VOLTAGE REGULATING DISTRIBUTION TRANSFORMERS FOR LV NETWORK VOLTAGE CONTROL AND SYSTEM EFFICIENCY

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ABSTRACT

The uptake of low carbon technologies within the UK from domestic and commercial customers, and the drive for developers to meet governmental environmental targets for home eco design presents voltage control issues on our LV networks.

Historically networks in the UK have a high level of dynamic monitoring on the HV, EHV and transmission networks. The LV network currently has limited or zero levels of monitoring, therefore system data is not readily available, making it more difficult to design and measure the performance of LV networks.

Given that the commercial and technical landscape is changing at this voltage level, a solution to manage voltage control has become essential.

INTRODUCTION

Distributed Generation systems are increasingly being developed and installed in the electricity network, most of which are located in the customers' premises and connected to the domestic LV network. Moreover, this type of installations is likely to increase rapidly in the next few years, particularly in the small-scale renewables area (PV, wind turbines) and micro-CHP systems.

At the same time, UK DNOs need to provide a safe, reliable and stable supply of electricity to customers as well as managing the changes arising from the substantial increase in distributed generation and the impact it has on the voltage.

As DNOs transition to this low carbon future, the demand on the current assets will become more onerous, however there will be an opportunity to deliver further capability. SPEN and other DNOs will therefore need to adapt its network to facilitate the market demands and accommodate the services they plan to provide. Key to the delivery of a future network is the transition from a TSO (Transmission System Operator) to a DSO. This will require the DNO to provide the platform and enable market participation.

DNOs and Businesses have already delivered new technologies to enable the transition to a low carbon future allowing early connection to the network.

In addition to this, the stability on UK DNO networks and their ability to provide a safe, secure and highly performing supply will be challenged, in particular, by the penetration of PV and the standard application of this technology in new housing developments. This has driven SPEN's initiative to balance voltage through the deployment of distribution tap changing transformers.

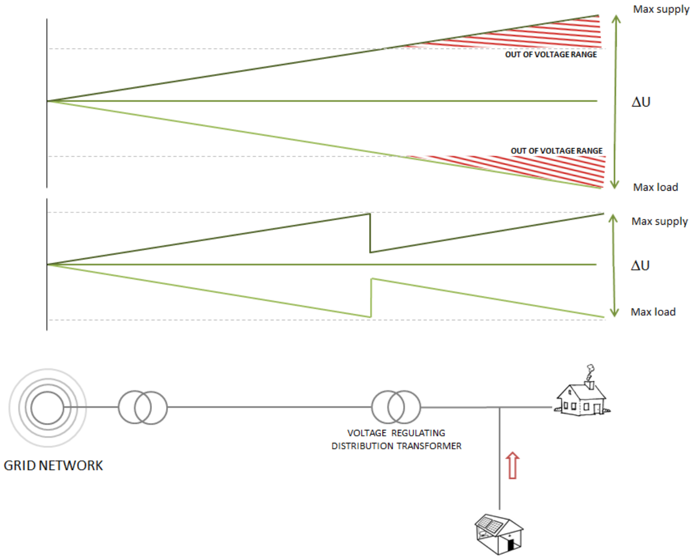

Figure 1: Voltage control at LV level using an automated distribution transformer

Distribution networks are currently designed for uni-directional power flow, from the National Grid Supply Points down to the lower voltage levels for load customers. Therefore, it is sensible to maintain the network busbar voltages as high as possible in order to maximise the thermal capability of circuits for the supply of load, with circuits reaching their thermal limit before exceeding the lower voltage limit. However, this arrangement severely limits the ability of LV networks to absorb generation.

In addition, the new generation profile that includes small scale renewables at lower voltage levels is starting to generate load fluctuations and unbalanced voltage profiles that need to be controlled at LV level.

There is therefore a requirement to undertake voltage optimisation activities that will create additional network capacity for the connection of embedded generation, maintain voltage stability to ensure security of supply and improve the energy efficiency of the customers.

SUBJECT

In order to adopt voltage optimisation into business as usual, the following developments have been identified:

Updating policy documents, in order to incorporate the application of voltage optimisation into network design and operation

Updating Voltage Control Relays: Many voltage control relays at substations are still of the electro-mechanical type and are unable to remotely control target voltage. Modern electronic voltage control relays offer far greater functionality and flexibility, including the ability to remotely configure the relay settings to balance the voltage levels.

Deploy Voltage Regulating Distribution Transformers: In order to provide voltage control in areas with high G83 PV penetration and to help managing generators that suffer voltage constraint at the point of connection. SP Energy Networks will soon install the first five units, which will create the opportunity to analyse the practical benefits from this application.

For the purpose of this paper, the third solution has been chosen for further analysis, with the purpose of identifying the technical requirements and potential of the intake of Voltage Regulating Distribution Transformers into the network.

