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A Roadmap for the Future: Enterprise Network Model Management at TenneT

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SUMMARY

Like most utilities today, TenneT have an approach to network model management that lacks an overarching design. TenneT maintain three totally separate network models, one for Planning, one for Operations Planning, and one for Real-time Operations. Additionally, various of those models are used by independent processes creating modeling to be supplied to ENTSO-E, to neighbouring Transmission System Operators (TSOs), and Regional Security Coordinators (RSCs). The heavily manual, scattered nature of existing model maintenance means duplicative effort on initial data population, ongoing effort spent in synchronization, an increased risk of error and valuable data ending up 'trapped' inside applications.

TenneT recognized that a "Single Point of Truth" (SPOT) approach to managing network model data, if correctly designed and implemented, could not only address the identified shortcomings but could also position TenneT to efficiently deploy future solutions. Using a Common Information Model-based information architecture developed by the Electric Power Research Institute (EPRI), the Asset Management, Energy System Planning and System Operations departments of TenneT explored the benefits and feasibility of enterprise-wide network model data management. TenneT developed an

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initial description of its vision and included the provision of a Network Model Management (NMM) component into the procurement specification for their NextGen EMS/SCADA project.

Enterprise data management improvement initiatives, by their nature, typically involve multiple departments and significant change to business processes. This renders them at higher risk of failure than typical technology projects and increases the importance of solid solution design and careful, strategic deployment planning. TenneT worked with EPRI to develop an initial roadmap comprised of 13 phases of activity, where every phase both built a portion of the long-term network model management foundation and provided tangible business benefit. The roadmap outlined, for each phase, the anticipated activities, benefits, risks, application requirements, business process changes, and achieved state of progress toward the solution vision. Points on the roadmap where progress depended on vendor product development were identified. Where alternative paths were possible, the sequencing options were called out. The roadmap outlines a high-level strategy that TenneT will both augment with detailed planning for each phase and will review and refine as it makes progress in its journey.

KEYWORDS

Network model management, Common Information Model, CIM, Enterprise data management, Transmission modelling

1. INTRODUCTION

For nearly a century, transmission utilities have used technology to understand and manage complex grid behavior. Starting as early as the 1930s, elaborate analog tools were used to simulate power systems with fixed (and limited) numbers of circuits and generators. Digital planning programs began to appear in the 1960s, and, in subsequent decades, operations and market tools incorporated the use of network analysis. Today, as a result of increasing grid complexity, transmission utilities, reliability entities and market operators across Europe and around the world employ a variety of network analysis products to perform more sophisticated, more frequent simulations of more grid conditions over wider varieties of time frames than ever before.

2. EXISTING NETWORK MODELING PRACTICE IN THE TRANSMISSION INDUSTRY

Given the degree of penetration and importance of network analysis, the need for accurate, accessible, and timely grid modeling in transmission is clear and compelling. But model management at the typical transmission utility today is a reflection of decades of organic growth of tools and processes; it is not the result of any intentional effort toward the creation of an overarching data management solution. It is common to find multiple network model data management silos, each centered around a particular tool used for a particular business purpose and each with its insulated community of tool users and model maintainers. Engineers in each silo independently acquire data from both previous studies and other utility departments (like station or line engineering) and use manual steps and individually developed aids (databases, spreadsheets, etc.) for converting and manipulating data into required forms.

When viewed from an enterprise perspective, the same time-consuming operations are repeated in every silo. As a consequence, power system engineers spend a significant amount of time engaged in network data management activities (data entry, mapping related data sets, error detection/correction) instead of the execution and analysis of engineering studies. The siloed approach also leads to an increased risk of error in data (and in studies based on those data) as well as creating a situation where valuable data (like SCADA measurements or relay settings), which are of use to multiple applications, are 'trapped' inside a single application.

3. TENNET NETWORK MODEL MANAGEMENT ROADMAP

Like most utilities today, TenneT has an approach to network model management that lacks an overarching design. TenneT maintains three totally separate network models, one for Planning, one for Operations Planning, and one for Real-time Operations, each of which source model data to additional processes that create modeling supplied to a variety of external entities. TenneT recognized that such a scattered and uncoordinated approach to network model management was not only inefficient, but its manual and unsynchronized nature carried risks to grid reliability as well. As a result, the Asset Management, Energy System Planning and System Operations departments of TenneT agreed to explore the benefits and feasibility of adopting a "Single Point of Truth" (SPOT) approach to managing network model data. The exploration led to the incorporation of a Network Model Management (NMM) component into the NextGen Energy Management System (EMS) project, a multi-year initiative currently underway to procure and implement a new EMS/SCADA system for the transmission system in the Netherlands. As a result, the tender for the replacement EMS included a requirement for a Configuration and Model Management (CMM) function whose initial purpose was to enable EMS configuration, but which would, over time, be enhanced to support enterprise-wide network model management as well.

TenneT realized that far more than tool procurement was going to be required to achieve its SPOT vision for network model data. Existing models needed to be synchronized, aligned, and unified. Existing work processes for data collection and processing needed to be redesigned. At the same time, recently introduced grid code requirements on data exchanges between stakeholders (TSO, DSOs, and Significant Grid Users) were changing the requirements landscape.

