Communication infrastructures to facilitate regional voltage control of active radial distribution networks

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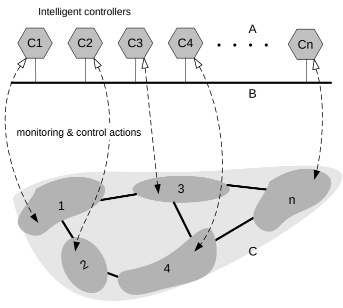
I. INTRODUCTION

The massive penetration of distributed generators into passive medium voltage (MV) power distribution networks brings enormous challenges in network management. An ongoing UK EPSRC research project, AuRA-NMS (autonomous regional active network management system), aims to tackle this issue through devolving current centralised control functionalities at DNO (Distributed Network Operator)'s control centre to a set of networked regional controllers deployed across the power distribution network to carry out either autonomous or cooperative control.

In this poster, by taking voltage control as an example, we investigate the communication infrastructures to facilitate regional control in 11kV radial networks. Our study shows that current DNO's SCADA are inadequate to support efficient regional control due to structural and communication capability constraints which calls for new communication infrastructures.

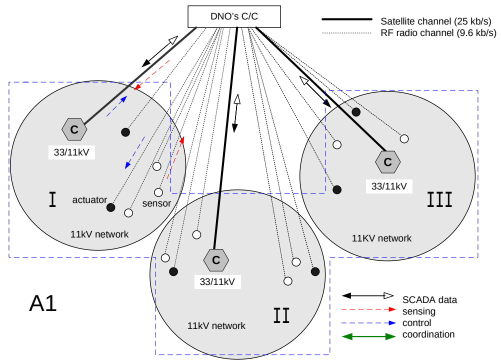
II. REGIONAL CONTROL MANAGEMENT SYSTEM

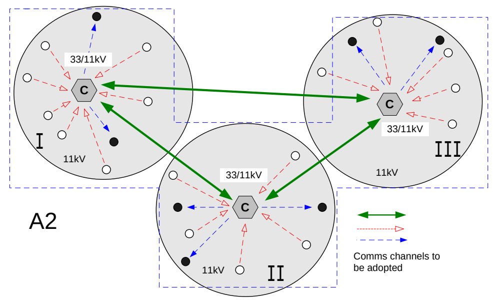


Conceptual regional control management system (A: control domain, B: shared communication domain and C: power distribution network domain)

The shaded area represents a power distribution network consisting of network components (e.g. DGs and loads) and interconnections (e.g. power line connections). The network is divided into a number of regions (1, 2, ... , n) and designated regional controllers (C1, C2, ..., Cn) are deployed which are able to access all local sensing and control devices to conduct local management through regional communication (arrows). A shared communication infrastructure allows distributed controllers coordinate their actions in finding control solutions covering a number of regions, when necessary, for various tasks, e.g. maintaining voltage profile. In AuRA-NMS, agent technology is exploited as a flexible tool for integrating and distributing the control algorithms across the hardware platform to achieve "plug and play" management. Compared to the overall central control, such a regional control approach aims to achieve more timely and accurate operations in individual regions as well as better network-wide management.

III. CASE STUDY: A 11 KV RADIAL NETWORK EXAMPLE



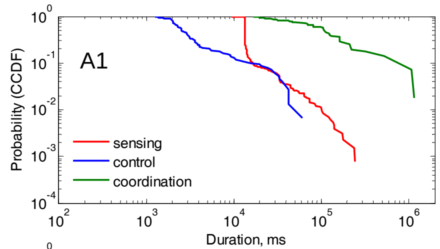


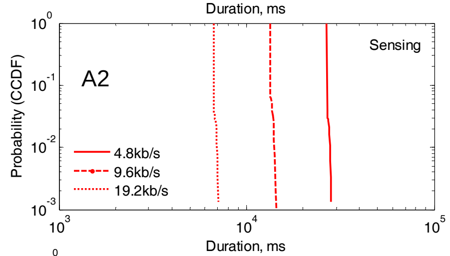
Note: the area of responsibility of AuRA-NMS varies in normal (circle) & abnormal (box) operating conditions

