IMPROVED ADMS WITH AN OPERATOR FRIENDLY INTERFACE

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Abstract

The purpose of an Advanced Distribution Management System (ADMS) is to consolidate the key operational functions of a SCADA system, Outage management System (OMS) and Distribution Management System (DMS) into a unified platform. This includes several key functions: SCADA operation, incidents and outages management, teams and field works management including switching operations and advanced applications for network analysis and optimization. The new generation of ADMS also implements a predictive operation strategy to enhance real-time operator responsiveness. The innovative aspects related to the new generation of ADMS built on top of an open architecture will be presented in this paper.

1 Introduction

Electrical distribution networks, a fundamental component of modern power systems, are currently encountering numerous challenges [1]. Integration of Distributed Energy Resources (DERs), aging infrastructure, increasing demand and electrification, cybersecurity vulnerabilities, climate change and extreme weather events and regulatory and Market Dynamics are examples of these challenges that have a profound impact on the development and capabilities of an ADMS. Key implications include:

- Improved Situational Awareness: ADMS must leverage advanced sensors, smart meters, and IoT devices to offer real-time visibility into grid operations, enabling effective management of DER-induced variability.
- Dynamic Load Management: The increased demand from electrical vehicles (EVs) and other loads requires sophisticated demand-response mechanisms in ADMS to manage peak loads and prevent system overloads.
- Enhanced Grid Resilience: Predictive analytics and automated fault detection capabilities within ADMS are critical for strengthening grid resilience against outages caused by aging infrastructure and extreme weather conditions.
- Optimization of DERs: ADMS solutions must include algorithms to optimize the coordination and dispatch of DERs, ensuring grid stability while maximizing renewable energy utilization.
- Cybersecurity Integration: Effective ADMS designs must incorporate robust cybersecurity frameworks to safeguard grid operations from potential threats.
- Regulatory Compliance: ADMS must support compliance with emerging regulations by providing tools for emissions reporting, facilitating demand response programs, and enabling participation in distributed energy markets.

Next in this paper we will address the challenges for the new generations of ADMS with special focus on the network monitoring and control and on the ADMS architecture.

2 New Generation of ADMS

A ADMS combines the functions of Supervisory Control and Data Acquisition (SCADA), outage management, switching, and advanced applications of network analysis and optimization into a single solution that can be used through a single user interface with a common user experience [2].

A common distribution network operations model (DNOM) is the underlying model for the advanced applications and must provide a good physical representation of the real distribution power system, matching its operational states and construction characteristics. The inclusion of DERs in the model is essential. The DNOM is composed by an as-built model and by an as-operated model.

The as-built state refers to the connectivity of the distribution network as it was designed and constructed with all switching equipment in nominal open or closed positions. Updates to the as-built DNOM should have no impact on online operations.

For the as-operated model, the DNOM must support an accurate representation of the dynamic operational state of distribution network connectivity. The as-operated state refers to the actual connectivity for a specific point in time with some switching equipment in abnormal positions. In addition to abnormal switching, the dynamic as-operated state can be affected by temporary line cuts and temporary switches and jumpers placed in the field to effect switching where no permanent switching is available. Abnormal switching, particularly with temporary switches and jumpers, may be used to energize across normal phasing.

The visual representation of the state of the network is a key point to provide an improved situational awareness to the control room operator.

Many types of data are brought together into the single UI/UX of the ADMS to create a very powerful view of the as-operated distribution network. These include:

1. The relatively static as-built description of electrical equipment outside the substation fence.
2. Substation electrical equipment, typically presented in schematic form.
3. Near-real-time switching equipment statuses and measurements of monitored voltages and flows from SCADA system.
4. Manual entries of non-telemetered switching equipment statuses, temporary cuts and jumpers, equipment safety tags, and informational annotations by various authorized users of the ADMS.
5. A connectivity analysis of the electrical equipment to determine the extents of energization and de-energization based on the open/close status of all switching devices.
6. Advanced application solution results, such as estimated power flows and voltages, typically updated every few minutes.
7. Abnormal topology/connectivity situations and operational limit violations.
8. Fault locations.
9. Tags and safety permits for planned work and restoration switching activity.
10. Customer/meter locations and connectivity to the distribution network.
11. Smart meter power-off notifications, power-restoration notifications, voltage ping responses, and requested measurements of voltage and power via advanced metering infrastructure (AMI) of meter data management systems.
12. Customer trouble call indications from call centers, interactive voice response systems, and individual users of the ADMS.
13. Confirmed as well as outage management-predicted open protection devices associated with outage incidents.
14. Dynamic crew locations.
15. Background layers of information, such as aerial views, street maps, and land-base extracts from the Geographic Information Systems (GIS).
16. DER locations, connectivity, and status.