TenneT recognized it had significant work to do to successfully plan and execute the NMM component of the NextGen EMS. Accordingly, the TenneT NMM Roadmap Project was initiated with the Electric Power Research Institute (EPRI) to create a roadmap that would form the basis for the NMM project plan and would guide the NMM project during its execution. During 2020, the EPRI team and a core team of TenneT employees in Asset Management, Energy Systems Planning and System Operations worked together to:

- Review TenneT's current and future network model requirements
- Document TenneT's current network model data management practice
- Explore the EPRI approach to effective network model management and how it might inform the TenneT vision
- Create a roadmap with a series of suggested phases for incrementally implementing effective network model management at TenneT

The TenneT NMM Roadmap Project is summarized in the sections that follow. Section 4 overviews TenneT current model management practice. Section 5 explores TenneT's long-term, single-point-of-truth model management vision. Section 6 summarizes the strategic plan outlined for the achievement of the vision.

4. EXISTING TENNET MODEL MANAGEMENT PRACTICE

Overview

The reliability and safety of TenneT's grid depends on network analysis activities that are continually being performed across TenneT in the domains of operations, operations planning, and planning (which includes maintenance planning, network development, and long-term planning). Each domain utilizes its own software tools and maintains its own data models. Additionally, each domain supplies modeling to one or more external entities like ENTSO-E, neighboring Transmission System Operators (TSOs), Regional Security Coordinators (RSCs), Distribution System Operators (DSOs) or other parties connected to the TenneT system. The TenneT grid thus ends up being represented by multiple models, maintained by dozens of staff across many organizations.

As-Is Data Flow Diagrams

The creation of as-is data flow diagrams was an initial project activity. It served to not only document existing TenneT practice, but also to provide insight on existing requirements and areas for improvement and to help establish a common understanding of current model management practice across TenneT departments. A collection of ten diagrams captures all of the major information exchanges that currently support the construction of electrical representations of the TenneT grid. Each diagram focuses on a specific aspect of an Operations or Planning process that creates, manages, or consumes network model data, documents the systems involved in the process, and highlights the flow of network model data among them. An excerpt from one of the diagrams – the one focused on Operations Network Security Analysis-related data flows - is shown in Figure 1.

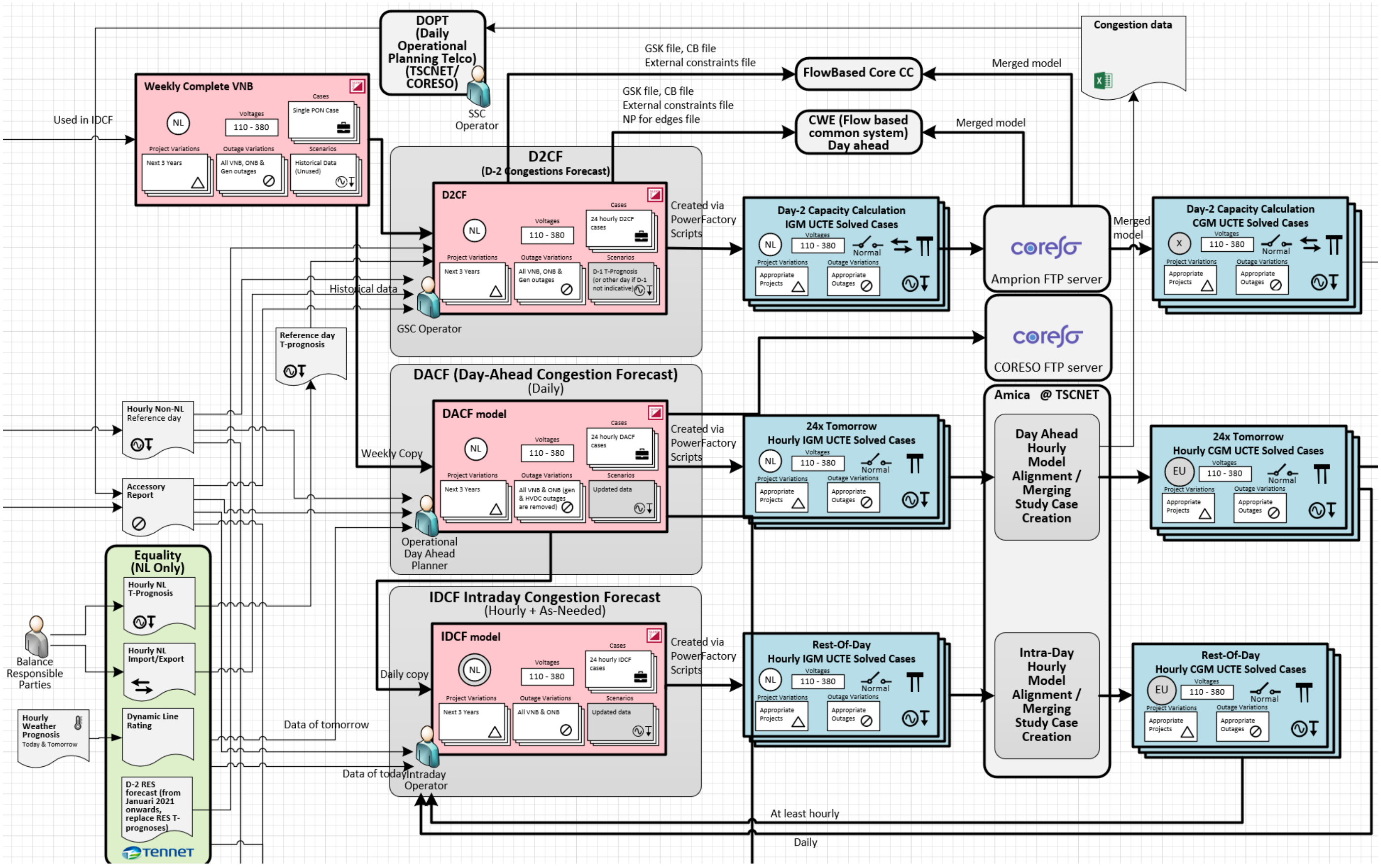

Figure 1: Excerpt from Operations Net Security Analysis as-is network model data flow diagram

