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New Settings Analysis Report

Evaluation of the New EAVC Settings Applied at Trafford Park North Primary Substation

Part 2

Fundamentals Reference F9183 V1.1

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Confidential

Electricity North West LTD

Enhanced Voltage Control

ENWL011

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About this report

Version Information

Rev	Date	Purpose of Issue / Changes	Authored	Checked	Approved
1.0	05/02/18	Issued to customer	J. Gault	H. Shishtaw	H. Shishtawi
1.1	16/04/18	Updated as per customer's comments	J.Gault	H. Shishtaw	H. Shishtawi

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Abbreviations

EAVC	Enhanced Automatic Voltage Control
DG	Distributed Generation
LDC	Load Drop Compensation
LV	Low Voltage

1 Introduction

New EAVC settings have been applied at Trafford Park North since May 2017. The performance of the EAVC and the tapchangers has been monitored since then and all monitoring data has been captured and recorded. The purpose of this report is to analyse the effects of the applied new settings.

1.1 Analysis

This report looks into the following key points:

- Voltage bias limitations due to transformers' circulating current, load and generation.
- T11's deviation of taps around T12's tap 5
- Comparison between the field collected LV data and the LV simulation results.

2 AVC Limitation due to Reactive Current Flow

2.1 Recorded Data

In Figure 1 there is a considerable amount of data compiled into one graph. The purpose here is to show the effect that the load, the circulating current and the generation level all have on the effective voltage target

2.2 Analysis & Observations

For clarity it is worth mentioning that T12 is operating on a fixed tap position (tap 5) for the whole period of the graph; this is because of T12's tapchanger problems. The reactive current measured by each SuperTAPP SG AVC relay is almost identical when both transformers are operating on the same tap position. The parallel transformers at Trafford Park North are identical.

As the effective target drops on T11, we see T11 responding with a tap down to position 4. The site reactive current remains summed at -320 amps. Using the impedance of the transformers, winding rating, MVA rating, tap step size and system voltage we can calculate the circulating current between the two transformers.

They are both 13.8% impedance, 1225A winding rating, 14MVA rating, tap step 1.43% and system voltage of 6.6kV.

First changing the impedance of each transformer to 100MVA base.

$$\left(\frac{100}{MVA}\right) \times \ Impedance = 100MVA\ Base$$

$$Impedance = \left(\frac{100}{14}\right) X\ 13.8 = 98.57\%\ per\ unit$$

In this case, the per unit circulating current between the transformers can be calculated using the expression below:

$$Circ\ Current = \left(\frac{No.of\ Taps\ Apart\ \times\ Tap\ Step\ Size}{\sum 100MVA\ Impedances}\right)$$

$$Circ\ Current = \left(\frac{1\ X\ 1.43}{98.57 + 98.57}\right) = 0.007254\ per\ unit$$

The actual circulating current in Amps can be then be calculated as:

$$\left(\frac{100\ MVA}{\sqrt{3}\ \times\ System\ Voltage}\right) \times\ Circ\ Current\ \times\ 1000 = Circulating\ Current$$

$$Circulating\ Current = \left(\frac{100}{\sqrt{3}\ X\ 6.6}\right) \times\ 0.007254\ \times\ 1000 = 63.453\ A$$

Using the real recorded data below, we can see T11's reactive current drops to -90 Amps from -160 Amps and T12's increases to -225 Amps.

Table 1 Transformer tap position and circulating current

Time	T11 Tap Position	T11 CT1 Reactive	T12 Tap Position	T12 CT1 Reactive
29/11/2017 21:52	5	-169	5	-169
29/11/2017 21:53	5	-169	5	-170
29/11/2017 21:54	5	-168	5	-168
29/11/2017 21:55	5	-166	5	-167
29/11/2017 21:56	5	-160	5	-159
29/11/2017 21:57	4	-90	5	-225
29/11/2017 21:58	4	-90	5	-225
29/11/2017 21:59	4	-89	5	-225
29/11/2017 22:00	4	-91	5	-227
29/11/2017 22:01	4	-96	5	-232

The circulating current gives a voltage bias to each SuperTAPP SG relay; referred to as V_{circ}.

V_{circ} can be calculated using:

$$\left(\frac{Circulating\ Current}{Winding\ rating}\right) \times\ Impedance = V_{circ}$$

$$=\left(\frac{63.453}{1225}\right) \times\ 13.8 = 0.715\%$$

Using the recorded data, we can see the real change in effective voltage targets.