As stated before a ADMS incorporates advanced applications for network analysis and optimization. The basic distribution network analysis functions include:

1. Power flow.
2. State estimator.
3. Short circuit.
4. Fault location.
5. Various derivatives of network analysis output, such as operational monitoring/violation-reporting and loss calculations.

Distribution network optimization functions have the additional goal of proactively suggesting how to adjust controllable distribution network equipment to meet desired network operating conditions. The distribution network optimization functions include:

1. Switching reconfiguration, which proposes switching plans for fault isolation and service restoration as well as planned maintenance work or circuit-load balancing/shifting (Optimal feeder reconfiguration).
2. FLISR (Fault Location, Isolation, Service Restoration).
3. VVC (Voltage Var Control), which involves demand management and loss minimization within voltage operating limits using taps, capacitors, and DERSs, such as photovoltaics and storage coupled with advanced inverters.
4. Contingency analysis.
5. Load shedding.

The increasing integration of renewable energy sources (RES) at different voltage levels of the distribution grid has led to technical challenges, namely voltage and congestion problems. On the other hand, the integration of new DER, namely flexible distributed generation technology, electric vehicles, storage, and demand response, provides the necessary flexibility to integrate additional RES, while maintaining the same levels of security. This context requires a paradigm shift in the grid operating philosophy to become more flexible, observable, and controllable.

The approach described in the paper differs from those on the market since it is developed from a perspective of grid predictive management, considering forecasting and optimization combined with functions that increase real-time network observability.

3 Improved Network Monitoring and User Interface

The ADMS aims to enhance the monitoring capabilities of distribution networks by integrating various information sources and tools to estimate the network's operational status. Increased observability can be achieved by providing pseudo-measurements, generated through historical data processing and load allocation tools, to the state estimation process or power flow tools, thereby filling any potential gaps in telemetry.

After estimating the network's operational status, results, alarms, and warnings are presented to the operator through various indicators. These indicators identify network areas

with technical issues (ex: over/under voltage, transformer congestion, etc.). The network status and identified technical problems are presented to the operator by network and categorized according to their relevance. References to the network's historical behaviour can also be included.
The definition of corrective control actions to address identified technical problems from the previous analysis can either be implemented automatically upon detecting the technical solution or presented as recommendations to the network operator. These control actions are determined by advanced applications for network analysis and optimization, which may have distinct objectives depending on the existing operational alarms and/or warnings. These objectives include network reconfiguration, device tap control, management of Distributed Energy Resources (DER), reactive power dispatch, or curtailment.
The most important aspects related with the way the relevant information is presented to the network operator, including suggestions of corrective actions will be discussed in this paper.

2.1 User Interface

The ongoing challenges faced by the new generation of ADMS highlight the need to rethink how tools are presented to operators. These systems must provide operators with a comprehensive, real-time, and predictive view of the grid and potential issues. By doing so, they not only enhance response times to problems but also support proactive network management, helping to prevent potential issues before they arise.
The new proposal involves presenting, within a single dashboard, not only a comprehensive overview of the network but also real-time and predictive insights into potential issues, along with a set of proposed solutions to address them.

The proposed dashboard (Figure 1) is divided into three distinct sections:

1. Top Section: This area contains graphics detailing produced power, consumed power, and losses.
2. Left Section: This area presents a list of graphical alerts, identified by severity and organized by type and network area.
3. Right Section: This section showcases the solutions proposed by the algorithms to address the identified issues. Additionally, users can navigate to a georeferenced map that visually represents the network layout in the areas where problems have been detected.

Fig. 1 Grid monitoring Dashboard.

