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Solution Architecture for Distribution System Planning (DSP)

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Abstract The purpose of this paper is to illustrate the solution architecture for modernizing the Distribution System Planning process. The solution architecture comprises of analytical and transactional applications integrated using a standard information model based on IEC CIM profiles.

Keywords DSP, IEC CIM, CPUC, SCIM, TOGAF®

California utilities invest billions of dollars per year in replacing and modernizing their electricity distribution infrastructure. The electricity system continues to evolve, and with the growing deployment of distributed energy resources (DER), changes are required to how utilities conduct distribution system planning. The integration of DER in Planning for the electrical grid is providing a lot of exciting challenges and opportunities.

1. The Business Need

In California, utilities are mandated to routinely file distribution investment plans. These plans make transparent the methods used and generally provide visibility into the existing state of the systems and utility planning processes. The California Public Utility Commission (CPUC) also requires investor-owned utilities (IOUs) to file Distributed Resource Plans (DRPs). The CPUC order requires utilities to consider locational benefits and costs of DERs on the distribution system and to identify tariffs and other mechanisms to deploy cost-effective DERs. Furthermore, utilities are expected to coordinate with other state DER incentive programs, articulate additional utility spending needed to integrate cost-effective DERs, and identify barriers to the deployment of DERs [1,2].

The modernization of the Distribution System Planning process requires the development of new tools and methods capable of transforming the distribution grid to manage both the challenges and opportunities associated with the requirements. Modern applications need to be introduced in the ecosystem to understand and make decisions as the grid complexity rises with higher DER penetration. Applications that are capable of leveraging various data sets, such as SCADA and advanced metering infrastructure, are playing a more significant role in the planning process.

In the past, the Utility distribution planning process was based on the annual peak load for every asset (A-bank transformers, substations, and circuits) in its system. While the method did disaggregate the peak hour into its various sources of load-based consumption, DERs, and load-growth projects (LGPs), the timing of the peak was assumed to be consistent year over year. Besides being labor-intensive, the output of this method was insufficient to meet the various regulatory needs. The new approach is highly automated; using time series data, it allows distribution engineers to determine the frequency of events that exceed upper or lower operating thresholds, duration of these violations, identify peak shifting, and understand annual requirements in addition to the peak load.

At the end of the process, mitigation to the circuit model, along with capital deferral opportunities (capital projects) have been identified. [3]

2. The Data Challenges

Moving from an annual peak analysis to time series-based analysis requires the ability to handle complex data sets (volume, velocity, variety).

As illustrated in Figure 2, there is a need to integrate a wide variety of data from different sources. Take the example of historical load and DER profile, which requires the integration of time-series data, SCADA, AMI, DER generation along with master data, electrical connectivity, hierarchy, customer master information, and DER Interconnection. The amount of time required to prepare the data for a given use case is directly dependent on the health of the data. For example, the various types of data necessary for the analysis include asset data from asset management

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systems, network connectivity data from GIS/EMS systems, or SCADA information, all of which are stored multiple systems and in a variety of sizes and formats.

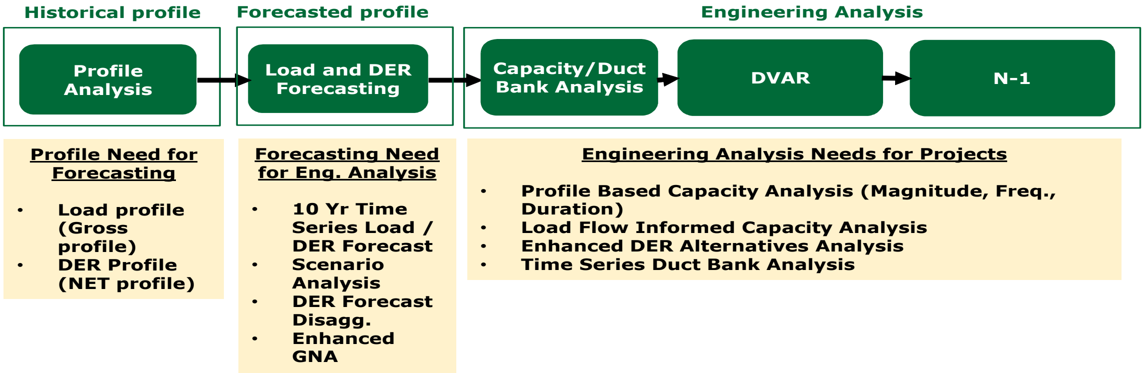

Figure 1. High level process steps for Distribution System Planning (DSP)