CASE STUDY- MARKLE MAINS (EAST LOTHIAN)

SP Energy Networks has identified specific points in the network where this system is expected to provide with an ongoing efficient solution to the voltage unbalances arising from the newly installed distributed generation systems.

A total of five voltage regulating distribution transformers have been purchased by SP Energy Neworks, of which the first unit will be installed at Markle Mains, in East Lothian.

Figure 2: Markle Mains farm

This Substation is currently feeding a farm with an existing 50kW PV system mounted on the roof. There is a biomass unit at the site that burns waste sourced wood to generate heat to dry wood chips and that also provides with hot water to the Farmhouse and associated farm tenant cottages.

In addition to this, it is planned to install two 45kW CHP units in order to increase the wood burning capability of the site.

To integrate this distributed generation system into the network a few connection options were considered:

Option 1-To provide a point of connection in East Linton Primary Substation, by building 2.3km of 11kV overhead line plus 100m of cable looped into an existing circuit. A 200kW transformer was proposed to be installed at the farm at the end of the overhead line. This level of expenditure far exceeded the budget available for the project.

Figure 3: Proposed OHL route for Option 1

Option 2- To install a tap changing distribution transformer at the site in order to regulate the voltage to the DNO standards. This would imply the installation of a short section of 11kV cable from the main 11kV network, and two LV cables to feed the customer and the LV network.

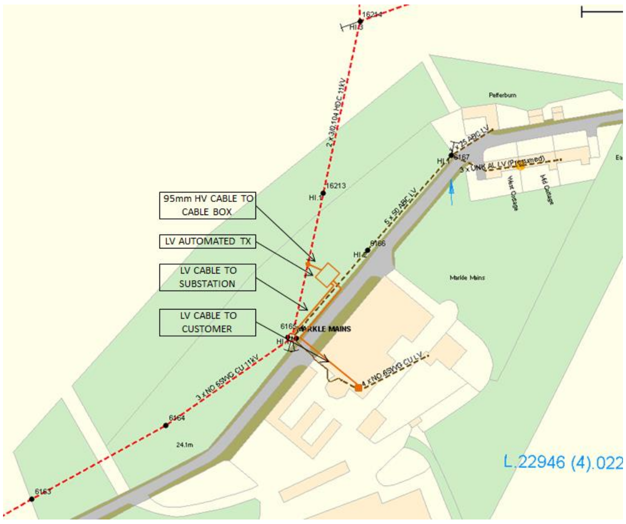

Figure 4: Description layout of proposed accepted solution

This solution was economically viable and within the project budget. The following benefits are expected from the implementation of this solution:

- The generation export is not subject to constraint
- It avoids the construction of an additional OHL across the land
- It minimises environmental impact
- It avoids additional assets, whilst making best use of existing asset infrastructure
- It provides an alternative economic solution to renewable generation connections
- The unit will operate independently and autonomously without intervention from DNO operations
- It avoids expensive and not always reliable communications issues to maintain its operation
- It will serve as a first trial for this type of solution in SP Energy Networks

Transformers technical information

Historically medium voltage distribution transformers in the UK have been fitted with Off-circuit tap-changers that need to be de-energised and isolated from the system before voltage adjustment can be carried out by varying the tap position. This cost effective solution typically has not been an issue as most distribution transformers installed on the network never required alteration of the tap position during service life.

The five units to be deployed on the SPEN network will be fitted with the latest on-load tap-changer vacuum technology which has only recently become available for medium voltage distribution transformers.

The on load vacuum tap-changers utilised are based on high-seed resistor type technology which is common and has been well proven on larger power transformers over many years. For the different projects, the 500 kVA transformers were specified at 11,000/415V with tapping's provided on the 11,000V winding for a variation of the no-load secondary voltage from +5% to –5% in 8 steps of 1.25% per step. The transformer tank is hermetically sealed integrally filled corrugated tank design for ground mounted installation. The transformers are supplied filled with synthetic ester liquid as per IEC 61099.

The tap changer motor drive is provided with a control unit that monitors the single phase voltage and regulates the tap-changer within the required limits. Additional features including remote communication, parallel operation regulation and three phase voltage/current measurement can be utilised as required.

As the standard for Voltage Regulating Distribution Transformers (IEC 60076-24) is still under development the transformers were specified to meet the requirements of IEC 60076-1 (Power Transformers – General) and IEC 60214-1(Tap-changers – Performance requirements and test methods) and EN TS 35-1 (Distribution transformers - Parts 1 and 2).

CONCLUSION

The changing system dynamics and growth of distributed generation in the network has raised the need of developing solutions to control the voltage unbalances in order to ensure reliable and stable supply to customers.

There is a variety of options currently being investigated from a DNO perspective, which can provide with a cost-effective solution for the different case scenarios.

SP Energy Networks is investigating, as part of this work, the installation of distribution voltage regulating transformers on sites where voltage unbalances are expected. As a result, five units will be installed in the Scottish Power network as a first trial to identify the feasibility of the system as a future business as usual solution.

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