As-Is Observations

The as-is data flow diagrams are accompanied by numerous observations about noteworthy features of existing TenneT model management approach, both positive and negative. The observations identify places where processes are effective, where effort is duplicated, and where work group knowledge is well-leveraged. They point out ways in which TenneT approaches are similar to or different from typical industry approaches, and instances where vendor tool capabilities are used in interesting ways. They pinpoint places where maintenance activities seem particularly cumbersome, where processes triggering is inconsistent, where updates are needed more frequently than they are done, and where effective synchronization processes are implemented. They identify occasions where potentially conflicting modelling is provided to different external entities, where data transformations are particularly challenging, where automation works well, and where flows are completely manual.

Key Findings

Taken together, the as-is data flow diagrams and as-is observations paint an accurate picture of the existing TenneT model management situation. The understanding they provide supports the identification of a set of key findings relative to existing TenneT model management practice:

1. *TenneT processes work to serve current needs.* Today's demands for network model data are relatively well met because of TenneT's dedication to designing, documenting, and following procedures. TenneT teams have above-average levels of intra-department communications and have employed tools to support synchronization.
2. *The vast majority of inefficiencies and risks related to network model management at TenneT spring from one of two causes:*
    a. *The maintenance of three independent network models.* TenneT maintains three totally separate network models, one for Planning (in PowerFactory), one for Operations Planning (in PowerFactory) and one for Real-time Operations (in the EMS), as shown in Figure 2. The manual maintenance of three, completely independent models of the

TenneT grid (and, in some cases, the surrounding foreign grids) means duplicative effort on initial data entry and ongoing effort spent to ensure that the modelling remains "in sync".

b. *The practice of copying PowerFactory models.* The current practice of copying PowerFactory models is understandable: the PowerFactory "project" brings along everything necessary for local case building. The multiple copies of PowerFactory "projects" in Planning and Operations are illustrated in Figure 3. Unfortunately, once a copy is created, it no longer is "attached" to the original PowerFactory model and changes made in one PowerFactory model are – in the version and manner used by TenneT – not easily transferrable to other models, even if the PowerFactory models are related. This leads to "stranded" modelling details in "downstream" copies (this is common in the TenneT Planning domain) and to the situation where corrections/updates made to one model need to be made across multiple copies (this is common in Operations Planning).

3. *The future will require more than existing TenneT processes can effectively support.* There is a daunting range of requirements on the horizon which demand increasingly frequent and complex external and internal model exchange. The challenges are significant. External data sharing is growing to support pan-European and regional reliability and market activities, coordinated planning and operation with distribution connected parties, and emerging "open data" expectations. The complexity and number of internal studies is growing as transmission grid behavior is influenced by increasing amounts of renewables and the uncertainties of climate change. It is almost certain that existing TenneT practices will have difficulty providing the modelling quality and timeliness to allow TenneT to continue to fulfil its TSO responsibilities as effectively as it currently does.

