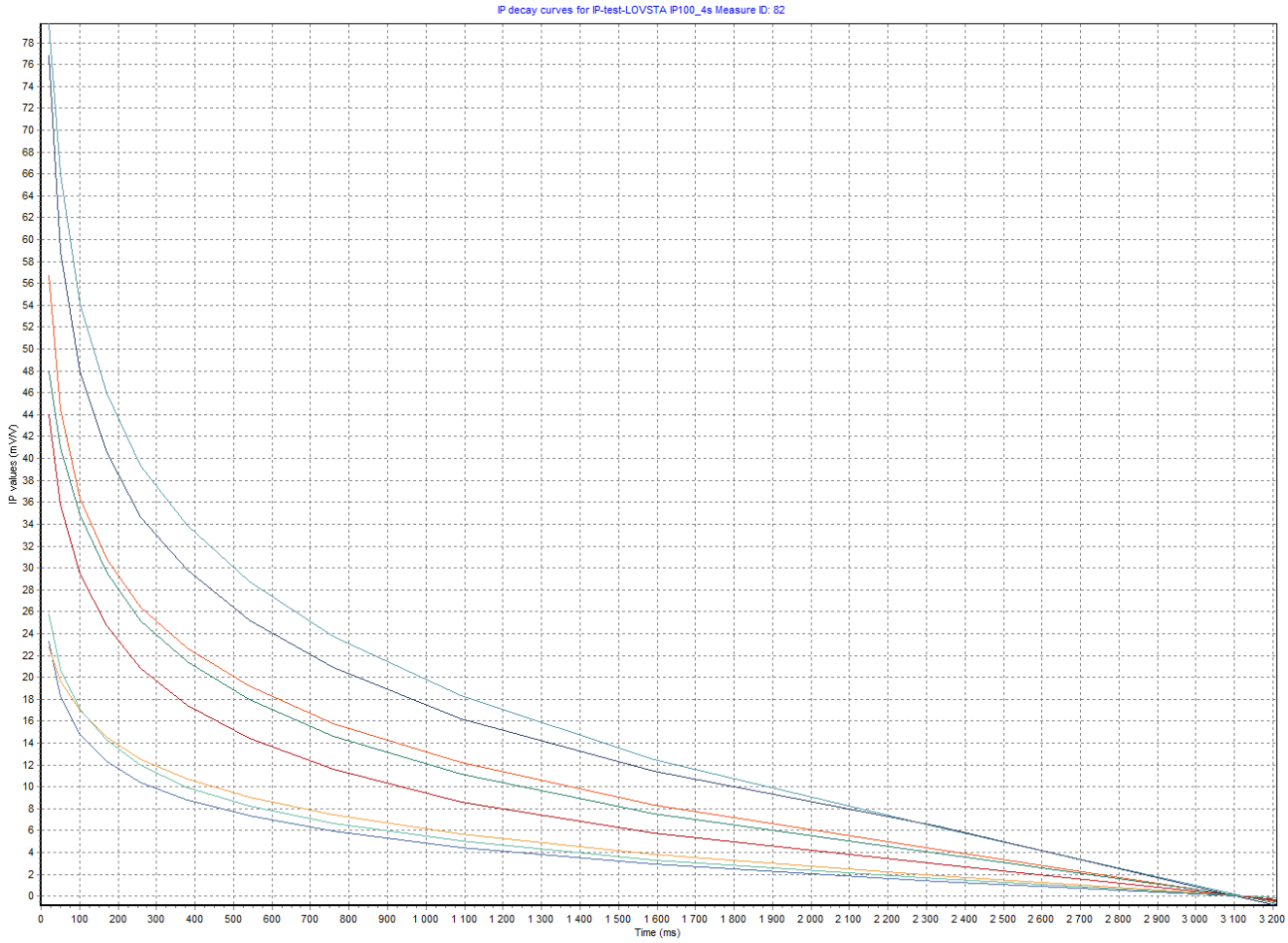
GUIDELINEGEO

IP using 100 % Duty Cycle



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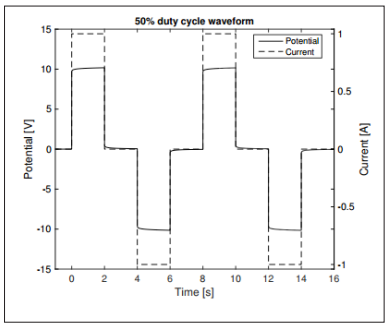
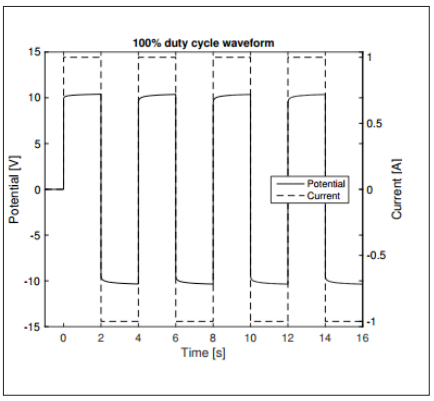
100 % Duty Cycle

Using a new measurement mode for IP (100 % duty cycle), data collection will be twice as fast and have twice the signal to noise ratio compared to the conventional IP method (50 % duty cycle) using the same settings.

Time-efficient IP measurements using 100 % duty cycle

The previous ABEM Terrameter LS, as most field resistivity/IP instruments, uses the time domain method to collect IP data. This method has traditionally used what is called a 50 % duty cycle - this means that measurement periods are divided into two equal parts. During the first part, the ON time, current is transmitted into the ground to charge it. During the second part, the OFF time, no current transmission is made, instead the instrument measures how the voltage decays as the ground discharges. During the ON time resistivity data are measured and during the OFF time IP data are measured. *To the right, a 50 % duty cycle measurement using two stacks (repetitions) can be seen.*





With the new ABEM Terrameter LS 2 it is possible to measure IP using 100 % duty cycle. This means that there is no OFF time, and that current is always transmitted into the ground. Instead of measuring IP when the ground is discharging, IP will now be measured during the early part of the ON time as the ground is being charged. With this new measure mode both resistivity data and IP data will be measured during the ON time, and the OFF time is not needed. By removing the requirement for an OFF period, it is now possible to measure IP twice as fast as with the traditional IP method. *To the left is a 100 % duty cycle measurement using the same ON time as the example above but, eight pulses can now be measured in the same time that only 4 pulses were achieved with the 50 % duty cycle.*

