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Dynamic Resistance Measurement (DRM) on a Variable Shunt Reactor (VSR)

Abstract

Dynamic resistance measurement (DRM) is an accepted method for diagnosing possible faults or defects in On-Load Tap-Changers and has an increasing use in the business.

Variable Shunt reactors (VSR) is seeing an increasing use in the networks to stabilize line voltages.

So far, DRM has only been used on transformers. This paper shows if it can be used on VSRs as well.

What is a dynamic resistance measurement?

Winding resistance measurements is a well known method in the business. It is a measurement done with a low DC current through a winding to make sure losses are as expected on a new transformer and to see that the values haven't change due to defects when measuring on units in service. This measurement could be called static resistance measurement.

The dynamic measurement means measuring the same but in addition it also measures the resistance during tap change operation from one position to the other through the whole range of positions.

By doing that, the voltage drop when the transition resistors are connected can be seen. The operation time for the OLTC is also possible to measure.

The measurement should be done with a DC current exceeding the peak of the magnetization current to keep the core saturated during the complete measurement in order to reduce the impedance as much as possible. If possible, one of the windings not measured should be short circuited in order to reduce the impedance even further.

The impedance causes slow reactions in current change during measurement and high impedances make the interpretation of the resulting curves difficult and endanger the value of the measurement.

What is a Variable Shunt Reactor?

A shunt reactor consists of one winding only and is connected between a high voltage line and ground. It can be three phase or single phase. It is made to have a certain inductance. Its task is normally to compensate for high capacitances to ground. It can be seen as a no-loaded transformer with a high magnetization current.

Long power lines will cause a voltage rise in the receiving end when lightly loaded and the shunt reactor compensates for that.

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Previously the reactor or reactors were connected or disconnected causing rather large steps in voltage. An alternative was to have several reactors that could be connected stepwise to reduce the step size.

By having the reactor equipped with a regulating winding and an OLTC, the reactance can be varied in small steps and with a considerable range. By that, the reactance can be smoothly adapted to the variations in load and the voltage can be adjusted more exactly.

Why is DRM measurement expected to be more difficult on a VSR?

Since no experience of such measurements existed before our measurements, only expectations existed. As said above, the measuring current should be kept higher than the magnetization current and preferably, another winding should be short circuited.

In a reactor, the magnetization current is equal to the load current and thus the measuring current can't exceed it. The primary reason is that it would require a huge instrument since the currents often are in the range of 100-300 A. Running full DC-current through a winding is normally not allowed of thermal reasons either. Thus, the impedance can not be reduced by keeping the measuring current higher than the peak of the magnetization current.

The second thing to reduce impedance, the short circuit of windings, is normally not possible either since there is no other winding.

The expected problem was thus that the impedance could be that high that the evaluation of the result could be difficult.

DRM on different OLTC types

Before starting the measurements it is worth considering the different response different OLTC types gives to the measurement.

The DRM is measuring the current through the winding. The current that changes is thus only what corresponds to the load current in real service. The circulating current that is caused by the step voltage in real service is not seen.

Without going to much into details, the so called flag cycle types which include most of the non-vacuum types of OLTC, will give the complete operating cycle to be seen on the DRM.

However, all the pennant cycle types, a principle used by most of the vacuum type OLTCs outside USA, will only show the main contact operations and nothing from the transition contacts since these are only switching circulating current.

In addition, the vacuum types has auxiliary contacts that are not seen either.

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The following measurement is done on a VSR with a vacuum type OLTC working according to the pennant cycle.
For information about the different operating cycles, please see IEC 60214-1 2003-02, annex A.

The VUCG operating cycle

The VUCG OLTC operates according to the asymmetrical pennant cycle but with the exception that it operates with the main contacts first in both directions. That is achieved by a mechanical rectifier in the mechanism and gives electrical advantages such as lower breaking stresses and longer contact life.

