Factors affecting time domain IP data quality

T. Dahlin[1]

(1) *Engineering Geology, Lund University, Sweden*

Acquisition of time domain IP data is logistically identical or similar to DC resistivity, but much more difficult from a measurement technical point of view due to the much smaller signals. In case of spectral IP it is also desirable to measure with short integration times, starting with as short delay as possible after current turn-off in order to achieve high frequency content. Signal levels of IP responses are often a fraction of the noise levels, making high dynamic resolution and adequate noise filtering key properties. Transmitted signal is also import, but there are logistical advantages of limiting the output power so that standard equipment of ERT type can be used.

An important factor for data quality is the signal-to-noise ratio, which varies strongly between different electrode arrays. Signal-to-noise ratio is often not a problem for resistivity data acquisition with modern good quality instruments, at least not for relatively small electrode spreads. For IP data acquisition, on the other hand, the signals are much smaller which makes them easily drown in noise. The signal levels are inversely proportional to the geometry factor, i.e. the larger the geometry factor the lower the signal-to-noise ratio. The Wenner array can be used as reference for calculating the relative signal-to-noise ratio of the other electrode arrays, and for the multiple gradient array (Dahlin and Zhou 2006) it falls in the range 0.3 – 1.6 (geometry factor 7.5 – 1.2) for s-factors respective n-factors going up to 7 or 8. For dipole-dipole array the relative signal-to-noise ratio is 0.01 – 0.3 (geometry factor 230 – 6.3) with the same range of n-factors. This means that 30 times more transmitted current is needed to achieve the same minimum signal-to-noise ratio when surveying with dipole-dipole array compared to multiple gradient array. Conversely, only 3.3 % of the transmitter output power is required to generate equivalent worst case signal-to-noise ratio for data measured with multiple gradient array compared to dipole-dipole array. Pole-dipole array is only a factor 2-3 weaker than the multiple gradient array for equivalent median depth of penetration, but it does require a remote electrode which is often problematic.

A common argument for using dipole-dipole array is to avoid coupling between the transmitter and receiver layouts. Coupling can be divided into inductive and capacitive coupling. Inductive coupling is not a problem for DC resistivity measurements, but can possibly be an issue for very early IP decay times. Capacitive coupling can become a serious problem when measuring IP using multi-electrode equipment with multi-core electrode cables used both for transmitting current and receiving signals. The problem appears to be strongly related to the electrode-to-ground contact (Dahlin and Leroux 2012). Experience shows that if the contact resistance is less than 1 kΩ, then IP data of very good quality can generally be recorded, whereas if the contact resistance is above 10 kΩ data quality can suffer significantly. In cases with high contact resistance, when it is not possible to reduce it with watering, putting extra electrode in parallel, etc., data quality can be improved by surveying with two sets of electrode cable spreads in parallel (Dahlin and Leroux 2012). Even if this means more complex field logistics and heavier equipment it is probably still more time and cost efficient compared to surveying with equipment designed for several kV and kW output which would be the alternative.

Electric noise from the power grid can be magnitudes larger than the IP signals, but it can often be efficiently suppressed for the integrated IP decay by averaging over multiples of the period of the base frequency. For spectral time domain IP the noise simple averaging is often not sufficient because of variation in the load on the power grid and since the base frequency can vary slightly. The standard EN50160 allows a frequency deviation up to ± 0.5 Hz if there is a sudden change in generation or load (Li et al. 2011). A more severe problem is electric noise from railway power systems (Fig. 1). In many countries the frequency is lower, 16 $^2/_3$ Hz, which means that the shortest

