PARTIAL DISCHARGE MONITORING ON MV SWITCHGEAR

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ABSTRACT

This paper gives the results of partial discharge measurements in the context of a joint project with the Belgian DNO's. The objective of this project was to gather experience with on-line PD "monitoring" in secondary substations to evaluate its suitability (compared to on-line "spot" PD measurements) for condition assessment of the selected enclosed MV switchgear.

INTRODUCTION

Enclosed MV switchgear (SWG) installed on the MV grid is subject to ageing and degradation. A major concern of Asset Management is to quantify asset related risk. MV switchgear approaching their end of life have to be identified and replaced before failure occurs, avoiding outages on the MV grid. For this identification on-line partial discharge (PD) measurements can be used, "spot" PD measurements are currently already widely used by DNOs. In order to carry out this monitoring, some secondary metal enclosed switchgear as well as cast resin insulated switchgear have been equipped in 2010 with on-line acoustic PD sensors combined with temperature and humidity sensors. They were a first pilot installation and served to gather first experiences with on-line PD monitoring on switchgear in 2011 and 2012.

MEASUREMENT SYSTEM

The measurement system was custom-built with parts that exist on the market, it was not bought as a turnkey solution (see Figure 1).

On-line PD monitoring system

The system used is the UE-ECM586 equipment. The frequency range goes from 36 to 44 kHz with a dynamic input range of about 100 dB and a 4-20 mA DC output.

Temperature and humidity sensor

The sensor used is a Yumo sensor with identification 907021/20 with a temperature range from -40 °c to 60°C and full range for the humidity (0 to 100%).

Other hard- and software

The rest of the hardware are a Siemens PLC of type S7-1200, a GPRS module MD720S with a Sitop power supply and UPS. The measurement systems have 4 or 8 analogue inputs. The software to manage the system was delivered in collaboration with Siemens. A dedicated PC with a fixed IP address completes the set-up. The measurement cycle and send cycle can be chosen separately for each system.

Figure 1: on-line PD monitoring system

MONITORING LOCATIONS

Figure 2: different examples of monitoring locations

As mentioned, metal enclosed switchgear as well as cast resin insulated switchgear have been equipped with the monitoring systems. The pictures in Figure 2 give some examples of the different locations. You can observe cast resin insulated switchgear in polyester cabinets as well as metal enclosed switchgear in concrete or brick cabins.

MONITORING RESULTS

In the following pictures four variables are represented: the level of partial discharges measured "PD" (green), the temperature "T" (red), the relative humidity "RH" (blue) and the dew point "T_d" (black). The dew point was added to see an eventual influence, but this was not the case.
The denominations given to each measurement point are based on the experience of people in the field (maintenance, repairs, incidents, …), the descriptions are not based on classification in standards or technical reports.

Equipment in "rather good condition", case A

One of the cast resin equipments was in "rather good condition", i.e. no problems with the switchgear were expected. We did find some correlations between the temperature, the humidity and the partial discharges. The first example (Figure 3) represents the data for October 14th 2011. We observe that the relative humidity does not exceed 50 % and that there are no PD present; the temperature is rather high and varies between 20 and 27 °C.

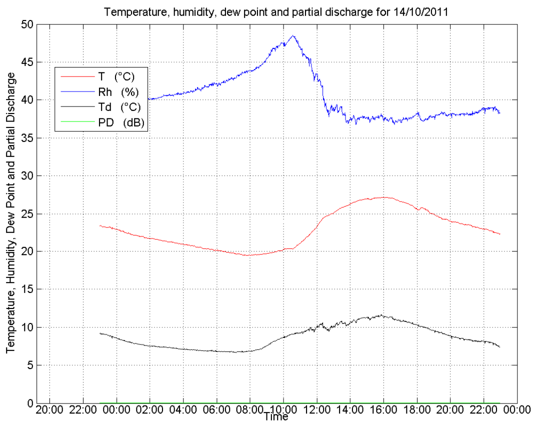

Figure 3: PD, T, RH and T_d for a cast resin equipment in "rather good condition", no PD

The second example (Figure 4) shows some partial discharges with a similar profile as the humidity, while the temperature is higher and lies between 25°C and 40°C.
The third example (Figure 5) gives an example of what happens when the RH remains above 50 % all the time: PD will be present all the time, and its profile will have the same appearance of the RH.
It is obvious that the partial discharges have a tendency to follow the evolution of the relative humidity rather than the one of the temperature. This will be confirmed by the other measurements. Overall, we notice the rather high temperature for this measurement point.

