SMART DISTRIBUTION TRANSFORMER AND ALGORITHMS FOR VOLTAGE CONTROL

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ABSTRACT

In general, electrical supply networks worldwide have been engineered to meet forecast peak demands and downstream loads. Due to decentralised production units, as for example photovaltaic installations, these networks became also upstream loaded at or close to their design capacity. There is a strong commercial drive for the network operators to defer the cost of reinforcing the network as far into the future as possible. This can only be done reliably if there is a good understanding of the true loading on the network and if practical solutions are available to actively control the networks. This paper will investigate the benefits of combining Smart Distribution Transformer (Smart DT) with automation solutions with innovative operating algorithms and communication technologies. The Smart DT is equipped with a compact on load tap changer to regulate the voltage in LV grids.

CG Power Systems' first 400kVA Smart DT has been successfully installed (December 2013) in a substation in Belgium where a lot of local photovoltaic installations are connected to the LV grid. The Smart DT is controlled by CG Automations Systems' algorithms that are using voltage and current measurements from smart meters installed at different locations in the LV network.

INTRODUCTION

In this paper the technology used in the Smart DT is described first in detail. Also the need for Smart DT's is explained. Also the first practical installation in a Belgian LV network is also described.

In a second part it is describes how the Smart DT can be controlled to improve based on algorithms that use measurements form the LV network.

HARDWARE/MECHANICAL IMPLEMENTATION

What is a Smart DT ?

A Smart DT is a self-regulating transformer which finds it application in areas with a lot of voltage variations on the LV grid. These voltage variations are often generated by decentralized production of electricity by solar panels, small wind turbines, CHP,…

The Smart DT is equipped with a small on load tap changer, the iTAP of MR [1]. Vacuum technology is used so no arcing in oil takes place. A big advantage of the compact OLTC is that it doesn't increase the length and width of the transformer; this means that the Smart DT fits into existing substations. Installing a Smart DT can eliminate the need for expensive grid expantion, e.g. extra underground cables. In this way it can allow more green energy to be fed into the LV grid.

Where is the Smart DT needed?

The Smart DT is needed in a grid situation where the LV often exeeds the voltage limits. Figure 1 represents the situation where the voltage level at the end of the LV lines exceeds the voltage limits. Figure 2 shows the situation where a Smart DT is installed in the substation. The Smart DT can change to the right tap position to keep the customer within the allowed voltage band.

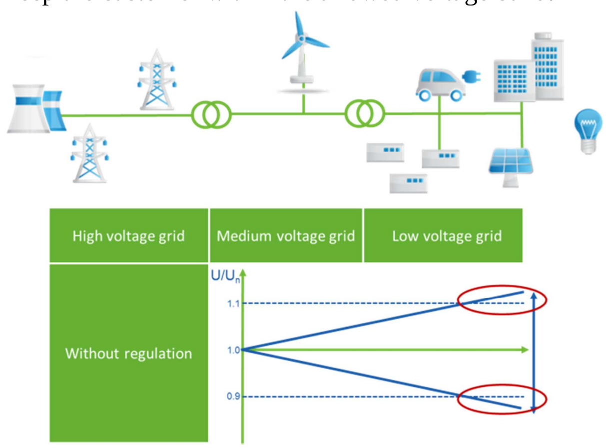

Figure 1 Voltage profile exceeding limits, without Smart DT.

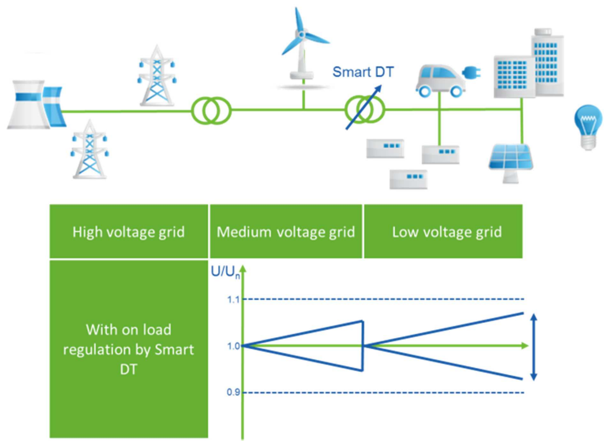

Figure 2 Voltage profile within limit, with Smart DT.

