A Data Acquistion System for Geoelectric Monitoring

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Introduction

A data acquisition system has been developed for automatic monitoring of variations in resistivity and induced polarisation (IP) effects, plus self potentials (SP). The system consists of electrodes, electrode cables, resistivity-IP instrument, relay switches, lightning protection, power supply, internet connection, etc. We have migrated through several generations of the system dating back to our first remote installation with automatic daily measurements in 1996. The system(s) have been used for a number of applications. Automated long-term monitoring has been done at 3 embankment dams in northern Sweden, out of which 2 are active at the moment (DAHLIN et al., 2001; SJÖDAHL et al., 2008, 2009). The purpose is to develop techniques for detecting anomalous leakage and internal erosion in the embankment dam, where the annual temperature variation is viewed as a natural tracer.

Short-term monitoring with the same objective has been done on embankment dams a couple of times, also with the aim to detect internal defects and anomalous leakage paths (SJÖDAHL et al., 2010, 2011). Here the monitoring period has been a few days in connection with planned change in reservoir water level.

Short-term monitoring has also been done at 4 different waste sites in southern Sweden, typically for 1-2 weeks, including 4 separate monitoring campaigns on one of the sites (JOHANSSON et al., 2011; ROSQVIST et al., 2011). The aim has been to detect variation in content and migration of fluids and gas in waste.

The intention of this article is to outline the main features of the system and summarise the experiences gained of geoelectrical monitoring. Glimpses of different steps in the development are given, from the earliest to the most recent version will be described here.

Before monitoring with permanently installed data acquisition systems started we did a time lapse survey on Lövön embankment dam in Sweden, where we installed and left the electrodes in place but connected the electrode cables and the instrument each time of measuring (JOHANSSON and DAHLIN, 1996). In this study it became very clear that the type of electrodes consisting of steel rods that are normally used for geoelectrical imaging surveys were poorly suited for long term measurements as the electrode grounding contact deteriorated seriously from one measurement time to the next. We then switched to buried plate electrode that functioned much better.

Electrodes and Electrode Cables

Stainless steel plates are preferred as electrodes for the resistivity-IP measurements, where we use sizes between 0.125m x 0.125m (short term monitoring) and 0.25m x 0.25m (long term monitoring, see Fig. 1). The plate electrodes are buried at shallow depths, providing much larger contact area than regular cylindrical electrodes. The electrodes are fitted to the electrode cables so that only stainless steel and no other metals are exposed to the environment in order to avoid galvanic elements and corrosion. The electrode cables are specifically made for monitoring installations with no exposed metal surfaces, and hence no exposed parts carrying dangerous currents and potentials. Lightning protection is connected between each incoming electrode and the relay switches and the instrument, and the power supply is also protected against over-voltage.

Fig. 1: Design of electrodes used for permanent installations for geoelectrical monitoring and photo from field installation in progress on Hällby embankment dam 1996.

At a couple of the embankment dam sites non-polarisable electrodes for SP measurement were included. In those cases every 2nd electrode is a stainless steel plate and every 2nd is non-polarisable. Only the steel places have been used for current transmission, while the non-polarisable one have been used for measuring SP as well as potentials for resistivity and IP.

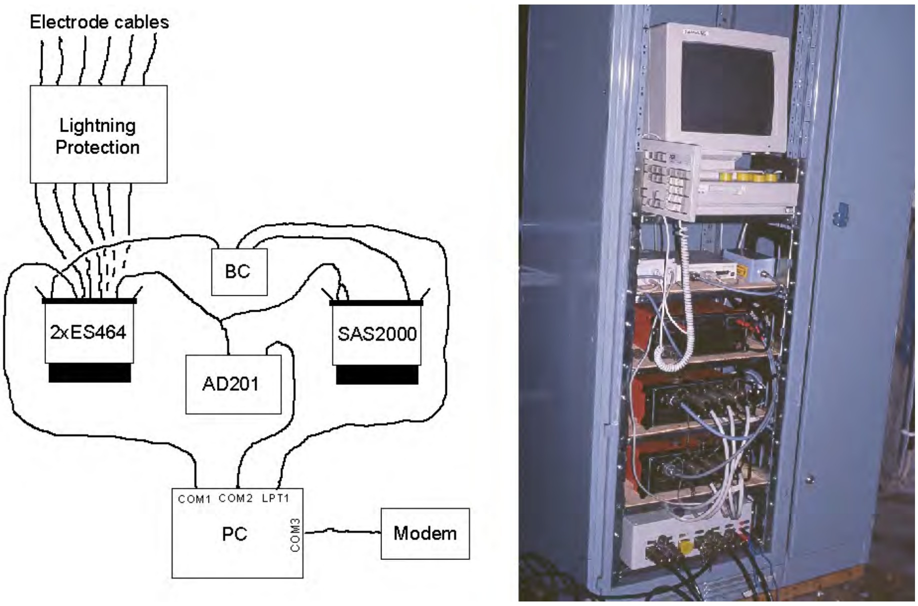

Fig. 2: The first permanently installed data acquisition system on Hällby embankment dam, installed in 1996.