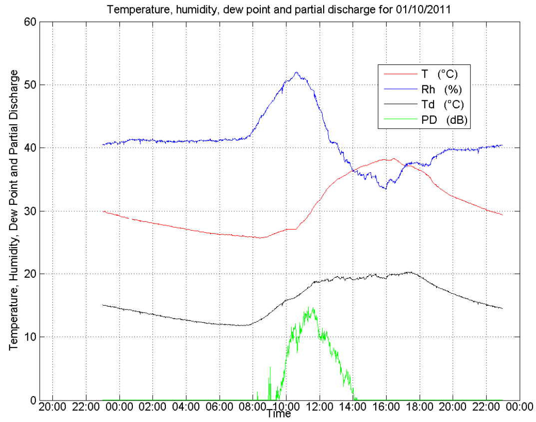

Figure 4: PD, T, RH and T_d for a cast resin equipment in "rather good condition", some PD

In short, we can conclude that, for this case:

- RH > 50% → PD present
- RH ≤ 50% and T >30 °C → PD present
- RH ≤ 50% and T ≤ 30 °C → no PD present

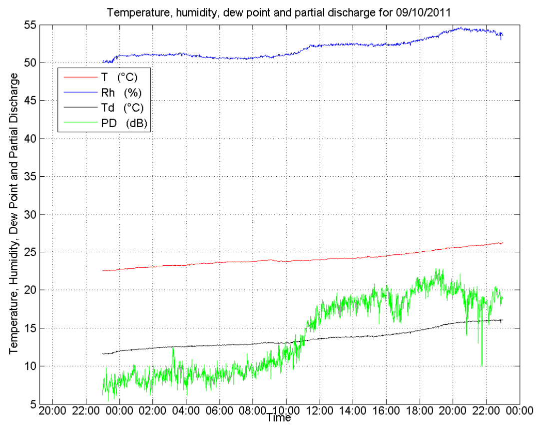

Figure 5: PD, T, RH and T_d for a cast resin equipment in "rather good condition", PD

Equipment in "medium bad condition", case B

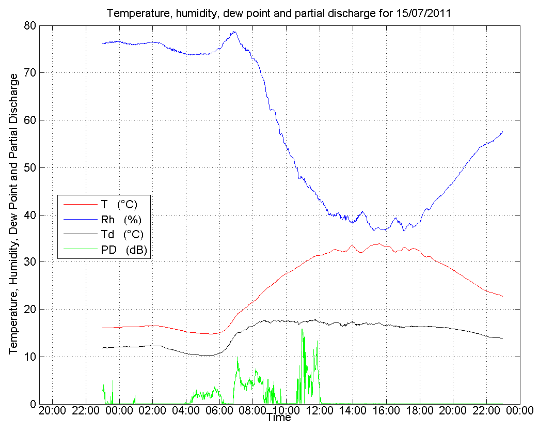

Figure 6: PD, T, RH and T_d for a cast resin equipment in "medium bad condition", few PD

A second measurement case that was analysed is a so-called "medium bad condition" equipment. In this case we know that the equipment has been functioning for a long time and the environmental conditions are not optimal, but not catastrophic either. Looking at the first example (Figure 6) we can see that once the RH has descended below 60%, the PD disappear as well, albeit with a delay of about 2 hours.

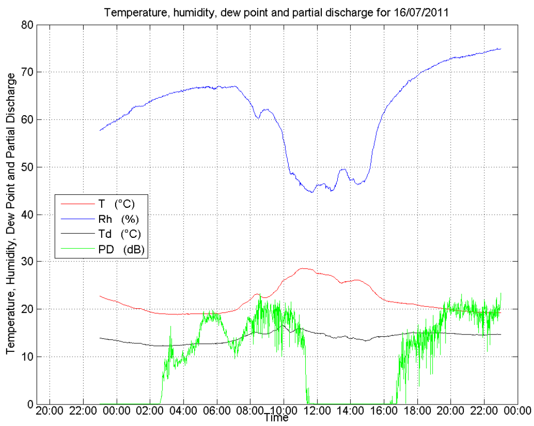

Figure 7: PD, T, RH and T_d for a cast resin equipment in "medium bad condition", PD low

This is again the case in Figure 7: in this figure we can see clearly that the profile of the curve of the PD is very similar to the one of the RH when PD are present, and there appears to be a time shift between the two curves. This is observed in almost all cases where PD are present.