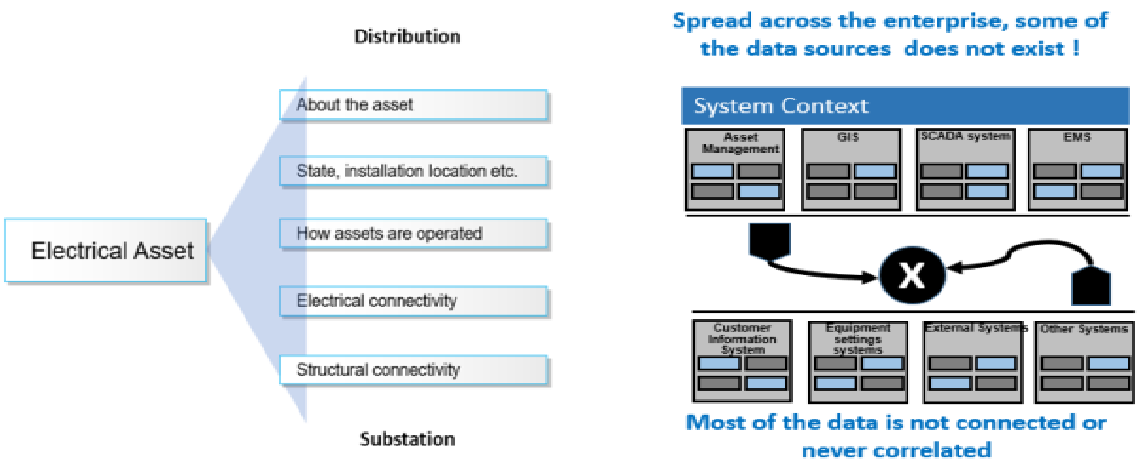

Figure 2. Asset and Connectivity information is maintained in multiple systems

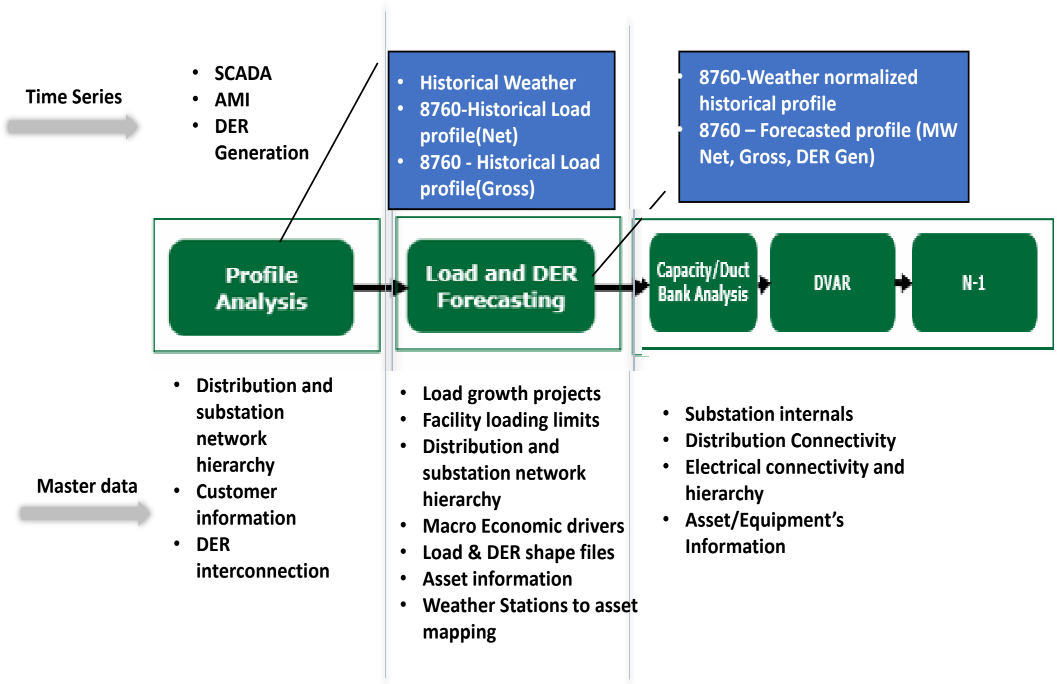

Figure 3. Data mapping

Existing utility IT systems are not implemented to enable the natural correlation of the data across various functional domains, due to data fragmentation across multiple enterprise systems. Take the example of electrical asset information, a relevant subject area required for the DSP process. As shown in Figure 3, an asset's information (asset characteristics, asset operational state, operational parameters, connectivity, location, etc.) is spread across multiple systems. [4]

3. Architecture Definition

Developing IT systems to support the DSP process, therefore, requires a comprehensive plan that creates a framework for developing or procuring applications that work together to implement the overall system. Following a systematic architectural approach facilitates defining components or building blocks that make up the whole information system. This well-defined architecture thereby provides a strategic context for the IT systems in alignment with the specified business requirements.

Adopting architecture framework like TOGAF ®, the Open Group Architectural Framework, can help to speed up and simplify architecture development along with making sure that there is comprehensive coverage of the designed solution. TOGAF has proven methodologies to architect and design a technically sophisticated design of a complex system of systems. Additionally, the use of this method can help to connect business, and IT teams towards achieving a common goal. [6]

One of the critical concepts of the TOGAF framework is the ability to decompose business capabilities and functions/services as part of the Business Architecture definition. For example, as illustrated in Figure 4, the business functions/services mentioned in Figure 1 are grouped under the "Analytical Capabilities." Individual features are further decomposed into smaller tasks, along with participating user rules and interaction between functions to meet the defined capability.

