# Swiss TSO Integrated Operational Planning, Optimization and Ancillary Services System

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***Abstract*—This paper discusses the problems of design and implementation of complex set of interconnected online and offline planning, optimization and monitoring tools of Swiss Transmission System Operator Swissgrid. After analyzing the requirements and challenges of the system, the paper presents its realization concept, as well as implementation results and the future plans. Solution under discussion widely uses microservices for network modelling and analysis and modern integration techniques to provide system with high flexibility and reusability, having shorter time-to-operation cycle and lower engineering costs than systems based on traditional approach.**

***Index Terms*—Power system planning, Operational planning, SCADA Systems, Redispatch, OPF, OPC**

## I. Introduction

Swissgrid is a Swiss Transmission System Operator (TSO), responsible for the 380/220 kV national power grid and provides services to other European TSOs as coordinator of ENTSO-E control block South. Swissgrid operates relatively small (6700 km), highly meshed (140 Substations) and highly interconnected (41 tie-lines) power system with approximate installed power capacity of 12'000 MW.

Historically, question of congestion management, including operational planning and corresponding alleviation measures is of high importance for the Swiss power grid, which due to its location and configuration is highly exposed to international energy exchange flows. That's why the company addresses the topic of advanced operational planning already since the early 2000-s, and, as one of the major participants of the Day-Ahead Congestion Forecast (DACF) European working group and member of TSO Security Cooperation (TSC), contributed a lot in establishing the state-of-the art operational planning approach in Europe.

After the power market introduction in 2009, ancillary services management and market-based mutual energy assistance services and redispatch became one of the major topics both for market and for network operation. Ancillary services in Switzerland include:

- Primary frequency regulation
- Secondary frequency regulation
- Tertiary frequency regulation
- Voltage control
- Black start abilities.

One can consider national and international redispatch and other congestion alleviation measures to be the part of ancillary services as well.

This new situation raised the question of development of the cross-business platform, covering corresponding parts of power grid and market operations: operational planning, online security analysis, security forecast and optimization calculation and real-time regulation reserves monitoring and activation. Design steps, functionality and main benefits of this solution are being presented in this paper.

## II. Operational Environment

Swissgrid operational environment consists of the SCADA/EMS system, optimized for the real-time operations and online estimation area security analysis. Addressing advanced European network security assessment, Swissgrid already in 2002 began with implementation of its new congestion management suite, starting with fully automated Day-Ahead Congestion Forecast solution [1], that went operational in 2003 and was later continuously extended, e.g. through the state estimator (SE)-based real-time snapshot model and intraday congestion forecast modules on the load flow analysis site. The Security-Constrained Optimal Power Flow (SCOPF)-based day-ahead, intra-day and close-to-real-time congestion alleviation and re-dispatch solution [2] and voltage optimization solution [3] rounded the suite functionality on the optimization side. During the ancillary services market introduction, alongside with the voltage optimization tool, the ancillary reserves and response monitor was implemented, using the same integration and visualization platform as the above listed systems [4].

## III. Drivers: Vision and Necessity

The vision was to develop integrated and scalable system, giving possibility of further energy quality management processes automation, where energy quality can be seen as a combination of:

- Frequency stability.
- Voltage stability.
- Energy availability, network security and Net Transfer Capacity (NTC) being part of it.

Economic aspects (minimal service price) and regulatory aspects (e.g. rules of non-discrimination or other regulatory policies) can be also treated as the energy quality criteria.

Significant progress in the area of IT security, IT solutions and IT integration standards that took place in the last decade brought the new set of requirements:

- Reduction of total costs of development and ownership.
- Increasing cyber-security requirements, including identity and access management (IAM) for credentials management by the services calls, storage and exchange access, etc.
- Compliancy to the best-practice IT-architecture requirements and high utilization of the new security abilities of the solutions and standards used.
- Increasing system availability and integrity requirements (also due to re-positioning of the roles of planning and optimization).
- Faster process and system restauration in case of problems – as the processes are coming closer to the real-time.
- Further enhancing existing system advantages as flexibility, low vendor dependency, high level of functionality re-use, etc.

