ACTIVE NETWORK MANAGEMENT OF VOLTAGE LEADING TO INCREASED GENERATION AND IMPROVED NETWORK UTILISATION

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ABSTRACT

This paper presents results from an application of the GenAVC active network management system to a generation project which required an existing 2 MW connection to be increased to 3 MW. Initial studies by the distribution network operator (DNO), EDF Energy Networks, indicated that the increase was not possible due to voltage rise limitations. Active network management in the form of a GenAVC system was installed on the network. The results demonstrate how GenAVC is able to adjust the substation voltage to allow 3 MW of generation while maintaining all voltages within limits. An assessment tool is also described which enables DNOs to assess the potential benefits of GenAVC before commencing a project.

INTRODUCTION

When planning demand network developments, network operators model distribution networks with load flows for maximum and minimum loads. A cautious approach is taken, because of the minimal amount of accurate data available and the simple models used, to ensure that load customers remain within regulatory voltage limits at all times, and that network assets are not overloaded.

With the arrival of generation embedded within distribution networks a similar modelling approach is normally taken to establish an acceptable limit of generation that can be introduced. Again, network operators employ a “worst case” approach to ensure that the network is not overloaded and voltage limits are not exceeded (Figure 1).

Active network management (ANM) techniques can increase the utilisation of voltage bandwidth and line and plant ratings by using the measured actual values, rather than the traditional simple open loop control models with conservative assumptions.

ACTIVE NETWORK MANAGEMENT OF VOLTAGE

Active network management (ANM) is usually considered in the context of how it can enable increased distributed (i.e. renewable) generation. This paper, addressing the voltage aspects of active network management, is no exception. In fact the principles embodied within the design considered in this paper are:

- to maximise the output of distributed generation
- while maintaining voltages within limits.

The key control parameters available to network operators to manage the voltage on primary distribution networks are:

- constraint of real power exported by generators,
- adjustment to the import (or export) of reactive power by generators, and
- control of on-load tap-changers (OLTCs) at primary substations.

Generators dislike constraint of their real power export since it directly affects their revenue. Both generators and network operators dislike generation importing reactive power as it can restrict the real power capability of the machine and increases network losses.

The method of control used in the work described in this paper involves direct control of the network voltage by adjustment of the voltage setpoint of the automatic voltage control (AVC) relay associated with the transformer OLTC. In effect this involves lowering the network voltage by as much as possible (while maintaining all parts of the network within limits) to allow maximum generation.