Increased data quality by super-positioning the signal

During resistivity and IP measurements the current transmission polarity is switched in order to remove ground SP (spontaneous potential) effects, which could otherwise cause an offset in recorded voltage values.

For IP using 50 % duty cycle, one cycle will consist of a positive ON time, an OFF time, a negative ON time and an OFF time. It is assumed that the ground has been completely discharged after the OFF time so, after each polarity switch, the charge-up effect is starting from zero. The voltage values in the IP decay are typically very small and can, in some situations, be difficult to differentiate from background noise.

IP using 100 % duty cycle has no OFF time, and one cycle will consist of a positive ON time, a negative ON time and a positive ON time. This means that at the polarity switch (positive to negative, and negative to positive) the ground will be discharged and charged at the same time. By super-positioning the discharge and charge-up (summing up the two effects) the result is a bigger IP response. With this bigger IP response, the signal to noise ratio (SNR) is increased, producing better data quality as it becomes easier to differentiate the IP decay from the background noise.

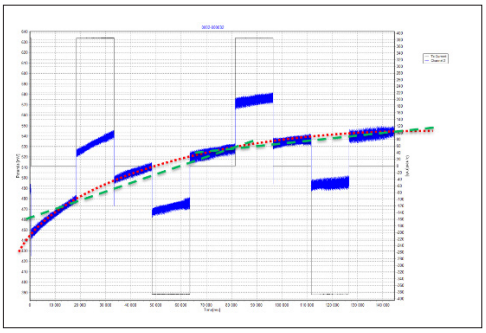
Exponential SP background removal for increased accuracy

Uncorrected SP effects can introduce errors in the calculation of resistivity and IP data. For that reason resistivity/IP meters normally use what is called linear SP trend removal. This means that before and after each measurement stack, SP samples are taken and any changes in the SP values can be detected. If the SP value has changed, the SP effect will be removed by using the two SP samples from the start and the end of the measurement cycle to create a linear background trend that is used to estimate the zero level when integrating the results.

