Institute of
Electrical Power Systems
Graz University of Technology

POSSIBLE REASONS WHY CALCULATIONS OF INDUCTIVE INTERFERENCE PIPELINE VOLTAGES ARE HIGHER THAN CONDUCTED MEASUREMENTS

Christian Wahl, Ernst Schmautzer

ABSTRACT

Due to bundled energy routes, high voltage energy systems (e.g. overhead lines) are often located near buried isolated metallic pipelines. Thus, **a possible high inductive interference from energy systems may produce hazardous AC pipeline voltages**. High induced voltage levels **can cause dangerous high touch voltages and AC material corrosion**. Therefore, European standards limit the allowed maximum voltages for long and short term interference. Consequently, pipeline interference voltage (PIV) **calculations are necessary to survey if given limits are exceeded**. Unfortunately, **the results of these – standardized – calculations are often higher than conducted measurements on pipelines**, despite using state of the art calculation parameters. **Investigations** on this discrepancy **are needed** to bring calculations and measurement data closer together **to avoid excessive measures which are often cost-intensive**.

Even with experience, it is difficult to identify the very well hidden, but crucial factors for the discrepancy on specific calculated and measuring positions. The **following factors are suspected to have different degrees of impact on induced pipeline voltages and have to be considered** individually and with each other:

- Load current instead of using the maximum operational currents
- Reduction effect of global earthing systems (GESs)
- Reduction effect of local earthing systems
- Reduction effect of practically achievable pipeline earthing systems
- Reduction effect of pipelines, running in parallel
- Reduction effect of parallel high voltage power systems (HVESs) with grounding conductors
- Incorrect or inadequate pipeline coating parameter
- The influence of the model-conform specific soil resistivity

IMPACT FACTORS ON PIPELINE VOLTAGES

Pipeline voltage reduction factors

Bigger pipelines usually run over long distances which means that they are unavoidably built near (sub-) urban areas or inside energy routes for route optimization and cost control. Therefore, other known and unknown buried conductive material can be located near the influenced pipeline. Depending on the geographical situation, it can be e.g. GESs, foundation earth electrodes, conductiong pipelines (water, local gas supply) as well as other transportation pipelines or HVES supply systems. As example, the voltage reduction effect of GESs and other (parallel) pipelines is described in the right handed column. Other reduction effects, caused by conductive material, operate similar.

Incorrect or inadequate pipeline coating parameter

It is generally known that the pipeline coating is crucial to avoid material corrosion. It is problematic that the value of the coating resistance can vary within a wide range. On the one hand, the material has been changed from bitumen with a low value (1 MΩm) to polyethylene with a high value (100 MΩm). One the other hand, with time, the resistance value can fall to 10 kΩm (bitumen) or 50 kΩm (polyethylene) due to coating holidays. To summarise, with a lower coating resistance value, a lower PIV can be expected which one should bear in mind when comparing measurements and calculations