New processes in ENTSO-E, including concentration of parts of planning processes at the central European entities TSC [8] and Coreso [9] and establishing of the new market platforms (e.g. Market Coupling between groups of European countries) raise the new requirements towards the planning process, shorter planning time frames and shifting of planning frames closer to the real-time operation point being part of them.

Instantaneously, the data quality at the national and international levels improves steadily, allowing exacter and more efficient grid modeling. This leads to the stricter ENTSO-E quality requirements [6], supported by the introduction of the new CIM-based data exchange format CGMES [7] as a replacement for ASCII-based ENTSO-E DEF, being standard in the last decade.

These new business models and processes significantly influence operational requirements that now can be formulated as follows:

- More accurate automatic network modelling.
- Possibility to perform manual corrections in a fast and efficient manner (e.g. necessity to perform manual topology changes by different substations for multiple models followed by N-1 AC model analysis in under 10 minutes).
- Use of archive and plan data from different sources for the model creation.
- Extended set of planning processes should be covered as a result of new business responsibilities.
- End-to-end process covering to minimize number of tools and simplify data management.
- End-to-end process monitoring: monitoring of every single process and overview over the whole process landscape.
- High flexibility of the process modelling, as well as possibility to split the process and delegate part of it to another team (e.g. from planning team to dispatching team or vice versa).
- Advanced visualization of different information sets, like network models, calculation analysis results, data and process flows, etc.
- Increased usability and error-resistance (operational engineers are executing complex volatile process under strength time constraints).
- Increased auditing of the automatic and manual planning and optimization process (some of the decisions can turn to be finance- or grid security-relevant).

Some of the requirements above could be addressed through the system evolution process, but others forced change of existing modelling approach and deep system re-design, increase of model accuracy in combination with the shorter time frames, being one of them.

## IV. System Design

Operational experience and the analysis undertaken, showed that most of the network modelling and analysis scripts used in the existing solution were similar, but missed some particular functionality or configuration abilities, what caused relatively high module change costs and test efforts in case of new process introduction. As opposite, the workflow automation approach and SCADA-based graphical user interface (GUI) for planning engineer proved to be an efficient solution.

Key improvement fields of the new system:

- Implementation of bus-breaker models for planning tasks (as replacement for traditional bus-branch model).
- Introduction of new functional modules design (“microservices”).
- Introduction of flexible unified environment for planning, optimization and reserves management.
- Implementation of scalable and high-available (redundant) solution.
- Integration with Geographic Information System (GIS).
- Integration with Enterprise Service Bus (ESB).