IP time window that can be extracted after averaging over a full power cycle is 60 milliseconds. This means that high frequency information from early time windows is lost. Another difficulty with noise from trains it that the disturbances are very dynamic in that the noise can vary strongly in amplitude when trains pass, and for surveys within kilometres of a railway with frequent train traffic this can have a severe impact on the data quality. Although data quality can be substantially improved by averaging over 60 millisecond intervals significant parts of the data may still be too noisy due to temporal variation in the noise (Fig. 2). Noise from DC powered trams and metro systems can also be difficult to handle. This calls for more advanced noise filtering approaches.
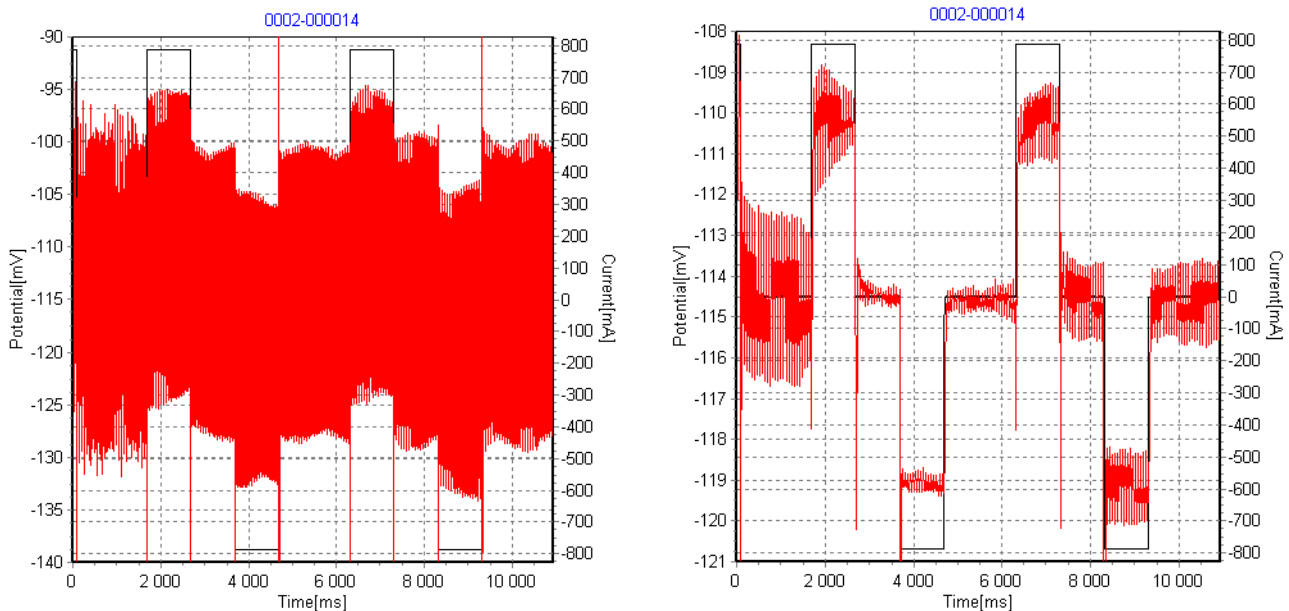

Fig. 1: Example of full waveform recording from IP measurement cycle with noise from railway traffic; a) unfiltered data, b) data averaged over 20 milliseconds (50 Hz).
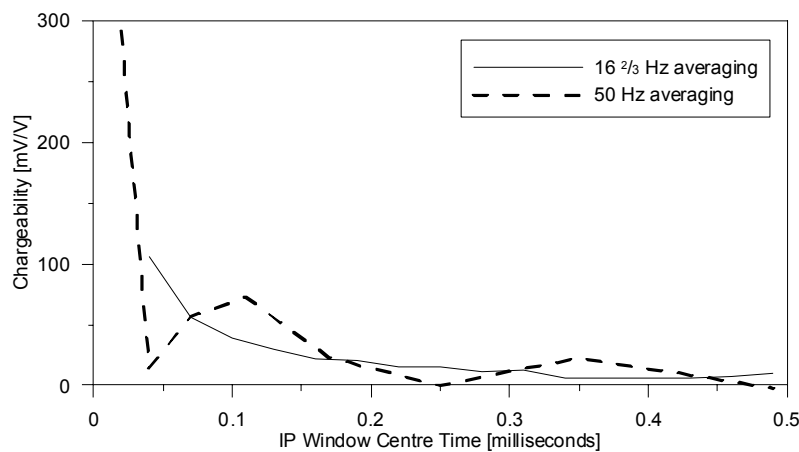

Fig. 2: Example of IP decay curve with railway noise (based on data in figure above) with data integrated over 20 ms multiples (50 Hz) and 60 ms multiples (16 ^{2}/3 Hz) respectively.

References

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