Varying the specific soil resistivity

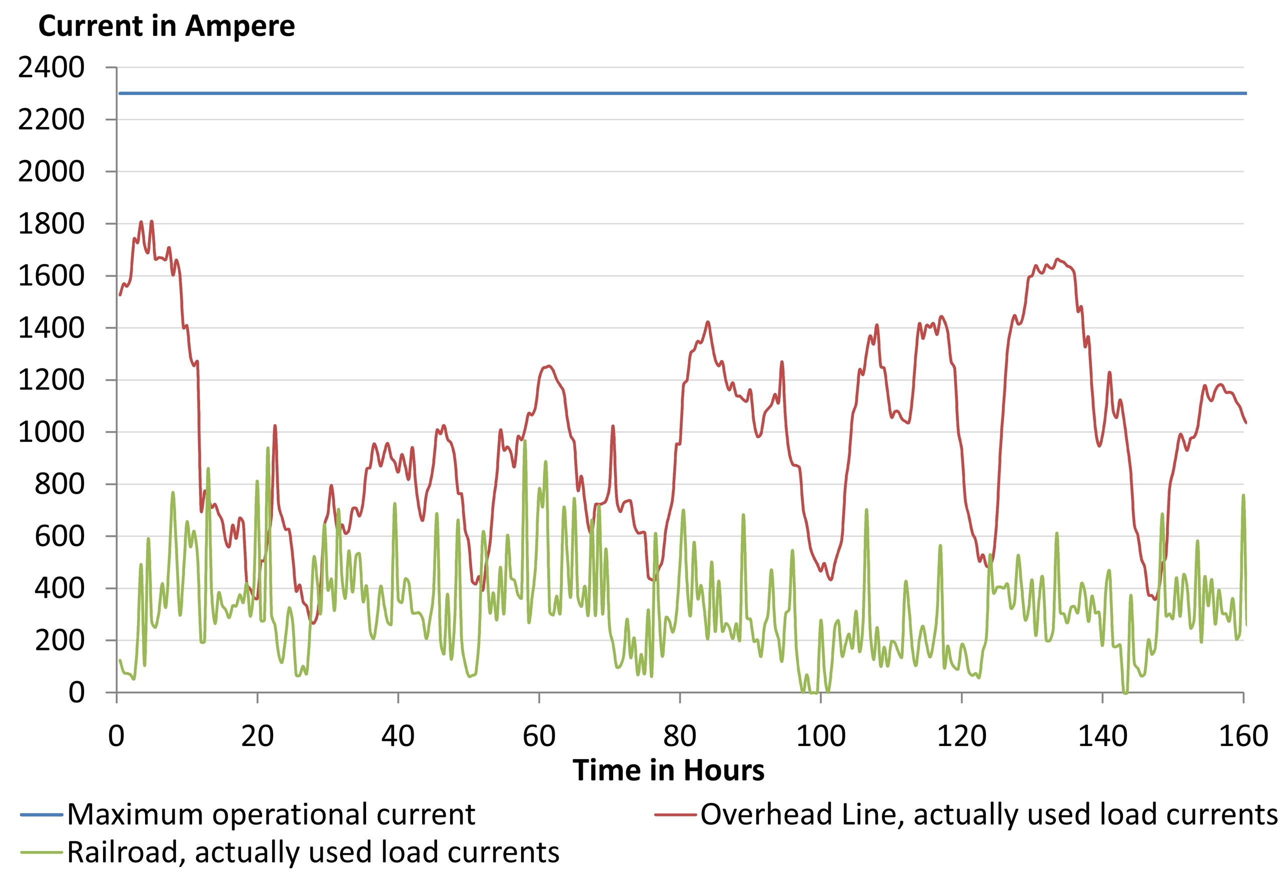
The soil resistivity has a very strong influence on the PIV. In areas with lower values, lower PIVs can be expected. However, weather and time of the year also influence the soil resistivity, changing the soil moisture and the soil temperature. The soil resistivity is lower when the soil moisture is high (e.g. due to high precipitation) and/or the soil temperature is high (e.g. during the summer). Therefore it is difficult to find the correct value of the soil resistivity along a pipeline due to the wide range of values and the fragmenting of the different types of soil.

Generally, the specific soil resistivity ranges between 25 Ωm and 10000 Ωm. Considering this variation is essential, both for calculations and measurements. Especially where measurements are conducted a detailed soil analysis is indispensable.

IMPACT OF THE LOAD CURRENT

Normally it is common practice to use the maximum operational currents in order to cover worst case scenarios for touch voltages or, depending on the type of the influencing system, 60 to 95 percent of this maximum load current for AC corrosion. In reality, these operational currents rarely occur.

For the comparison of a one week lasting measurement and its associated calculations on the same pipeline locations it is indispensable to use the correct actually used load currents to get comparable results. The difference between such currents and maximum operational currents is illustrated for an overhead line and a railroad system can be seen in following Figure.