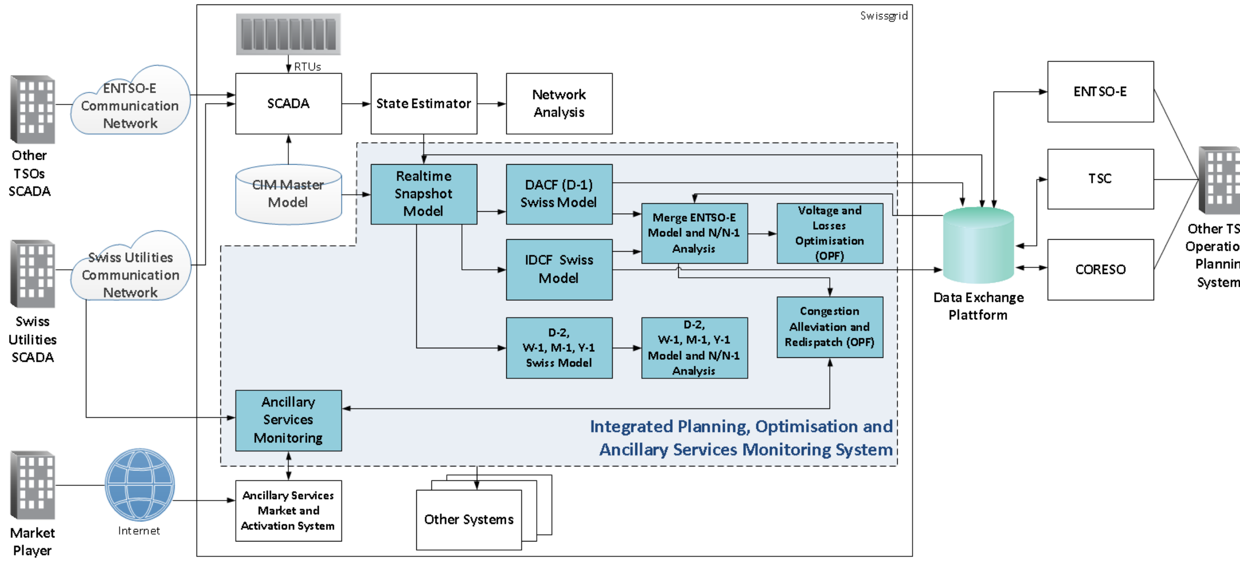


Fig.1. Swissgrid integrated operational planning, optimization and ancillary services monitoring system and its place in the application landscape (simplified). Arrows represent the main model data flows (file-based) in Swiss and European processes.

### *A. Overall System Design*

System design takes in consideration different availability, security and flexibility requirements of various application groups and separates the planning system and market system with their high volatility from the secure and relatively conservative SCADA/EMS environment. Correspondingly, systems that should support operational planning, optimization and re-dispatch processes were brought together, what resulted in the system architecture, presented at Fig.1.

The following processes were integrated through the common platform in one system:

- Operational planning: day-ahead, two-days-ahead, weekly, monthly, yearly (D-1, D-2, W-1, M-1, Y-1 to Y-5, correspondingly).
- Ancillary services monitoring.
- Online network congestion alleviation (national and international redispatch, topology and transformer tap position modification) based upon ancillary services reserves.
- Online network security prognosis (h-1 to h-7).
- Network congestion optimization prognosis (similar functionality as online network congestion alleviation)

System uses the multi-layer architecture, typical for the modern industrial automation solutions:

- Data services for real-time and offline data.
- Communication layer (OPC / OPC UA / Web Services).
- Automation layer (technical and business process workflows).
- Basis services (security, logging, alarming, etc.).
- Business logic (microservices for network analysis and optimization, data preparation, reporting, etc.).
- Graphical user interface.

Most of the solution components can be exchanged with reasonable effort without influencing the whole system, thus reducing the vendor-dependency and allowing continuous functionality and cost management.

The system is designed as high-available (redundant) system with so-called “controlled redundancy”: not only it switches to the reserve servers in case of HW or SW failure or malfunction, but it also can be manually switched over, or can be fully or partially set in single (not redundant, e.g. for system maintenance purposes) or parallel (for intensive calculations) modes. The system switchover can be performed virtually at any time, without losing results from the previous steps, what proved to be useful in case of multiple calculations, e.g. for 24 hours of the future days.

### *B. Microservices*

Based upon the experience and analysis of the new requirements, the new functional modules design was proposed, using the so-called “microservices” approach: the functionality needed was subdivided in the modules, large enough to keep the system engineering efficient and small enough to cover most of change requests without code modification, through parameterization via specified interfaces only [5]. The set of 28 functional microservices was worked out, allowing coverage of all the Swissgrid operational planning and network optimization processes (around 40 processes resulting in 100 technical workflows).

Microservices can be divided into several main groups:

- Network modelling.
- Load flow and network security analysis.
- Network optimization.
- Supporting services (data preparation, file parsing, reporting, messaging, etc.).

Realization of the new microservices-based process consists of engineering of technical workflow that calls the microservices in the proper sequence via the predefined interfaces and uses the results of their work in the further steps. Microservices are designed to support parallel calls, allowing conflict-free simultaneous use of the same microservices in different configurations in parallel processes.

Proposed approach decreases system engineering time significantly, minimizes (in ideal case – eliminates) coding and reduces the test effort. On the other side it increases requirements towards design and configuration quality, as building the process of existing modules can sometimes be more sophisticated than programming it from scratch. Experience shows though, that business and IT application engineers are well-prepared for this complexity, and the possibility to skip the development phase brings significant advantage for the end-user, like utilities, which do not want to build up own software development competence.

### *C. Network Modelling*

Aside with the structural re-design of the system, the set of major functional changes in network modelling was implemented, introduction of switchable devices (switches and breakers) for planning process being one of the most significant of them. Firstly, it should increase the interactive productivity of operational planning engineers, secondly – bring the operational planning model closer to the network operation SCADA/EMS presentation, and thirdly, it was seen as a necessary step to introduce automatic topology changes roll-out over multiple models (e.g. 24 hours of one day, or 7 days of the week, etc). This step also allowed to move to the new planning model creation approach, where only the online values including topology should be updated in the CIM-derived master model, giving some advantages in process speed and complexity reduction.