Instrumentation

The first generation of the system installed consisted of a mixture of components, an ABEM Booster SAS2000 was used to transmit current, two units of ABEM Electrode Selector ES464 to switch electrodes, a Lawson Labs AD201 24 bit A/D-converter for measuring potentials, and lightning protection designed and built at Lund University (Fig. 2). The data acquisition was controlled by a standard desktop PC via serial ports and a parallel port interface for controlling the SAS2000.

The second generation of the system installed also used an ABEM Booster SAS2000 to transmit current and 1-2 units (depending on site) of ABEM Electrode Selector ES464 to switch electrodes. Measurements and control of the transmitter was taken over by a Terraohm RIP224 receiver and control unit equipped with 24 bit A/D-converters, which was designed and built at Lund University as the lightning protection. The data acquisition was controlled by a standard desktop PC via serial ports.

Fig. 3: Temporary installation of the present data acquisition system on a landfill in 2011.

The most recent data acquisition system comprises an ABEM Terrameter LS configured for automatic measuring at pre-selected intervals (Fig. 3). The instrument has a built-in relay switch that handles 64 electrodes, but we have expanded it with a number of Electrode Selector ES10-64C relay switches to allow for more electrodes. The instrument software runs on a Linux platform, and timing of the data acquisition is controlled by cron. Each time it is due cron starts up acquisition software and carries out measurements according to the selected protocol(s). After finishing a measurement round the instrument turns off the software and all data acquisition hardware, which means that the power consumption in stand-by mode is minimised. In this case a PC is not needed to control the data acquisition, but depending on the speed of the Internet it may an advantage with a compact industrial type PC for more stable remote control and data transfer.

Remote Control and Data Transfer

In the early systems remote control and data transfer was done via telephone modem using pcAnywhere. The telephone lines were often poor and communication with the data acquisition system required endless patience and was a source of lots of frustration.

Remote control and data transfer is nowadays done via a mobile broadband internet modem with built-in router, etc. The monitoring systems transfer data automatically via SFTP, using a data transfer system design is outlined in Fig. 4. Data archiving has been identified as a field needing a systematic approach, and a standardised data format is also needed.

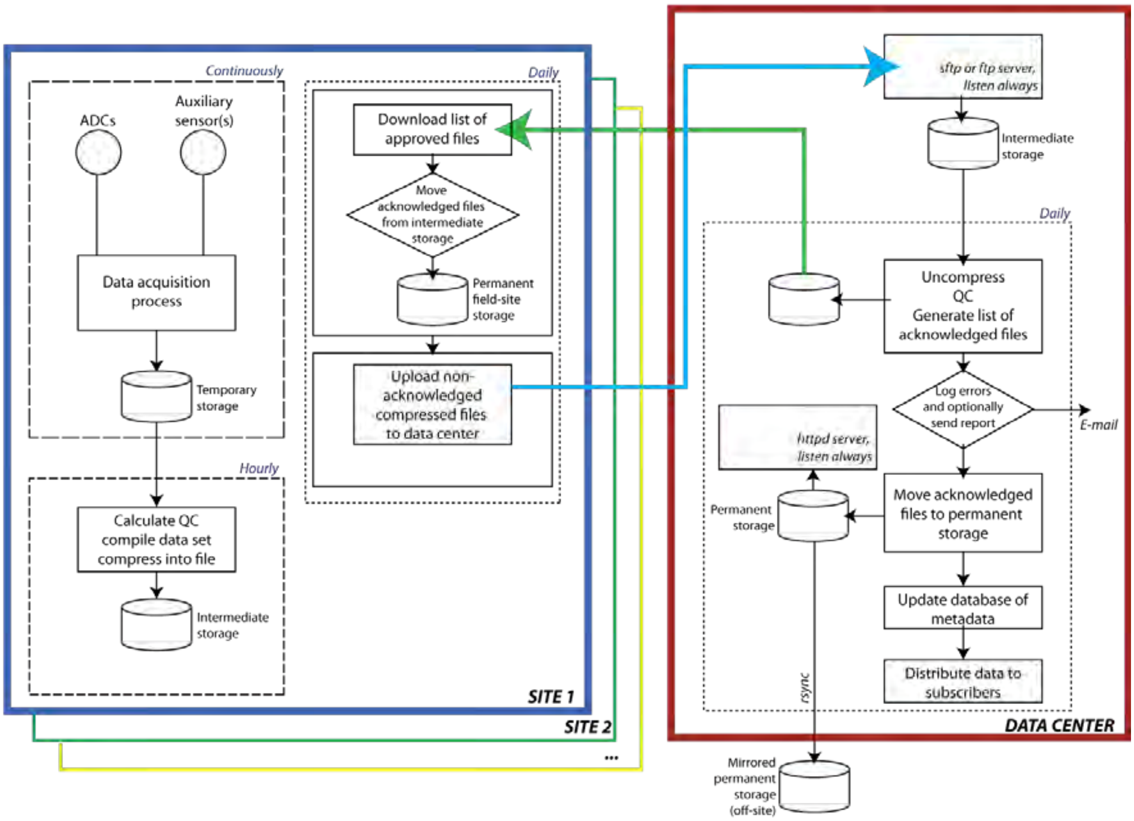

Fig. 4: Overview of data transfer system principles.

