LFEnergy

Version 1.0

Topics

- LFEnergy Introduction
- LFEnergy Project contribution summary
- LFEnergy Functional Architecture
- LFEnergy Projects Landscape
- LFEnergy Projects Categorization
- Infrastructure Layer
  - SEAPATH
  - OPENLEADR
- Platform Layer
  - RIAPS
  - GXF
  - COMPAS
  - FledgePower
- Application Layer
  - SOGNO
  - Operator Fabric
  - OPENEEMETER
  - PowSyBL
- Other
  - EM2
- EdgeGallery and LFEnergy Collaboration

LFEnergy Introduction

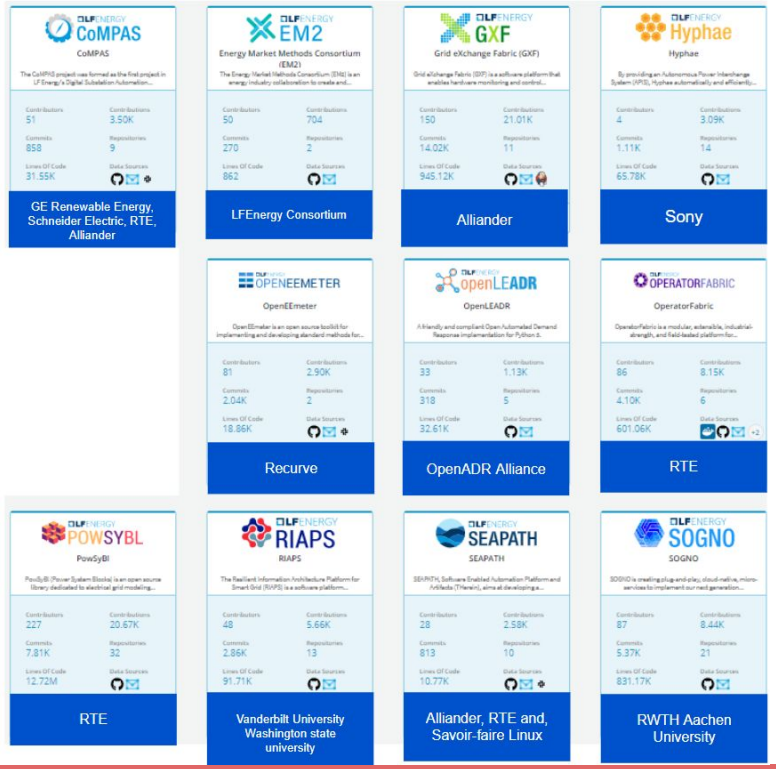
- LF Energy is an open source foundation focused on the power systems sector, hosted within The Linux Foundation.
- It is an umbrella organization that will support and sustain multi-vendor collaboration and open source progress in the energy and electricity sectors.
- LF Energy will focus on providing reusable components, open APIs and interfaces through project communities that the energy ecosystem can adopt into platforms and solutions.
- Building a common infrastructure enables energy companies and solution providers to differentiate at higher value layers and services, while reducing cost and integration complexity at non-differentiating layers.

Current community members

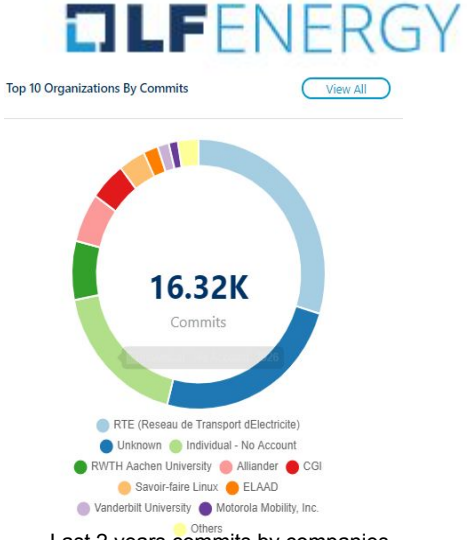
- Launched at 2018 June-July.
- Founding members RTE(Réseau de Transport d'Électricité), The Electric Power Research Institute, European Network of Transmission System Operators, Vanderbilt University, Alliender.

https://www.lfenergy.org/why-lfenergy/

LFEnergy Project Contribution Summary



Last 90 days activity



Last 2 years commits by companies

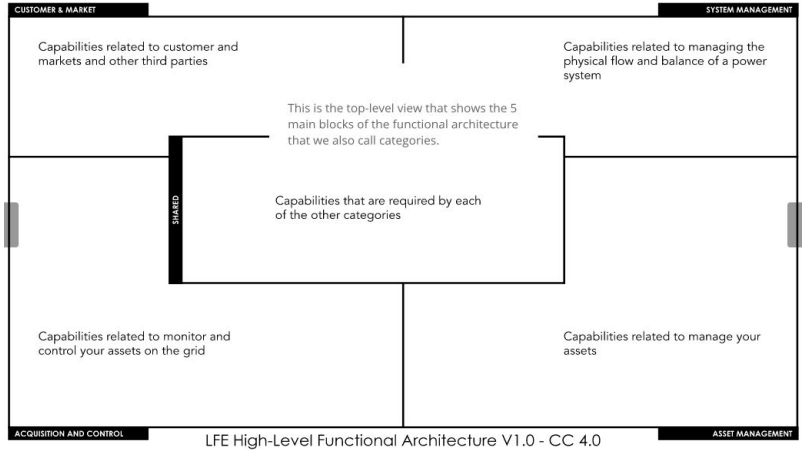
PowSyBL	commit: 1.08K LOC: 819.91K
Gxf	commit: 393 LOC:1.04M
ComPAS	commit: 377 LOC: 200.29K
Operator Fabric	commit: 1.08K LOC: 819.91K

4 Most active projects((90Days)

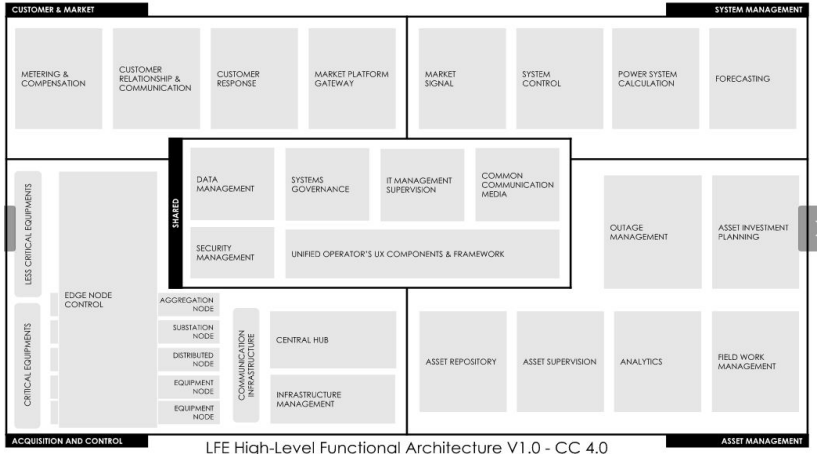
https://insights.lfx.linuxfoundation.org/projects/lfenergy-f

- ❑ Moderately Active Community
- ❑ RTE, ALLIANDER, ELAAD are leading contributor companies
- ❑ RWTH, Vanderbilt Universities are leading contributor Universities
- ❑ GXF, Operator Fabric, PowSyBL, ComPAS and SOGNO are most active projects