Operation principle of the tap changer

The on load tap changer uses the reactor switching principle. Figure 4 shows two different tap positions.

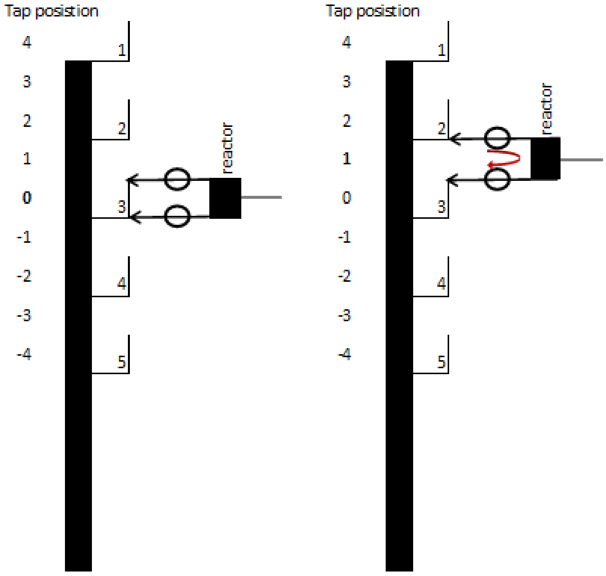

Figure 3 Tap changing principle.

The situation represented on the left is the nominal position where a full tap from the transformer is used. The current is divided between the two vacuum switches and goes through the reactor to the bushings of the transformer. When switching to tap position +1, the first vacuum switch opens before it leaves the previous position. Once the first vacuum switch is open, the contacts move towards tap position +1. In the meanwhile the full current is flowing through the second vacuum switch which still makes contact. When the first vacuum switch has reached the next tap of the winding then it closes again. This situation is shown on the right hand side of Figure 3; this is a stationary bridging position. In this bridging position the reactor acts as an impedance to limit the circulation current that flows between the two tappings of the transformers winding and it also acts as a voltage divider between the two tappings from the transformers winding. The voltage to the bushings is the average of the two connected taps of the transformer. In this way 9 tap positions are created with only 5 taps in the transformers winding.

Figure 4 shows the reactor coils inside the Smart DT. They are mounted under the cover of the transformers.

Figure 4 Reactor coils inside the Smart DT.

How can the Smart DT be controlled?

The Smart DT regulates the voltage by changing the transformers ratio. To change the voltage under load a compact on load tap changer is used. In this case the iTAP if MR [1].

On a standard Smart DT there are three different ways of control:

Manual control

The tap changer can be controlled manually, in this mode it only changes it tap positions when requested by the user.

Automatic control

The standard automatic control keeps the bus bar voltage at the transformer as close as possible to a reference point set into the controller.

Remote control

The tap changer can also be controlled by other systems through the available communications interfaces and protocols. The control unit of the iTAP is equipped with and Ethernet and RS232 interface and the following protocols: IEC60870-5-101, IEC60870-5-104, and IEC61850.

First Belgian Smart DT

Figure 5 shows the Smart DT during installation into a Belgian substation where a lot of PV panels are connected to the LV grid.

This Smart DT of 400kVA has 9 tap positions of 1.25% on the HV winding of 10.6kV to 400V.

Figure 5 Installation of Smart DT in Belgium.

CONCLUSION

This paper describes a solution to the possible voltage violations that are cause by decentralised production units like photovoltaic installations. The solution consists of installing a Smart Distribution Transformer (Smart DT) that is controlled by CG Automations Systems' algorithms that are using voltage and current measurements from smart meters installed at different locations in the LV network. The measurements are sent from the smart meters to a central processing unit trough power line communication. The central processing unit decides to change the voltage on the transformer if needed.

REFERENCES

[1] Maschinenfabrik Reinhausen GMBH**.** GRIDCON iTAP. [Online] [Acessed: 17 03 2014.] http://www.reinhausen.com/en/desktopdefault.aspx/tabid-1515/1834_read-4692/