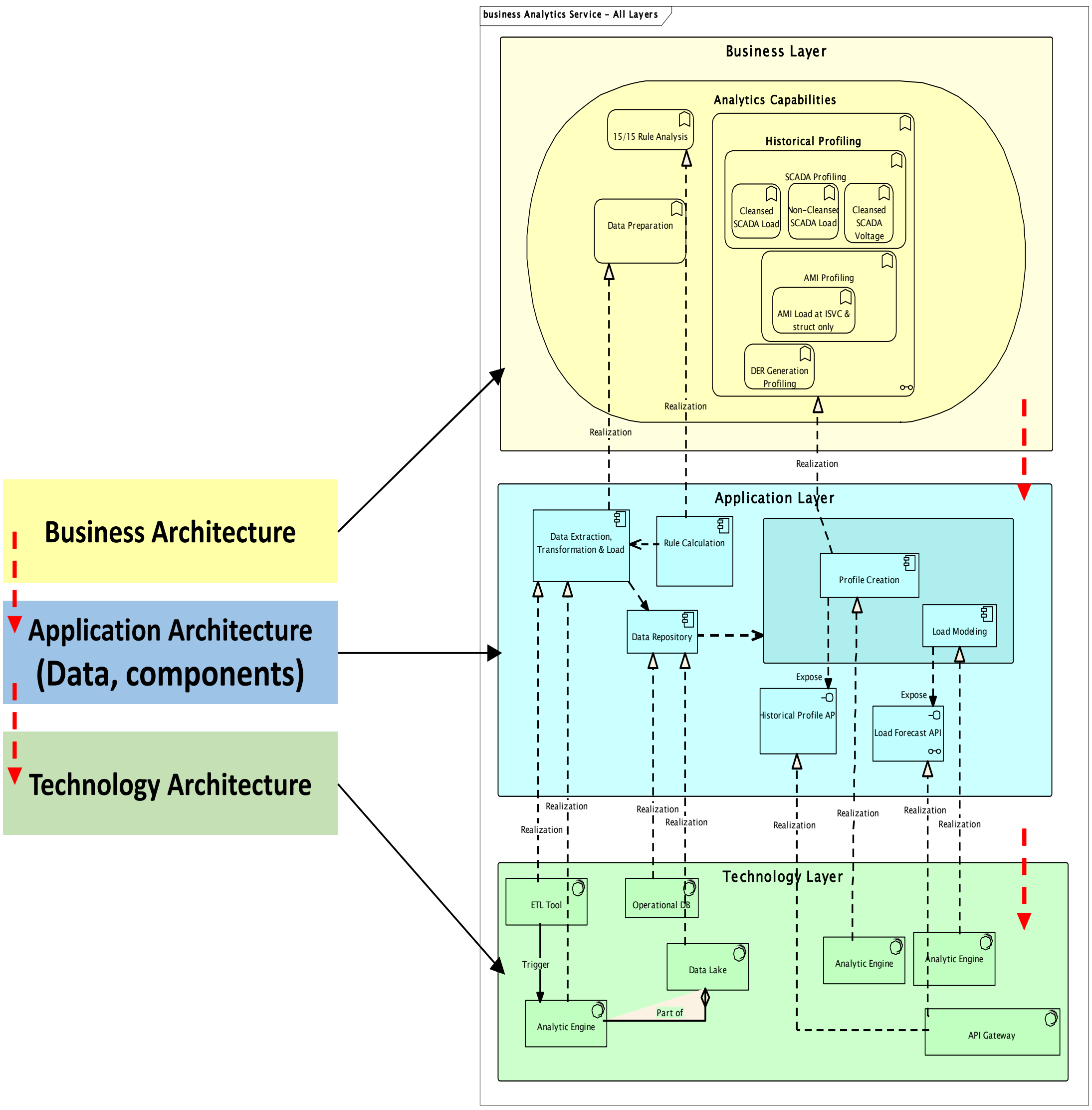

Figure 4. TOGAF Representation of Analytical Capabilities (shown using ArchiMate Notation)

The business architecture definition will help to align the architecture vision with business goals and demonstrate how the elements such as capabilities, functions, processes fit together.

The next step in the architecture process is to identify the application and technology architecture to implement a specific business function. The information/data architecture guides the connection of business architecture to application and technology architecture. As shown in Figure 4, to develop the forecasted profile, foundational data objects like Network Connectivity Model, AMI Measurements, SCADA Measurements are required. These data objects are all canonical and created from the Common Information Model (CIM), which will be briefly described later in this paper.

The solution component for the forecasted profile uses the information objects and transform them into results. This type of articulation also helped to identify the technical capabilities and specific technology requirements. Following the TOGAF ® prescribed approach enabled us to understand:

1. How the information is flowing between various functions
2. Data / Information classification
3. How the capabilities and application should use and operate the data
4. Identification of information/data entities
5. Application definitions
6. Technical capabilities and specific technical requirements

4. Architecture Development