Second major improvement was introduction of exacter transformer models (especially three-winding phase-shifting transformers, being in operation in Europe, but having simplified representation in most load-flow products, available on the market).

Third major change was introduction of the new Swissgrid CIM-based master data model (while using PSSE RAW33 model format in system internal data flow).

### *D. Business Process Modelling and Service Integration*

Introduction of dedicated workflow automation functionality was one of the main innovations of Swissgrid DACF system in 2003. This approach proved its efficiency and stability in over 10-years of operation.

It was decided to keep the workflows concept, but to change the workflows design and to change the service interfaces, as a part of microservices introduction, to OPC UA and web-services (compared to the file-based interfaces of the previous generation of the system).

Using the OPC data bus allowed integration with various SCADA products, giving different system operators direct monitoring and control access to the process execution and parameterization.

To simplify integration with other IT-systems (including market systems, ERP, etc.) the ESB integration was implemented, allowing bidirectional data exchange between systems with various interfaces like OPC, web services, etc. Any data exchanged over the OPC hi-speed data bus can be accessed via service interface by any privileged system.

### *E. User Interface*

From the first operational experience in 2003 was clear, that a fully-automatic planning system would be possible, but the data and process quality at that time point did not allow to obtain the sufficient results quality. That's why the data monitoring system, followed by the full-scaled SCADA-based visualization and control operator GUI was introduced.

Over the years not only the amount of information increased, but also the value of different information types has changed, causing the necessity of operator interface re-design, whilst the new visualization tools and more IT-experienced user category allowed implementation of new solutions. Multiple usability and GUI optimization activities were undertaken in 2011-2014, resulting in the new style-guide and GUI design principles that were used for realization of system under discussion (Fig.2.).

Application of the style guide allows unified look-and-feel of the system, resulting in lower engineering and education costs, higher user acceptance, providing higher flexibility during business process optimization. The new style guide supports different color schemes (darker and lighter, depending upon the lighting conditions), as well as alternative symbols for the users with color vision deficiency. Additionally, system user interface supports on-the-fly language switching between several languages.

All system user interfaces can be also accessed via mobile devices (e.g. smartphones and tablets) with the role-based and location-based security models behind, allowing context-dependent monitoring and control of the processes under responsibility.

To reduce system engineering and maintenance costs integration with geographic information system (GIS) was realized, allowing automatic generation of single-line diagram of power network in following configurations:

- Schematic 2D-view
- 2D view with satellite or streets map (e.g. Google Maps)
- 3D view with landscape and satellite map

In all three cases the full set of SCADA visualization functions including dynamic object coloring, sizing, zoom and de-cluttering are available.

Along with using the geographic data-based grid visualization services for own purposes (reserves monitoring, voltage monitoring, security or redispatch measures visualization, to name a few), system under discussion provides interfaces for other systems to provide the data for visualization, allowing hence creation of complex integrated view on the process and supplying user with most complete information (Fig. 3).