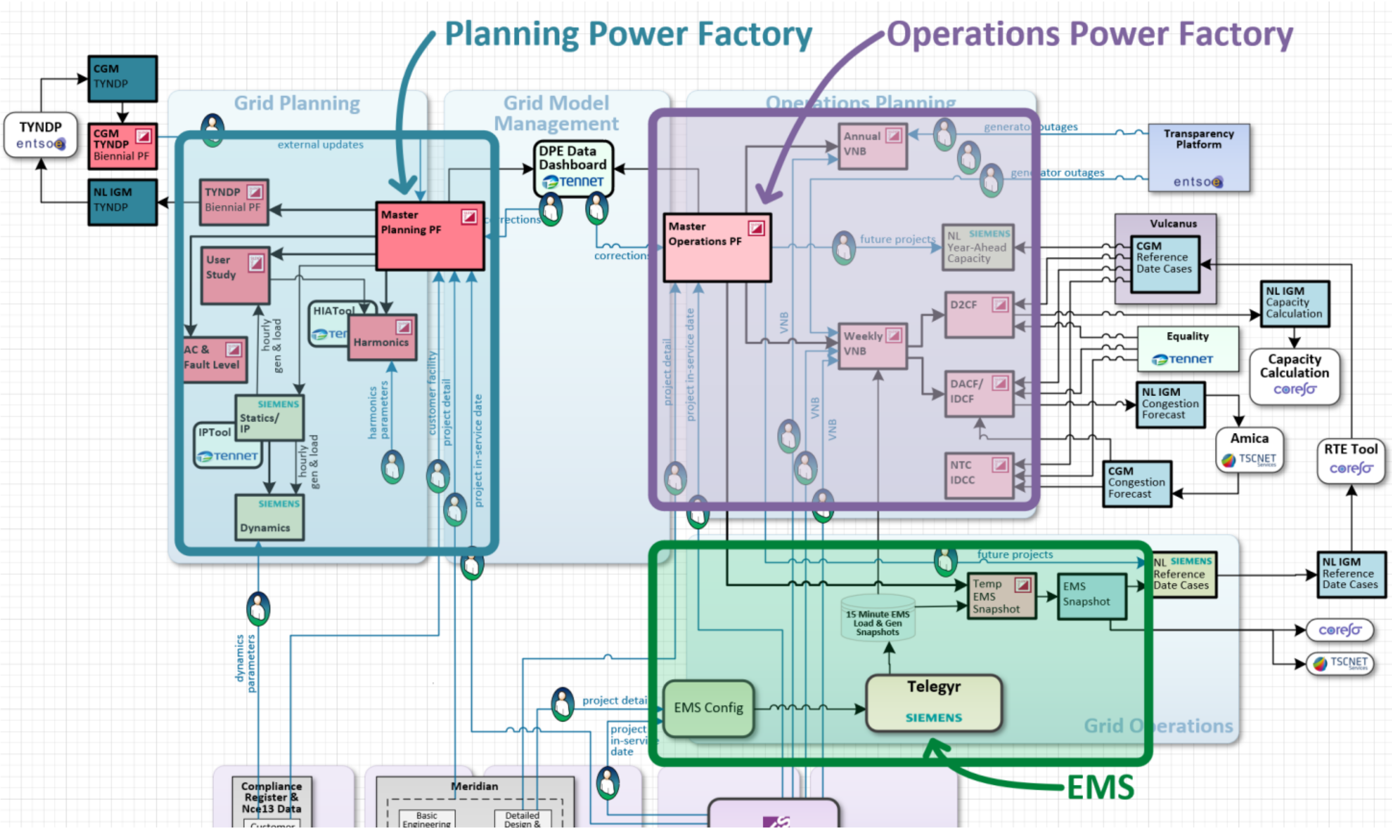

Figure 2: Manual maintenance of three independent network models

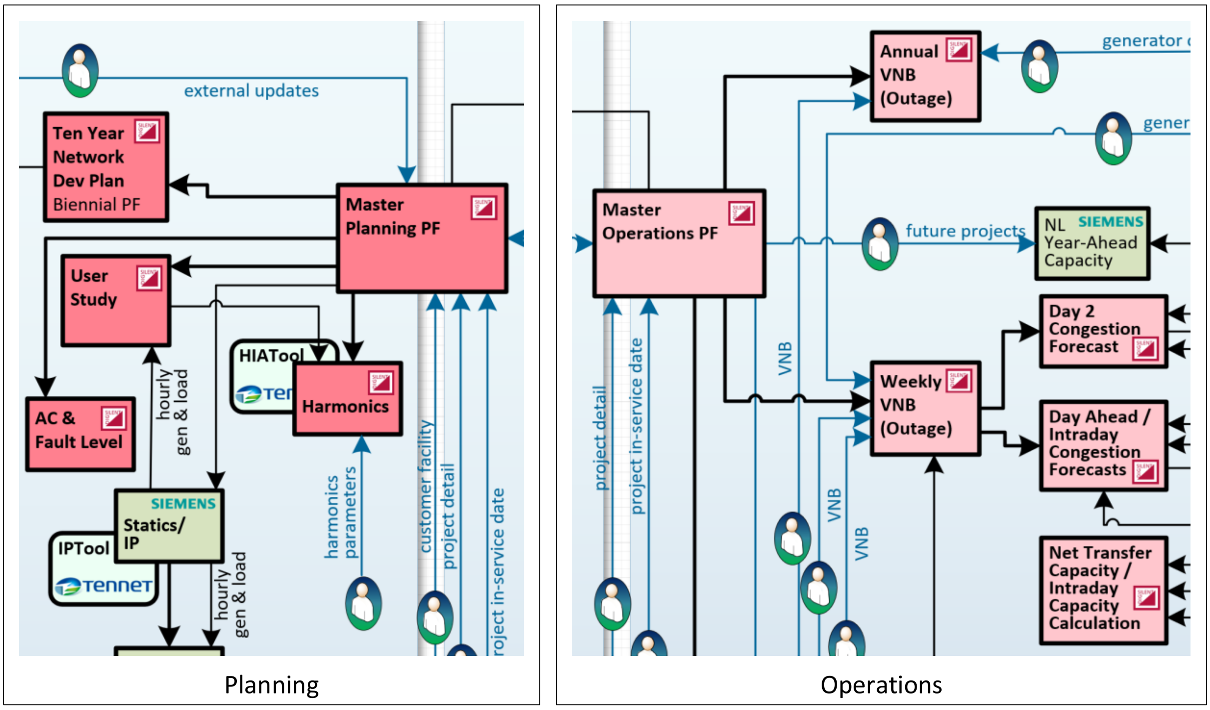

Figure 3: Copies of PowerFactory (PF) "projects" in Planning and Operations

5. THE TENNET NETWORK MODEL MANAGEMENT VISION

Overview

TenneT recognized that a SPOT approach to managing network model data, if correctly designed and implemented, could not only address the identified shortcomings but could also position TenneT to efficiently deploy future solutions. Using a Common Information Model (CIM)-based information architecture developed by EPRI, the Asset Management, Energy System Planning and System Operations departments of TenneT explored the benefits and feasibility of enterprise-wide network model data management. TenneT developed an initial description of its vision and included the provision of a Network Model Management (NMM) component into the procurement specification for their NextGen EMS/SCADA project.

