White paper

DVtesting Regulators

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Introduction

DVtest or a Dynamic Resistance Measurement (DRM) testing is an off-line, non-destructive test in which a DC current is injected through a transformer winding and tap changer as it moves through all of its positions [1]. Results from the current signatures are examined and compared against previous tests or similar unit test results. This test on a regulator may be used to detect problems such as tap changer slow transition time, contact problems, and open circuits among others [2].

Regulators are low cost regulating transformers, or more precisely regulating autotransformers. Some utilities do not like to put their expensive power transformers in danger of failing by placing an unreliable tap changer (OLTC) in the main tank. Others have a need for voltage regulation closer to the load, and for that reason we find many regulators in the USA networks. Most of them have 33 positions and regulate the voltage +/- 10%. The most common configuration is to provide 16 steps of 5/8% (0.625%) each, in both raise and lower position.

Regulators can be divided into large three phase units, and smaller single phase units. While larger three phase units have all the characteristics of an autotransformer with a normal tap changer, smaller ones have special design with super fast tap changers, some for example operate within 250mSec. In other words that regulator can change 4 tap positions within 1 second, see figure 3.

As one side of the regulator is called SOURCE and the other LOAD, the voltage is varied at either side as required. The neutral point/bushing is usually called SL or S0L0. Type A regulators as per ANSI standard vary the voltage at the Load side while keeping the Source voltage constant, while type B does inversely, and is called inverted design, changes the Source voltage while the Load side is kept constant. This is achieved by placing the tap changer in the Load or in the Source side. That will be important when deciding how to test a tap changer in a regulator.

One big difference in their design characteristic, compared with an autotransformer is the resistance and inductance at the tap changer neutral position. The winding resistance of the neutral position can be down as far as 2 milliOhm level, while the end tap would measure 10 times resistance of the neutral tap. This is due to the fact that at the neutral position we have regulation of 1:1 and no regulating winding is in the circuit, only tap changer contacts and connections. At the extreme tap positions we have full regulating winding in the circuit.

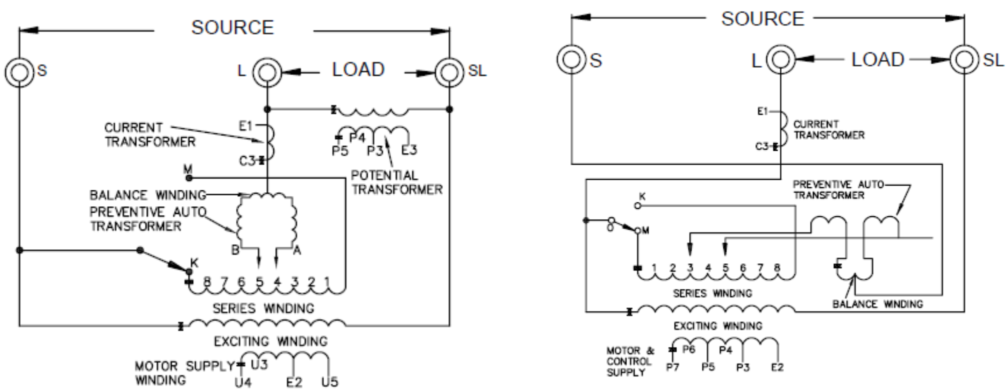

Figure 1. Schematic of two single phase regulators type A (left) and type B

DVtesting Tap Changer of a Regulator

The DVtest or the dynamic recording of the test current provides very different overall graph compared with transformers. The ripples are changing their value from small to very large value at the neutral position; see figure 2, and then getting smaller again as other extreme position is approached.

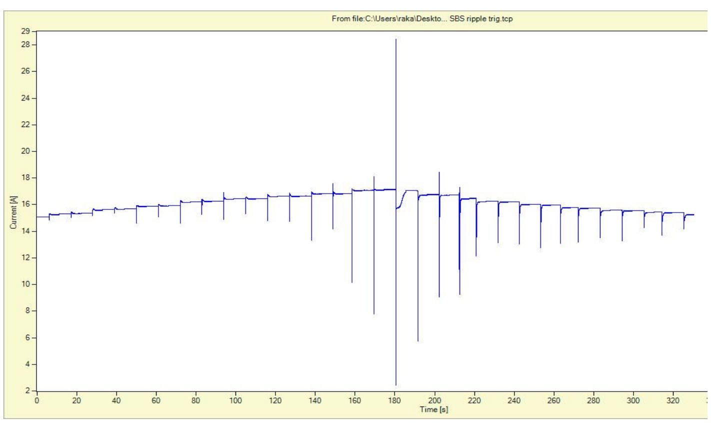

Figure 2. DVtest graph of a typical regulator

Regulators can be equipped with tap changer of either reactance or resistance types. The reactance types are predominant in the USA networks. Ripple shape is characteristic for each construction of the tap changer. Regulator ripples are very much the same shape but different magnitude of their transformer counterparts. For that reason during the result evaluation, attention should be paid to the type and manufacture of the tap changer itself. The figure 2 graph shows different ripple shape for transitions before and after neutral position. This is normal for some reactance type tap changers.

