LONG OFFSET TRANSIENT ELECTROMAGNETICS (LOTEM): AN INNOVATIVE EXPLORATION TECHNIQUE FOR DEEP EARTH STRUCTURES

B.Tezkan

Germany, Institute of Geophysics and Meteorology, University of Cologne

Long-**o**ffset **t**ransient **e**lectro**m**agnetic (LOTEM) is an active geophysical method to investigate the subsurface distribution of electrical conductivity. Penetration depths can be achieved up to 6 km. In general, this information can be derived out of the distribution of the EM field due to a known source. This source can either be passive as in the magnetotelluric (MT) method, where natural ionospheric fields are used as source, or active if some kind of transmitter is used. In LOTEM the source field is generated with a grounded dipole antenna of 1-2 km length through which a strong direct current is injected into the earth. This current is regularly reversed in polarity. With each reversal of the current flow a system of secondary eddy currents is induced into the subsurface causing an EM field. LOTEM is a special mode of the transient EM (TEM) method optimized to achieve maximum exploration depth. For this the distance between transmitter and receiver has to be greater than or equal to the depth of exploration giving the method the ‘longoffset’ part of its name. The EM field can be measured with magnetic and electric antennas at different locations. From its distribution it is possible to draw conclusions on the subsurface conductivity in the surveyed area. Traditionally EM methods have been used in the exploration for conductive targets.

Especially in mining geophysics or in geothermal prospecting different kinds of EM methods are well accepted and frequently used. However, in the exploration for electrically resistive targets like oil or gas reservoirs most EM methods lack of sufficient sensitivity. There is a direct context between the sensitivity to resistive targets and the different sources used in different methods. Generally, the source field can be split up into two parts the inductive part and the galvanic part. Simplified the first is responsible for the sensitivity to conductive targets whereas the latter is responsible for the sensitivity to resistive targets. However, most of the EM methods, including MT and all methods using a loop transmitter, lack the galvanic part in their source and are therefore less sensitive to resistive targets. In total LOTEM can distinguish between conductive and resistive anomalies and resolve the resistive anomalies much better than the conventional MT-method.

To realize LOTEM measurements a transmitter capable of delivering a strong and well regulated current with a steep switch-off and on is necessary. At the University of Cologne, we normally use a Zonge GGT-30 transmitter powered by a 3-phase 400 Hz generator.

This combination is mounted on a trailer for optimum flexibility in the field. The combination weighs around 1200 kg and can be dragged by a medium size 4WD car. As the transmitter operates with voltages up to 1000V the grounding points have to be

guarded during operations to prevent by passers from touching them. Therefore, beside one transmitter operator at least two guards are necessary for save operations. The receiver system consists out of several digitizing units linked to a central PC by a digital line. The whole system can be controlled by the operator at the central PC. The PC operates from a car battery or a small generator to be independent from power sources and vehicles. As magnetic sensors large multiturn loops of $40x40m^2$ are used.
The whole equipment for a line with 4 stations can be carried in a 4WD station wagon or pickup. Normally field operations are best with two independent receiver teams consisting out of an receiver operator and two or three helpers each. After setting up the transmitter and the receiver spreads operation starts and some hundreds to some thousand transients have to be stacked to improve the signal to noise ratio (SNR). This procedure takes some hours up to one or two days depending on noise conditions and signal strength.

To get a qualitatively optimal signals we save every raw time series and perform digital pre stack
filtering on each of them.
Power line noise is treated with specially designed digital lockin filters. Stacking is carried out as robust procedure, eliminating pulse-like distortions such as atmospheric sprites.
After processing the data has to be interpreted to create a resistivity depth section or a 3D subsurface resistivity map.
Normally at first 1D inversions are carried out to fit layered earth models to the data. In areas of basically stratified geology this interpretation is often sufficient. However LOTEM is also applicable to areas of much more complicated geology. Techniques used at the University of Cologne allow to model 2D or 3D geological structures even including complicated topography.
Part of the research at the University of Cologne is to further improve LOTEM interpretation techniques. 2D and 3D inversion codes are currently under development and have been tested at first targets.
Like in all other geophysical methods no unambiguous geological information can be derived out of LOTEM measurements alone. Best results are achieved when combining LOTEM with other information. Specially well logging or seismics can strengthen resistivity values or depths. By combining seismics and LOTEM porosity values can be estimated under favorable conditions.
Selected LOTEM field examples will be shown in the presentation, after introducing the principles of the LOTEM method.