Following the well-defined architecture definition process will result in establishing a system architecture capable of addressing the processes and outcomes identified in the business goal. Figure 5 illustrates the high-level application architecture to support the afore-described distribution system planning process. The business functions and capabilities identified during the business architecture process are assigned to individual applications to illustrate the disposition. At a high level, participating systems can be grouped into two categories: (1) enabling systems (Connectivity Information System, DER Intake System) – responsible for providing the required data for (2) the core systems (Analytical platform, Engineering Analysis Tool) - responsible for implementing the identified business processes. These participating systems are described in the remainder of this section.

Connectivity Information System (CIS): The accuracy of planning, forecasting, and electric system modeling depends upon the accuracy and precision of the underlying electric connectivity model, spatial data, input modeling parameters, and computational capabilities available. Hence maintaining and managing the electric connectivity model through the lifecycle of the grid is critical.

Utilities, in general, have multiple enterprise systems in the area of asset management, work management, engineering, mapping, GIS, and more. The CIS provides a single version of the truth about grid connectivity by consolidating the information from these source systems and representing the real-world scenario of the grid (electrical and structural networks), including the status of various equipment, configurations, and settings. The electrical connectivity model provides different business capabilities, including tracing of the circuits, simulation capabilities, topology of the entire grid, end-to-end connectivity information, schematic diagram generation capability for circuits, geographic view of the network, etc.