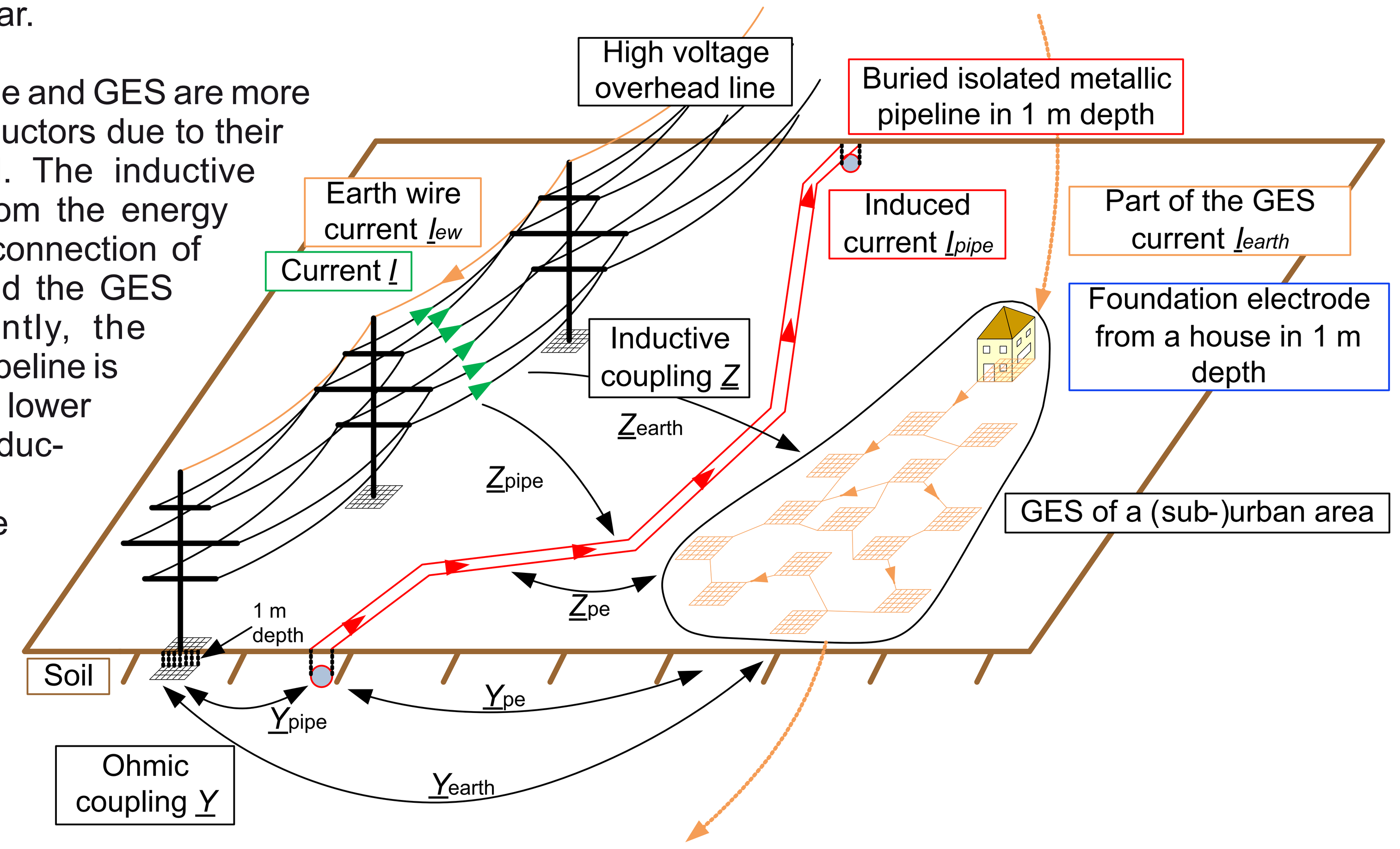


REDUCTION EFFECT OF GLOBAL EARTHING SYSTEMS AND OTHER PIPELINES

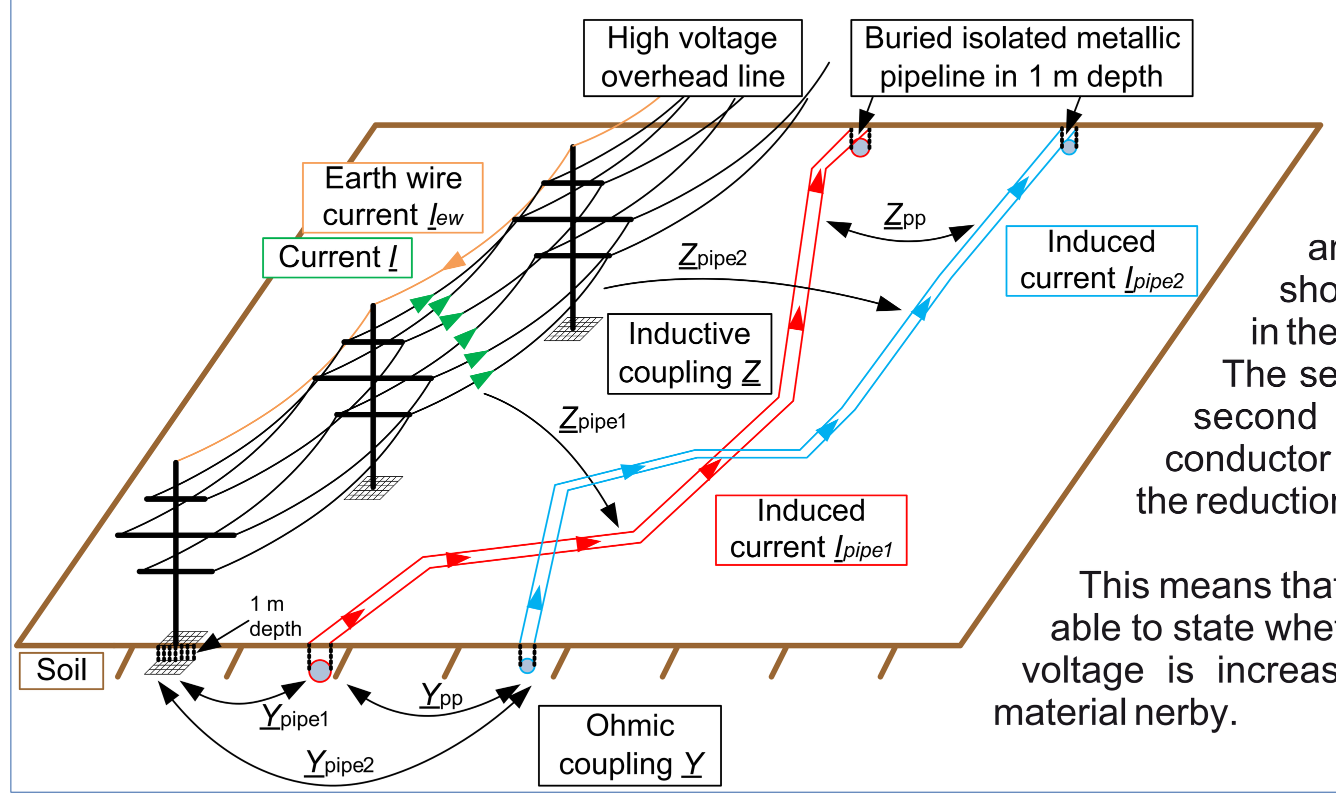
In short, GESs consist of connected foundation electrodes and other conductive material buried in the soil within a (sub-) urban area. If an HVES is located near a pipeline and a GES, a configuration arises as depicted in the following figure and two interference effects appear.

Firstly, in these cases, pipeline and GES are more or less parallel metallic conductors due to their similar conductive material. The inductive coupling impedances Z_{gkL} from the energy system turn into a parallel connection of the pipeline coupling Z_{pipe} and the GES coupling Z_{earth}. Consequently, the coupling impedance to the pipeline is reduced with the effect of a lower PIV. Thus, GESs have a reduction effect.

Secondly, the inductive coupling leads to induced pipeline voltage and this results in the currents I_{pipe} and I_{earth}. These currents result in an additional inductive coupling Z_{pe}, additionally increasing or reducing the current I_{pipe} and thus the PIV.



Because of bundled energy routes, transport pipelines are built near other pipelines. Therefore two or more pipelines can run parallel over a long distance. If an HVES is located near a configuration with two pipelines, a setup appears as can be seen in the lower picture and the two interference effects have to be noticed again.