Before and after tapping apart the effective target changes are as below

Table 2 Voltage target change due to transformers tapping apart.

	Effective Target before	Effective Target after	Change
T11	6.52	6.57	+0.76%
T12	6.52	6.47	-0.76%

This correlates with the calculated voltage bias for V_{circ} of 0.715%

For each tap step that T11 deviates from T12 there is a total limiting bias on AVC of over 1.5%; where each SuperTAPP SG relay is pulling the transformers together to reduce the circulating current. This circulating current bias can act against other applied voltage bias calculations.

3 T11 Deviation around T12 Tap position

3.1 Recorded Data

In Figure 2 the data is showing the deviation in T11's tap position around T12's tap position over a 1-month period. For the duration of the month T12 is fixed in position 5.

3.2 Analysis & Observations

From our previous voltage bias calculation for V_{circ} we know that for each tap there is a 0.76% V_{circ} bias on each SuperTAPP SG relay's effective voltage target.

T11 is for the most part only one tap apart from T12, tapping to either position 4 or 6. We can also see that on only one occasion the effective target has risen high enough to allow T11 to tap to position 7, overcoming over 1.5% of V_{circ} bias. Several times the target dips low enough to take T11 down to position 3, again overcoming a V_{circ} bias of 1.5%.

The bandwidth set for Trafford Park North is 1.5%. Due to the circulating current bias we frequently have voltage deviations of up to 1.5%, where T11 will always be close to either end of the band and T12 frequently out of band when T11 taps.

The list of Voltage biases used to calculate the effective voltage target of a SuperTAPP SG relay are below:

- Basic target voltage (set point rather than a bias)
- LDC Bias
- Generator Bias
- Site Circulating Current (V_{circ})
- Network Circulating Current Bias

In Figure 1 T11 taps down in response to a rise in generation and a rise in busbar voltage. After the tap down, the bar voltage continues to rise, but no more tapping occurs because the V_{circ} bias is strong enough to pull T11 towards tap 5.

4 LV Data Comparison to Simulated Results

4.1 Recorded Data

In Figure 3 there is a voltage drop comparison of the real recorded data and the simulated data from the IPSA model of Trafford Park North. By picking a period of 30 minutes of real data, the simulation model has been setup with the same load levels and generation level as the real data. The voltage drop can then be compared. The period was chosen randomly; while the transformers were on the same tap position.

4.2 Analysis & Observations

The real recorded Tenax Rd LV data is captured every 10 minutes. This reduces the resolution of this data set to give 3 points of measurement; however using the timestamps the exact voltage drop can be calculated.

The real busbar voltage at Trafford Park North varies over the 30 minutes period. Dropping and rising under normal load conditions. At the same time the LV data at Tenax Rd has been captured. The data is matched using the time stamps, we can see the LV data follows the bus bar voltage captured at Trafford Park North. The simulation model is set up to mimic the real load at Trafford Park North during the 30 minutes period, and then the voltage drop has been compared.

The real voltage drop is from 1.36% up to 1.74% for the 30 minute period. The real load is constantly varying around the simulated model load. It can be expected that the voltage drop will fluctuate during this time. The simulated model has a voltage drop of 1.5%. The real and simulated voltage drop is very close, only deviating up to 0.24% away from the simulated 1.5%.

5 Conclusion

This report mainly comments on the performance of the installed EACV relays at Trafford Park North after applying distributed generation related settings.

Any voltage control scheme should be, essentially, capable of:

1. Marinating the busbar voltage to an adequate level ensuring the end customer receives voltage within the statutory limits.
2. Maintain a healthy parallel operation by minimising the circulating current between transformers operating in parallel.

Historically, there were not enough DG plants to deal with from an AVC point of view. However, with the increasing penetration of DG, it is essential for voltage controllers to be able to address the issues that the DG can introduce into the system.

At Trafford Park North, DG related EAVC setting were applied. The applied settings are meant to:

1. Run the system on a lower voltage level when it is lightly loaded, and increase the voltage target in proportion to the true load supplied. This is done by utilising the AVC LDC function.
2. Maximise the DG contribution by decreasing the voltage rise at the point of common coupling. This is achieved using the "GenBias" feature within the SuperTAPP SG relay.
3. The generation contribution is measured in real time and fed to the SuperTAPP SG relays. The relevant settings to address the additional measurement have been adjusted correctly within the SuperTAPP SG relay.

The above settings have been designed using the simulation data addressed in previous reports.