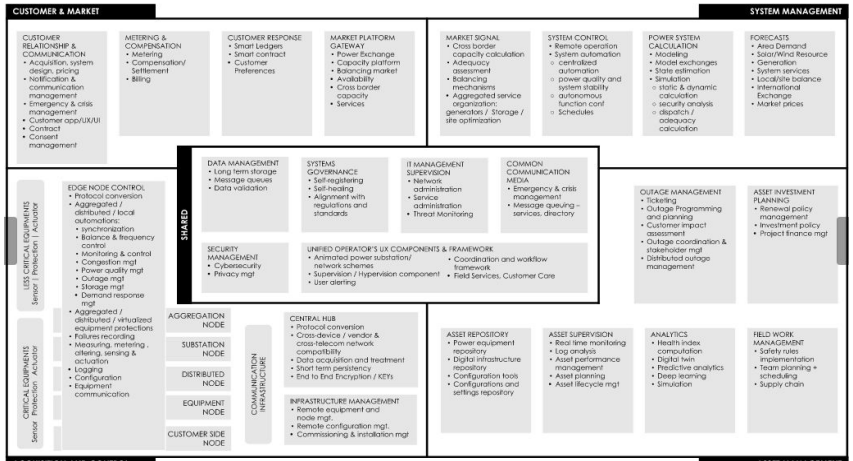
LFEnergy Functional Architecture



LFE High-Level Functional Architecture V1.0 - CC 4.0



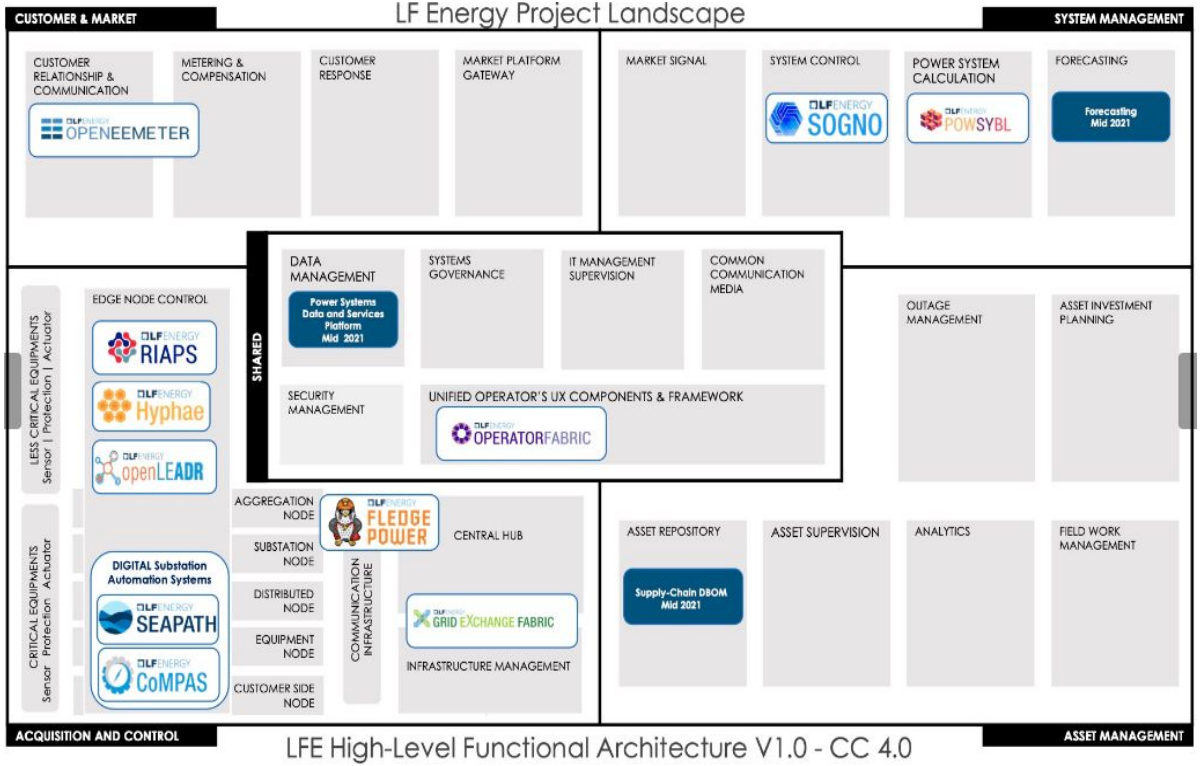
LFE High-Level Functional Architecture V1.0 - CC 4.0



https://wiki.lfenergy.org/display/HOME/High-Level+Architecture+Glossary

- Functional Architecture shows of LFEnergy's areas of focus

LFEnergy Project Landscape

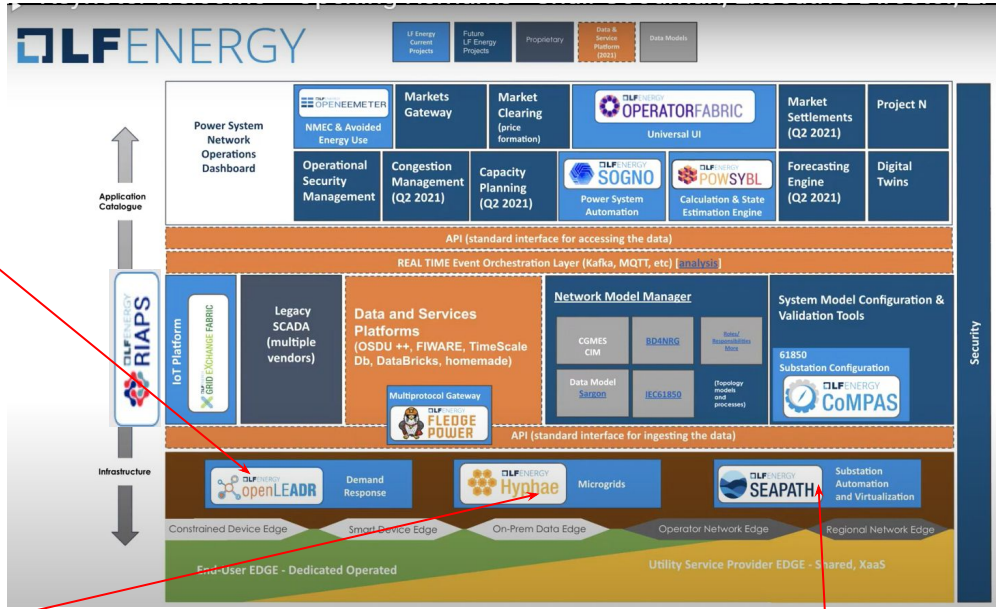


https://wiki.lfenergy.org/display/HOME/High-Level+Architecture+Glossary

- Projects which are inducted in LFEnergy
- Most of the projects are developed by different company even before LFEnergy started hence there are overlapping functionalities.
- This mapping is done based on the projects main focus area
- There are no blueprint to integrating the projects.

LFEnergy Project Categorization (Infrastructure Layer)

Name	OpenLEADR
Proposed By	Open ADR Alliance
Type	Python library
LFEnergy Landscape	Edge Node Control [the digital functionalities that are shared amongst all nodes]
Desc	Open standard for Demand response & distributed energy resource interface that allows DR provider to communicate DR, DER and TE signals to participating customer over internet.
Status	Incubation



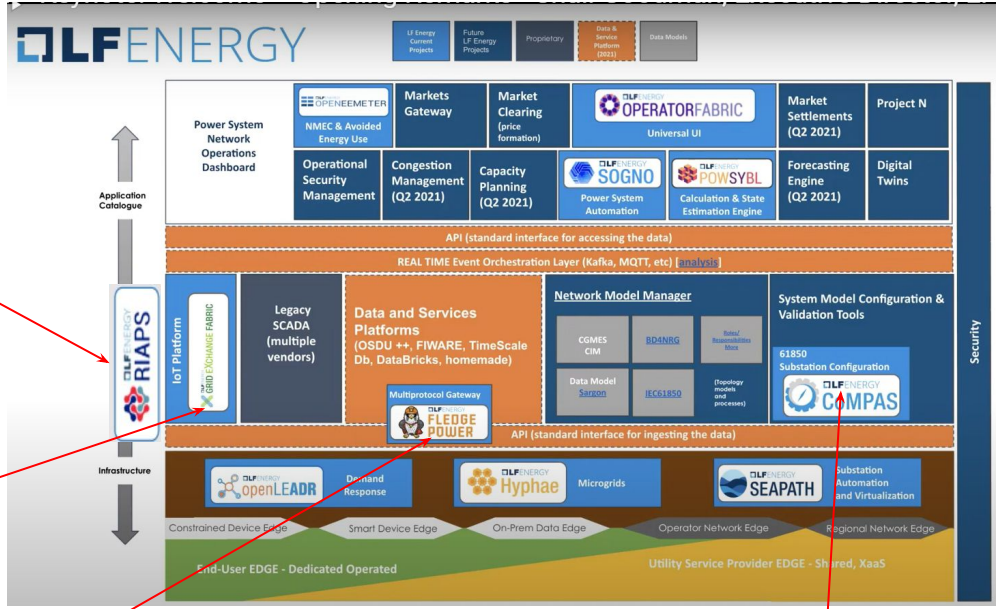
Name	Hyphae
Proposed By	Sony
Type	Microgrid controller and platform
LFEnergy Landscape	Edge Node Control [the digital functionalities that are shared amongst all nodes]
Desc	By providing an Autonomous Power Interchange System (APIS), Hyphae automatically and efficiently distributes locally-produced renewable energy over a DC grid
Status	Incubation

Name	SEAPATH
Proposed By	Alliander, RTE and, Savoir-faire Linux
Type	Platform
LFEnergy Landscape	Edge Node Control [the digital functionalities that are shared amongst all nodes]
Desc	Provides open source real-time platform that can run virtualized automation and protection applications.
Status	Incubation

LFEnergy Project Categorization (Platform Layer)

Name	RIAPS
Proposed By	Vanderbilt University, Washington State University
Type	Distributed Application development platform
LFEnergy Landscape	Edge Node Control [the digital functionalities that are shared amongst all nodes]
Desc	Software platform for building distributed real-time embedded applications for smart grid.
Status	Early Adoption

Name	GXF
Proposed By	Alliander
Type	IOT Platform
LFEnergy Landscape	Central Hub and Infrastructure Management
Desc	Grid eXchange Fabric (GXF) is a software platform that enables hardware monitoring and control in the public space.
Status	Early Adoption



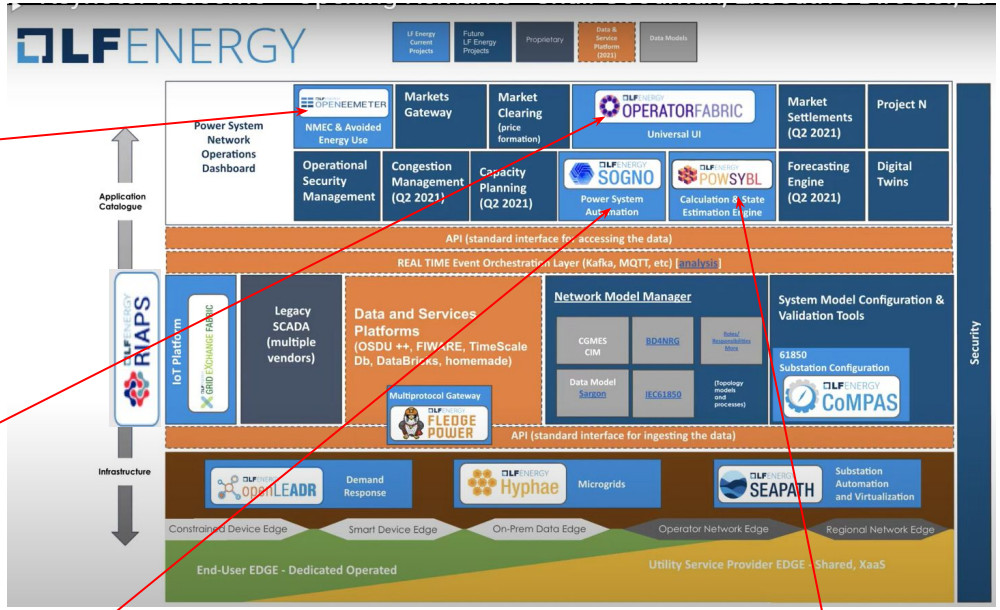
Name	FledgePower
Proposed By	Dianomic, OSIsoft
Type	Protocol translation Gateway
LFEnergy Landscape	Communication Infrastructure
Desc	FledgePOWER is a multi-protocol translation gateway for power systems based on the industrial IoT LF Edge project Fledge.
Status	Incubation

