2012 2nd International Conference on
Applied Robotics for the Power Industry (CARPI)
ETH Zurich, Switzerland. September 11-13, 2012

Robot for Inspection of Transmission Lines

Alisson Fonseca, Ricardo Abdo and João Alberto

***Abstract*- This paper is a brief summary of the design and manufacture of an electric robot, whose purpose is to inspect transmission lines, aiming to find defects, such as broken conductors, broken space dampers etc. This project was developed by a group of electrician, mechanical, electronics and automation engineers from the following areas in FURNAS: the technical center for tests and measurements, the division of transmission lines and the regional department of Parana. Thus the group was very heterogeneous, combining engineering staff and people who actually face the difficulties in inspecting transmission lines**

***Index Terms*—Robot, Transmission Lines**

I. Introduction

Eletrobras FURNAS was founded in 1957, and nowadays is responsible for supplying regions where live 51% of the Brazilian people, which respond for 65% of the GNP (Gross National Product). FURNAS' role in some States supplying is: 97% in Distrito Federal, 92% in Rio de Janeiro; 91% in Mato Grosso; 81% in Espírito Santo; 61% in Goiás; 58% in São Paulo; 45% in Minas Gerais and 16% in Tocantins. These States represent a strategic area of the Country where are installed most of the industries and factories.

FURNAS' complex is composed by 12 hydroelectric plants, 2 thermal plants, which represent an installed generating capacity of 10,050 MW, almost 10% of Brazilian Generation, besides 49 substations and 19,419 kilometers of transmission lines, which transmits more than 40% of all Brazilian energy. A map of FURNAS generation and transmission system can be seen in Figure 1.

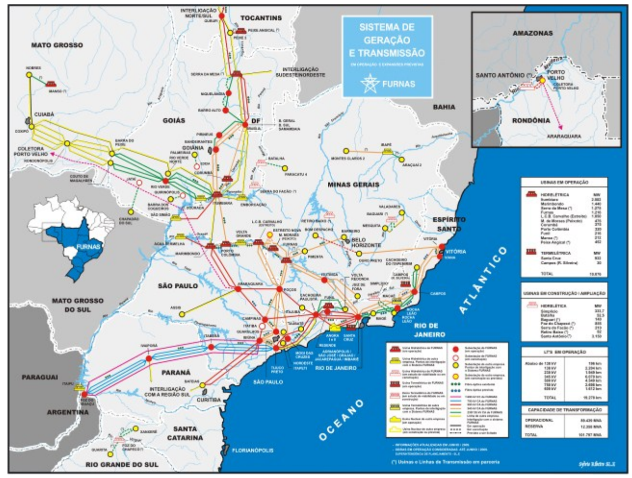


Fig.1. FURNAS Generation and Transmission Map

Due to the great importance of FURNAS transmission lines to the Brazilian Electric System, it becomes essential to execute systematic inspections of those lines. Some of the most important goals of the lines inspections are the detection of broken conductors, corrosion on ground wires, spacers dampers, insulators and interferences along the right of way of the transmission lines. As Brazil has continental dimensions and varied forms of terrain, FURNAS maintenance staff faces many difficulties accessing the lines, such as valleys, rivers, mountains etc. The current inspection relies on the use of human labor and also on the use of helicopters, which represents a high cost and sometimes it is not fully effective in detecting some defects.

For this reason FURNAS invested in the design and manufacture of a robot that will move on the ground wire of the transmission line. The robot has a camera capable of shooting camcorder with good resolution details of the objects that should be inspected. The robot sends the images to a base located on the tower nearest of the span under inspection. From that base, the operator can control the robot's movements, the movement of the camera camcorder and also analyze the details.

II. History of the Work

FURNAS Maintenance Engineering and also some Regional Departments, such as Parana, were concerned about the need of having a high quality inspection in order to prevent fails in the transmission system. Some occurrences that happened in other Brazilian power utilities had huge and bad consequences for the network, resulting in some considerable financial losses.

Corresponding authors: alissonf@furnas.com.br, joaoao@furnas.com.br, rfabdo@furnas.com.br
Alisson Ribeiro Fonseca is a mechanical engineer and works in the technical center tests and measurements. Ricardo Fraga Abdo is an electrician engineer and works in the department of equipment and transmission lines of high tension. Joao Alberto is an electronics engineer and work in regional department Parana.