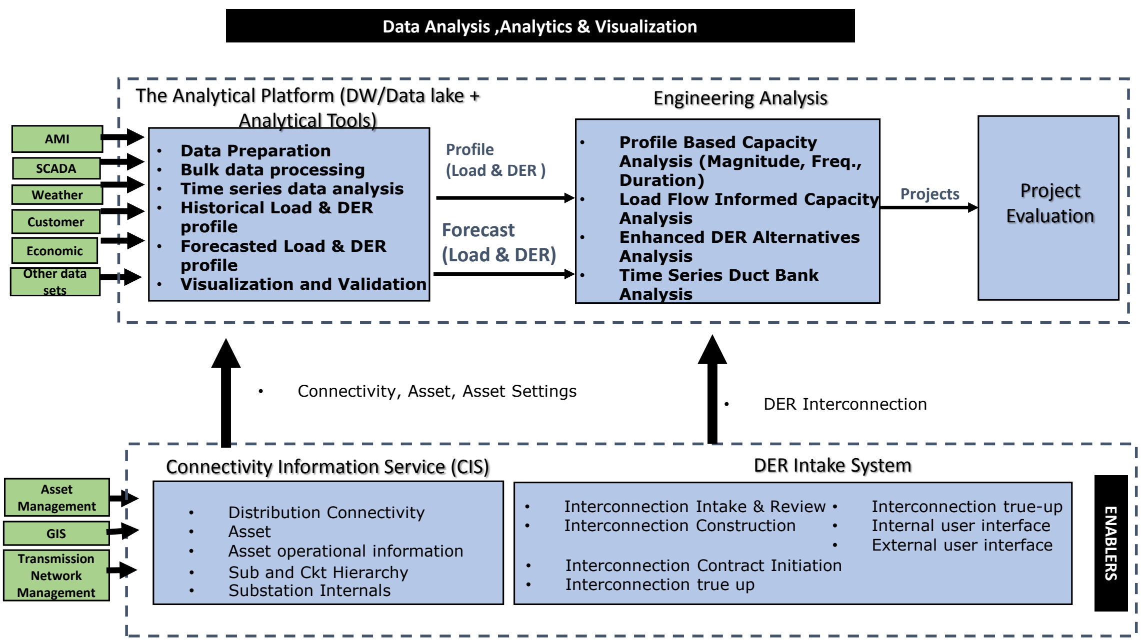

Figure 5. High-level Application landscape

The CIS system need to be designed to collect information (asset, connectivity, and others) and provide the information as APIs (Application Programming Interfaces) for other applications - including Analytical Platform and Engineering Analysis applications - to consume.

DER Intake System: As stated above, the growing deployment of distributed energy resources (DER), is prompting changes to how utilities conduct distribution system planning. The DER intake system plays a central role in the intake and processing of interconnection applications by coordinating with other systems to implement the end-to-end business process.

This system will be the single source of truth for all DER information across utility territory. For each DER application, the data managed by the system includes the location, type (technology, fuel type, etc.) and size of generation along with other technical details (single line diagram, number of panels, etc.) which are required to meet all the CPUC's Rule 21 requirements. [1,2]

The Analytical Platform: Calculation of historical profile (DER & load) and forecasting (load & DER) requires the processing of millions of assets - Poles, conductors, transformers, etc., smart meters/AMI, SCADA, customer data, weather data, DER performance data and more. The time-series data (SCADA, AMI, weather, and others) tends to be being large volume; hence it is crucial to have a platform to support performance and scalability. Processing this kind of data (volume, velocity, and variety) sets requires a new processing model that has better storage, decision-making, and analyzing abilities.

The critical requirement here is the ability to analyze and aggregate the data with-in a time frame. The analytical platform, based on what is commonly referred to as "Big Data" technology, provides the capability to split the task that needs tremendous computing ability to calculate into several small jobs and assign them into specified computing resources for processing.

Data integration also plays a vital role in this process. The data integration capability component of the analytical platform helps to aggregate the data collected from disparate data sources, formatting them into one unified view. One of the vital integration aspects is the out of box support for critical functions like anomaly detection. The integration process is designed to support:

1. Identification of data entities
2. Identifying data redundancies
3. Identification and processing of missing values and abnormal values as part of the cleansing process
4. Data transformation, including standardization of data, attribute construction, skewness processing, discretization, and others.