Name	COMPAS
Proposed By	GE Renewable Energy, Schneider Electric, RTE, Alliander
Type	System model configuration
LFEnergy Landscape	Edge Node Control
Desc	open source software components related to IEC 61850 model implementation (profile management) and configuration of a power industry Protection Automation and Control System (PACS).
Status	Incubation

LFEnergy Project Categorization (Application Layer)

Name	OPENEEMETER
Proposed By	Recurve
Type	Library
LFEnergy Landscape	Customer Relationship & Communication
Desc	OpenEEmeter library contains routines for estimating energy efficiency savings at the meter.
Status	Incubation

Name	Operator Fabric
Proposed By	RTE
Type	Operator Platform/Dashboard
LFEnergy Landscape	Unified Operators UX Components and Framework
Desc	modular, extensible, industrial-strength and field-tested platform for systems operators.
Status	Early adoption



Name	SOGNO
Proposed By	RWTH Aachen University
Type	Application Capabilities + Platform
LFEnergy Landscape	System control
Desc	microservices based control center software solution
Status	Early Adoption

Name	PowSyBL
Proposed By	RTE
Type	Library
LFEnergy Landscape	System Management
Desc	Power System Blocks, makes it easy to write complex software to simulate and analyze power systems
Status	Early adoption

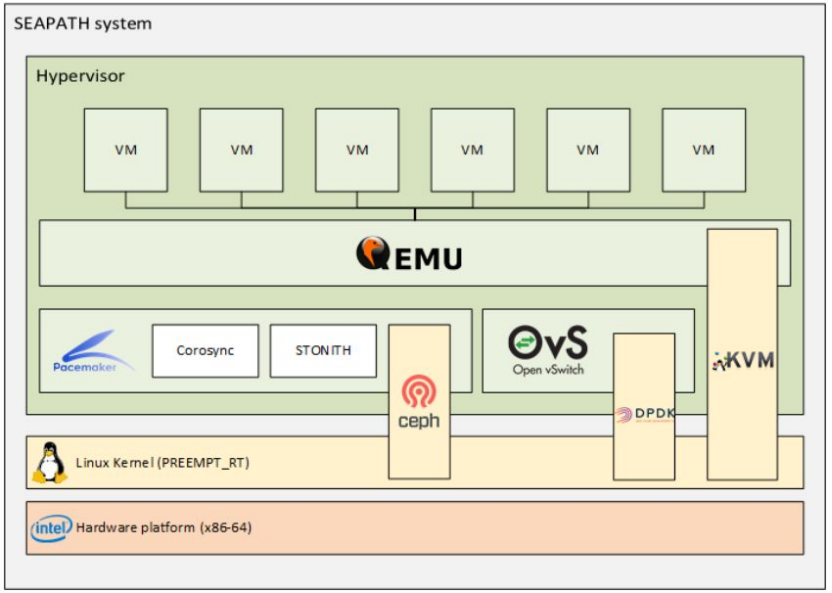
Infrastructure Layer

https://wiki.lfenergy.org/display/HOME/SEAPATH#SEAPATH-WhatisSEAPATH?

SEAPATH

SEAPATH, Software Enabled Automation Platform and Artifacts (THerein), aims at developing a “reference design” and “industrial grade” open source real-time platform that can run virtualized automation and protection applications (for the power grid industry in the first place and potentially beyond). This platform is intended to host multi-provider applications.

- Hosting of virtualization systems:
- High availability and clustering:
- Distributed storage:
- Intelligent virtual network:
- Administration



SEAPATH architecture

How Realtime: They use full preemptable Linux Kernel which brings real-time features.It uses a customized linux distribution using Yocto project which helps create tailored Linux images for embedded and IOT devices. Also Cyclictest tool measure system latencies in various level.

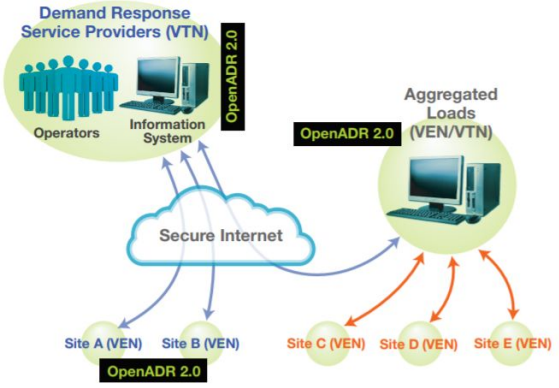
- ❏ This project started and developed from scratch in LFEnergy itself by Alliander, RTE and, Savoir-faire Linux.
- ❏ SEAPATH has two parts
  - ❏ Node cluster installer : Installs a node stack specifically chosen for real time and low latency
  - ❏ IaaS: Supporting HA, VM Management (Not feature rich like openstack)

NOTE: As per LFEnergy no open source provide virtual infrastructure which supports all 3 requirements for virtualized platform

- ❏ It supports VM based workloads. Don’t have any cloud native technology.
- ❏ Project is in Incubation state, in future if edgegallery needs realtime edge stack then this project can be referred.

OpenLEADR

- Open Automated Demand Response (OpenADR) is an open and interoperable information exchange model and emerging Smart Grid standard.
- OpenADR standardizes the message format used for Auto-DR so that dynamic price and reliability signals can be delivered in a uniform and interoperable fashion among utilities, ISOs, and energy management and control systems.
- “Source code for an OpenADR VTN(Virtual top node) and VEN(Virtual End node) in python3”



OpenADR architecture

```python
from openleadr import OpenADRClient
import asyncio

async def main():
    client = OpenADRClient(ven_name="Device001",
                           vtn_url="http://localhost:8080/OpenADR2/Simple/2.0
    client.on_event = handle_event
    await client.run()

async def handle_event(event):
    """
    This coroutine will be called
    when there is an event to be handled.
    """
    print("There is an event!")
    print(event)
    # Do something to determine whether to Opt In or Opt Out
    return 'optIn'

loop = asyncio.get_event_loop()
loop.create_task(main())
loop.run_forever()
```

Sample usage of library

- OpenLEADR is a library. It implemented OpenADR2.0 standard. Donated by OpenADR alliance.
- It can be used by infrastructure when automated demand response (OpenADR2.0) signals processing is required.
- Project is in Incubation state, can only be considered only if use case demands it.

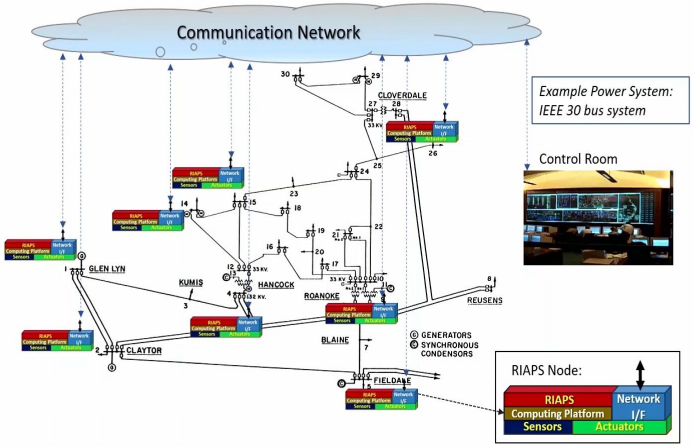
Platform Layer

RIAPS

The goal of RIAPS (The Resilient Information Architecture Platform for Smart Grid) is to provide a run-time and design-time software environment for building applications that execute on the Smart Grid. RIAPS has completely distributed computing model.

- RIAPS computing nodes can be attached to various grid elements: substations, breakers, relays, transformers, etc.
- A dedicated node is available on the network to serve as the control node. The control node runs a development environment for building the RIAPS applications and an application, called the RIAPS control app that is used to download code to the RIAPS target nodes and to launch them.

RIAPS Vision



- Push computation and control to the *edge*
- Use a *common* technology stack
- Facilitate the *integration* of heterogeneous devices
- Provide core services to enable the *rapid* development of *smart* apps

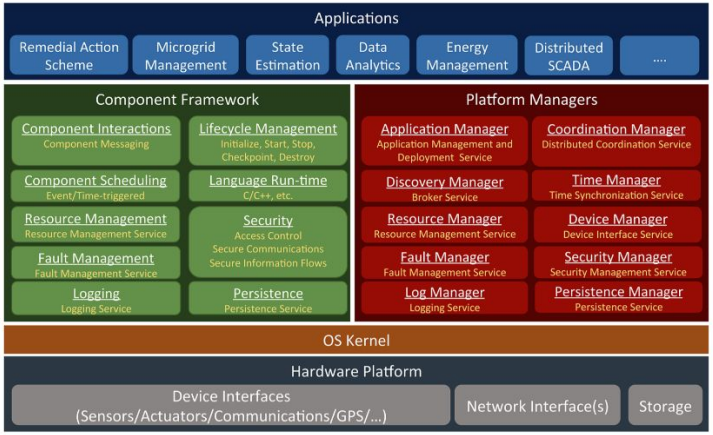
5

- RIAPS was developed as an ARPA-E project at the Institute for Software Integrated Systems(ISIS) at Vanderbilt University, in coordination with NCSU's FREEDM Center and Washington State University. Started at 2016 and it was contributed to LFEnergy in 2019
- RIAPS provides a platform to develop and deploy distributed applications.
- RIAPS is in Early Adoption. But is not very active for last 1 year.