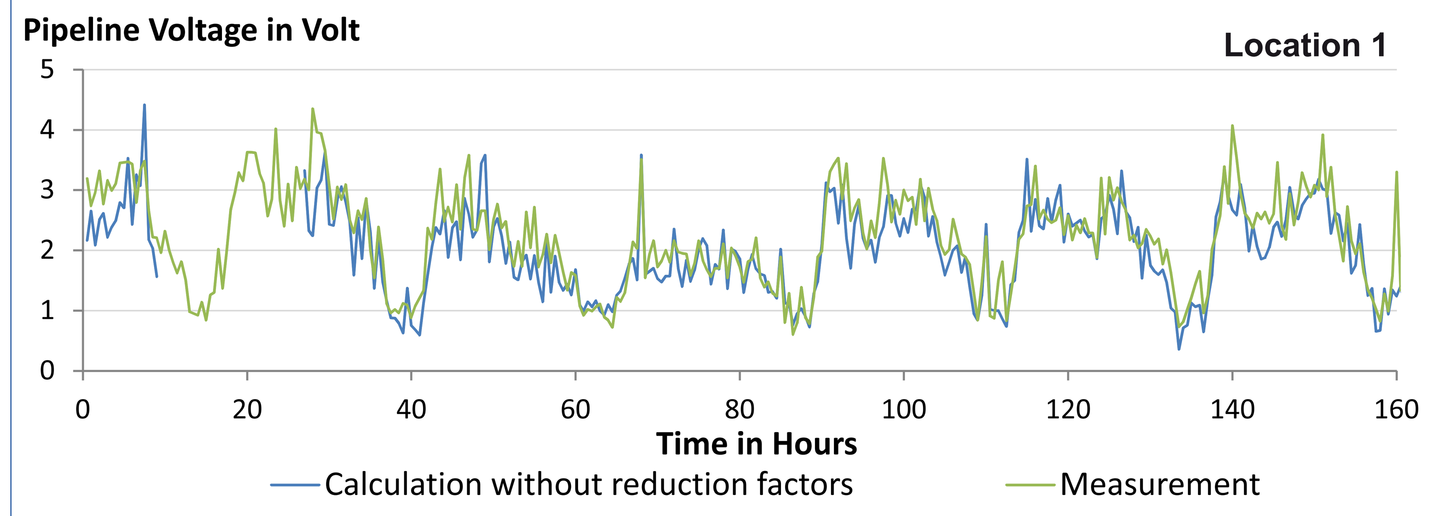
The first effect is due to the inductive coupling between the HV power line and the pipeline causing currents in both pipelines. Depending on the current flow direction, the current I_{pipe2} can increase or reduce the current I_{pipe1} and vice versa. The left-handed picture shows an example, where both currents flow in the same direction.

The second effect is based on the fact that the second pipeline (blue) works as a reduction conductor on the regarding pipeline (red), similar to the reduction effect of the GES.

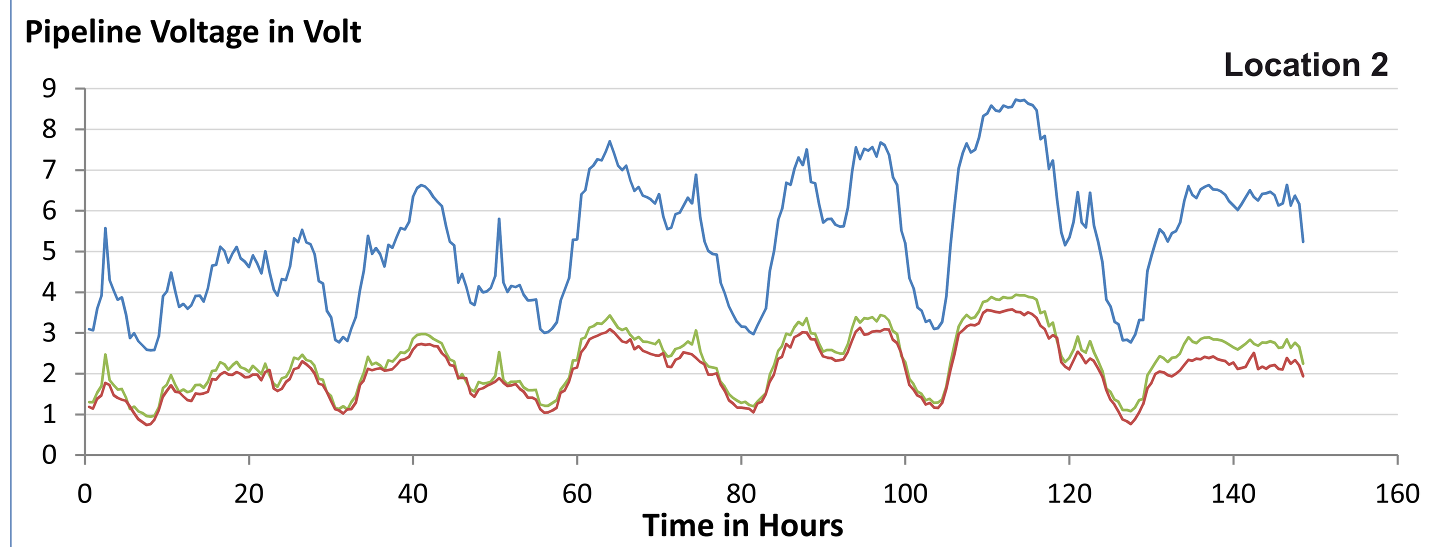
This means that both factors have to be considered to be able to state whether the pipeline current and interference voltage is increased or reduced in case of conductive material nerby.