The actual VSR

The data of the actual VSR is the following:

Power: 127-209 MVAr
System voltage: 420 kV
Connection: Three phase star point
Regulation: Coarse/fine in star point, max power in pos. 1
Inmpedance/inductance: 1386Ω/4,4 H- 845Ω/2,7 H
OLTC: ABB VUCG
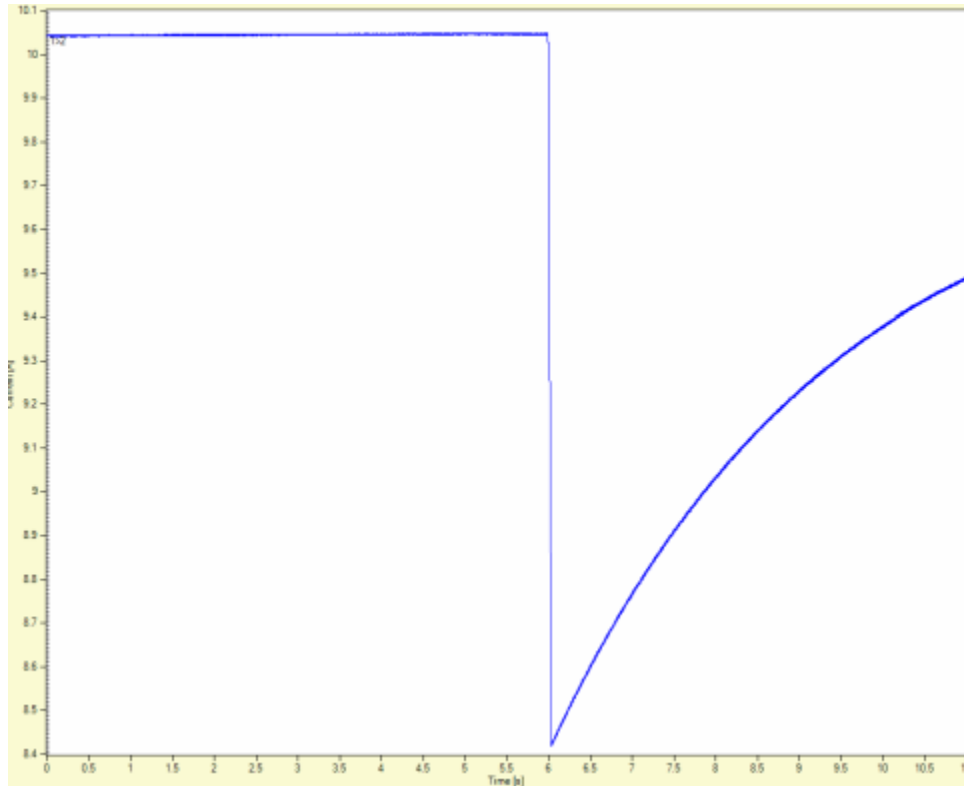Transition resistance: 11,2 ohms

Instrument and test current

Instrument: RMO 60 from DV power
Measuring current: 10 A DC
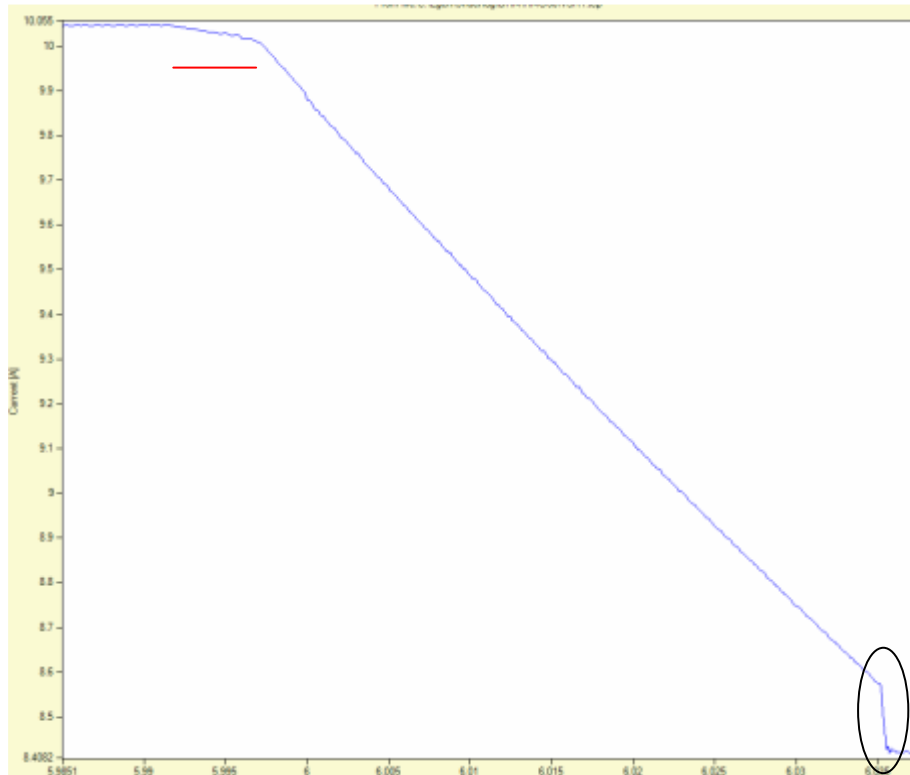
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Measurement 1

Since we couldn't lay back on any previous experiences, we started with a measurement from position 1 to position 2 which connects more turns. It looked like this (one phase):

A surprisingly fast response when the resistors are connected and slow when they are disconnected.