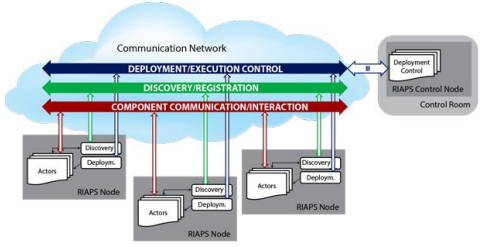
Features

RIAPS includes:

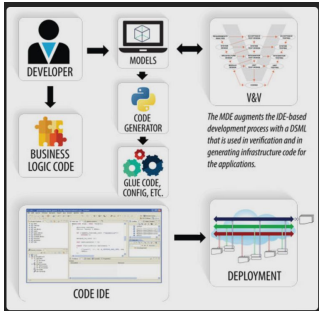
- Application run-time system
  - A component model
  - A component execution engine
  - A messaging framework
  - A resource and fault management framework
  - A security framework
- Run-time services
  - Discovery service
  - Deployment service (supports resource and fault management)
  - Time synchronization service
- Design-time tools
  - Modeling languages for architecture and deployment
  - Software generators
- Operation services
  - Application deployment and control tool



RIAPS architecture



operational architecture of a RIAPS-based system



Dev toolkit

- ❑ It supports application lifecycle management, fault management etc
- ❑ Support service registry, communication across nodes.
- ❑ They also provide development toolkit for code generation, deployment from IDE.

RIAPS is mostly providing features which EdgeGallery already supports and doesn't have any power sector specific functionality which could be leveraged by EdgeGallery.

RIAPS Demo

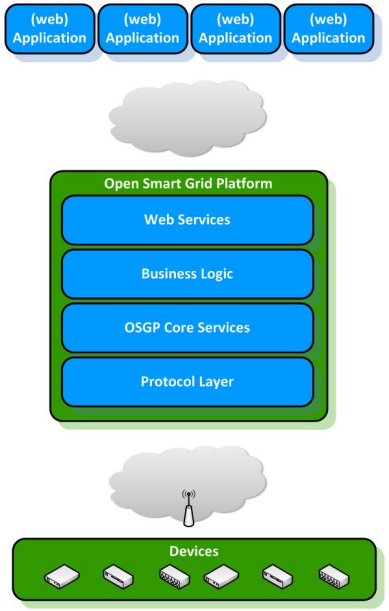
Project Name	Description	Presented by	Video Link/Code
RIAPS at LF Energy Summit	It demonstrates how it can be utilized to run a simple application. Also shown is a microgrid resynchronization application created with this platform	NSF FREEDM ERC	https://youtu.be/AQ1DDM0xL3U
Nested Microgrid Reconfiguration Demonstration	It shows the a distributed secondary control for a nested Microgrid reconfiguration application on the RIAPS platform. The application achieved seamless transition for microgrid reconfiguration while maintaining the voltage unbalance factor at critical loads within acceptable range. The system utilized an Opal-RT real-time simulator, TI F28377S DSP, TI Beaglebone Black single board computers and a controlling application on a Linux machine.	North Carolina State University NSF FREEDM ERC team	https://youtu.be/hexNaxsreIM
Timed Distributed Coordination Service	This application demonstrates the Timed Distributed Coordination services available on the RIAPS platform. This service enables group formation, leader election, consensus on an action and future execution time, along with execution of the action precisely at the same time across the group members.	Vanderbilt University team	https://youtu.be/YIKX5r56jZU
Real-time Wind Curtailment Remedial Action Scheme Application	This application shows the Remedial Action Scheme for Wind Curtailment application on the RIAPS platform. The system utilized a RTDS real-time simulator, Actuator/PMU/Relay hardware, TI Beaglebone Black single board computers and a controlling application on a Linux machine.	Washington State University team	https://youtu.be/60N064BG-64
Transactive Energy Application	This application shows a Transactive Energy application integrated with the Adaptive Distributed Control for Microgrid Synchronization application on the RIAPS platform.	North Carolina State University NSF FREEDM ERC	https://youtu.be/4SXsEI9yhZU
Loadshed App	The loadshed application demonstrates how loadshedding algorithm can be implemented in RIAPS. The application uses the GridlabD interface to connect to a simulated power network, receive simulated measurement data from it, and control various switched loads in the simulation.	RIAPS	**https://github.com/RIAPS/example.loadshed**

- Demo application code is not open source (except Loadshed App)

GXF

Formerly known as the Open Smart Grid Platform, Grid eXchange Fabric (GXF) allows you to monitor and control hardware in the public space. GXF is currently deployed in several public use cases, including microgrids, smart metering, public lighting, and distribution automation.

- Acts as a **connecting link** between (web)applications and smart devices
- The open Source approach **prevents vendor lock-in**
- State of the art **security,** authentication, encryption of data.
- Fully **scalable,** dynamically scaling up and down as more devices and applications are added.
- **Multiple devices** and **multiple communication protocols** are supported
- The open smart grid platform is **optimized** to provide reliable and efficient delivery of command and control information for e.g. smart meters, direct load control modules, solar panels, gateways and other applications.
- The open smart grid platform simplifies the implementation of smart devices resulting in a shorter time-to-market by having built-in **device management** features
- The platform supports various IP data communication infrastructures to communicate with the devices (internet, lan, GPRS, CDMA, UMTS, etc.).
- Adding servers can be done in **runtime**



Basic Architecture

- GXF from Alliendar earlier known as Open Smart Grid platform came to open source around 2016. Joined LFEnergy in 2020
- GXF is a IOT Platform (PaaS) with power sector specific domain features/Capabilities
- Alliendar demonstrated various real world use cases. Like public lighting in amstartdem smart city project . Zown Currently Firan built one successful POC for microgrid operation using GXF, POC for direct load control and several others.
- GXF is in Early adoption stage and is among top 3 active projects.
- GXF is one of the option to incorporate Power sector specific platform features/capabilities to EdgeGallery.

GXF Architecture

Application Integration Layer(Web services)
In this layer, web services are exposed to the outside world. Applications can connect to the application integration layer and use the required functionality of GXF.

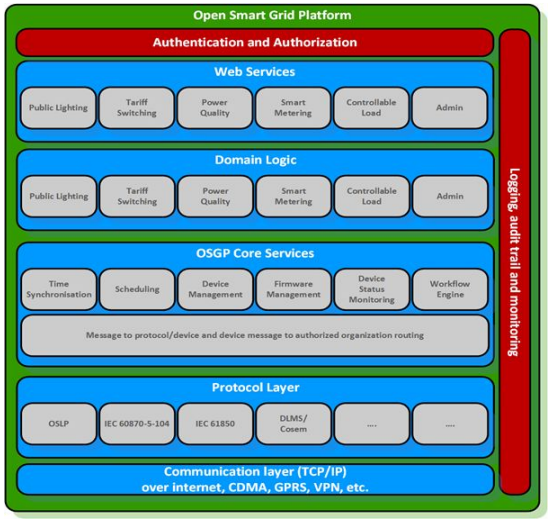
Domain Layer
In the domain logic block the business logic of the functional domain can be found. This is where the translation of a functional named command will be translated into an generic intermediate format. **EG. in the case of public lighting the command "Turn light on" will be translated into a command like "set switch(1) in closed position".**

Core Layer
In the core component of GXF, the following generic functions can be found like Device management, Firmware management, Time synchronization, Workflow engine, Device installation services, Scheduler, Device Status Monitoring, Routing of device command to appropriate device protocol.

Protocols Layer
The different protocol adapters are found in this layer
Currently the following protocols are available:

- Open street light protocol (OSLP)
- DLMS/COSEM
- IEC61850

GXF Layered Architecture



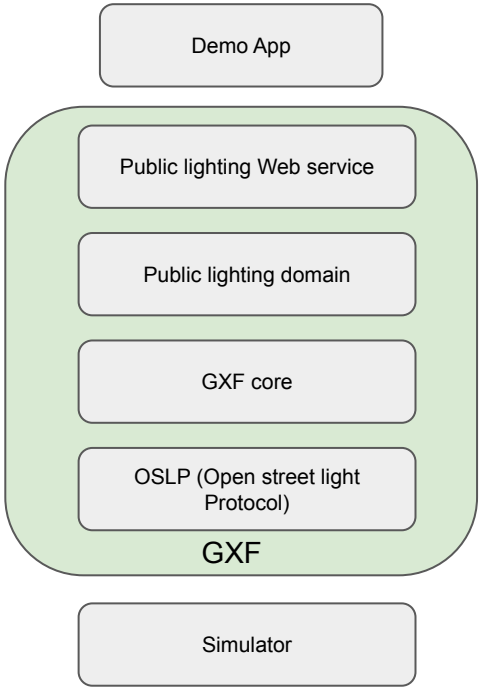
GXF architecture

- Power sector specific protocols like OSLP, DLMS, IEC61850 are provided by GXF
- Domain Layer provides business logic (capabilities) for power sectors specific domains like “Smart Metering”, “Smart Lighting”, “Micro Grid” etc.
- For application integration layer SOAP is chosen in the open smart grid platform web services over REST for several reasons. If someone want REST API they have to write another integration layer for Rest to soap conversion. These API’s are exposed to applications
- Core layer is a more generic one.

GXF Demo: Public Lighting

What: Manage and operate Smart lighting devices using GXF. It demonstrates how to create a Web Request, and send it to the Platform using a signed request over HTTPS and control the simulated device. Through it's front end it allows the user to easily add a device, see which devices are registered on the platform and switch/set a light.

It used simulator in place of actual device.

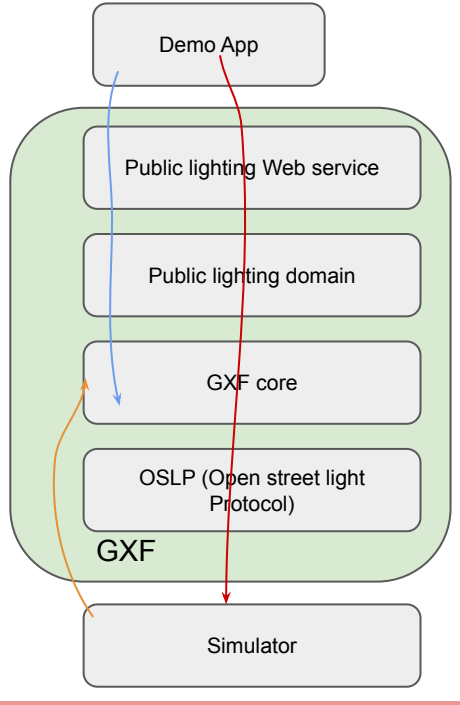


Demo Topology

- ❏ Platform and application installation
- ❏ Source Code

- ❏ Possible demonstration if GXF is integrated with EdgeGallery.
- ❏ The demo uses power sector specific OSLP protocol to control public lighting. This application is for Municipality, large organizations etc.
- ❏ There is another app FlexOVL (Flexible system for operating public lighting) ; **NOT an Opensource** is used by netherlands to controlling, scheduling public lighting, billing, power consumption monitoring etc.