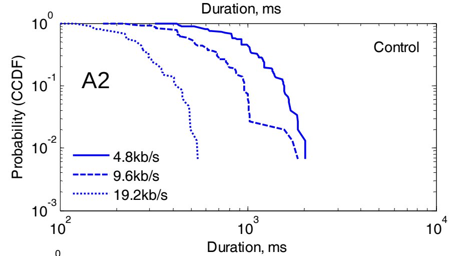
- **Scenario 1 (A1)** – conduct regional voltage control by utilising existing SCADA communication infrastructure. The RF radio channels between 11kV devices and control centre need to be re-configured or upgraded to support more real-time measurements and additional channels may need to be added. The satellite channels between primary sites and control centre may need to be upgraded with more capacity to cope with additional AuRA-NMS traffic demand, particularly under abnormal operating conditions.
- **Scenario 2 (A2)** – utilising a new communication infrastructure by introducing new channels between 11kV devices and regional controller and channels among controllers. The communication technology and channel capacity for both short-range intra-region communication (e.g. GSM/GPRS) and long-range inter-region communication (e.g. satellite, fibre) need to be carefully selected and dimensioned. In such a configuration, the AuRA-NMS operation relies on a separate communication system which minimises the potential interference to current SCADA operation and provides a standalone system to manage the distribution network.

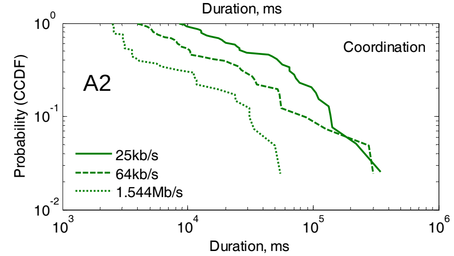
IV. RESULTS

For active distribution networks, maintaining the voltage profile within the regulated limits under various network conditions is essential. The voltage control algorithm running in individual controllers acquires local network measurements (e.g. feeder voltage, current and power, transformer voltage, current and tap position) periodically to identify voltage excursion and issue control signals when necessary. The results presented in term of complementary cumulative distribution function (CCDF) show the time duration to complete measurement collection (500/region, 20 s), control actions (1/200 s, uniform dist.) and coordination process (1/200 s, uniform dist.) for scenarios A1 & A2.









V. FINDINGS & ISSUES

Figure 1 demonstrates that it takes up to 3 min, 50 s and 16 min in terms of communication to complete sensing, control and coordination process respectively in scenario A1, showing the inadequacy of supporting timely control with existing SCADA system. Figure 2, 3 and 4 show the performance for sensing, control and coordination traffic with different channel capacities in scenario A2: 11kV devices-to-controller (4.8, 9.6 and 19.2kb/s) and inter-controller (25kb/s, 64kb/s and 1.544Mb/s), respectively.

Adopting suitable communication technologies is a key issue. The 11KV networks are generally geographically large, including rural, urban, suburban and some very remote sites, which calls for different technologies and makes it more cost-effective to adopt a mixture of solutions (e.g. cellular network, satellite, optical fibre, PSTN). If the DNO's sites are within a local network service provider's coverage, then the public communication network could be an option. Also, DNOs could build their private network (e.g. mobile radio or microwave) to obtain full control with increased flexibility, security and reliability. When the sites are extremely remote and no other options are available, then satellite communications (GEO or LEOs) may be the only viable solution.

VI. REMARKS

Current DNO's communication provisions are not able to support AURA-NMS operation in a reliable and timely manner. The implementation of AuRA-NMS requires new communication investments such as introducing new communication channels, installing new IEC 61850-compatible IEDs and intelligent distributed control units across the power distribution grids. Building suitable and cost-effective Information and Communication Technology (ICT) infrastructures will have a great impact on the performance of AuRA-NMS operation to meet the challenges of active distribution network management.

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REFERENCES

Q. Yang, J. Barria & C. Hernandez Aramburo, "Communication infrastructures to facilitate regional voltage control of active radial distribution network", the 52nd IEEE Midwest Symposium on Circuits and Systems, Mexico, August, 2009.

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