Study Committee B5

Protection and Automation – PS2

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ALGORITHMS FOR AUTOMATIC DETECTION OF FAULTS/HARMFUL EVENTS ON 132-150 KV OVERHEAD LINES

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Motivation

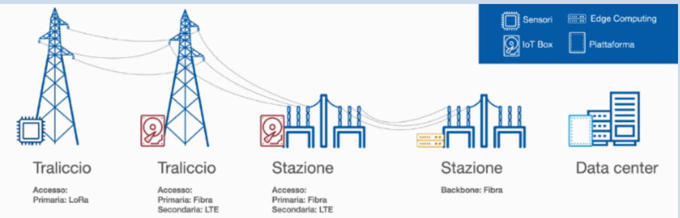
- In the last years, statistics show a growing trend of harmful events caused by adverse weather. This trend suggests a revision of power systems management criteria, with the aim of reducing the effects of faults and/or harmful conditions.
- Additional information about the status of the power system can allow a significant improvement compared with the current standards. In particular, additional information can allow automatic detection of some types of harmful events.

Experimental setup & test results

In Italy, Terna started a pilot project with the installation of distributed processing sensors and advanced analysis for reactive fault localization, structural and environmental monitoring and the creation of a platform for data centralization.

The objectives are the construction of an infrastructure of data collection from sensors installed on Terna's assets and the development and experimental installation of sensors for supports structural monitoring.

In the Figure below: data transmission scheme from sensors on pylons to data center



Method/Approach

- This paper presents three algorithms aimed at automatic recognizing of the following fault and pre-fault situations: conductor breaking, fallen trees on line conductors, snow/ice accretion on line conductors.
- The three algorithms are based on the real-time prediction of the mechanical voltage of the phase conductors, and consistency with the actual measured values.
- In addition, the algorithms exploit the correlation between electrical and mechanical information, i.e. the information extracted from the electrical protections and the information provided by the mechanical and environmental sensors.

Conductor breaking

- A conductor breaking leads to a sudden decrease of the tension measured by the load cells. The logical scheme for automatic detection of this event is based on abrupt changes of the conductor tension.

More precisely, the algorithm is based on the binary comparison, at each sampling step, between the current tension measure and the value measured at the previous step: in case of breakage, this comparison points out a sudden drop.

- If the event occurs in a span located at the extremity of the line section:

- the local load cell captures a large tension decrease.
- The other load cell is 'far' from the breakage point (at a distance of some spans). Here, the mechanical action of the suspension insulators between the load cell and the break point causes a smaller tension change. After breakage, the tension value can be assumed lower than the minimum tension measured with undamaged conductor.

- If the event occurs in an 'internal' span of the section, both load cells are 'far' from the break point and capture a limited tension decrease.

In any case, therefore, the event is detected when the conductor tension measured by the load cells falls suddenly below a proper threshold value representing the minimum value of the mechanical tension of the intact conductor during operation.

In order to avoid possible errors in case of tension transients caused by snow detachment, wind-forced oscillations etc., in addition to the previous mechanical conditions, the startings of the protections located at the ends of the line are a further (electrical) condition required for detection of a conductor breaking.

Fallen trees on line conductors

Fallen trees increase the tension of the involved conductors.

- If the event occurs in an extremity span of the line section, the tension increase is measured by the local load cell. Conversely, the tension increase measured by the far load cell is much lower.

Compared to the case of conductor breaking, the tension changes caused by fallen trees have opposite sign (and are expected to be smaller).

- If the event occurs in an internal span of the section, both load cells will measure a limited tension increase.

For automatic detection, we propose considering the difference (error) between the measured tension and the computed (or predicted) tension of each conductor. The latter is computed using the well-known 'change-of-state' equation, in which the line and environmental variables (for example, the current air temperature) are known and no mechanical overload is considered.

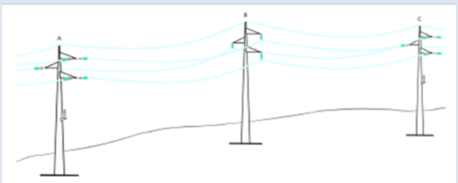
- In order to avoid false positive results due to measurement errors, wind push on the conductors and so on, detection should be enabled when the above error exceeds a proper threshold.

- Transient situations like a strong gust of wind can cause the error to exceed the threshold for a short time. In order to discard such transient situations, the detection of this event is enabled if the mechanical overload persists for more than a suitable time (for example, about 10 s).

- Finally, the algorithm generates the signal 'fallen tree' if, in addition to a persisting measured conductor tension higher than expected, the line protections startings are also detected.

Snow/ice accretion on line conductors

Recent data show a significant increasing trend of snowy events. In particular, wet-snow sleeves form more frequently than in the past. Wet-snow form with an air temperature between 0°C and +2°C and can form heavy sleeves on the conductors, which can even exceed 20 kg/m. Such large mechanical overloads can cause conductors' (and ground wires') breakage and, in extreme cases, pylons' collapse.



- Compared with the previous events, the accretion of snow/ice sleeves on the conductors' surface causes a more gradual and progressive tension change.
- This event normally involves the whole line section between two dead-end towers (or more adjacent sections), causing a more or less uniformly distributed mechanical overload on the conductors.
- Therefore, the load cells along the line are expected to measure a similar progressive tension increase.

The main purpose of the automatic detection logic is to avoid the formation of too heavy sleeves that can damage the OHL.

The proposed algorithm considers again the difference (error) between the measured tension and the computed (or predicted) tension of each conductor, over a sufficiently long time period.

The basic condition for detection of this event is a progressive increase of the error over a proper threshold.

For automatic detection of this event, the algorithm requires two further conditions:

- air temperature and wind speed (measured by the weather stations along the line) compatible with ice/snow accretion;
- no starting of line protections (indeed, this event is not a fault).

Conclusion

The availability of an overhead line monitoring system that observes mechanical quantities and environmental parameters, cooperating with an algorithm of recognition of the fault situations considered, can considerably speed up the fault finding operations and therefore the repair and restoration operations.
Moreover, the knowledge of the mechanical state of the lines of the National Transmission Grid can serve the operations of electricity dispatching.
The three algorithms presented in this paper can effectively recognize the different harmful events considered, as demonstrated by digital simulations.
Attention is paid to two frequent types of fault: faults derived from the fall of plants on the lines and faults derived from conductor breaks. These contingencies, in particular the latter, originate permanent ground faults and cause permanent damage to the line.
In addition, attention is paid to a possible pre-fault contingency, such as the formation of heavy snow or ice sleeves on the conductors. Although this stress does not represent an immediate danger for the mechanical structure of the line, sleeves weigh down the conductors which, by deforming elastically, reduce the ground clearance and the distance between them. If sleeves become too large, the situation can degenerate into earth or two-phase faults leading to the line failure.
Clearly, a subsequent implementation and experimentation phase will be necessary for calibration and field testing.