EPRI's Network Model Management Approach

The TenneT vision for network model management draws from a body of EPRI research [1, 2, 3] developed over the last eight years that focuses on implementing effective inside-the-utility management of network model data. The vision for improved model management is based around the architectural transition illustrated by Figure 4 and Figure 5. In both figures, enterprise sources for network model data are shown on the left – sources such as engineering design, facilities records, work, and asset management. On the right side, consumers of network models are shown, which would typically be various planning, protection and operations functions. And in the middle, network model information flows between sources and consumers.

Figure 4 illustrates information flows typical at today's transmission utility. Between sources and consumers there is a tangle of point-to-point interfaces: some are automated, some are manual, many are inconsistently triggered, and nearly all require some sort of transformation between the structure of data provided by the source and structure required by the consumer.

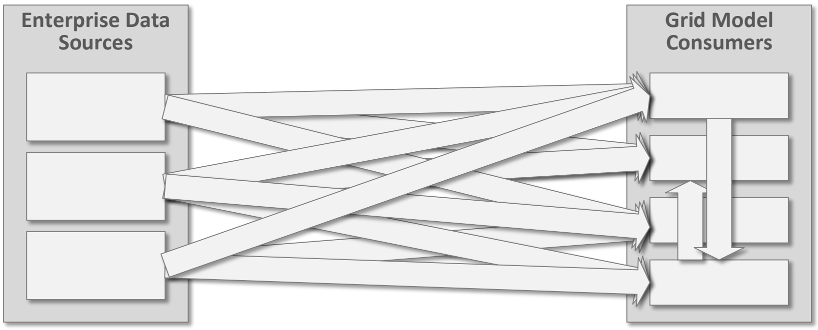

Figure 4: Typical transmission network model data flows

Figure 5 reflects EPRI's NMM approach. Between suppliers and consumers, a Network Model Management function is introduced. Its role is a) to gather source data and maintain a master repository of behavioral network modeling for the electric distribution system and b) to host a variety of model transformation and assembly activities that create the modeling required by network model consumers.

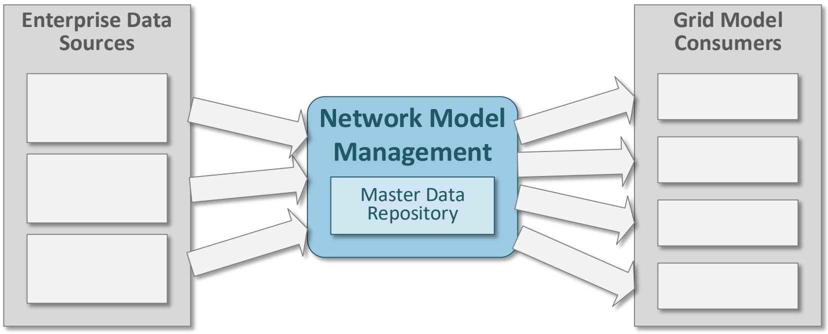

Figure 5: Basic Network Model Management (NMM) architectural concept

This architectural concept, focused on consistent, enterprise-wide management of network model data, enables a utility to enter its network model data once and leverage it across the enterprise. Data management processes are streamlined and labor is minimized as duplicate modeling is eliminated, as work steps are automated, and as time spent synchronizing, validating and correcting data is minimized. Errors are caught, corrected, and made available to all, simulation results are accurate and can be shared among applications, multiple external model sharing processes use a single consistent source, and the utility is positioned to add new analytic tools with a minimum of effort and cost.

The TenneT Network Model Management Vision

TenneT's ultimate network model management vision is based on an EPRI NMM information architecture that expresses the EPRI network model management approach outlined above in more specific business function terms. The information architecture identifies the common utility business functions that create, manage and consume network model data. And it articulates which business function is responsible for each sort of network model data and which business functions need each type of network model data. A very high-level overview of the NMM information architecture is shown in Figure 6.

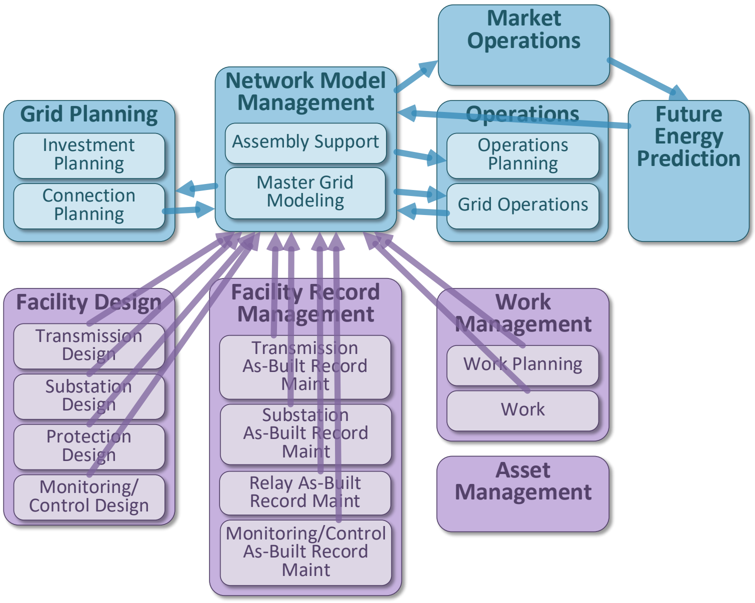

Figure 6:NMM information architecture business functions

The core Network Model Management business function is comprised of two major complementary subfunctions, both of which rely on Common Information Model (CIM) data constructs:

- Master Grid Modelling establishes a set of supporting processes to maintain network model source data in interlocking but non-overlapping modules, such that each module becomes a clear 'single source of truth' for the enterprise. Among other things, master modeling assigns a master resource identifier to each component which identifies that component wherever it is represented in any modelling.
- Assembly Support uses the master data modules as input to automated, configurable processes that create modelling to meet the requirements of each consumer (internal or external).

