Live working washing of line insulator chains using tap water, a telescopic arm and robot head.

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Abstract
This paper presents the development of techniques for the live working washing of insulator chains, results achieved, current restrictions, difficulties encountered and opportunities for improvement.

Introduction
Many power lines near the mainland Italian coasts are affected by insulator salt deposits. This occurs when onshore maritime winds carrying microscopic droplets of brackish water evaporate upon contact with the insulators and consequently deposit salt. System electrical insulation does not suffer as a result of these deposits as long as they remain dry. However, when the salt becomes damp for any reason, insulation is compromised and the line cannot be kept in service.

Thus, the need has arisen for a method to effectively remove the salt from insulators. The conventional insulator cleaning method is manual after having disconnected the line from service. This method is extremely demanding due to the prolonged service interruption period and to the large number of operators required to carry out the work. A valid alternative would be potential salt removal by washing insulators with a jet of water.

Development
The first stage was to define objectives. These can be summarised as follows:
- Operation to a height of approximately 30 metres from the ground.
- The use of tap water (conductivity between 10 and 1000 microsiemens per centimetre).
- Maximum possible cart manoeuvrability.
- Good washing efficiency.

Tap water was chosen rather than demineralised water for the following reasons:
- It can be done. That is, even if the stream of water is conductive, liquid atomisation ensures insulation at the proper distance from the nozzle.
- Demineralised water is very aggressive and tends to decay metal parts by triggering corrosive action.
- Demineralised water conductivity cannot be kept low when it is stored in metal containers and machinery.

Having defined the objectives to be achieved, implementation was assigned to a consortium of two companies: one specialising in lifting arms and the other in advanced technical solutions. The latter was supported by consulting services
provided by the French company Serect, which had already trialled live working insulator washing, although it had not used lifting arms with robot heads.

The unit was divided into two carts with 4 driving wheels each: one with a lifting arm and washing nozzle, and the other with a simple tank water storage function.

**System description**

A 5-section telescopic arm plus an articulating arm (jib) with two extractable sections are fitted onto a rotating tower. The robot head is mounted at the end of the jib (Fig. 1). The robot head has a self-levelling system to maintain the main platform in a horizontal position automatically. There are three sequential remote-controlled joints that allow for independent orientation along three axes. The following are fitted to the end point: a swivelling nozzle with interchangeable nozzles used to spray water, a camera to aid in direction, and sonar for judging distances. The operator’s position is fitted with a seat and a console and is installed protruding from the rotating tower at the bottom of the arm.

A service tank used for washing water plus the pump system are also fitted to the same cart. The power required to move the arm and operate the washing pumps is provided by a diesel motor separate from the drive engine.

**Automation and safety devices**

Proper operating procedure is controlled by several devices that allow the system to be used safely. These are described below.

Measurement of leakage current along the jet with an alarm threshold and a system-blocking threshold (2 mA).

Measurement of water resistance in relation to nozzle diameter, power line voltage (preset) and water pressure. If values are outside expected parameters, the system is blocked.
Minimum tank water level so as to prevent pumps operating dry.

In addition to camera-sourced images, the console display also shows sonar-detected distance, water conductivity, leakage current and the residual quantity in the washing water tank.

There is an electrical connection between the lifting arm and the cart frame using strong stranded copper wire to prevent even small leakage currents from damaging the tower bearing.

**Operation**
The cart with the lifting arm must be appropriately positioned adjacent to the base of the pole. It must then be set in a horizontal position by operating the stabiliser feet it is equipped with until all of the wheels come away from the ground.

Before lifting the arm, the cart must be attached to the ground by means of three stakes embedded in the earth at some distance from the pole. The area must also be fenced off and only the console operator may be allowed inside this area. The operator must not come down from his position until the arm is lowered again.

Arm movement is controlled from the console by means of joystick-type levers. The operator positions the head with the aid of the camera and sonar so that he can see the insulator chain from below at an angle of approximately 30° to the horizontal (Fig. 2).

At this point, the operator actuates the jet and washes the insulators by swivelling the nozzle, starting from the bottom of the chain (Figs. 3, 4 and 5).
Remarks on the jet
The jet used is a “full jet” type with no cyclical interrupting devices which would make it pulse flow.

The jet can be divided into three areas. The first is at the nozzle exit: a steady, continuous, uninterrupted stream of liquid. In this area, the tap water jet acts as an electrical conductor.

In the second area, adjacent to the first, the jet loses uniformity and atomises. It becomes a stream of generally very small separated drops. In this area it does not conduct electrical current and can be considered to be insulating.
In the third area, even further from the nozzle, the jet loses its impact force and as a result loses washing efficiency.

**Remarks on the insulators**

Insulators contaminated with salt maintain insulating capacity as long as they are in a dry atmosphere. Wet insulators maintain insulating capacity as long as the water making them wet is clean (in particular, free from salt).

The fundamental principle of live working washing is a consequence of the above two statements: the insulators must be dry if contaminated, and clean if wet. As a result, washing must be as quick and as thorough as possible to avoid discharges along the chain.

**Operational consequences**

The operating procedure to be adopted follows as a consequence of the two considerations above. The nozzle must be kept at a distance from the live parts equal to or greater than all of the first area plus part of the second, which ensures insulation. The distance must not, however, reach the third area in order to prevent the jet from getting the insulators wet without actually cleaning them.

We must also consider the fact that washing an insulator causes water that is probably contaminated to drip onto the surface below. Consequently, the insulators that have already been washed should be rinsed as the operator moves upwards with the jet along the chain. This results in an oscillating jet movement: it moves up to wash a section of the chain (one third, as a general rule), then comes down again to rinse it, then moves up for another section, then comes down again and moves up until it reaches the top. It then makes a final pass down for the last rinse.

**Results obtained**

Live washing trials did not report any drawbacks. The insulators were found to be clean and there were significant savings in time and human resources.

In order to assess washing efficiency, contaminated insulator salinity was measured before and after the insulators were washed under the same contamination conditions. Before washing, the equivalent salt deposit density (ESDD) was about 0.4 mg/cm², whereas it dropped below 0.02 mg/cm² after washing.

**Difficulties encountered**

The first difficulty concerns ground morphology, which in some cases seriously impedes the washing cart from reaching the pole.

Another difficulty lies in finding the right head position in order to wash the maximum number of chains. Considering that washing a chain requires less than one minute and positioning the head requires half an hour (and even more in problematic cases), it is clear that the less the head is moved the more time is saved. In some cases, proper positioning of the head is very difficult or even impossible.
Another problem is represented by the wind, which makes aiming ineffective and distorts sonar measurements.

**Potential improvements**
In order to deal with the issue of wind interference better, a wind gauge can be installed on the head, with wind speed and direction shown on the console.

Another improvement lies in extending nozzle swivelling movement, currently limited by the camera. Larger movements would increase flexibility and solve some positioning problems.

A second, alternative distance measurement system would prove useful on those windy days that cause distorted sonar readings.