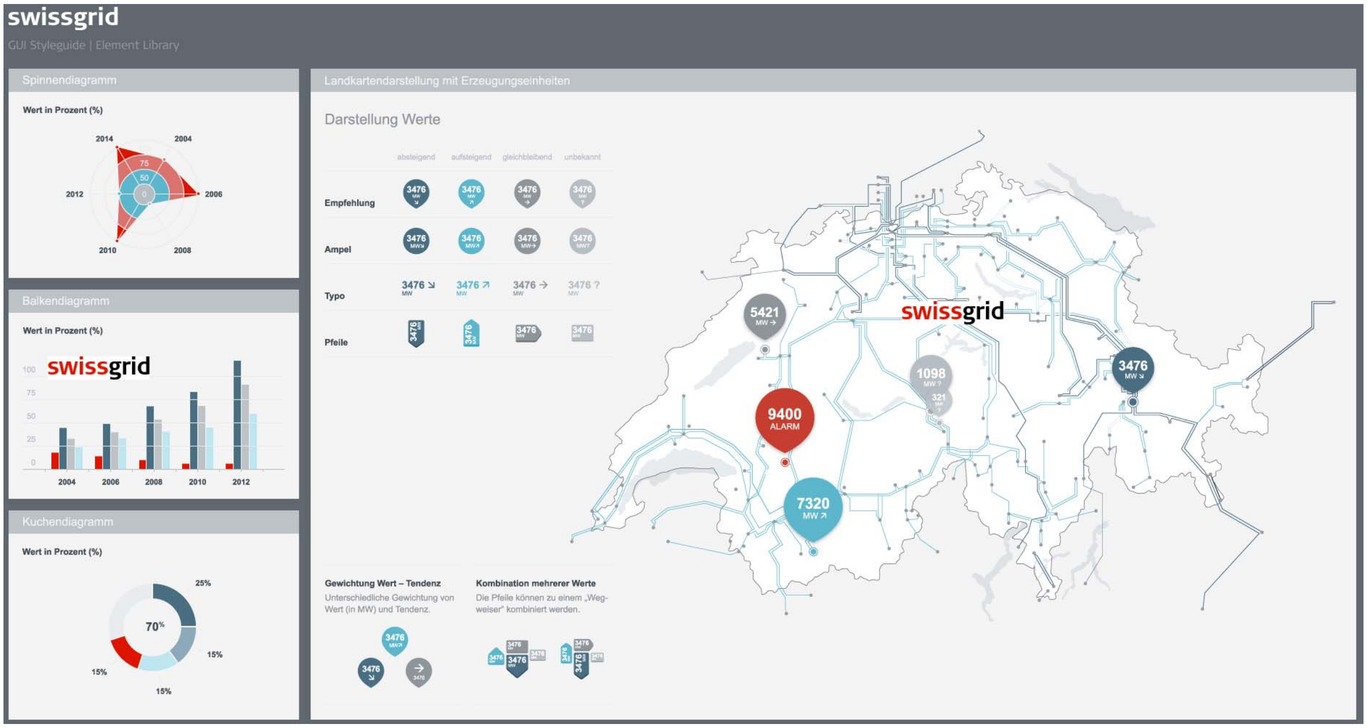


Fig.2. Example of user interface according to the new system style guide (© Swissgrid, 2015).