Guided by the NMM information architecture, TenneT outlined its long-term NMM vision at a more concrete application level (see Figure 7.) TenneT envisions implementing a Configuration Model Management (CMM) tool that fulfils the Network Model Management business function responsibilities: it manages a master Enterprise-Wide Network Model and from it creates the cases and models needed by both internal TenneT applications and the growing variety of external consumers.

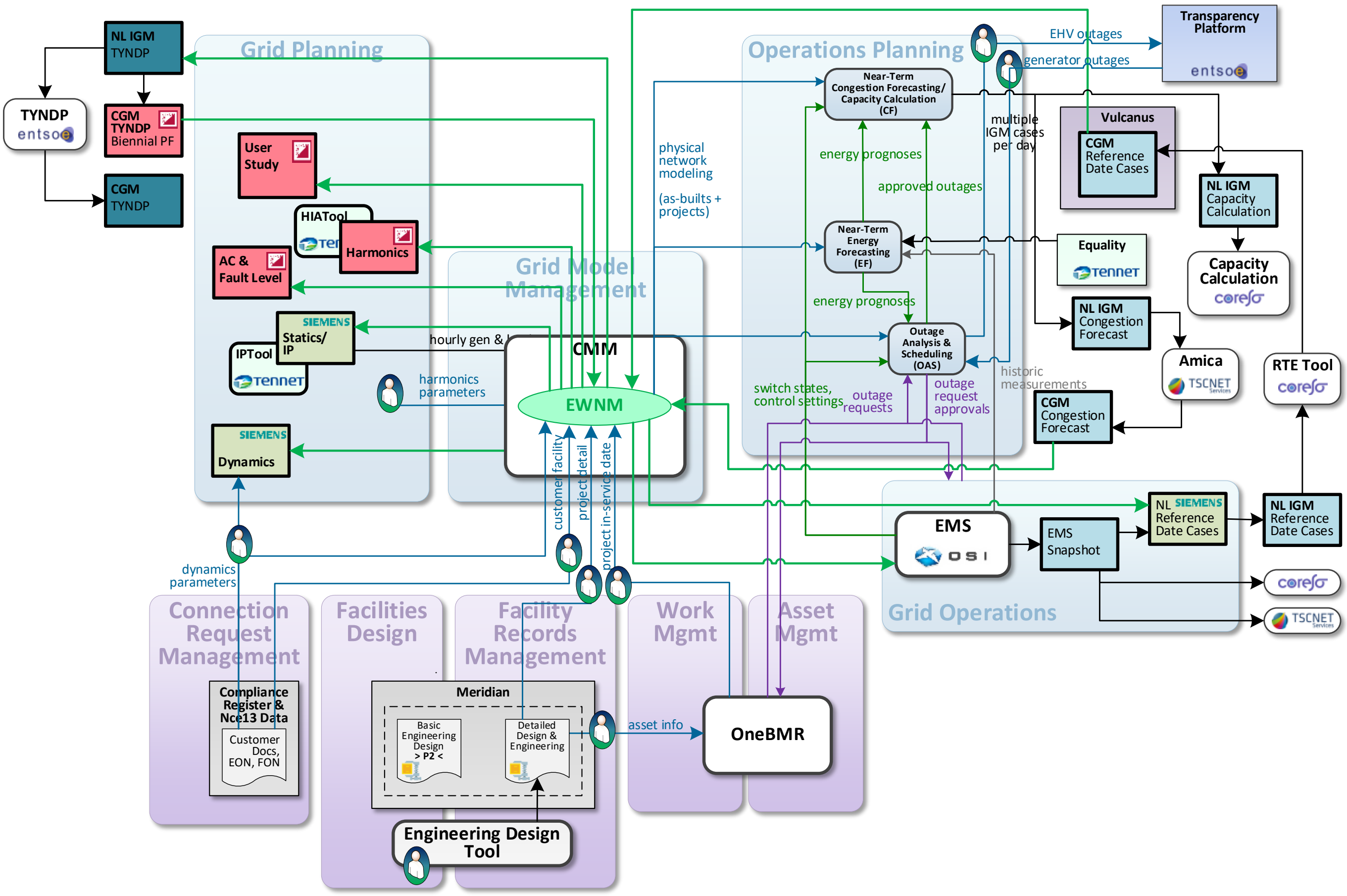

Figure 7:TenneT's network model management vision

The CMM hosts the manual and/or automated processes that gather master data from planning, facilities design and records management tools and it maintains an up-to-date version of the EWMN containing the as-built of the TenneT grid (along with its history). As part of its Master Grid Modeling responsibilities, CMM also maintains current versions of all future projects in the EWNM.