It can be noticed that the voltage control system installed at Trafford North is utilising the DG measured currents and is using them correctly. For instance, the load masked by the DG is revealed by the SuperTAPP SG relay algorithms. This can be observed when comparing the data collected at Trafford Park North's busbars combined with the LV data connected at Tenax Road with the simulation data. Hence, correct LDC has been applied throughout the trial period, as well as correct GenBias level.

Unfortunately, and due to the fact the one of the transformers has been on fixed taps, the performance cannot be fully evaluated and analysed. This is because of the circulating current bias that couples the transformers together and minimises the circulating current. On the bright side, we can see that, and during abnormal conditions, the EAVC prioritise correctly; where minimising the circulating current (security of supply) has higher priority than accommodating DG into the network.

It is recommended that more trials and data analysis are conduced to study the effect of the generator settings more closely and comment on them. However, the results we have seen so far, although partially masked, are satisfying.

Figure 1 Effective Voltage Target Vs Time

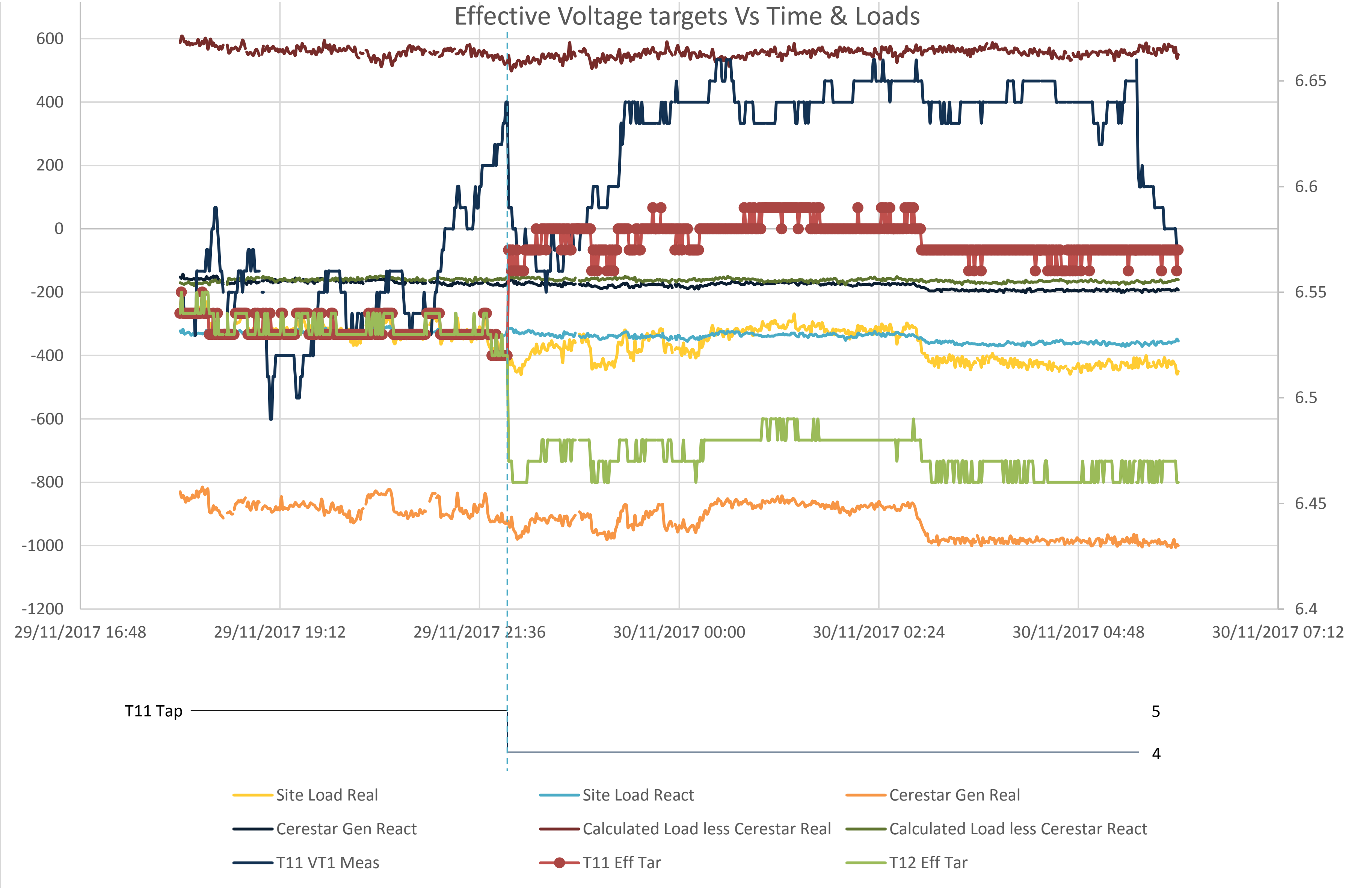

Figure 2 Tap Position Vs Time

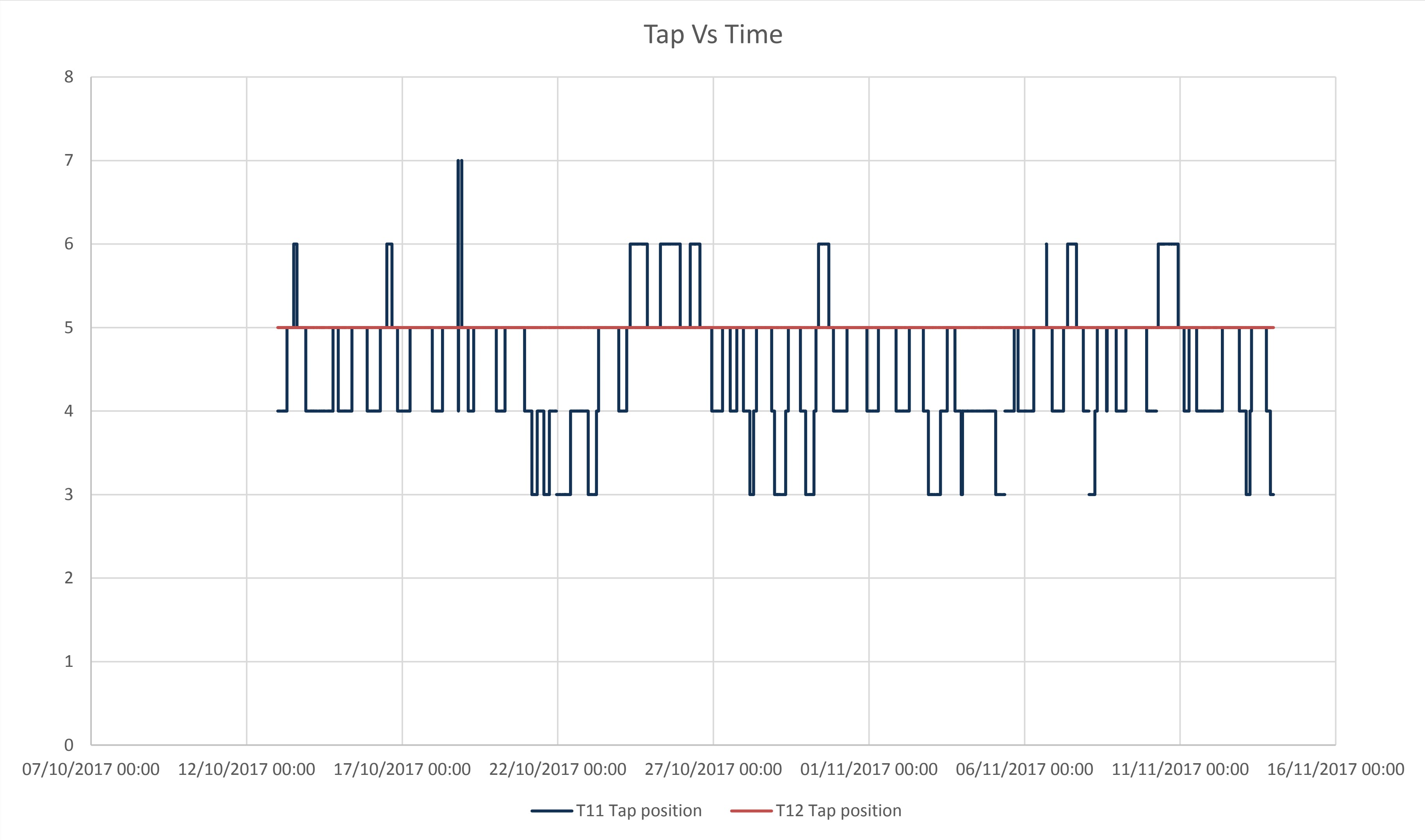

Figure 3 Trafford Park North Real data vs Simulation