GXF Demo: Public Lighting



NOTE: Installed only required components for public lighting demo app

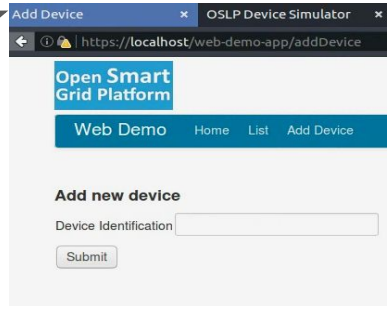
Steps 1: Add a device to demo app

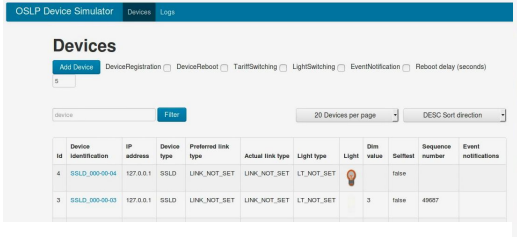
Steps 2: Simulate the device to simulator

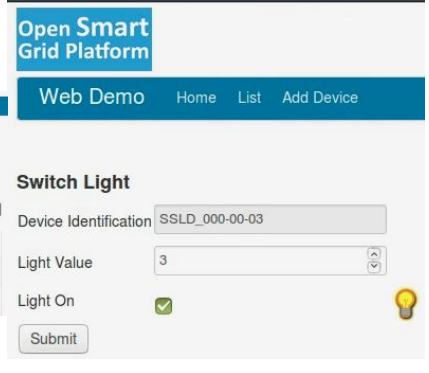
Steps 3: Register the device (mentioned ip, protocol used, and other information) to demo app via gxf.

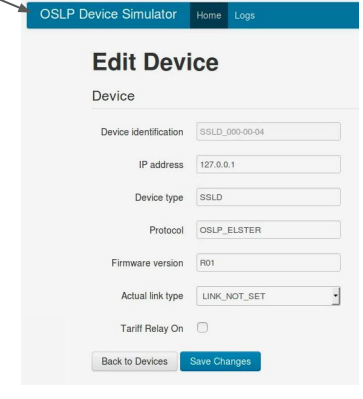
Steps 4: Manage/operate the device from demo app.

Steps 5: View the Devices status(on/off) in simulator.









GXF - EdgeGallery Integration

Why to integrate?

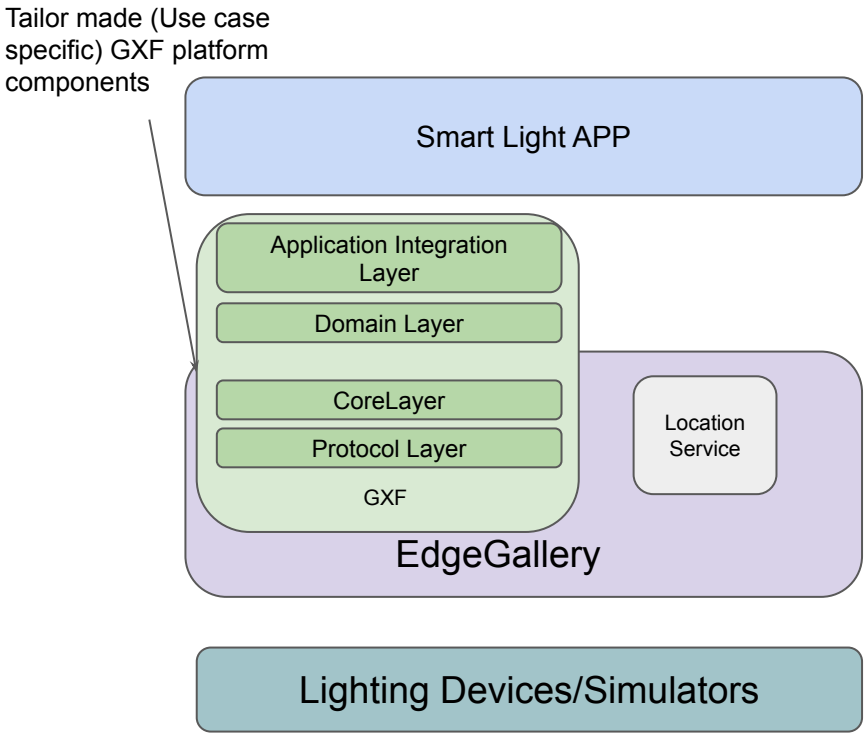
To enable power sector specific platform/capabilities in EdgeGallery. GXF is an IOT platform specific to Power sector(Electircal). It provide components which helps to build applications around power sector specific devices like smart light, smart meter etc.

What to integrate?

It has 4 layers. Each of the layer except core layer has domain specific components. We can pick up only those components which are specific to certain usecase(eg smart light) and integrate to Edgegallery.

Eg, Smart lighting usecase we can integrate below components

- App integration layer
  - Generic webservice layer (common webservices)
  - Public Lighting webservice layer
- Domain Layer
  - Generic domain layer
  - Public Lighting domain layer
- core layer
- Protocol Layer
  - Protocol-Adapter-OSLP: Public Lighting and Micro Grids

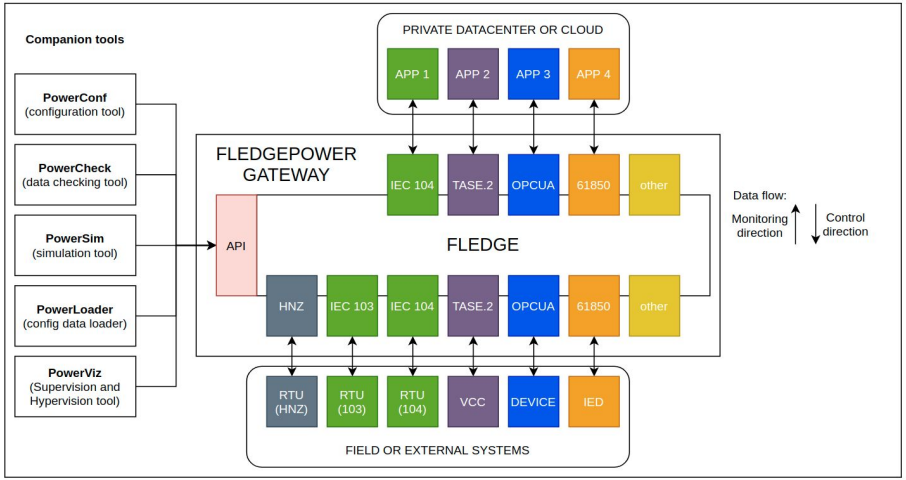


FledgePower

FledgePOWER is a multi-protocol translation gateway for power systems based on the industrial IoT LF Edge project Fledge.

Telecontrol protocols are used at many levels of the system: locally, at various connection nodes of the network, at a central level, and at the interface with network operations.

FledgePOWER solves the problem of multiple protocols translation by providing the industry with a flexible, lightweight, industrial-grade, open source gateway that embeds Fledge (LF EDGE).



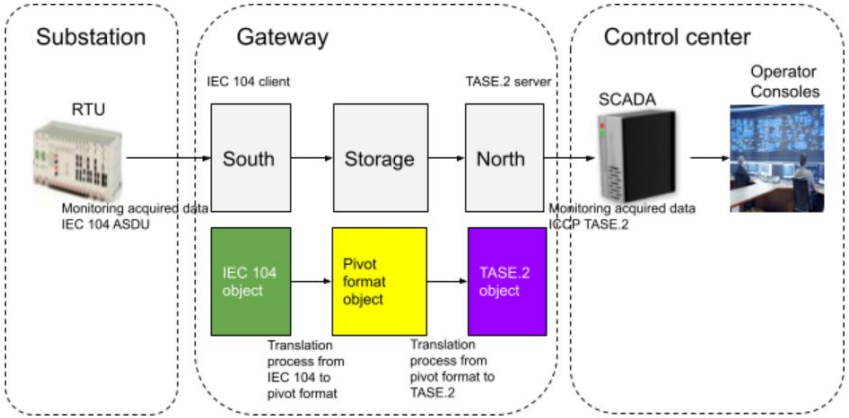
3 main component:

1. Multiple protocol south bound (field device/ IoT)
2. Multiple protocol north bound (data center/ cloud)
3. Setpoint control (specific to fledge power)

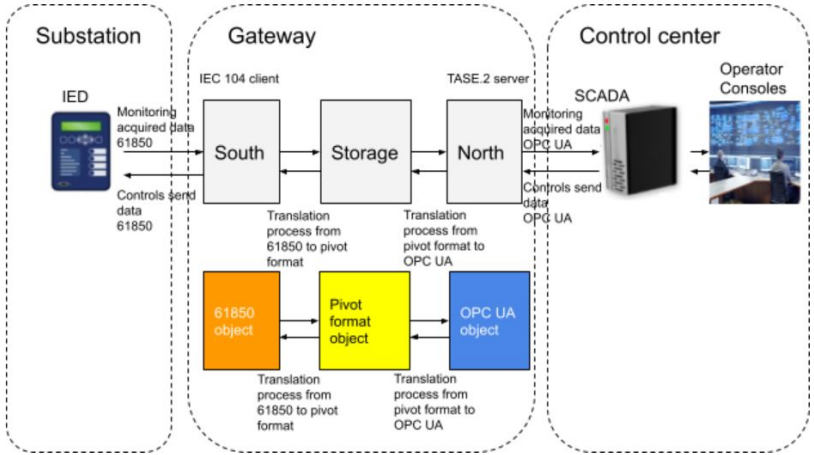
NOTE: No code available yet wiki

- FledgePOWER is a cross foundation collaboration between LF Edge and LF Energy
- No release has happened for FledgePower even code is NOT opensourced yet and project is in Incubation state.
- Fledge Power is going to reuse Fledge
- Fledge Power is not going to use as IOT platform rather going to be used as protocol translation layer. It added more protocols (IEC 104, IEC 61850 etc) to it.
- If EdgeGallery decides to use Fledge for IoT platform. FledgePower could be leveraged by EdgeGallery to include power sector specific protocol layer (after the code is available)