The CMM is also tasked with providing network model data as required by consumers across the enterprise. In the TenneT vision, some existing consumer applications remain and some are replaced:

- On the planning side, TenneT's ultimate vision leaves the bulk of its current tools in place performing the functions that they currently do today (dynamics studies, fault level analysis, harmonics, and so on), but the convoluted, largely manual processes for creating models for those tools are replaced with modelling generated by the CMM based on the EWNM. The CMM also takes on the responsibility for creating the TenneT footprint cases contributed to the ENTSO-E Ten Year Network Development Plan (TYNDP) process.

- The main Operations application, the new EMS, which is implemented as a replacement for the existing EMS in an early step of the plan, has its modelling sourced from the EWNM. It is anticipated that the CMM will be capable of supplying the modelling in a way that enables future EMS capabilities (like one-project-at-a-time online model updates).

- Operations Planning is the area of largest uncertainty. Current plans are that the outage management function, the near-term energy forecast function, and the creation of congestion forecast Individual Grid Model (IGM) cases will be sourced from applications that operate in closer alignment with the EMS to better support the increasing real-time focus of those external data sharing processes. Regardless of how the particulars of the solution play out over time, the intent is that the core network modelling of those functions will come from the EWNM.

6. THE TENNET NETWORK MODEL MANAGEMENT ROADMAP

Overview

Together, TenneT and EPRI outlined a high-level strategy, the TenneT NMM Roadmap, for incrementally implementing the TenneT network model management vision. The Roadmap is intended to help guide TenneT's strategic decision-making as it undertakes the journey toward achieving its vision. It was crafted against the backdrop of the many changes which are occurring in TenneT's world: multiple major initiatives are underway, vendors are developing products for future delivery to TenneT, regulations driven by the energy transition are growing, and requirements related to network model data exchange are constantly increasing. That flux made the creation of a definitive roadmap challenging. However, it was important to TenneT to explore and document a single "reasonable path forward": doing so outlined a plausible plan against which course changes could be identified and evaluated.

The Roadmap

The TenneT NMM Roadmap, whose high-level structure is shown in **Error! Reference source not found.**, outlines a series of incremental phases comprising TenneT's path toward enterprise-wide network model management. The Roadmap considers the planned activities of the NextGen EMS upgrade project – an initiative which simultaneously delivers urgently needed Operations domain capabilities and starts building TenneT's network model management foundation.

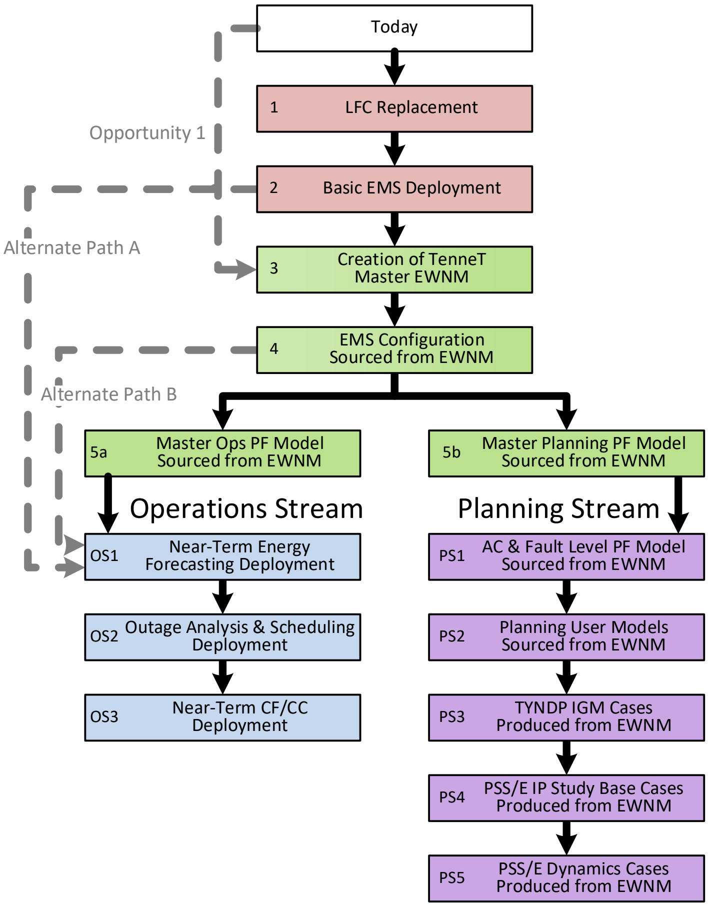

Figure 8:Overview of TenneT's NMM Roadmap

The Roadmap suggests six initial phases, in line with the upgrade project, that are essentially linear in nature:

- Phase 1 – LFC Replacement
- Phase 2 – Basic EMS Deployment
- Phase 3 – Creation of TenneT Master EWNM

- Phase 4 – EMS Configuration Sourced from EWNM
- Phase 5a – Master Operations PF Model Sourced from EWNM
- Phase 5b – Master Planning PF Model Sourced from EWNM

In each phase, the Roadmap points out places where alternate approaches could be taken and/or phase overlapping might be possible. At the completion of the six initial phases, TenneT will have implemented centralized network model management: a single Enterprise-Wide Network Model (EWNM) will be supplying modelling to the Master Planning PowerFactory Model, the Master Operations PowerFactory model, and the EMS.