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Let us magnify:

This picture shows the connection of the resistors only. First there is a slow decrease in current above the red line in the picture remaining for appr. 6-7 ms. This is the arcing time of the main vacuum interrupter. The arc has a voltage drop of about 17 V corresponding to a resistance of 17V/10A=1,7 Ω (Winding resistance neglected). The time constant (L/R) is thus 2,7/1,7=1,6 seconds.

The second part, between this first time and the larger slope within the circle, remains for about 37 ms. That is the time when the transition resistors are connected, That time added with the arcing time is the true mechanical time when the main vacuum interrupter is open and is here about (7+37=) 44 ms which is as expected.

The time constant when the resistors are connected is: 2,7/11,2=0,24 seconds that is 6,6 times faster than with the arc only. That explains the faster slope in the second part of the curve.

The third part, that within the circle rightmost in the curve, is when the next tap is connected. That is connected by the main contact without any resistance more than that of the loop itself connected. The inductance increases by 4% and the current decreasing. The time constant is small since the inductance in one loop is small and the transition
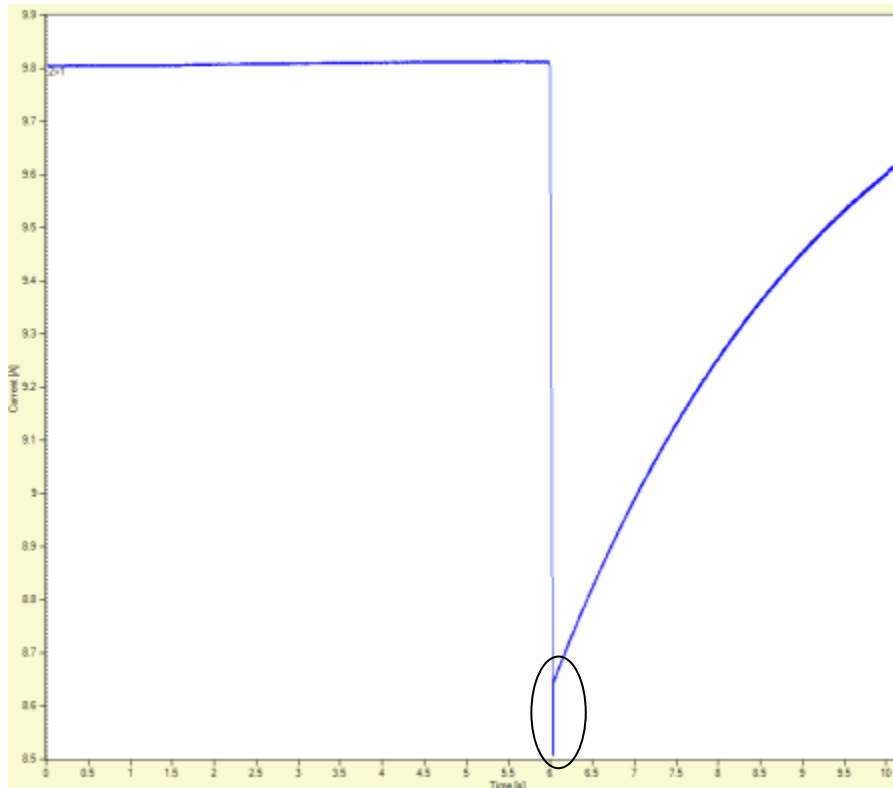
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resistance is high.

After that the current increases again but now slowly since the resistance now decreases by a factor of appr. 10 and the time constant increases correspondingly.