978-1-4673-4587-3/12/$31.00 ©2012 IEEE

Initially the idea was having the robot using a combustion engine, but this was soon dropped because its impossibility to run on live line. In 2009 this work started to be driven a by CTE.O (Technical Centre for Testing and Measurements) and in 2010, two engineers attended CARPI 2010, hosted in Montreal, Canada, which was an event that helped substantially for the improvement of the project.

After that, some concepts changed and the robot was driven by electric motor. Besides that, a new mechanical design was done to maintain greater stability of the robot in the electric cable. It was also specified a radio system capable of transmitting in real time the control signals to the robot and camera and camcorder images to the computer located at the base.

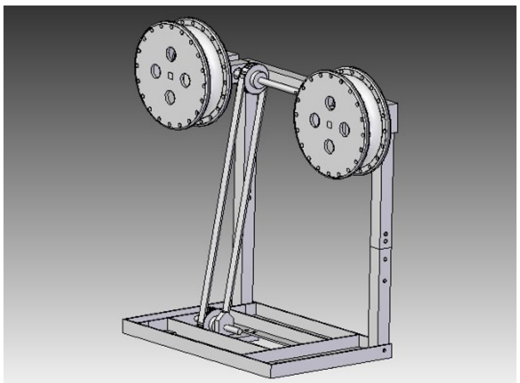


Fig.2. Mechanic architecture of the robot

Fig.3. Robot with a combustion engine

Fig.4. Robot with an electric engine

III. Technical details of the project

A. Logistics solution

The robot moves along the ground wires and goes from one tower to another. The great advantage of the robot moving on the ground wire is the possibility in placing it on the cable, since there is no need to equalize potential with the live line, thereby simplifying this operation. The robot moves through two wheels that are on the cable. The robot system was developed to advance, return and stop controlled remotely. A rescue system is still being developed if there is any failure in the robot. The distance between the ground wires and the conductors is not a problem, since the camcorder has a good resolution and tools of zooming in the objects to be recorded.

B. Solution of motorization

In the choice of the engine, it was taken into consideration appearance, weight, power consumption, torque and rotation. The DC motor has a torque variation of rotation and independent of the inclination of the terrain, in sloped or flat spans, the engine consumes very little power battery. Thus the relation between weight and power of this engine is excellent. The DC motor used has the following characteristics: nominal voltage is 24V, 46W rated power, rated rotation of 45 rpm, rated at nominal current 5A, maximum current 18,6A, nominal moment 10 Nm, maximum moment of 48 Nm. Reduction 63:1 and weight of 1.1 kg.

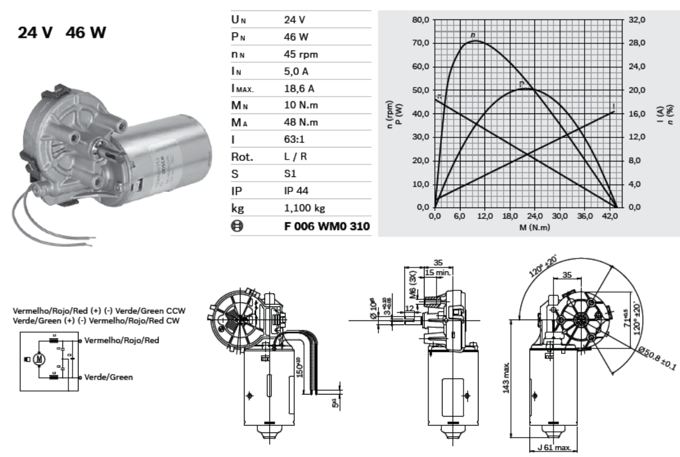


Fig.5. Technical data of the engine.

C. *Solution of motor control*

The controller works on a supply voltage from 10 to 40 V, 15mA of load current and maximum current is 50A. This engine has a start and stop ramp from 0 to 5 seconds and can operate from -40 to 60ºC. The controller's weight is 190g.