Engineering Analysis Tool: The engineering analysis tool assesses the performance of equipment in the distribution system and identifies the additional capacity that the electrical equipment can withstand before an overload-related failure (i.e., a violation) occurs. One of the critical capabilities is the capacity analysis process:

1. Profile Analytics: Allocation of forecast load to all nodes in the connectivity below circuit-level according to the proportions indicated by the historical AMI and SCADA load profiles.
2. Substation and Circuit Capacity Analysis: Comparison of the predicted loads on substation buses, transformers, breakers, and conductors of circuits to known short-term and long- term limits and determining if there are any violations.
3. Duct Banks Analysis: Determination of whether ducts in a duct bank will exceed pre-configured temperature limits.

The Engineering analysis tool also provides a user interface where a planner can visualize load profiles, violations by criteria, time-series power flow information, etc.

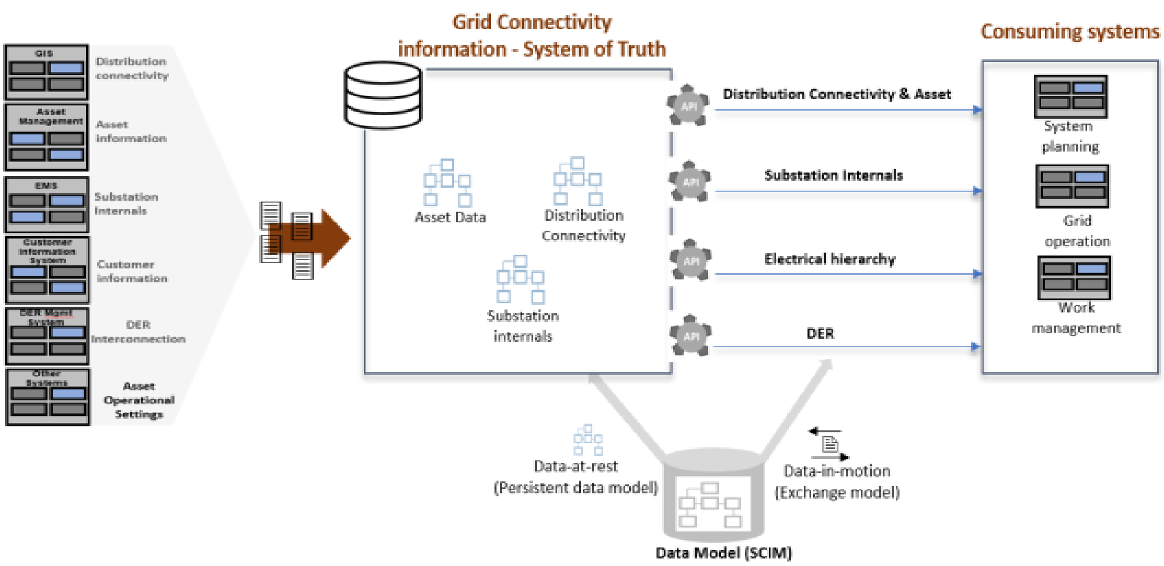

Figure 6. Connectivity Information Service -CIM extended used data-at-rest & data-in-motion

