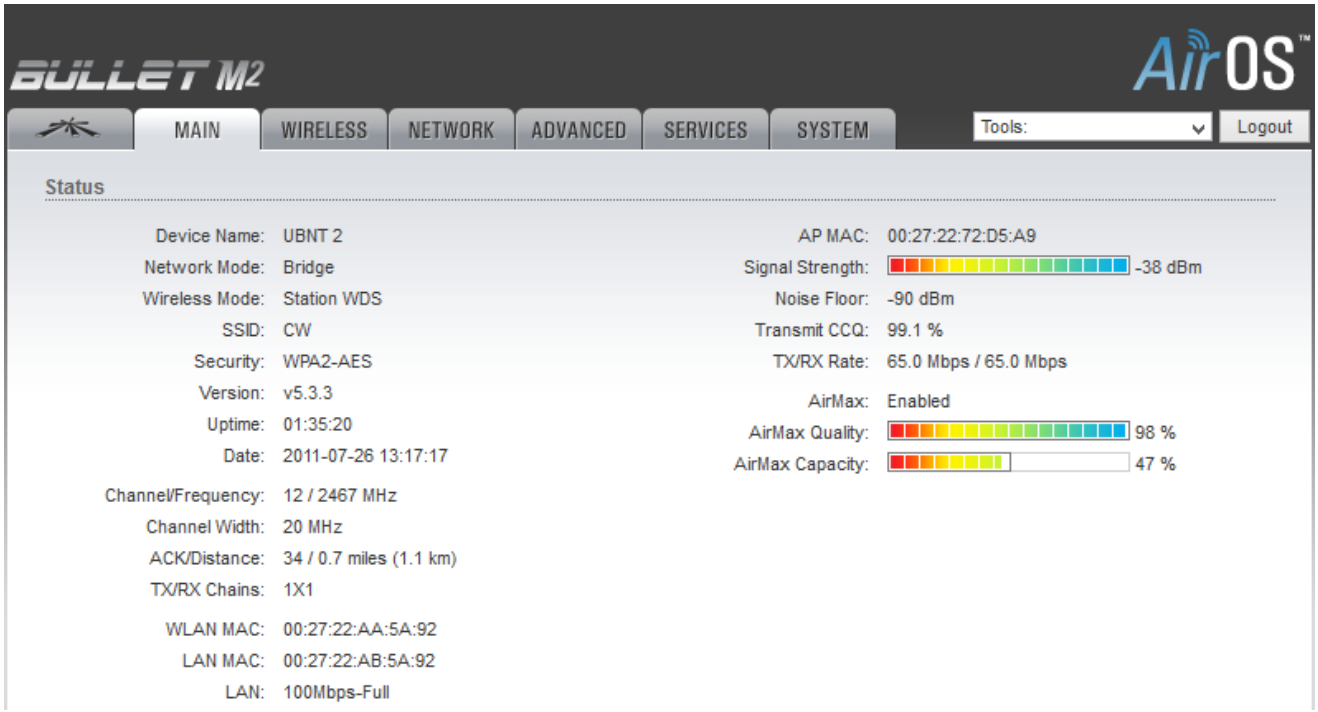

Figure 3.10 – Signal Strength

CONCLUSION

Current electric power lines in Russia have went through multiple reforms and changes. But the necessity of the power lines to adapt requires constant development, at this current phase there is another global changes and re-solved of the problems occurred. Under such considerations reforms to establish and built an efficient energy electricity market, in the Unified Energy System of Russian Energy Strategy require:

- Improvement and development of electrical networks for the interstate transport
- electricity in the CIS and its exports to the neighboring countries
- Support for energy efficiency projects as one of the strategic directions of increase of efficiency of power industry
- Russian Market Integration with the European Union's electricity market and other countries of the Eurasian continent
- Creating a strong electrical connection between Eastern and European parts of Russia by building power transmission lines of 500 kV and 1150, and for 2010 - DC transmission, passing through the territory of Russia. [28]

In conclusion we can say a new approach for conducting diagnoses will allow wide use of the main scientific and practical results obtained by using the "cable walker"

After apply the upgrading design of the wireless communication in the cable walker we will be able to provide the wireless network with a completely transparent operation for the user, guaranteeing at the same time the control in the access to the diagnostics in real time.

Use "cable walker" greatly facilitates and speeds up the numerical experiments in diagnostics of the overhead power lines. The use of modern wireless network system can significantly reduce the time and labor costs in the evaluation of the physical state of the electric towers, the searching of faults in the physical components of the overhead lines. In the future the drone can be implemented in the educational process in the preparation of electric specialists, in laboratories and workshops on research work of building electrical structures.

This work can undoubtedly be applied in México as an innovation in the activities to identify a physical fault in the transmission lines, identifying the areas of opportunity and deficiencies of them more quickly without putting at risk the integrity of the worker and thus Perform preventive maintenance or corrective maintenance and improvements to transmission lines in order to provide greater reliability and thus ensure the supply of electricity in a cost-effective manner, talking about transmission lines just in

México city exits a total of 142 lines, of which 116 are of aerial trajectory and 26 are of underground trajectory, corresponding to a total of 1632 km of transmission lines, so there is a great market to explore.

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