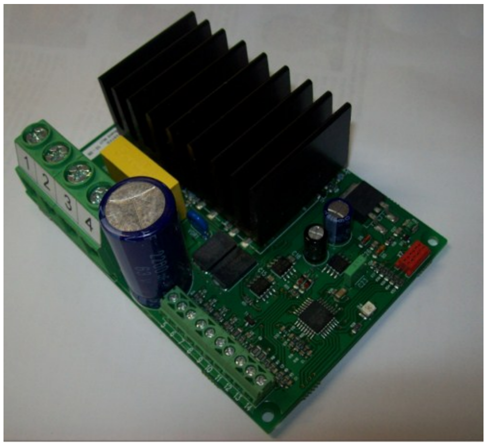


Fig.6. Electronic Control Board

D. Solution of communication

Images are transmitted by radio and are viewed by the operator through the base of a laptop which is also used to control the movement of the robot and positioning of the camera. The characteristics of radio used by the robot are: radio range up to 8 kilometers and frequency of 2.4 GHz. Radio 54 Mbps. Omnidirectional Antenna 8dBi. Industrial Ethernet Switch 8 ports 10/100. PLC with 10 inputs 12 Vdc, 6 relay outputs and 2 analog inputs 12 Vdc supply voltage. Ethernet, serial port 232/485 and HMI incorporated. It makes online programming.

Fig.7. Radio transmission

E. Solution of energizing

The system of lithium ion batteries was chosen, since they have a very good weight and load capacity, beyond that the battery can be recharged without having to be completely empty.

F. Mechanical solution

The design of the robot was considered by the influence of the wind acting on it, so that the robot has two wheels supports and also an intermediate wheel which prevents the robot from falling down in case of strong wind and also serves to aid traction in cases of embossing steep. Aluminum frame with welded and bolted joints, aluminum wheels with rubber and transmission by belt. The welding was carried out by TIG welding method which enables a very secure unity and possible weight loss. Weight reduction was a rather thought.

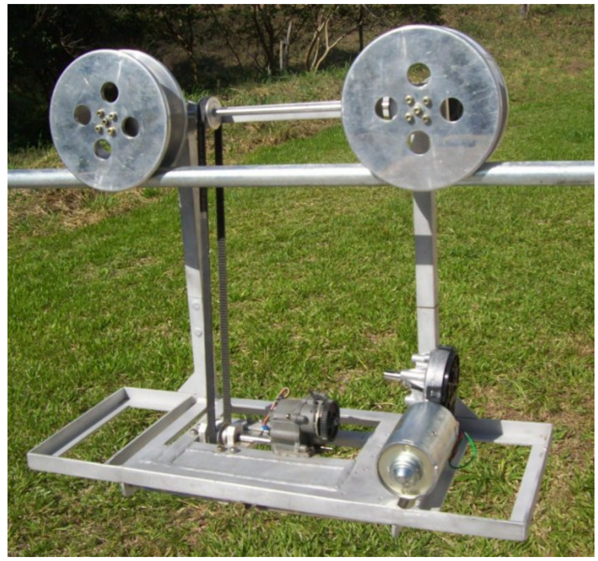


Fig.8. Mechanical structure

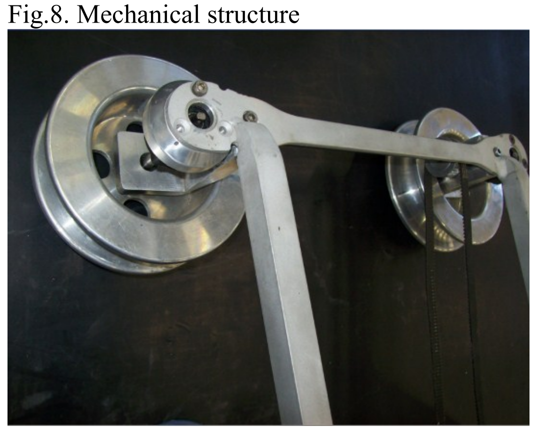


Fig.9.Detail of attachment of the wheels

G. Supervisory system

The supervisory system allows you to control the movements of the robot forward, backward and to stop. The system also allows control of positioning and focusing of the camera image. The characteristics of the supervisory system are: station supervisor for Windows 2000/xp with 15 screens. It doesn’t contain ODBC connection, capacity 300,000 records in data log alarms.

H. Rescue System

The robot has a rescue system, which can be used in case of failure of the same, along the cable. The system is composed of a set of ropes and pulleys accompanying the robot during its movement.

I -Solution of shooting

The camera lets you view the ground wire and conductors, and also other components, such as insulators, spacer dumpers and towers, as it has movements that are controlled remotely, because the images are sent in real time to the operator which is located at the base. The features of the camera used by the robot are shown below:

Camera PTZ (Pan/Tilt/Zoom) Day Night with vandal-proof box,24 V AC power.

