SP ENERGY NETWORKS

Flexible Networks for a Low Carbon Future

AVR Planning Methodology

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1 Introduction

This planning methodology describes the process required to assess the capability of an automatic voltage regulator (AVR) to mitigate voltage drop experienced as a result of load transfer based network control and/or automation. This is based on application to an 11kV distribution network to increase the capacity headroom through network reconfiguration. Voltage constraints are increasingly likely as the length of HV feeder transfer grows.

The method outlined here is based on that applied during the 'Flexible Networks for a Low Carbon Future' LCNF project, but is generalised to address typical situations (particularly with respect to the scope of network monitoring) when evaluating the application of network automation and AVRs to 11kV networks in general.

AVRs are also applied to mitigate voltage rise along long circuits due to generation. This generic methodology is equally applicable to assessing the capability of AVRs for enabling generation connections.

In this guide, an "11kV network" is a part of the 11kV distribution system, supplied from one or more primary substations, which is electrically continuous at 11kV. In loadflow analysis terms, such a network could be analysed using a single 11kV swing bus.

2 Summary of Assessment Process

The process of assessing the effectiveness of an AVR to keep the voltage along an 11kV circuit within statutory limits under various load transfer network configurations can be considered in a number of stages as follows:

1. Network model build
2. Definition of modelling scenarios
    a. Network configurations
    b. Load conditions including representation of demand and generation
3. Power flow analysis
    a. Scenarios without AVR to identify optimal AVR location/s
    b. Rerun scenarios with AVR to confirm location/s
4. Confirm AVR positioning with wayleaving and rerun studies if required

Each of these assessment stages, together with required data, is described in the following section. This can be integrated with application of the Network Reconfiguration Planning Methodology – Section 7 Detailed Power Flow Assessment of Transfer Options, where potential voltage issues are identified.

The use of AVRs for generation connections and corresponding appropriate planning methodology is still under discussion and so not addressed here. Whilst there is a place for AVRs in facilitating renewable energy, they must be subject to appropriate design guidelines in future.

3 Methodology

3.1 Network model build

A network model should be constructed as follows in power flow analysis software such as IPSA, DigSilent Powerfactory or PSS/E:

- Extraction of circuit data (connectivity, length, conductor type, impedance, conductor rating) from network asset database,
- Extraction of transformer data (location, rating, impedance) from network asset database,
- Apply appropriate assumptions for network asset characteristics where data is not available based on surrounding assets and/or typical asset specifications.

The minimum scope of the network model should be from the 11kV busbars at the primary substation to the LV busbar at each secondary substation, and to the metering point of HV customers. It is only necessary to model the 11kV circuit on which the AVR is to be deployed and any interconnecting 11kV circuits.

3.2 Definition of modelling scenarios

3.2.1 Network configuration

Definition of network configuration scenarios should be consistent with requirements defined for load transfer based network control and/or automation, as described in Network Reconfiguration Planning Methodology and Application Guide. This will consist of a “base” case with the network in existing configuration (normal and backfeed) and a number of load transfer network reconfigurations.

3.2.2 Load conditions

Definition of loading scenarios should be consistent with requirements defined for load transfer based network control and/or automation, as described in Network Reconfiguration Planning Methodology and Application Guide. These should include;

- The times of peak demand on the HV feeder from which load is to be transferred,
- The times of peak demand on the HV feeder to which load is to be transferred,
- The times of peak aggregate demand on the HV feeder from which load is to be transferred and on the HV feeder to which load is to be transferred,
- The potential impact of any connected generation under load transfer conditions.

The following load data is required:

- For each secondary substation or HV customer which is explicitly represented in the loadflow model, the measured or allocated real and reactive load.

Load data can be extracted from the network load database. Half-hourly average or spot measurements are preferred. Measured primary substation voltage should be used if available.

3.2.2.1 Secondary Substation Loading Methodology

Measured loads should be used where available. If not, the peak loading at each secondary substation can be estimated based on common rules-of-thumb for ground mounted and pole mounted substations (e.g. proportion of load measured by Maximum Demand Indicators loading, percentage of transformer rating respectively). Detailed analysis of secondary substation peak loading indicated that these simple assumptions are fairly representative (Technical Note on Investigation of Diversity in Secondary Substation Load). Intermittent point loads (such as large pumps at waste water treatment works) are not represented so well. Loads can then be globally scaled to match required peak HV circuit loading.

3.3 Power flow analysis

3.3.1 Without AVR

To determine the optimum location of the AVR, load flow studies should be run for the modelling scenarios to determine the extent of any voltage excursions.

3.3.2 With AVR

Once the optimum location/s is identified, modelling scenarios should be rerun with the AVR model to evaluate the capability of the AVR to maintain the network with statutory voltage limits and AVR current rating. Results should inform the final selection of feasible load transfer network reconfigurations.

3.3.2.1 AVR Model

The AVR can be modelled using a simple transformer model, with manual tap settings or with more sophisticated AVR models in power system software such as IPSA. The IPSA AVR model was developed as part of Flexible Networks. The IPSA AVR model enables selection of the appropriate control mode (Bi-directional, Co-Generation etc.) to automatically determine the required tap position. It was validated against measurements from detailed AVR performance testing at the Power Networks Demonstration Centre.

Proper consideration should be taken of the appropriate regulator basic settings (such as set point and band width), Reverse Power Sensing control modes and of other settable parameters, such as Line Drop Compensation values. The presence and behaviour of generation on HV circuits for load transfer based network control and/or automation applications will influence selection of the appropriate mode for example.

It is also noted that, by constraining the allowable tapping range of the AVR, the "load bonus" function of an AVR (referred to by Cooper Power Systems as the "ADD-AMP" capability) can also be considered. The "ADD-AMP" function permits an increase in the maximum current rating of the AVR to be achieved provided that the tapping range of the AVR (and therefore the extent of voltage control that it is able to provide) is correspondingly limited.

For SPEN, the nominal rating **only** of the AVR is considered for design purposes. There are currently some issues associated with integrating the use of the "ADD-AMP" feature into business as usual including initial setup at commissioning (for a particular current rating) and reset following maintenance or repair. These could be addressed if in future there is shown to be a strong case for using the "ADD-AMP" feature.

3.4 Confirm AVR positioning

For physical installation of AVRs, there are some key locational constraints that must be observed e.g. location of AVR with respect to spurs, as this may significantly affect the influence of the AVR on network voltages.

However, it is recognised that there are practical installation limitations that must also be considered as part of the site selection process e.g. wayleaving process, radio reception for telecontrol etc.

There is therefore a need to provide some locational flexibility in the analysis to cope with these practical issues, with some iteration for example on pole ranges traded off against AVR performance.

Modelling scenarios should be rerun once the final positioning of the AVR is confirmed, if required.