Subsequent roadmap phases split into two parallel "streams". The Planning domain stream includes five suggested phases and the Operations domain stream consists of three phases, the sequencing of which will be finalized as work moves forward and vendor tool capabilities become clearer. Each stream seeks to both improve model management and streamline processes within its domain.

A Typical Roadmap Phase

In the Roadmap, each phase is thoroughly described:

- The new activities that will be supported at the end of the phase are identified.
- The CMM capability required to support the phase is outlined.
- New applications, and required updates to existing applications, are detailed.
- The consequences and benefits flowing from completion of the phase are described.
- The activities of the phase are outlined, including elements like application testing and deployment, data preparation and population, business process design and documentation, and interface design and coding.
- The state of network model management at the end of the phase is documented, addressing elements like what information the EWNM contains, which applications are receiving modeling from CMM, and how many applications still have modeling maintained independent of the EWNM. This is described both in words and via a diagram. As an example, the diagram for Roadmap Phase 5a – Master Operations PF Model Sourced from EWNM is given in Figure 1.
- Potentially beneficial additional activities are identified, as are alternate sequencing paths that should be considered.
- Dependencies on vendor product development are called out and possible strategies for mitigation (if the vendor cannot or will not deliver) are identified.

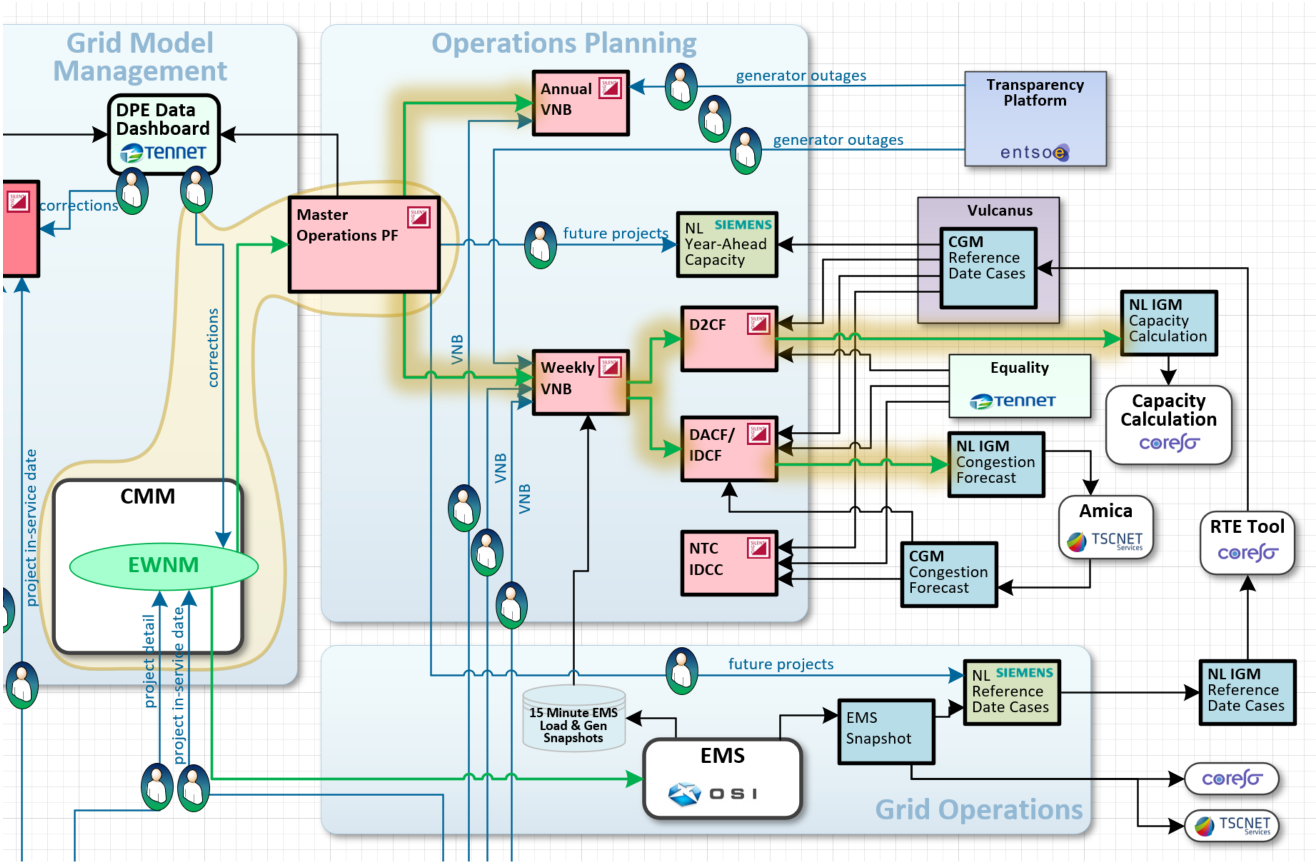

Figure 1:End state of phase 5a – Master Operations PF Model Sourced from EWNM

7. CONCLUSION

The TenneT NMM Roadmap, built on a shared understanding developed during the evaluation of TenneT's current network model management practice and refined during the creation of TenneT's network model management vision, articulates one possible path forward for TenneT. The Roadmap, to be truly useful, must simultaneously be used as the guide for today's moment-by-moment decision-making and be viewed as a "best guess" strategy, subject to re-evaluation and adjustment based on tomorrow's circumstances and requirements.

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