Fig.10. Armored camcorder

IV. Results, conclusion and future vision

Nowadays the robot can move only between single spans of towers because it can't overcome a tower, but new studies will be done so that the next version of the robot will be able to overcome a tower, which will result in much higher productivity in the inspections. We believe that this first project will encourage other developments that will help the company to reach the top of the quality in the subject of the automation. We also believe that this is a great alternative to make our processes more agile, economical and safe. FURNAS is supporting the idea and providing everything the technicians and engineers need to develop this research. Besides that, there is a very well equipped research center and there are many specialists in FURNAS working on this subject. We believe that in few time the investment will have its return.

V. Acknowledgment

The authors gratefully acknowledge the contributions of many FURNAS managers, especially Mr. Ricardo Medeiros, superintendent of the Maintenance Engineering area, for their support and belief in this project.

VI. References

[1] V. M. Paulo, M. Jose and Q. B.Alexandre "Soldagem Fundamentos e Tecnologia 2.nd ed (2007). Ed. UFMG. Belo Horizonte.

[2] M.Sarkis. "Mecânica Técnica e Resistências dos Materiais. 14 nd. Ed. (2004). Ed. Érica Ltda.

[3] A.L. Casillas " Formulário Técnico" 19 nd. ed (1981). Ed. Mestre Jou.

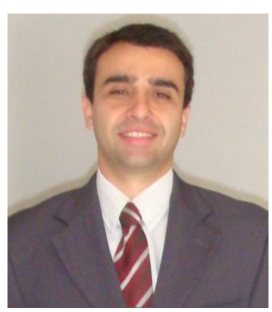
Books:

[4] Catalogue engines Bosch 2010 and 2011

VII. Biographies

Alisson Fonseca Ribeiro was born in Minas Gerais, Brazil on November 21th 1974. He graduated too on Mechanical Technical by the technological Center of Minas Gerais (CEFET-MG) in 1992. He graduated on Mechanical Engineering by the Catholic University of Minas Gerais (PUC-MG) in 2000. At that year he worked for the Usiminas Mecânica. Since 2006 he works for Eletrobras FURNAS in the Technical Center Test Measurements (Maintenance Engineering). Abdo also has graduated on Welding Engineering by the Federal University of Minas Gerais (UFMG) in 2008 and another MBA on Business Management by Fundação Getulio Vargas (FGV) in 2003.
Alisson has experience in design and manufacture of mechanical parts, nationalization of components, equipment modification and improvements.

João Alberto de Oliveira (1974) was born in Itumbiara, on January 23, 1974. He graduated from the Center of Technological Sciences - FEJ of Santa Catarina, and post-graduated from the National Service of Industrial Learning - SENAI.
João has been classified as work featured in 2nd place by the Technical Committee of the XII ERIAC - Ibero-American Regional Meeting of CIGRE in 2007. Had work selected for public presentation at the Fourth Congress of Technological Innovation in Electric Power - CITENEL in 2007. Contributed to the development of electronic equipment for diagnosing corrosive foot towers by injection of electric currents in closed-circuit conditions.
He was awarded the GOLD HOUSE promoted by FURNAS in recognition of their contribution to development outcomes of the innovative idea of using live line plate to replace cavalote bent on 750kV lines. Also presented in 2008 ICOLIM development of a yoke for special fittings replacement in the biggest 600kV HVDC overhead Line



Ricardo Abdo was born in Rio de Janeiro, Brazil on October 26th 1978. He graduated on Electrical Engineering by the Federal University of Rio de Janeiro (UFRJ) in 2000. At that year he worked for the National Electric System Operator of Brazil (ONS). Since 2001 he works for Eletrobras FURNAS in the Transmission Lines Department (Maintenance Engineering). Abdo also has graduated a MBA on Maintenance Engineering by the Federal University of Rio de Janeiro (UFRJ) in 2009 and another

MBA on Human Resources and Finance by Veiga de Almeida University in 2012.

Abdo is experienced in the following activities:

- Analysis on Transmission Lines Performance;
- Management of Research and Development Projects;
- Management and Teaching of International Trainnings on Transmission Lines O&M and Occupational Safety, such as for EDM (Mozambique Power Utility) employers in Mozambique in 2006;

Abdo is FURNAS Representative the following work groups

- Technical Group of RINDAT (National Integrated Network of Lightning Detection);
- Transmission Lines Technical Group of ABRATE (Brazilian Association of the Transmission Utilities);
- Commission of Revision of Brazilian Technical Standards.