Power Supply

Power supply has so far been provided by the power net grid. In cases where power consumption is provided by batteries or solar panels the latest system can be optimised for minimum power consumption via standby mode between measurements. Adjusting output power and optimising the measuring protocol to reduce the number of current transmissions by using the multi-channel capability are other ways to save energy.

Experiences

The data acquisition systems have mostly operated in a stable way, with occasional breakdowns. The reasons for problems during the period 1996 to 2011 have been (listed in order of frequency):

- Modem and Internet connection breakdown and stability at the monitoring site has by far been the largest problem through the years. In recent years more stable solutions have come.
- Transmitter malfunction due to worn out components has occurred a handful times due to worn out polarity switch relay or transistor. It should be noted that the transmitters used have been SAS2000 which were designed for manual resistivity surveying in the 1970-ties and never were intended for automated imaging many hours every day year after year.
- Relay malfunction in the electrode selectors (3 occasions).
- Malfunction of server in Lund due to lightning transient.

- Electrode disconnection by animals (short-term monitoring).
- Remote cable damage (short-term monitoring).
- Electrode connection corrosion (open take-outs in short-term monitoring), see Fig. 5.
- Damaged serial port in a PC due to electric transient (one occasion).
- Damaged input channel of RIP224 due to electric transient (one occasion).

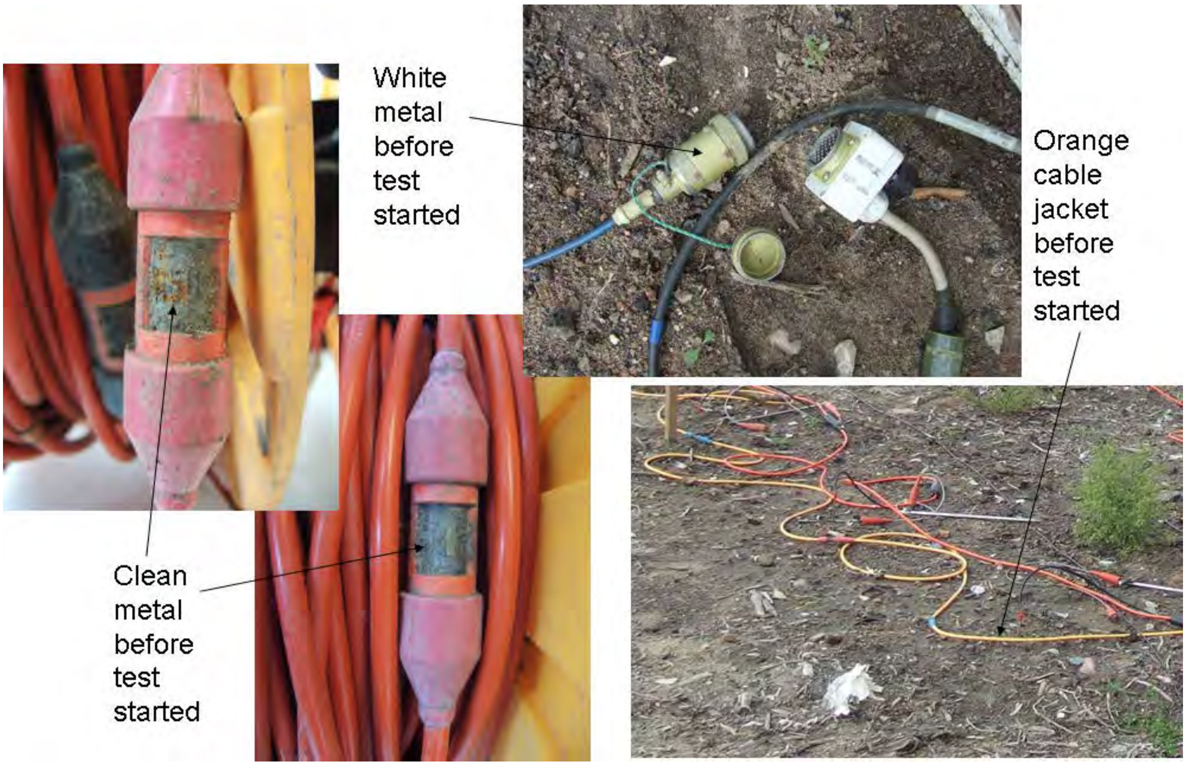

Fig. 5: Photographs showing corrosion, etching and bleaching of electrode cables and connectors resulting from a few weeks exposure to the atmosphere on a landfill.

Summary and Conclusions

The overall experiences of our geoelectrical monitoring activities can be summarised as follows:

- Automatic monitoring has been carried out at a number of sites since 1996.
- Data acquisition and transfer solutions have mostly been stable.
- Most trouble has been caused by communication problems.
- Poor ground to electrode contact was reduced by buried plate electrodes.
- Corrosion problems were eliminated by insulated pig-tail electrode connections.
- Long time series of IP data remain to be analysed.

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