PRACTICAL RESULTS

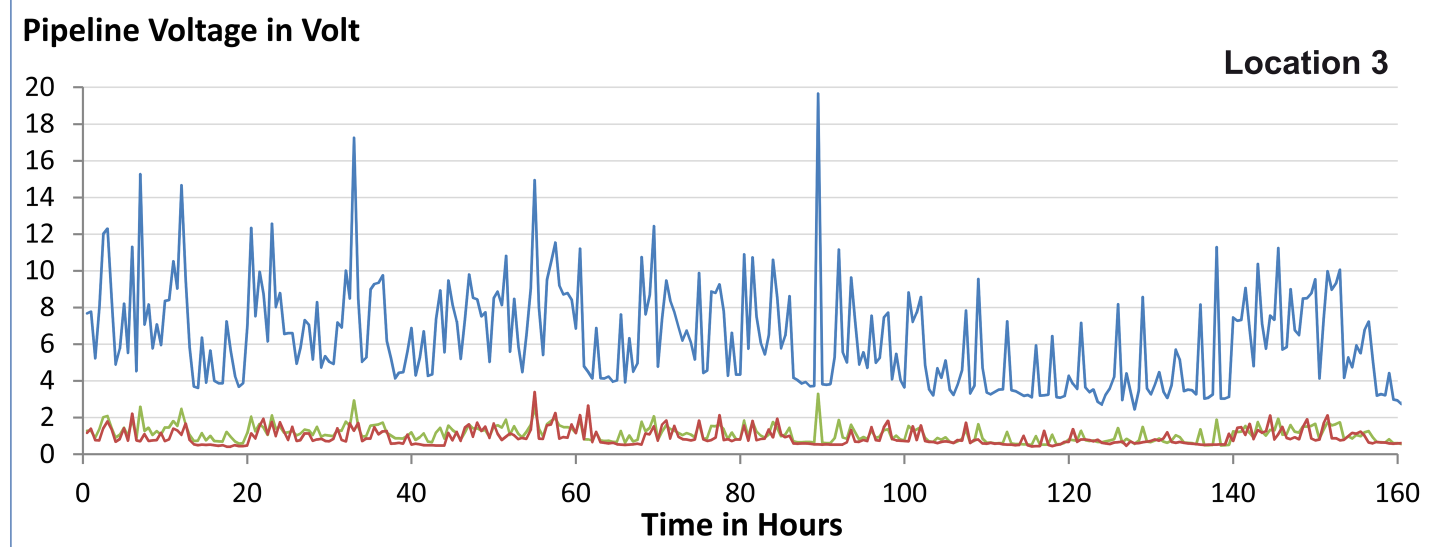
The following four figures show different examples of calculations using the actually used load currents and comparing them to measurements done during a measurement period of 140 to 160 hours at different pipeline locations.