FledgePower Flow



Monitoring



Monitoring and control

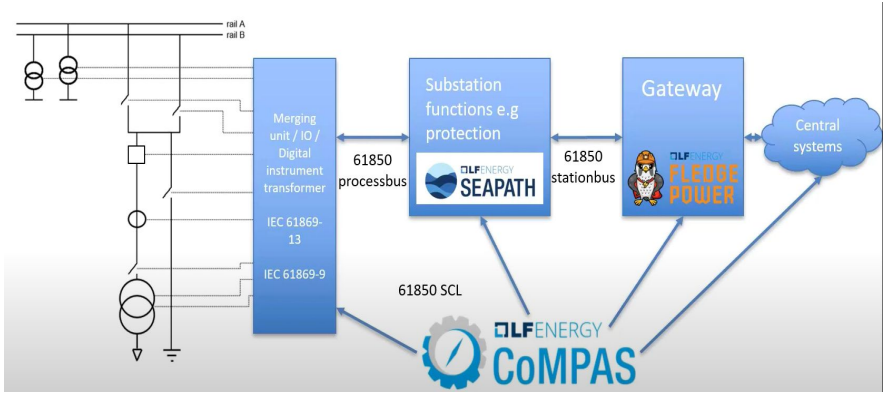
- Plan is to use Fledge Power as protocol translation layer for other LFEnergy projects in future.

CoMPAS

Acronym: **Co**nfiguration **M**odules for **P**ower industry **A**utomation **S**ystems

It does following:

- Configuration management of a power industry Protection Automation and Control System (PACS).
- IEC 61850 model implementation (profile management)



Example: How compas configure various part of substation architecture.

- ComPAS is proposed by GE Renewable Energy, Schneider Electric, RTE, Alliander. It is the first-ever LF Energy project built from the ground up. It was launched in June 2020
- Project is in incubation stage. ComPAS is not yet released.
- CoMPAS is IEC61850 compliance configuration and model implementation. It works with another open source project OpenSCD for substation configuration file format.

Application Layer

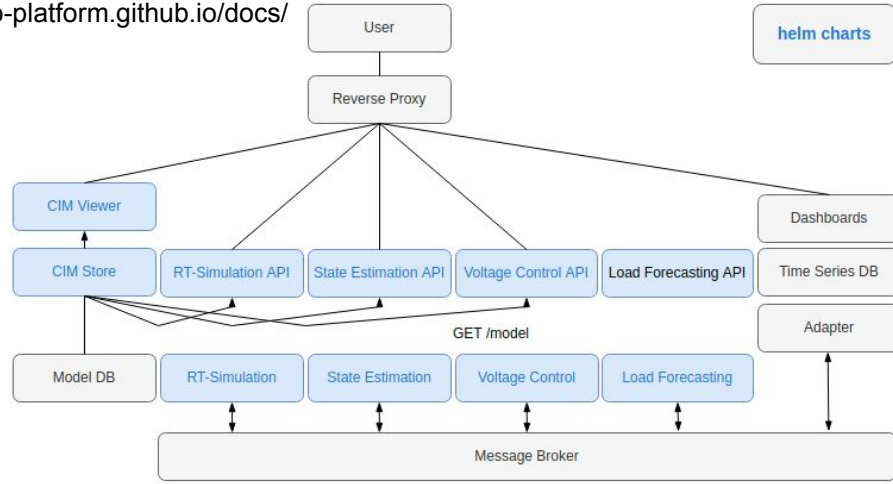
SOGNO

https://sogno-platform.github.io/docs/

Definition: SOGNO(Service-based Open-source Grid automation platform for Network Operation)aims at facilitating the transition to a modular microservices based control center software solution.

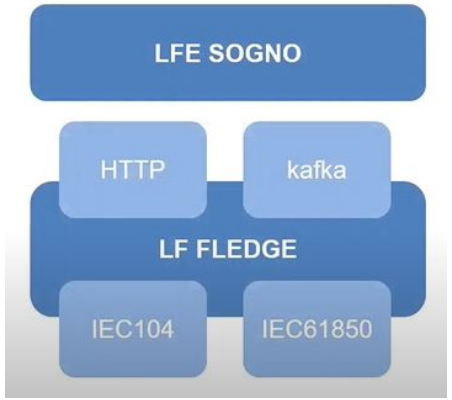
Goal: It provides system operators and automation software developers with an open source framework that exposes open APIs to plug in new automation functions and supports industry standards such as CIM IEC61970. The vision is to integrate today's SCADA systems with SOGNO and gradually move functionalities into microservices.

Due to the integration of real-time simulation, the SOGNO project supports a seamless integration of development, testing and deployment. New automation functionalities can be developed and thoroughly tested against a virtual real-time representation of the power system before deployment.



Architecture

- SOGNO contributed by RWTH achen university, Currently in Early adoption stage.
- Its among top 5 active projects in LFEnergy
- SOGNO aim to replace legacy scada automation functionalities in to micro services.
- SOGNO constitutes component in three categories
  - Framework:
    - Message Broker, CIM Adapter/Viewer, TS Db, Visualization Tools/UI etc.
  - Power sector specific Capabilities/Services
    - State-estimation
    - load prediction
    - voltage control
  - Power sector specific Simulator
- EdgeGallery could leverage SOGNO provided Power sector specific capabilities/services & Simulator as part of EdgeGallery Developer Platform features.



Also SOGNO Roadmap suggest they may integrate with fledge in future for protocol layer

SOGNO Demo: State estimation

Why State Estimation: State Estimation (SE) is mainly used to filter redundant data, to eliminate incorrect measurements and to produce reliable state estimates

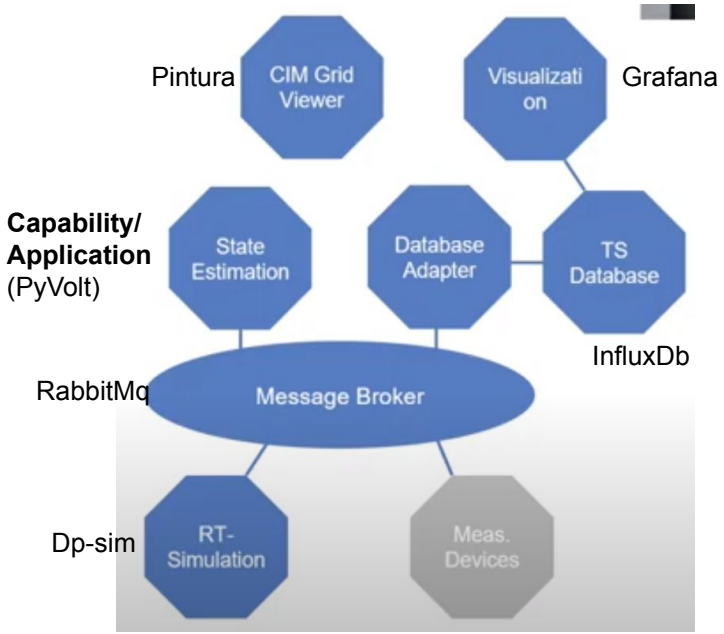
What: Demonstrate state estimation application which **estimate the electrical state of a network** by **eliminating inaccuracies** and **errors** from measurement data.
Input: Number of **measurements**.
Output: Set of voltage absolutes and voltage angles for all buses in the grid.

State estimation Flow
State Estimation is usually used as a end application or a capability which could be used by applications like voltage control/ contingency analysis etc

- ❏ This can be used as a end application and can also be used as a capability by other automation application ([As per Sogno Demonstration] but API document or APIs are not available).
- ❏ In case EdgeGallery uses SOGNO this could be a demo application

https://pandapower.readthedocs.io/en/v1.4.1/estimation.html

SOGNO Demo: State estimation cont..



Demo Topology Components

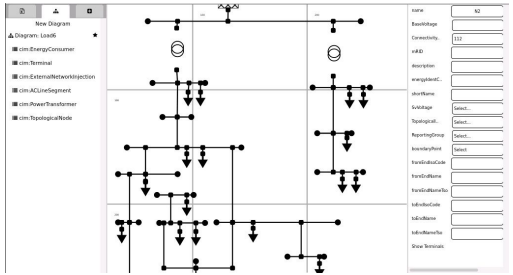
Step 1: Install Platform Component
   a. RabbitMq
   b. InfluxDb with telegraph adapter
   c. Grafana
   d. Pintura (Grid Topology Visualization)
   e. Dp-Sim (Simulation)

Step 2: Import and View Grid topology in Pintura

Step 3: Visualize output without state estimation

Step 4: Install Application (PyVolt)

Step 5: Visualize output with state estimation



[Installation steps]

SOGNO - EdgeGallery Integration

Why to integrate?