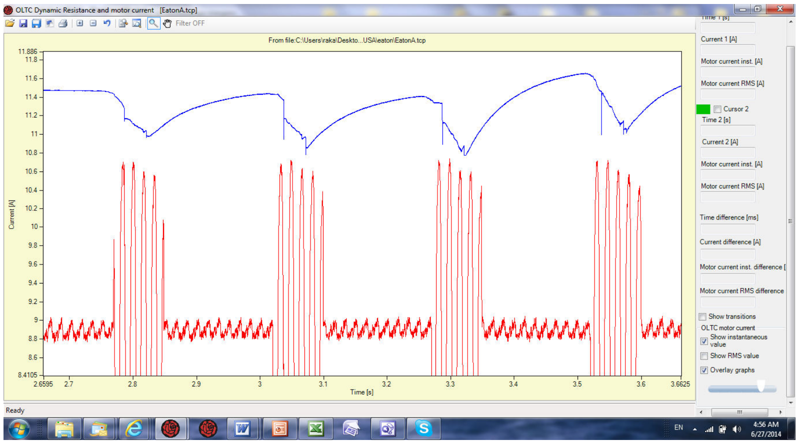

Figure 3. Four transitions in one second of a fast regulator

Three phase

DVtest on a three phase regulator may be performed using a single phase instrument or a three phase DV Power instrument like TWA40D. The three phase instrument allows connecting all bushings at one time, and then we would consider S (source) side as the HV side, and the L side as a LV or secondary winding. Both neutral test leads are connected just like for an autotransformer, to the S0L0 bushing.

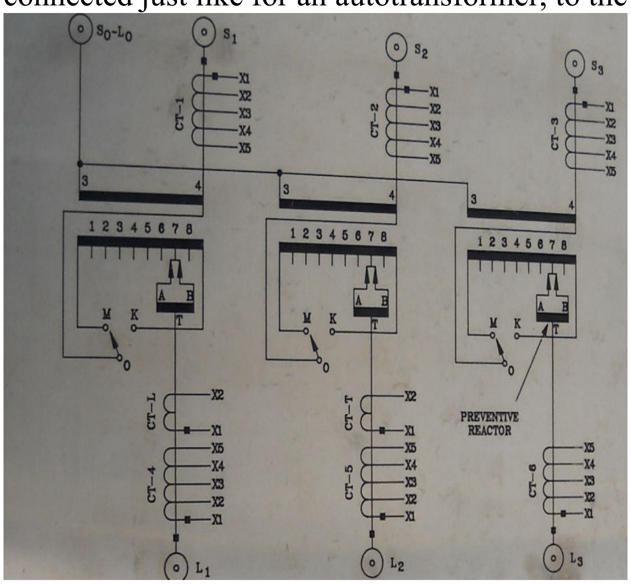

Figure 4. Three phase regulator

Test should be performed the way to include the tap changer. Three phase instruments provide for three options: LV, HV, and BOTH [3]. Selecting the appropriate option requires reading and understanding the nameplate schematic. An example may be the schematic of figure 4. In that case, testing HV winding (S0L0 to S) would not provide ripples as the current is going through the common winding only. Testing LV (in this case S0L0 to L) is the right way to perform the DVtest in order to obtain the desired graph.

Of course, for investigative tests one can use the three phase instruments in a single phase test mode and perform any type of connection permutation.

Single phase

Performing a test using one of the single-phase DV Power instruments allows for selecting connection of test leads the way we want. Normally one lead would be connected to the S side, while the other to the L side. Alternatively, one would be connected to the SL terminal – but then attention should be paid that the tap changer is indeed in the test loop (see note about A type and B type). If not, the graph obtained would be just a straight line.

Testing between S and L has one disadvantage: very low resistance and inductance of regulating winding only, while testing between “SL” (neutral bushing) and S or L terminal includes the common winding in the test loop and makes the ripple smaller and response time different.

Issues

With its inherent low resistance/inductance at the neutral position, regulator creates several interesting issues that tester needs to understand in order to properly evaluate results.
The specifics could be: too high of a ripple as in figure 5. Almost all ripples are reaching 100% on that graph. The reason is construction characteristics of the regulator and test connection used: S to L. In that case recommendation is to change the connection. As the ripple may show 100% - which is not the real situation as the current oscillates, an alternative test connection should be applied.