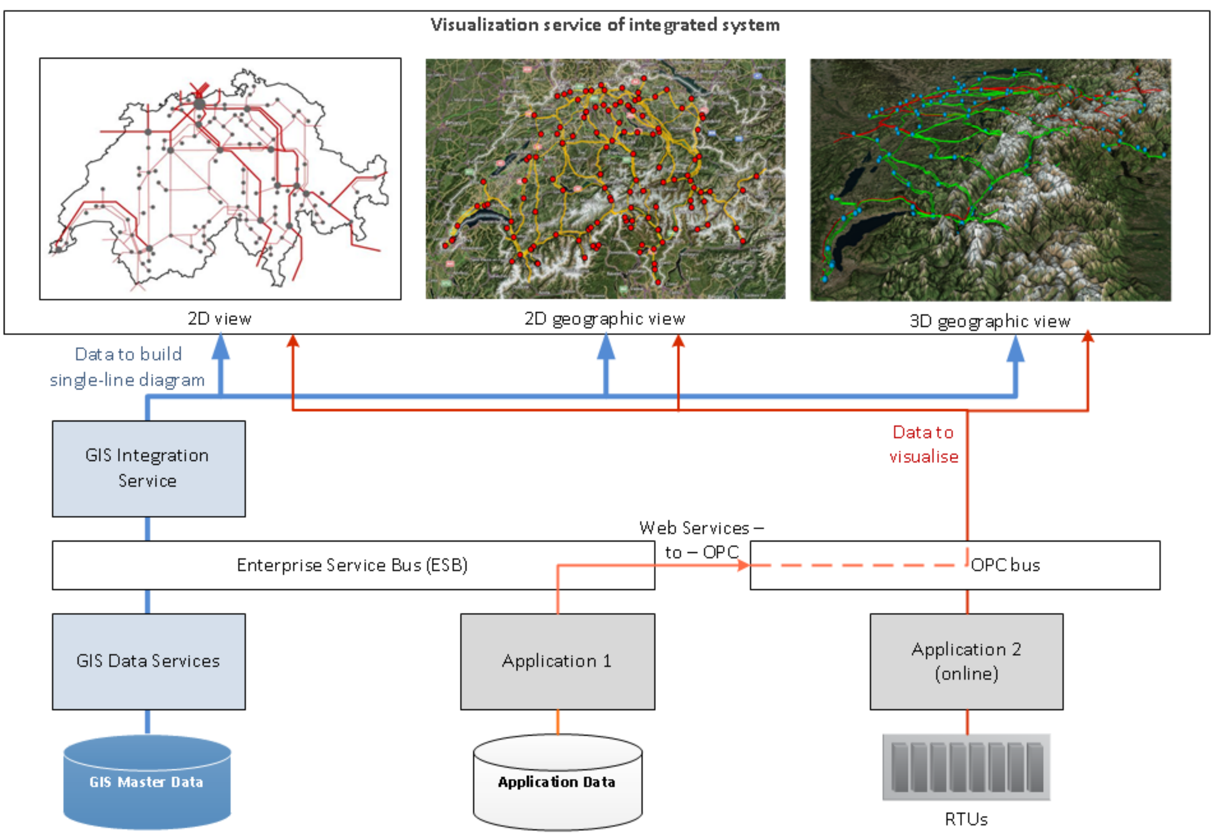


Fig.3. GIS integration- and visualization services of integrated planning, optimization and monitoring system.

## V. System Development and Operation

Due to multiple project constrains, including new TSC requirements, introduction of new Swissgrid SCADA/EMS system, European Market Coupling activities, to name a few, it was decided to realize the system based on the products in operation, undertaking them major release upgrades.

Parts of the system (e.g. ancillary services monitoring) were only subject to GUI re-design. Other parts (e.g. operational planning) were developed completely new.

Three different vendors were involved to develop different microservices. Project duration lies by approximately 1.5 years, effort being almost equally distributed between external vendors (microservices development) and internal application engineers (IT-system, workflows and GUI engineering and functionality tests).

The whole system is integrated into the company's monitoring and life cycle management infrastructure. Additionally, system provides developed self-diagnostics and self-monitoring abilities, being able to monitor not only its own functionality, but also the surrounding infrastructure and systems. Self-restore functionality allows automatic system restauration through workflow restart, system reset, etc.

Built-in business activity monitor allows monitoring every single microservice, every single process part (workflow) and every end-to-end process. Business activity information is displayed via the system user interface, is used to generate system operator and IT-operator alarms, and is archived for the further analysis and statistics.

## VI. Conclusions

The main advantages of the new system design from business perspective are:

- Combination of the operational planning and congestion alleviation and re-dispatch tools gives the advantage of smooth, non-contradictory congestion management flow, whilst the ancillary reserves monitoring system gives the up-to-date information about the redispatch reserves available.
- Functionality is more transparent to the business, as part of it is realized via graphical workflow tools, and part is controlled through the parameters, reducing the code modifications significantly.
- Functionality specification is more straightforward through business functionality division in micro-services with the clear functionality and interfaces.
- Subdivision of the application functionality into the single microservices supports the functional reusability inside application, as well as during design and engineering of new processes and applications.
- Extended microservices and workflow parameterization increases flexibility of solution both for the system engineer and the end-user.

From the IT perspective this solution brings following advantages:

- Faster realization time, in the normal case realization is reduced to engineering and parameterization, skipping the development phase.
- Lower change effort, as the functional changes can be normally localized to the single functional modules, lowering the overall system impact and testing effort.
- Development of the operational technology software domain towards best-practice service-oriented IT solutions. Every vendor can concentrate on its professional domain using easy-to-follow IT-guidelines for microservices.
- Lower vendor dependence, as different microservices can come from different vendors.

The downside is, as in most service-oriented approaches, the higher specification effort and necessity of integration skills.

The further planned steps include deeper system integration into the end-to-end business processes with the means of company's enterprise application integration solution, replacing the proprietary solutions through the standard ESB functionality, and continuous functional development, including increasing ENTSO-E CIM support and new analysis and reporting functionality.

As a special future step one can mention possible further integration of presented system with ancillary reserves allocation and activation system, resulting in the semi-automatic market operation system, supporting possible introduction of the nodal market model.

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