It is however seen that the expectation of a slow curve is not correct. At least not for the decrease in current. As we saw above, the operation time for the main vacuum interrupter was clearly seen and since this is a pennant cycle operation, only the main vacuum interrupter operation can be seen.
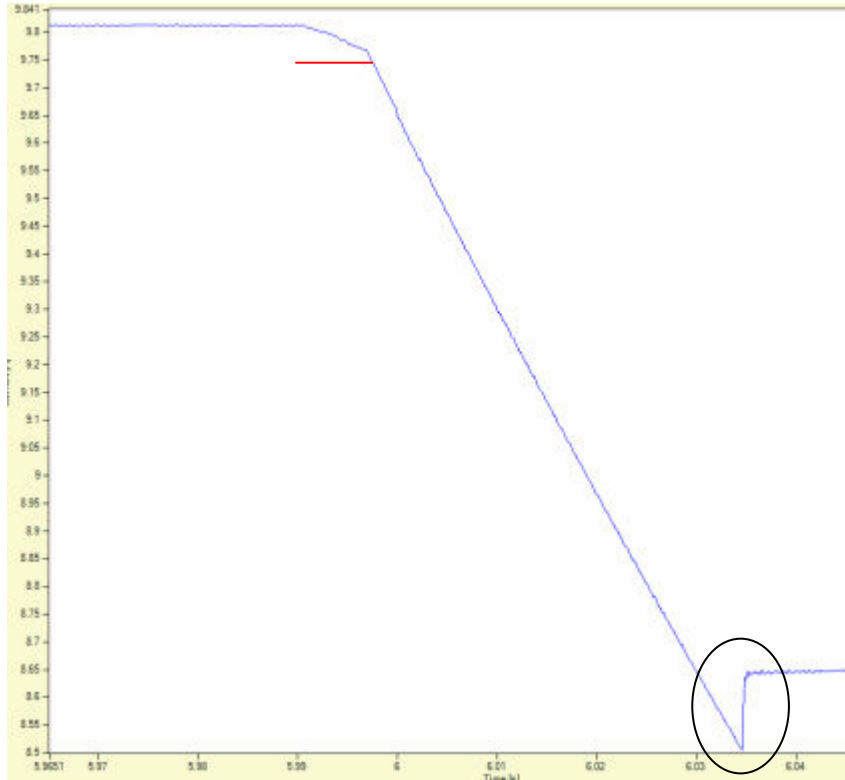
Measurement 2

This measurement is from position 4 to 3, which is in opposite direction compared to measurement 1 and now turns are disconnected:

Similar to the previous one except where the circle is.

Let us magnify:

This picture shows the connection of the resistors only. First, as before, there is a slow decrease in current above the red line in the picture remaining for appr. 6-7 ms. This is the arcing time of the main vacuum interrupter. The arc has a voltage drop of about 17 V corresponding to a resistance of 17V/10A=1,7 Ω (Winding resistance neglected). The time constant (L/R) is thus 2,7/1,7=1,6 seconds.

The second part, between this first time and the larger slope within the circle, remains for about 37 ms. That is the time when the transition resistors are connected, That time added with the arcing time is the true mechanical time when the main vacuum interrupter is open and is here about (7+37=) 44 ms which is same as in measurement 1.

The time constant when the resistors are connected is: 2,7/11,2=0,24 seconds that is 6,6 times faster than with the arc only. That explains the faster slope in the second part of the curve.

The third part, that within the circle rightmost in the curve, is when the next tap is connected. That is connected by the main contact without any resistance more than that of the loop itself connected. The inductance now decreases by appr. 4% and the current
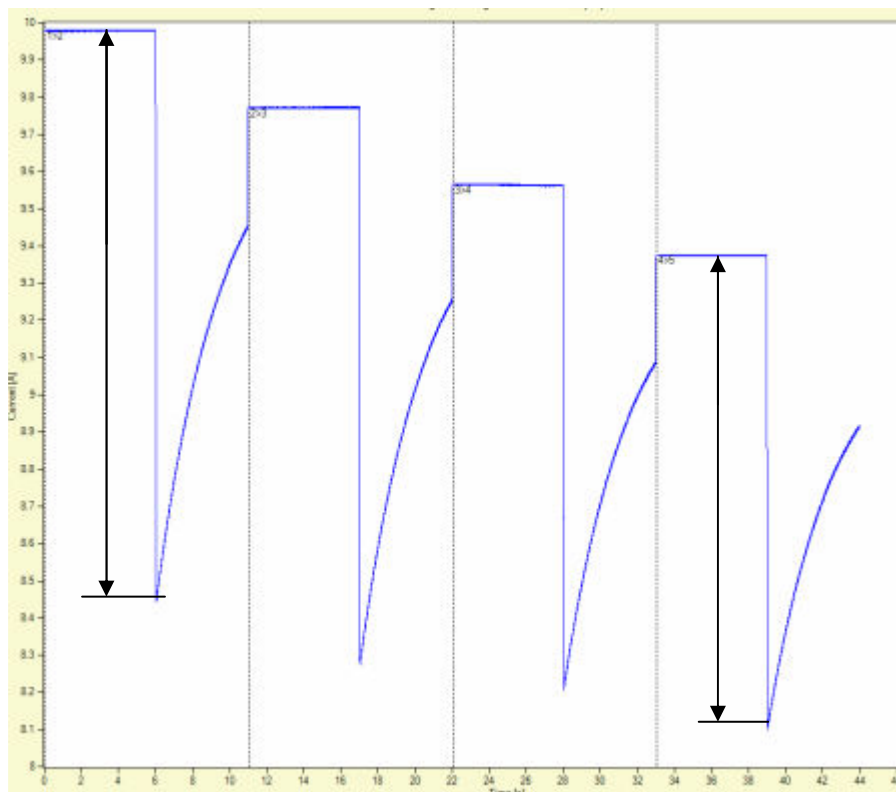
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increases.
The time constant is small since the inductance in one loop is small and the transition resistance is high.