2.2 Advanced network monitoring MV Networks

MV networks application functions, such as network visualization, connectivity and energization analysis, power flow, short circuit, fault location, FLISR, and VVC should all consider all the controllable DER present in the network, like renewable generation, flexible loads, and storage.

The power flow analysis is important to understand the impact of the DER injections on circuit voltage and "hiding" the actual levels of native load that a utility must be prepared to support in the event of a sudden DER shutdown.

The VVC function can recognize that high-voltage limits have been violated and recommend a plan consisting of active or reactive power set points for the renewable generation smart inverters or for the flexible loads, state-of-charge set points for the storage devices, to mitigate the violations. VVC is a good tool to orchestrate this collection of highly distributed DER controls with the tap-changing equipment and capacitors on the feeder.

The ADMS monitoring supported by multiple data sources aims to provide extended monitoring capabilities of distribution networks, combining different sources of information (e.g. historical data, typical load profiles, RTU measurements) and tools (such as load allocation, state estimation and power flow).

Increased observability may be achieved by providing pseudo measurements, generated by the historical data processing and load allocation tools to the state estimation process or power flow tools, filling in any possible gaps in telemetry.

After the network's operational status is estimated, results/alarms/warnings are presented to the operator through several indicators, identifying network areas with technical problems such as over/under voltage, feeder & transformer congestion, areas with hindered observability or with unusual behaviour, as well as switching devices statuses.

The network status and technical problems identified will be presented to the operator by network areas defined by the operator and categorized according to their relevance. Reference to historical behaviour of the network can also be included, identifying existing loading patterns in areas with unusual higher or lower demand, for example. The application may recommend actions and suggestions to solve identified problems.

The corrective control actions to solve identified technical problems are determined by a Voltage/Var Control with reconfiguration (Distribution Optimal Power Flow tool) or an Optimal Power Flow tool, supported by Load Allocation tool, which may have distinct objectives depending on the existing operational alarms and/or warnings, namely: voltage control, transformers and capacitor banks tap control, DER management, reactive power dispatch or curtailment, and others. These recommendations, or automatic control actions, can be either implemented automatically after detecting the technical solution or presented as recommendations to the network operator. The optimization process includes both technical and economic constraints of the network and all taken actions, automatic or manually approved, are registered in the historical database.

The predictive management of DER tool [4] deals with multi-temporal characteristics of DER, e.g., state-of-charge (SoC) of energy storage systems, and load shedding "rebound" effect, along with traditional resources (e.g., OLTC, circuit breakers). The purpose of the predictive management DER tool is to assist the operator in the management of the grid, producing control actions to solve foreseeable operational problems, such as voltage violations and line/transformer congestions. The tool uses grid operation snapshots, provided by the load allocation module (using load/RES forecasts as input), and information regarding DER flexibility. The tool typically runs for a 24-hour sliding window; however, the user can define the optimization horizon and the duration of each optimization period.

2.3 Advanced network monitoring Low Voltage Networks

LV networks require granular monitoring and management strategies to address the challenges posed by load growth and DER. Advanced monitoring systems must provide real-time visibility into voltage profiles, power quality metrics, and bi-directional power flows at multiple connection points. This requires the integration of smart meter data, low voltage monitoring devices, and edge computing technologies to enhance network observability and control.

Comprehensive network visibility must be complemented by predictive tools for operators to be better equipped to address challenges such as voltage violations, transformer loading issues, and network congestion before they escalate. These tools leverage historical consumption patterns, renewable generation forecasts, and, where applicable, energy storage systems to develop optimal control sequences.

Combining the aforementioned data sources and tools, the LV ADMS is now capable to forecast demand per feeder and phase, and the voltage per connection point, enabling the identification and sizing of the LV Grid constraints in slots of minutes, and to scale operating envelopes as a tradable item for the DSO negotiate with Flexibility providers, and in this way, keep the LV grid securely operated.

By integrating advanced monitoring, predictive tools, and sophisticated control strategies, LV network management can address the complex challenges introduced by evolving energy landscapes. This approach complements the functionalities outlined for MV networks, ensuring a cohesive and comprehensive strategy across all voltage levels.