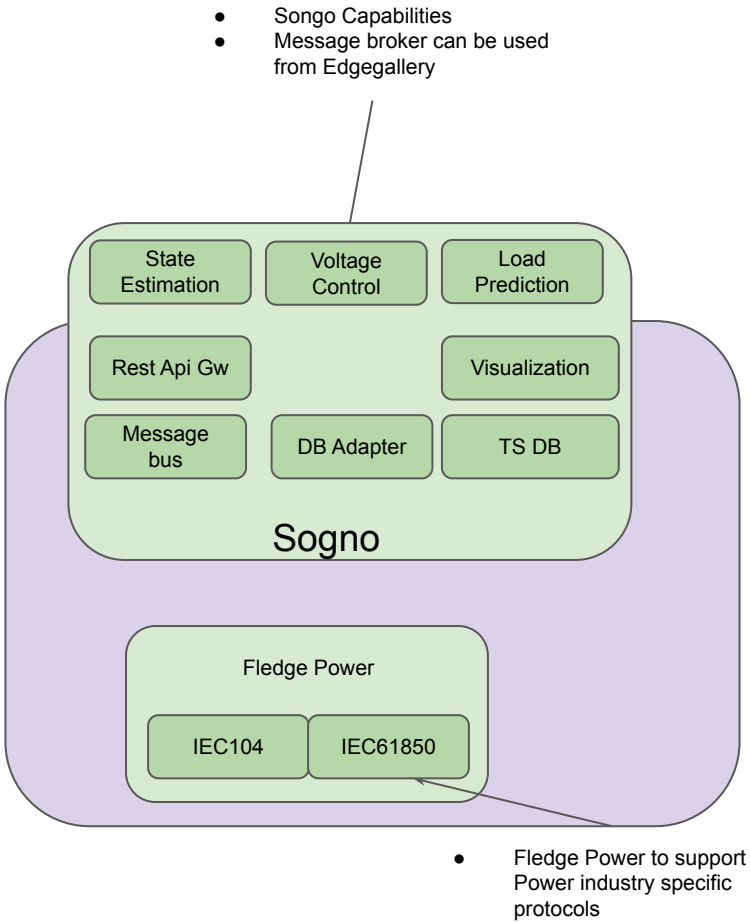
1. **To enable power sector specific capabilities/applications.**
2. **Provide power sector specific simulator.**

Sogno provide a basic platform(Which currently includes Message Broker: RabbitMQ; Real-time simulation: DPsim; Database adapter: telegraf; Time-series database: influx; Visualization: Grafana; CIM grid viewer: Pintura) and some power industry specific application state estimation, load prediction and voltage control.

What to integrate?

- Message Broker: RabbitMQ
- Sogno capabilities
  a. State-estimation: pyVolt
  b. Load prediction: proloaf
  c. Voltage control: covee
- Real-time simulation: DPsim
- Database adapter: telegraf
- Time-series database: influx
- Visualization: Grafana
- CIM grid viewer: Pintura

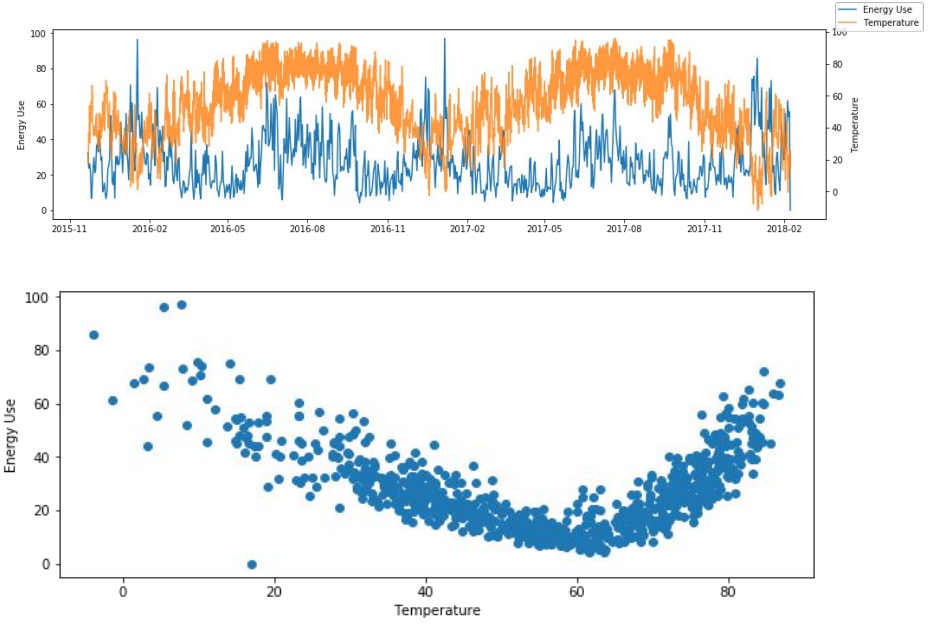
For protocol layer we can integrate Fledge power which also there in Sogno roadmap.



OPENEEMETER

The OpenEEmeter, as implemented in the eemeter package and sibling eeweather package, contains the most complete open source implementation of the CalTRACK Methods, which specify a family of ways to calculate and aggregate estimates avoided energy use at a single meter particularly suitable for use in pay-for-performance (P4P) programs.

Capabilities
- Contains reference implementations of standard CalTRACK methods
- Enforces standards compliance by incorporating data sufficiency checking and first-class warnings reporting
- Facilitates integration with external systems and testing of methodological variations with modular design
- Uses public weather sources by default, but allows for flexibility
- Is built on top of the popular python scientific stack (scipy/pandas)
- Includes visualization and debugging tools



- OPENEEMETER library is contributed by Recurve and in incubation stage.
- OPENEEMETER provide the library to calculate and visualize energy usage estimation in P4P programs/Demand response system.
- No readymade application available around this library. Someone need to write application around this library. Github example of "How to use" exist.

OperatorFabric

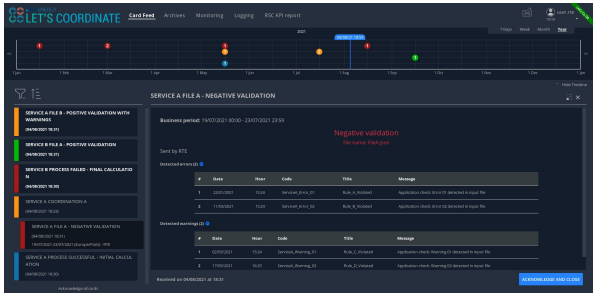
Why: Utility systems operators must interact with multiple applications to perform actions, watch for alerts, and many other activities.Currently different operators and applications has their own dashboards, no standard way of presenting a task/process, notification, alarm etc, So coordinating complex tasks which involved multiple operators and application is tedious.

OperatorFabric is designed to aggregate notifications from all these applications into a single screen and allow the operator to act on them.

Features:

- System visualization and console integration
- Precise alerting
- Workflow scheduling
- Remedial action manager
- Historical data

Current way of coordinating a task involves multi dashboard

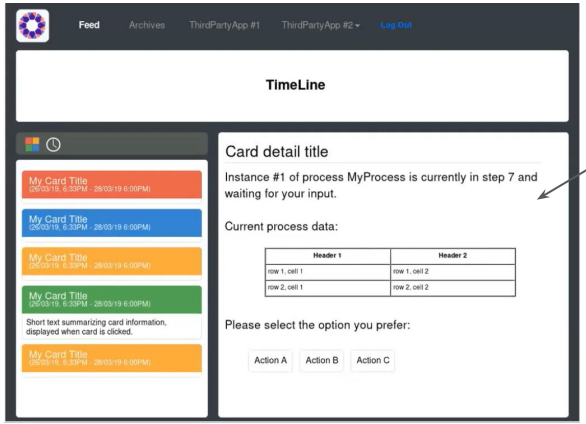


Single dashboard of operatorfabric

- ❏ Provided by RTE and in early adoption stage. Among top 4 active project
- ❏ OperatorFabric is a platform for systems operators for accomplishing task which need manual intervention and coordination between several entities(Operators, application etc).
- ❏ Its not an electrical domain specific project, it can support other domain like water, other utilities.

https://www.lfenergy.org/projects/operatorfabric/

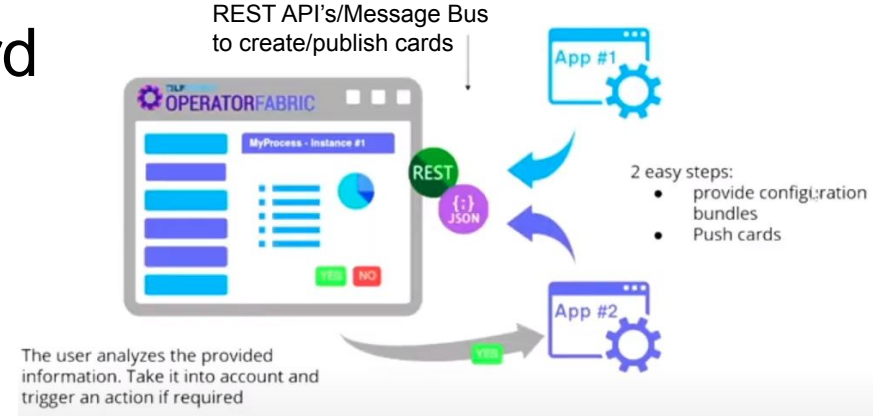
OperatorFabric : Concept of Card



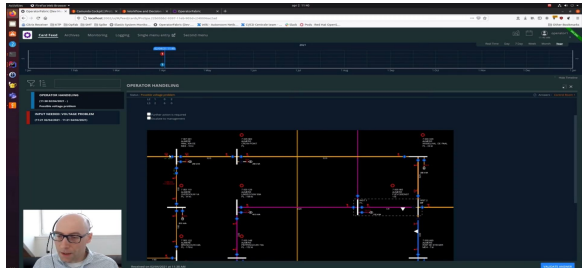
Card details is html page and can display anything(table, charts, action button etc) with the help of css

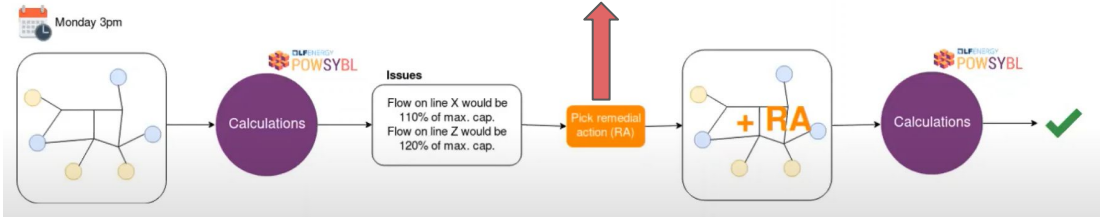
A card

- A card contains data regarding events that are relevant for the operator. A third party tool publishes cards and the cards are received on the screen of the operators.
- Card can be created by an operator or an application.
- A card can be forwarded from one operator to another operator or application.
- Cards will be color coded based on severity