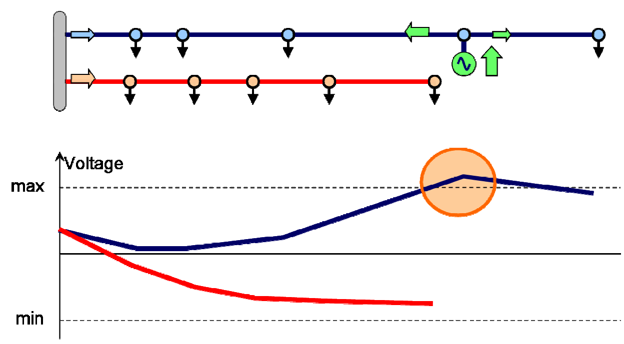

Figure 1 Voltage Rise with Distributed Generation

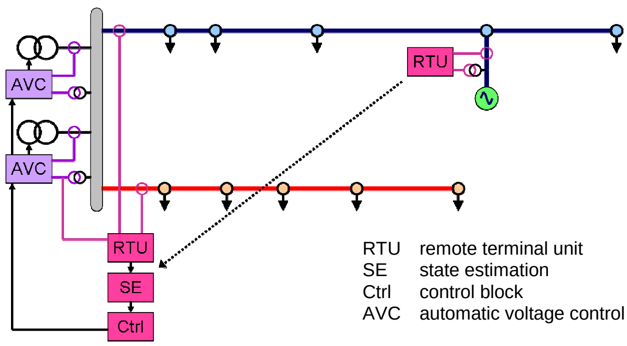

Figure 2 Implementation of Active Network Management of Voltage

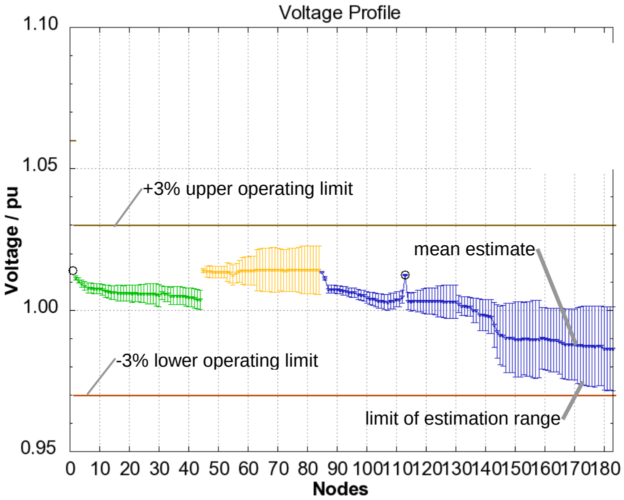

Figure 3 Voltage Profile of Case Network Without Generation (10th March 2008 03:00)

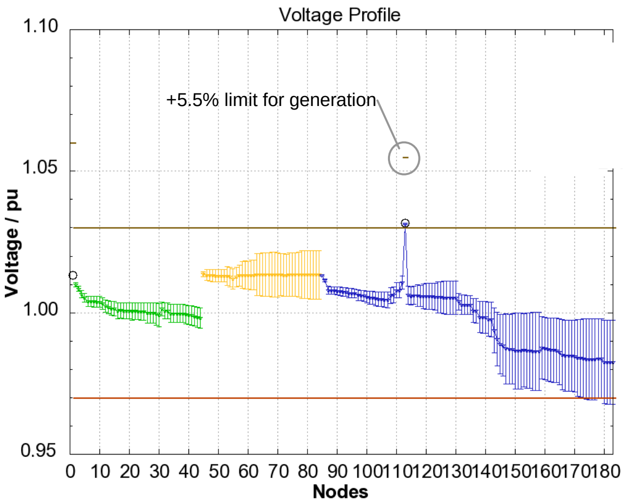

Figure 4 Voltage Profile of Case Network with 2 MW Generation (10th March 2008 11:00)

The principles of this system have been presented previously [1-3] and are described briefly. The system makes a few key measurements at the generation site and the primary substation (Figure 2) and uses state estimation to establish voltages throughout the network. It can then adjust the setpoint of the AVC relay to enable generation to be maximised and maintain voltage within limits.

RESULTS

Results presented here are from the early commercial operation of the GenAVC ANM solution on a UK distribution network. The installation is at Steyning 33/11kV Primary Substation on EDF Energy Networks' network in West Sussex.

A landfill gas generator with an existing 2 MW connection onto the Steyning Primary distribution network wished to increase its output to 3 MW. Studies by EDF Energy

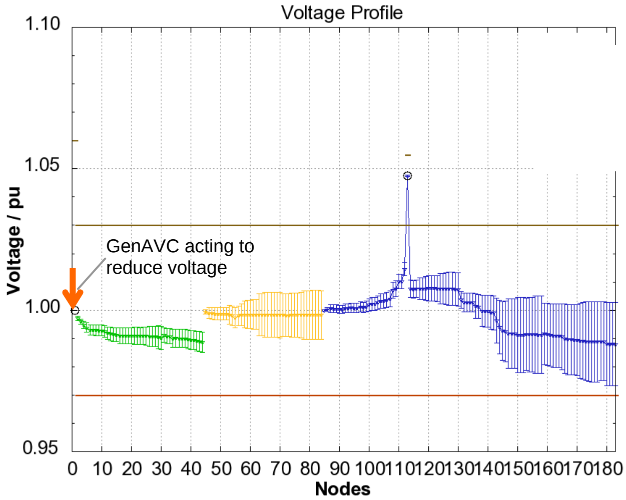

Figure 5 Voltage Profile of Case Network with 3 MW Generation (4th May 2008 15:00)