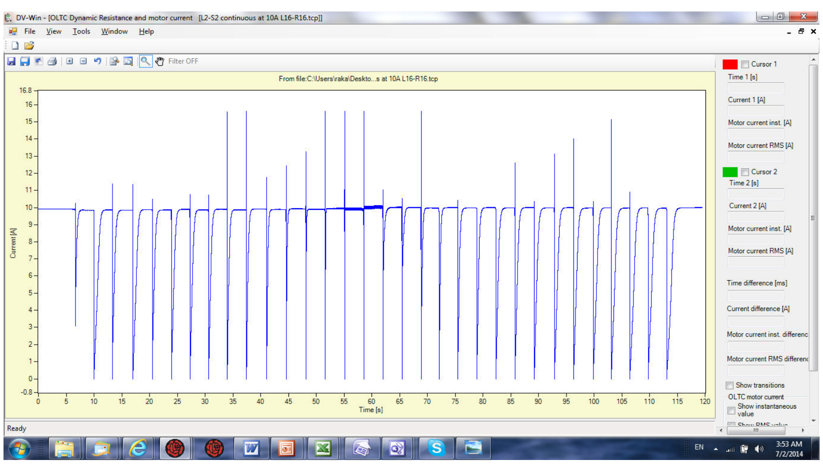

Fig.5. DVtest graph using S to L connection showing very high ripple

Once the test connection is changed to record the current between SL and L terminals, the same regulator responded differently. Figure 6 shows the ripple values that are in the order of 20-50% but never reaching 100%.

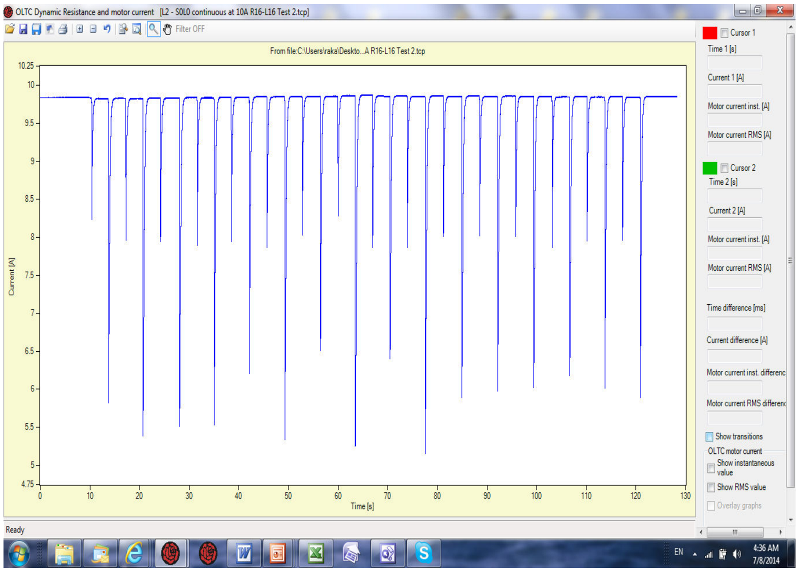

Fig 6. DVtest graph using SL to L connection with normal ripples

Another specific issue at neutral on regulators is slow recovery time. As the test is performed using DC current, the inductance of the regulator winding once introduced in the test loop following the neutral position where inductance is zero, makes current increasing very slow. This is visible on the graph of the figure 2 in smaller degree, while at figure 7 it is extreme. Graf in figure 2 is of a slow tap changer, recorded by waiting for a few seconds between transitions. The figure 7 graph was recorded with high speed regulator, where transitions last very short and time to re-establish current after changing taps through neutral position is few seconds. This is significantly longer than it takes to switch from position N (17) to 33; for this particular regulator about 4 seconds.

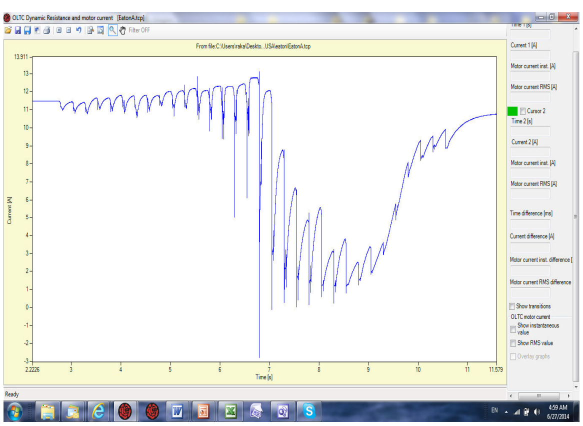
Fig.7. Slow recovery after neutral position

Conclusion

It is very useful to perform the DVtest on a regulator, as it can be a good diagnostic tool for condition assessment of the tap changers. Many problems can be detected including mechanical, electrical, contacts, control, etc. Note should be taken that the graph is specific when analyzing it. Two important issues are: to pay attention how the test leads are connected, and be aware about neutral specifics.

References

1. R. Levi, B. Milovic, “OLTC dynamic testing”, Proceedings TechCon USA, San Francisco 2011
2. R.Levi, G. Milojevic, “From the AMforum Knowledge-base: Case studies of OLTC problems detected by DVtest”, TechCon – Training Track presentation, Sacramento CA, February 2015
3. DV Power, Instruction manual TWA40D, Lidingo Stockholm 2015