4 Open Architecture

One of the major obstacles to deploying and adopting ADMS platforms is the complexity of integrating the various systems of the utility to ensure seamless integration [3]. The main challenges for integrating an ADMS with other utility IT systems are related with data integration and interoperability, legacy systems compatibility, communication infrastructure and protocols, data quality and cybersecurity and data privacy. Utility IT ecosystems include multiple systems such as Customer Information Systems (CIS), Enterprise Resource Planning (ERP), SCADA, and GIS.
Integrating systems with varying levels of data quality can lead to errors in ADMS operations. For instance, GIS inaccuracies can impact network modelling and fault location. Managing and consolidating data from multiple IT systems while maintaining consistency, accuracy, and completeness is a significant challenge.
Finaly, integration with IT systems expands the attack surface, exposing the utility to greater cybersecurity risks, including unauthorized access and data breaches. Ensuring compliance with cybersecurity regulations, adds complexity to integration projects.
Another aspect that needs to be considered is the complexity of adapting the ADMS to the business processes of the utility. Utilities have their own established internal processes. These processes cover many aspects of the utility from the operational processes, either inside or outside the control room, to planning, maintenance, top management support, etc. The ADMS should facilitate the digitalization and implementation of all these business processes.
The architecture of an ADMS to facilitate seamless integration with other utility IT systems and facilitating the customization of the utility business processes should consider various aspects. Key aspects include:

1. Adherence to Standards: Utilize industry standards such as the Common Information Model (CIM) to ensure compatibility with other utility systems.
2. Modular and Layered Architecture: Implement a modular, service-oriented design that allows individual components to function independently while integrating seamlessly with other systems.
3. Data Management and Integration: Establish a enterprise service bus (ESB) to facilitate data exchange between systems.
4. Open APIs and Interoperability: Provide well-documented, secure, and open application programming interfaces

(APIs). Support custom adapters or connectors to bridge gaps with legacy systems that may not have standard APIs.

Based on these principles we preconize and open architecture for an ADMS in Figure 2.

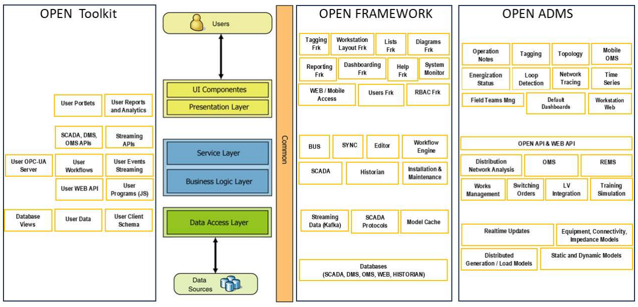

Fig. 2 Open architecture diagram.

This architecture is composed by the following elements:

1. A set of computational components provides the core of ADMS functions with a well defined API.
2. These ADMS computational components are built on top of an open framework.
3. The open framework provides a full stack environment enabling the development of new computational components, ex: database and persistence resources, IT message BUS and IOT protocols, realtime SCADA core, workflows engine, configuration services and instalation support.
4. A framework layer providing basic functions like, users management, tagging, workstation layout management, RBAC, WEB and mobile access, etc.

In addition, an OPEN toolkit is available. With this toolkit it is possible to extend the functions provided by the core of the ADMS. These extended functions may consist not only of the integration with other utility systems but also the development of utility specific applications adapted to their specific workflows.

4 Conclusion

The implementation of a new generation of an ADMS represents a significant advancement in the management of modern power distribution networks. By integrating the key operational functions of SCADA, OMS, and DMS into a unified platform, the ADMS enhances the efficiency and reliability of grid operations. The new generation of ADMS, with its predictive operation strategy and open architecture, offers innovative solutions to the challenges posed by the increasing integration of RES and DER. This approach not only improves real-time operator responsiveness but also ensures a more flexible, observable, and controllable grid.

The enhanced monitoring capabilities and user interface of the ADMS provide operators with comprehensive insights into the network's operational status, enabling timely identification and resolution of technical issues. The integration of advanced applications for network analysis and optimization facilitates the implementation of corrective control actions, ensuring the stability and security of the distribution grid. As the power industry continues to evolve, the adoption of such advanced systems will be crucial in addressing the complexities of modern energy management and supporting the transition towards a more sustainable and resilient energy future.

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