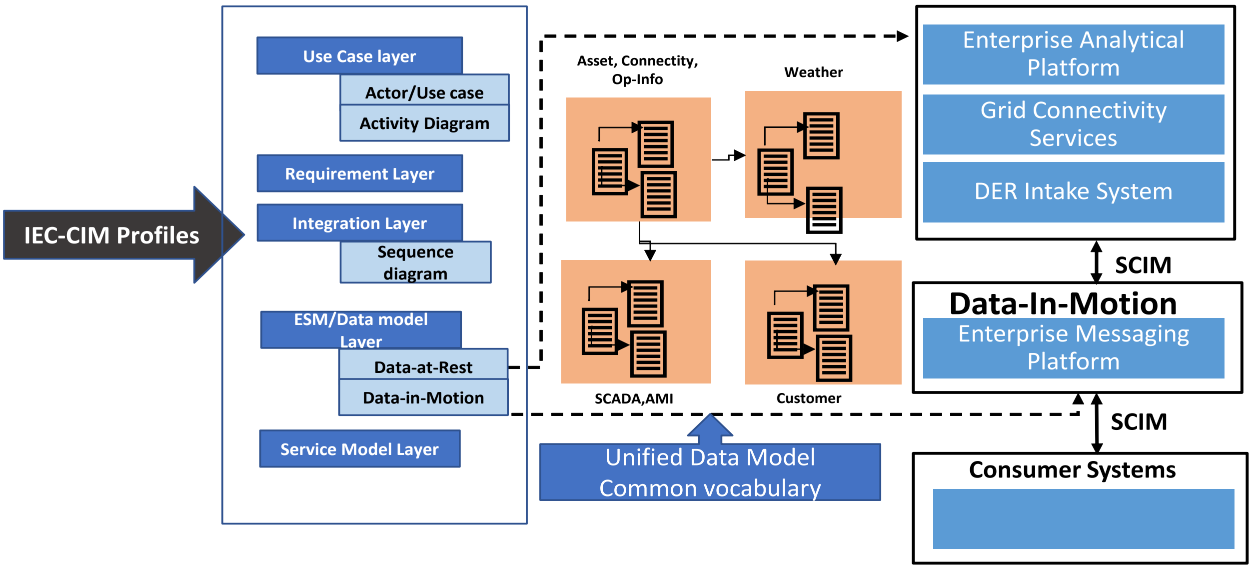

Figure 7. Top-down Modeling Approach

5. Model Driven – A Common Vocabulary

Consistent system development, integration, and analysis require an effective information management strategy. It is vital to model and prepare the data by logically correlating and organizing before it is used for processing. Utilities can adopt the industry-standard IEC Common Information Model (IEC CIM) as a foundation for its enterprise semantic model. [7] However, rather than being limited by what is available in the standard, approach should be to use the CIM as a foundational model and extends it to cover the enterprise information needs.

To illustrate this concept further, take the example Connectivity Information System (CIS) system design. CIS is developed as system of truth for grid connectivity information, integrating data from GIS, asset management, EMS, and other operational applications.

All illustrated in Figure 6, the CIM extended model is used for storing (data-at-rest) the asset, connectivity, and other related information in the CIS database. The same enterprise semantic model is used as an exchange model (data-in-motion) for application data change using the APIs.

Following the top-down modeling approach, as shown in Figure 7, helps to simplify application development and reduces the complexity in information modeling and system integration. [5]

6. Conclusions

A clear vision, goals, objectives along with thorough architecture and system design process is vital for modernizing the distribution system planning. The business processes adopted in the past will not work; hence it is crucial to enable information systems to support the new business processes which are capable of allowing customer choices. "A modern grid achieves safety and reliability of the grid through technology innovation to the extent that it is cost-effective to ratepayers relative to other legacy investments of a less modern character" [1,2].

REFERENCES

Periodicals:

[1] February 2020: California Smart Grid Annual Report to the Governor and Legislature in Compliance with Public Utilities Code 913.2 https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/About_Us/Organization/Divisions/Office_of_Governmental_Affairs/Legislation/2020/2019%20Smart%20Grid%20Annual%20Report.pdf.

[2] Distribution Resources Plan (R.14-08-013) from https://www.cpuc.ca.gov/General.aspx?id=5071.

[3] Vidyod Kumar M. Importance of Data Modeling in Analytics and Beyond! Retrieved August 02, 2020, from https://energycentral.com/c/iu/importance-data-modeling-analytics-and-beyond.

[4] Vidyod Kumar M. Shawn Hu and Greg Robinson, "Enterprise Analytics for SCE's Distribution Planning," Distribu TECH conference proceedings, January 2020.

[5] Viddyod Kumar M. Importance of effective Data Management in analytic August 02, 2020, from https://energycntral.com/c/iu/importance-effective-data-management-analytics.

Standards:

[6] TOGAF® https://www.opengroup.org/togaf.

[7] IEC (International Electrotechnical Commission) TC57 (Technical Committee on power systems management and associated information exchange) Working Group 14 (enterprise business function interfaces for utility operations): https://www.iec.ch/dyn/www/f?p=103:14:0::::FSP_ORG_ID,FSP_LANG_ID:2393, 25.