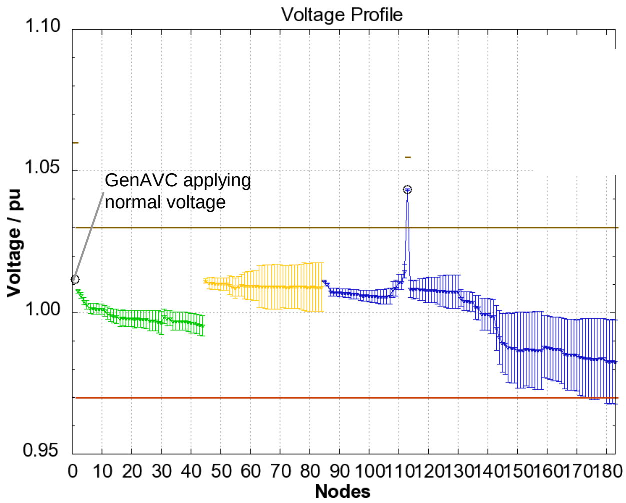

Figure 6 Voltage Profile of Case Network with 3 MW Generation (10th March 2008 15:00)

Networks showed that with the existing 2MW, at times of minimum load, the voltage at some points on the network could rise above the operating limit of +3%, beyond which LV customers could experience voltages in excess of regulatory limits. Therefore this generation occasionally had to be constrained and an increase in generation could not be accommodated.

A solution using conventional methods would involve laying a 4.5 km cable from the generator to the substation. Instead active network management for control of voltage was installed on the network by Econnect in the form of a GenAVC system. The installation of GenAVC has demonstrated how a 50% increase in generation size was feasible without any change to the existing distribution circuits. The graphs of Figure 3 to Figure 6 show some snapshots of voltage after GenAVC was installed and illustrate how ANM is able to solve the voltage control problem with increased generation that would not normally be possible.

Figure 3 shows the voltage profile of the network without generation. The error bars around the mean estimate (solid line) are a by-product of the state estimation process and indicate the range of possible values within which the actual voltage resides. The voltage profile complies with EDF Energy Networks' operational limits of ±3%.

Figure 4 shows the voltage profile 8 hours later when the original 2 MW generation was in service. EDF Energy Networks permitted the voltage at the generation point of common coupling (PCC) to rise to +5.5% (1.055 pu) so long as other load points did not rise above +3% (1.03 pu) to allow for distribution transformer tappings. The voltage at the generator PCC is now above the 1.03 pu limit but beneath the 1.055 pu limit.

Figure 5 and Figure 6 show the situation with 3 MW export after GenAVC had been installed and illustrate the need for active network management in this situation. The two figures show estimated voltage profiles in March and May. The concern for the network operator is the potential for the voltage at points of load (distribution transformers) to rise above the 1.03 pu operating limit. Figure 5 shows the situation in May, where active network management has reduced the primary substation voltage from its normal operating level of 1.015 pu to 1.0 pu. In taking this action GenAVC has prevented the generator PCC from going above the 1.055 pu limit and prevented other load points from reaching the 1.03 pu operating limit. (Consider which points would be in excess of the upper limit if the whole voltage profile was raised by 0.015 pu.)

It can be seen from Figure 6 (March) that a level of 1.0 pu could not be used throughout the year because it would cause some parts of the network to fall beneath the lower operating limits of 0.97 pu. GenAVC is able to evaluate the current state of the network and choose an appropriate operating point for the prevailing conditions, in order to maintain voltages within limits at all locations at all times.

It is by evaluating the voltage through the network using state estimation that the system is capable of making the judgement as to whether it is acceptable to reduce the system voltages. If doing so would result in a lower operating level from being breached, no voltage reduction would occur and the generator would need to constrain real power export.

The installation of GenAVC in this location enabled the landfill gas generator to increase generation from 2 MW to 3 MW, rather than flaring off excess gas in the environment. Further detail on the project and generation technology may be obtained from the authors.

BENEFITS

The technical benefits of active network management for this case are clear. There was an existing generation connection and the application of active network management enabled this connection to accept increased generation without the need for the additional 4.5 km underground cable.

In terms of commercial benefits the generator obtained a connection at a substantially lower cost than if new cabling was required. In fact without active network management it is likely that the capacity increase would have been uneconomic and probably would not have gone ahead.

MODELLING THE GENAVC ANM SOLUTION

The implementation of this project demonstrated that active network management was capable of increasing generation by 50% over what was previously achievable. However, before a decision to go ahead with an active network management project a network operator must be confident that the solution will achieve its objectives.

With conventional network reinforcement the network operator will perform load flow studies to establish that the proposed solution will meet technical requirements. For active network management to become an accepted solution a tool must be available to allow system planners to study its effect with a high degree of confidence.