After that the current increases again but now slowly since the resistance now decreases by a factor of appr. 10 and the time constant increases correspondingly.

It is again seen that the expectation of a slow curve is not correct.

Measurement 3

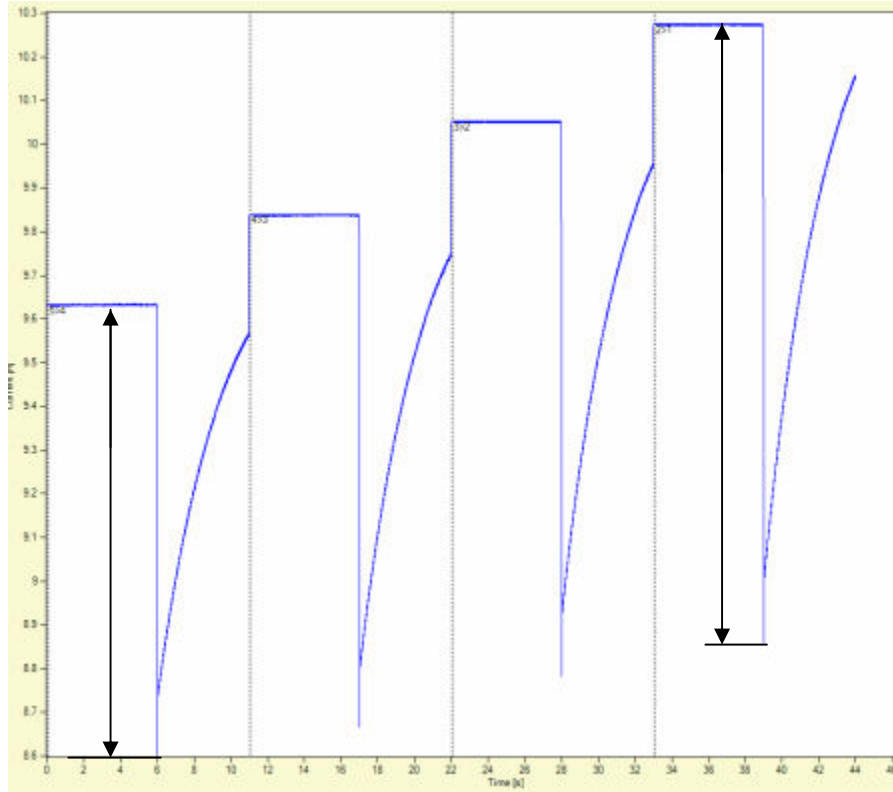A measurement from position 1 to 5 was made:

The instrument wasn't run in the continuous mode. That's why there is a step in current between the operations.

Ripple 1 shown by the leftmost arrow is larger than ripple 2 shown by the rightmost arrow. That is not due to the OLTC but to the fact that we are connecting turns in this direction and increases the inductance and impedance. That means that both the impedance and the time constant increases.

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Measurement 4

Now from position 5 to position 1:

Now the ripple increases for each operation since turns are disconnected and both impedance and time constant decreases.

Conclusions

The dynamic resistance measurement on variable shunt reactors will cause no problem. The response when changing resistances will be fast enough to clearly show the ripple as well as transition times.

The result for an OLTC operating according to the flag cycle can be assumed to be fairly the same.

Although the measurements in this paper is made on a large shunt reactor, it can be stated that the same conditions will apply even to smaller shunt reactors.

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