The linear SP trend removal works very well if the SP changes are small, or vary at a steady rate. But if the SP changes are non-linear or larger in size, the linear SP trend removal will not be ideal and will result in a difference between the integrated and the actual resistivity/IP value. The measured IP signals are typically very small, and introducing this error in the calculated IP value can have a big effect on the reliability of the final model.

In the new IP measure mode an exponential SP trend removal has been implemented. This means that non-linear SP changes can be measured much more precisely and will be incorporated in the resistivity and IP integration for a more accurate result.

In the figure to the right full waveform data from a measurement can be seen. The blue line represents the measured input voltage, and it is strongly affected by non-linear SP effects. The green dashed line represents how the linear SP trend removal would have been used to estimate the zero level and there is a distinct difference from the actual SP variation and the calculated SP effect, especially in the first part of the measurement. The red dotted line represents the exponential SP trend removal, and as can be seen it has a much better fit to the actual SP effect.



Input channel filters optimized for IP

The input channels of the new ABEM Terrameter LS 2 have been changed in order to give a higher bandwidth for IP data. The new filter design allows for inclusion of more low and high frequency IP components in the calculations than the previous Terrameter LS. This means that the Terrameter LS 2 can start measuring IP decays earlier after current turn off, and that measurements are improved during very long IP times.

Additional IP parameters and processing features available with Aarhus Workbench

Traditionally IP data have been processed and inversed as an integral IP data set. This means that even if multiple IP windows have been used for increased decay information when measuring, the modelling software will handle the data as if only one, very long, IP window was used. This severely limits the scope for quality evaluation as well as the processing and interpretation possibilities. This ‘simplification’ of the IP decay may also negatively impact upon the end result in terms of model accuracy.

Using Aarhus Workbench with the ERT/IP modules the full decay data, using all IP windows, will be analyzed. This gives a much better view and understanding of the data quality. The IP decay is represented graphically, showing each IP window. In the data processing it is possible to exclude an entire decay curve or, if only parts of the IP decay are affected, individual IP windows can be excluded whilst good segments can still be used.

In all other modelling software for time domain IP data, the IP result can only be represented as chargeability. For frequency domain IP (sometimes called spectral IP) two additional parameters, C and Tau, have been used to fit the IP signal and model the data. These parameters have previously only been available from frequency domain IP data, but Aarhus Workbench is currently the only commercially available software offering this capability for time domain IP data by using Cole-Cole parametrization. Applications for Tau and C values are currently the subject of much research, but potential uses include gaining additional information about the geology, such as grain size and fluid conductivity.

The advantages with IP using 100 % duty cycle

The three biggest advantages are:

1. Using a 100 % duty cycle, IP data can be collected twice as fast as when using the 'standard' 50 % duty cycle.
2. As the signal to noise ratio is twice as high using the new method, IP data quality will be much better than before.
3. Exponential SP trend removal makes the IP calculations more accurate.

These are important factors which strengthen the argument that external high power transmitters are not always necessary.

The advantages with Aarhus Workbench ERT/IP for IP data

- Better quality control as the entire IP decay can be seen
- Better processing possibilities as individual sections (IP windows) can be excluded if necessary
- Uses Cole-Cole or Constant Phase Angle analysis for better IP modelling
- Two additional IP parameters, C and Tau (if using Cole-Cole parametrization)

To make full use of the advantages with the new measure mode in the ABEM Terrameter LS 2, Aarhus Workbench is a great tool. The other commercially available inversion software cannot process and model IP data in the same way.

References

IP using 100 % duty cycle along with the additional processing are methods and processes that have been developed by Aarhus University and Lund University. The work done by Guideline Geo is to implement parts of the new methods in the ABEM Terrameter LS 2. For more information and research papers we refer to publications of Aarhus University and Lund University.

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For a full list of publications see Aarhus University and Lund University web sites

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