Modelling is important both for the network operator and the generator. For the network operator it is important to know the limiting points, and how often limits will be reached. The generator will wish to obtain a realistic estimate of the amount of energy which can be exported, in order to obtain financing for their scheme.

EDF Energy Networks and Econnect Ventures collaborated to produce a web-based assessment tool that can provide an indication of the available daily generation export over a year. This tool (Figure 7 for a screenshot) operates in a similar manner to GenAVC itself using a model of the network and using historical load data that is readily available from network operator data archives. The output (Figure 8) is graphs which show the levels of generation that

Figure 7 Output from GenAVC Assessment Tool showing Available Generation

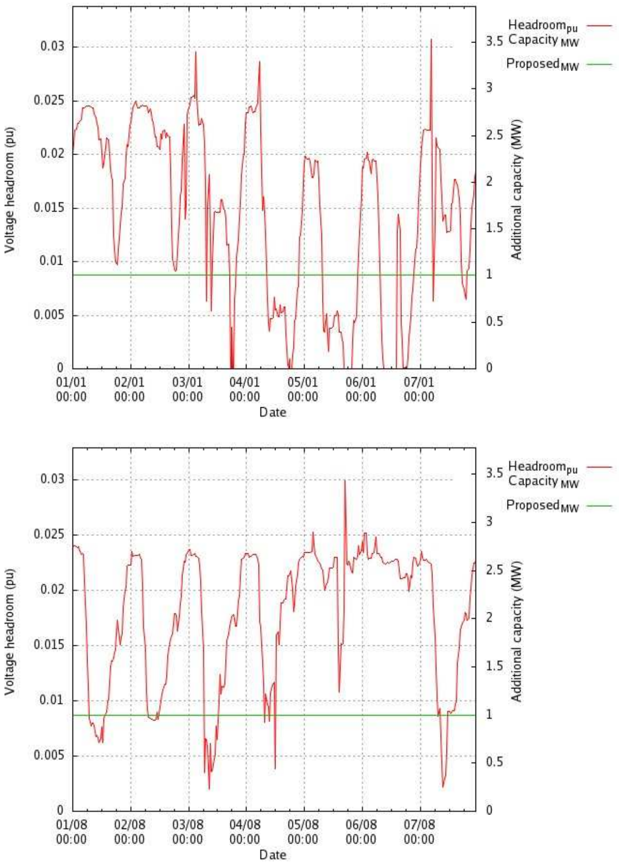

Figure 8 Output from GenAVC Assessment Tool showing Available Generation for (a) January (b) August 2006

could reasonably be expected when using GenAVC. The tool is available online to interested network operators at genavc.econnect.com.

Maximising network utilisation implies that there will be times when compromises must be made, which may result in constraining generation under certain conditions. The stochastic nature of loads (and some generation) means that the energy which can be exported from generation is non-deterministic.

The graphs of Figure 8 show an assessment of the Steyning network with the original generation. Two weeks have been displayed (one in Winter and one in Summer) which show how the capacity for additional generation varies during the year. The flat green trace shows the required additional generation while the red trace shows the capacity for additional generation (right-hand scale).

The graphs show that for a significant proportion of the time there is capacity for the required additional 1 MW generation through the application of GenAVC. Although there are times during the year when there is no scope for additional generation (the red trace falls beneath zero), there are other times when it would be possible to export additionally more than 2 MW.

The actual results since the commencement of GenAVC operation agree with the assessment. In fact while GenAVC has been operating there have been no occasions when the generation has needed to be constrained because of high voltage.

CONCLUSIONS

Active Network Management techniques have long been used within transmission systems for efficient management of the network. However, for distribution networks their aim is quite different – to increase distributed generation. Given this, and that the use of ANM within the distribution industry is relatively new, modelling helps to give network operators and generators confidence in the technique.

Results from an assessment tool have been presented which demonstrate that it is possible to model the potential increase in capacity which active network management of voltage can bring to a generation project. The subsequent installation of active network management in the form of GenAVC enabled a landfill gas generator to increase generation from 2 MW to 3 MW. The alternative would have been installation of a 4.5 km cable – which could have been uneconomic causing the development project to cease.

The work described in this paper was carried out as an Innovation Funding Incentive (IFI) project. IFI introduced by the UK regulator, OFGEM, encourages network operators to engage in collaborative R&D projects. The Steyning network is now a Registered Power Zone (RPZ).

REFERENCES

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