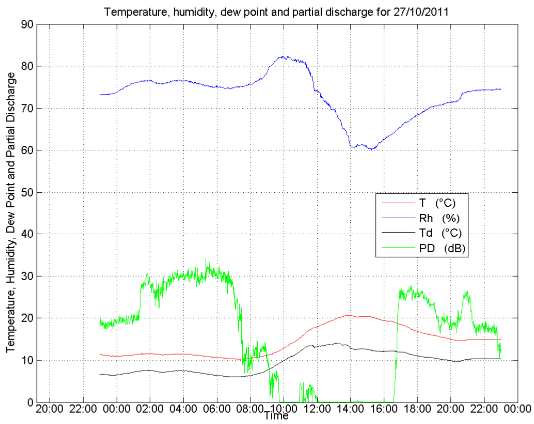

Figure 8: PD, T, RH and T_d for a cast resin equipment in "medium bad condition", PD high

In Figure 8 we observe that, even though the RH does not descend below 60%, the PD disappear. This shows us that not only the value of the RH is important to have PD, but also the evolution of the RH and T are important. In this case, when the relative humidity goes down, the temperature rises. This allows the PD to disappear completely. We can also see that, once the RH goes up again, the PD return very fast and are immediately high. We can see in this case that the partial discharges are due to the environmental conditions and are not as such related with the "bad condition" of the switchgear itself. In conclusion, for switchgear in "medium bad condition", we see that partial discharges will appear when the environmental conditions are less than optimal, but they will disappear once the ambient parameters become less stringent.

Equipment in "very bad condition", case C

A third measurement case was chosen, knowing that the equipment was near its end-of-life time and was to be replaced soon. When opening the polyester cabinet in which this switchgear was housed, a pungent ozone odour was present. Nevertheless, the partial discharges disappeared completely when the RH was low (30%), (Figure 9), although this was only a temporary situation occurring on a warm, dry and sunny day.

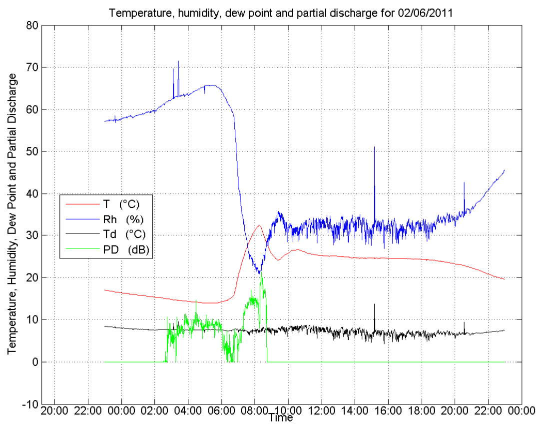

Figure 9: PD, T, RH and T_d for a cast resin equipment in "very bad condition", some PD

Figure 10 shows us a different view on this equipment. Although we observe that the RH remains below the verge of 60% all the time, ,PD do appear, and not at a low level! The values go up to 32 dB. In this case the temperature is also rather high, even during the night-time. We can see that during the night time, the partial discharges level becomes zero.

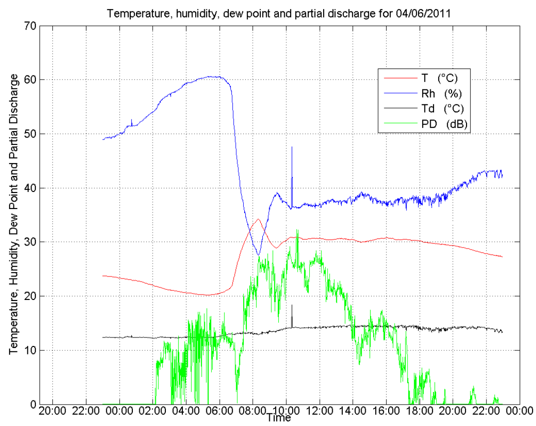

Figure 10: PD, T, RH and T_d for a cast resin equipment in "very bad condition", variable PD

Finally, Figure 11 gives a last example of the partial discharges for this "very bad condition" case: partial discharges are present all the time, and at a (very) high level. The level of PD does no longer follow the RH curve.