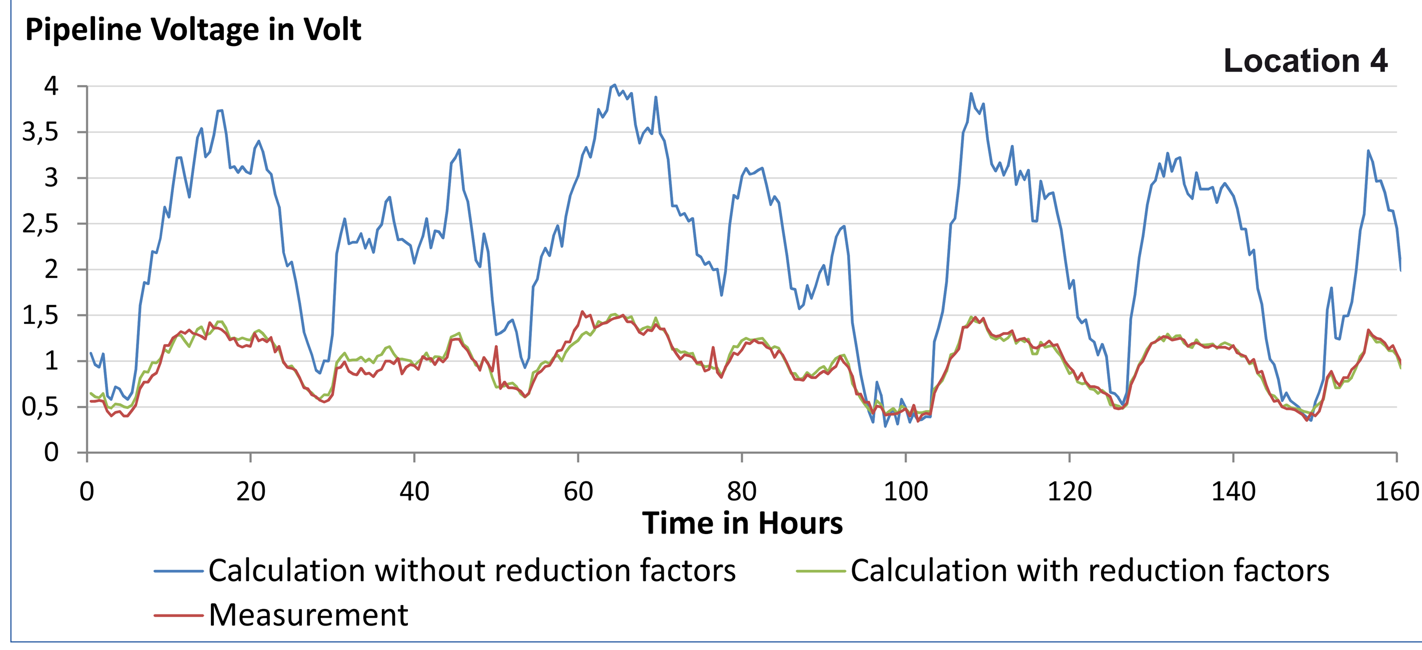
The first picture on the left side represents location 1 and shows a nearly identical voltage characteristic between measurement and calculation since the model parameters reflect the real conditions very well.



The calculations in Location 2 und 3 without reduction effects show results higher by a factor of up to 7, compared to calculations considering conductive material nearby. These two figures show an intense voltage reduction, based on the geographical closeness of two different things: in location 2, another pipeline in combination with the reduction factor of two parallel high voltage overhead lines and in location 3, a rural area with a well-developed and extended GES.



As shown before, the load currents from railway and overhead power line systems are different, which can be shown clearly in these two figures. Because of the non-abrupt change of the current, it is clear that in location 2 only an overhead line induces the pipeline voltage. In location 3 a railway system is the reason, typically causing the value of the current to change very fast.



The last figure (location 4) shows a combination of two reduction effects: the voltage reduction effect due to a parallel pipeline and also a voltage shift due to inadequate soil resistivity. Apart from the reduction effect, the specific soil resistivity was essentially lower than expected because the calculation result is massively lower than before.

CONCLUSION

Even if calculations are done very carefully with established and generally agreed calculation methods, conducted measurements show mostly lower voltage levels than the calculated ones for the same pipelines and pipeline locations. **With the consideration of the reduction – or even increasing – effects presented in this paper, most of the discrepancies between measurement and calculation can be explained when all important parameters are known.**

Knowledge of the correct specific soil resistivity and pipeline coating resistance is a precondition since both parameters can influence the PIV in the measuring position. The value of the load currents during the measurement period must be known, as it is essential to correctly interpret the measurement data. Much more complicated are conducted materials within the interference area because they can act as a reduction factor, decreasing PIVs. They can also produce influencing voltages and in an unfavourable case, may even increase PIVs too.

The examples show that with consideration of all presented effects, **most of the conducted measurements can be explained and even better, they can help to calibrate the calculation.** With this research **it is possible to reduce or avoid unnecessary measures while necessary actions**, e.g. AC earthing systems or special safety working methods along the pipeline, **can be used more effectively and efficiently.**

TU Graz
10th Pipeline Technology Conference
8-10 June 2015, Berlin, Germany

Contact: Dipl.-Ing. Christian Wahl BSc, Inffeldgasse 18 / I, 8010 Graz, Tel. +43(0)316/873-8056, Fax: 108056, e-Mail: christian.wahl@tugraz.at, www.ifea.tugraz.at