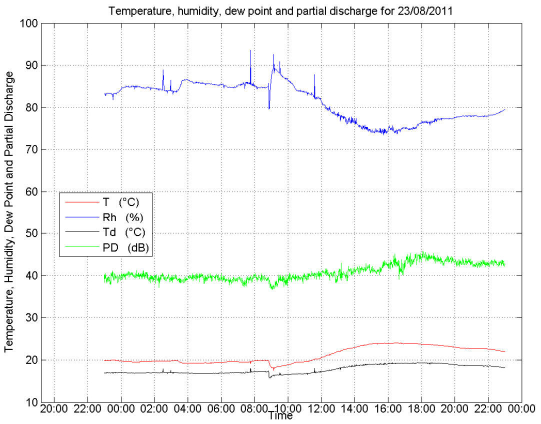

Figure 11: PD, T, RH and T_d for a cast resin equipment in "very bad condition", high PD

Equipment in industrial environment

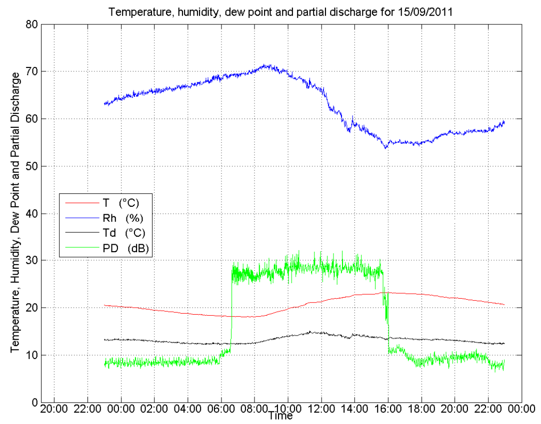

Figure 12: PD, T, RH and T_d for a metal enclosed switchgear in an industrial environment

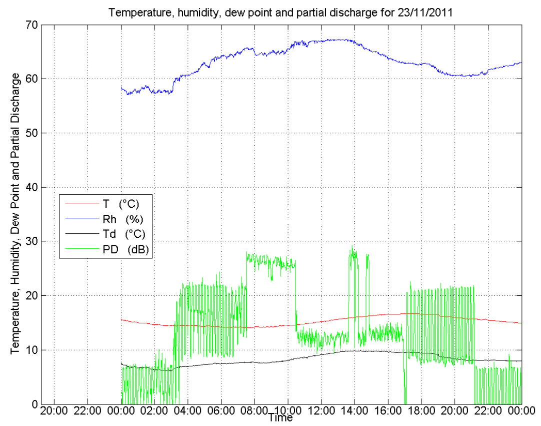

Figure 13: PD, T, RH and T_d for a metal enclosed switchgear in an industrial environment

In case of a switchgear in an industrial environment, it is possible to measure "erroneous" partial discharges. These are signals at the same frequencies of partial discharges, that are transferred through the electrical grid. The pattern of the measurement can be linked with the operating hours of a normal working day (Figure 12). This means that, when someone executes a spot measurements at any given time, the results can be different accordingly. It is difficult, and sometimes even incorrect, to draw conclusions based on those measurements. It can even go further than this: a certain production cycle of a factory can have intermittent charges that can result in an even more variable profile of the so-called "partial discharges" (Figure 13). This shows that spot measurements can be difficult to interpret

ENCOUNTERED DIFFICULTIES

Some difficulties were encountered during this field campaign: The biggest problem for the cast resin MV switchgear was the lack of available space within the cabinet and the presence of a power supply. Establishment of a durable communication turned out to be laborious: a fixed IP address, the antenna for data communication and the SIM cards used in the GPRS module are crucial for achieving this. Another issue was the material of the metal-clad switchgear: the magnetic microphone (acoustic, with magnetic head) needs to be compatible with the surface of the switchgear.

CONCLUSIONS

The monitoring data obtained show that the PD measurement results allow to make a correlation between the condensation and the partial discharge level especially when the monitored specimen is in medium bad condition. The monitoring results obtained on a cast resin switchgear in very bad condition illustrated that PD "monitoring" gives more exploitable evidence based on the evolution of the PD activity (and not only based on the level of the PD), but the results also illustrated that the increase of the PD level is too fast to program an intervention (3 months between acceptable and urgent level indications). In other words, the presence of a very high PD level combined with growth, indicates the necessity to replace the switchgear within a very short term.

It also appeared that PD measurements by ultrasonic sensors can be influenced by disturbances coming from other customers, through the MV network. It was possible to identify these disturbances by analyzing the monitoring results because of their special pattern, but this would not have been possible in case of spot measurements.
The results of this study indicate that in case spot measurements are made, it is necessary to make several measurements to ensure the relevancy of the conclusion drawn from them.

Finally, the on-line monitoring of switchgear is very interesting for the assessment of the equipment, but is in practice expensive and thus not suitable for general use.