Sample Flow of Operator Fabric





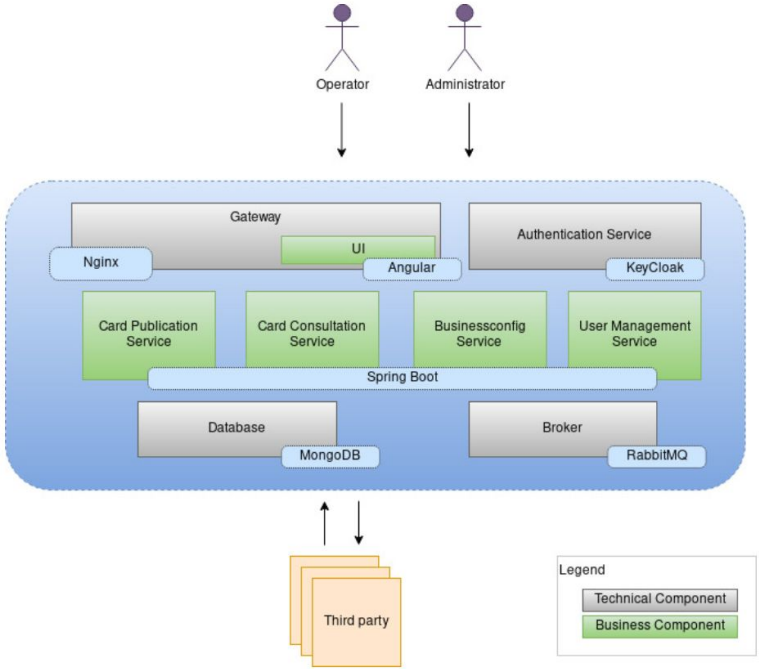
https://www.youtube.com/watch?v=AESNIWLNr4Q&t=410s

OperatorFabric: Architecture

OperatorFabric is based on the concept of cards, which contain data regarding events that are relevant for the operator. A third party tool publishes cards and the cards are received on the screen of the operators.

Following components
Card Publication : this component receives the cards from third-party tools or users
Card Consultation : this component delivers the cards to the operators and provide access to all cards exchanged (archives)
Card rendering and process Configuration: this component stores the information for the card rendering (templates, internationalization, …) and a light description of the process associate (states, response card, …). This configuration data can be provided either by an administrator or by a third party tool.
User Management : this component is used to manage users, groups, entities and perimeters.

Along with realtime event notification operator fabric also supports internationalization, time-zone management, light/dark mode for the UI, authorization mechanism.



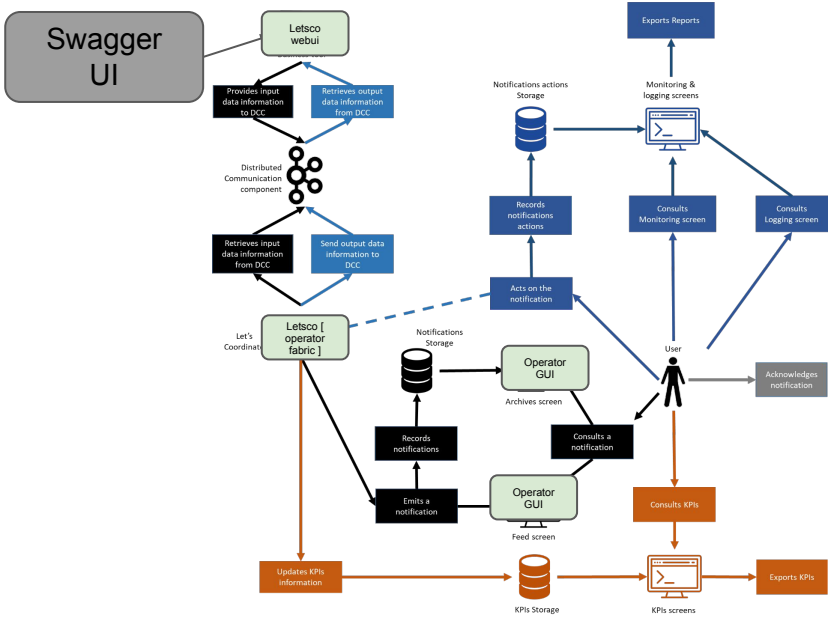
OperatorFabric: Let’s coordinate Application and Demo

What is Letscordinate: Let’s Coordinate is an implementation of operator fabric framework specific to power sector. It used to support RSC services between Transmission System Operators (TSOs) and their Regional Security Centers (RSCs).
It offers these features :

- Receiving and handling of operational notifications,
- Archiving of previous notifications,
- Monitoring ongoing coordination cases or correlated logs,
- Selecting which notifications users want to receive,
- Displaying RSC KPI figures and report.

Demo:
Shows the coordination between multiple TSOs and RSC.

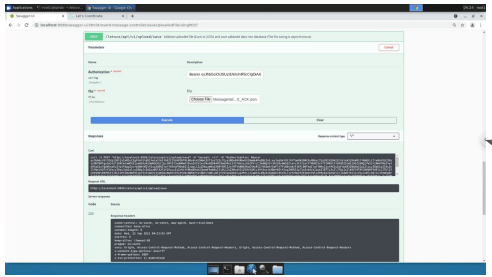
- ❏ The demo shows a Swagger UI (Which represents RSC App) publish event and remedial actions via REST API to letscordinate application.
- ❏ The event will received by letscoodinate frontend and then publish to kafka.
- ❏ The letscoodinate backend components(which includes operator fabric) receive the event and publish a card to the operators.
- ❏ There are 3 operators account. RTE, Terna, Amprion.
- ❏ The card can be viewed on operators GUI. Operator can take action on the card if required.
- ❏ Operators can see the action taken by other operators and monitor status of the card.



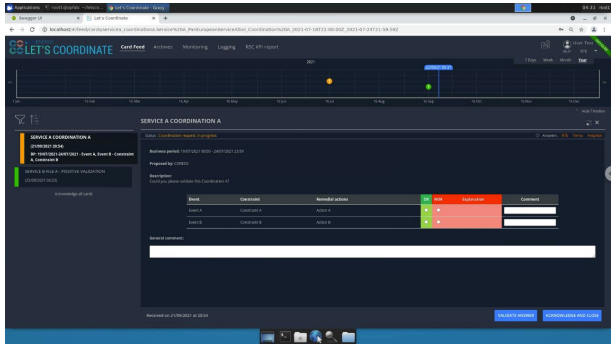
demo topology

Document: https://letscoordinate.github.io/
Youtube link: https://youtu.be/edYu95cpBTA
Github + Installation: https://github.com/opfab/letscoordinate

OperatorFabric: Demo

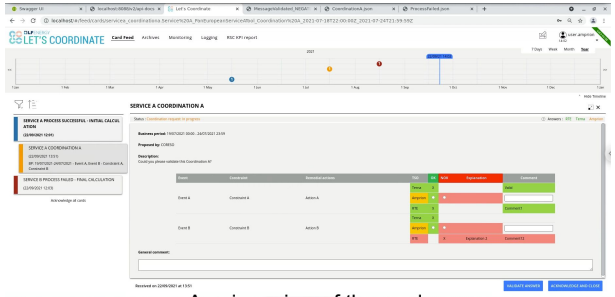


Step 1: Swagger UI send an RSC event which need to be published as card



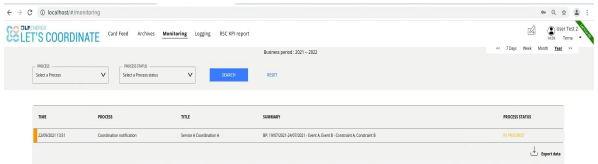
RTE view of the card

Step 2: Card Received on operators dashboard
- 3 operators (RTE, Ampiron, Terna)
- It presented some remedial actions for events to each operator

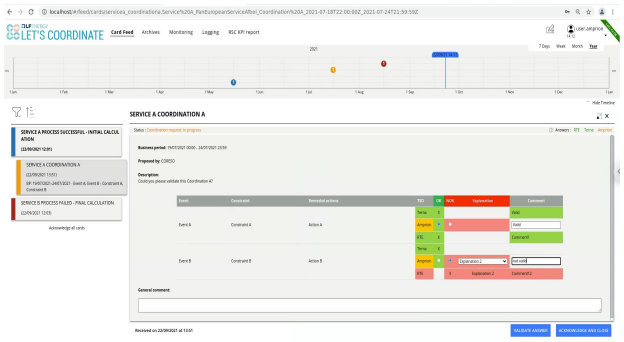


Ampiron view of the card

Step 3: Operator(s) take some action on the card and submit. (Select actions, give some comments etc)



Step 4: Operator can monitor the status of the card.
- Can view the action taken by other operators



Ampiron taking action on the card

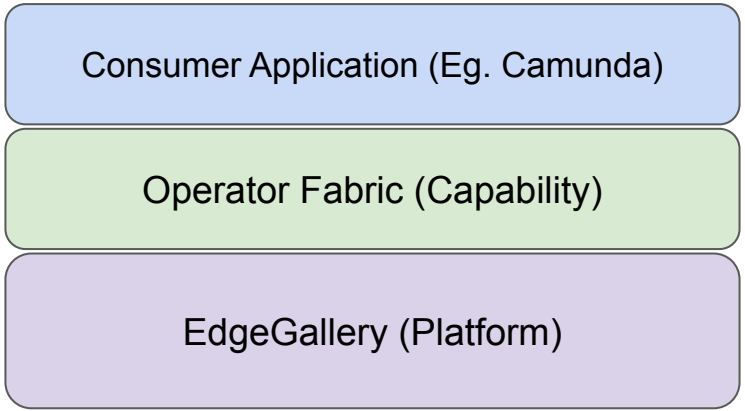
Ampiron viewing the card status

[Installation steps]

OperatorFabric - EdgeGallery Integration

Why to integrate?
Edgegallery can offer operator fabric as a Capability for conusmer applications which demands different level of human intervention..

- ❏ Applications can publish/subscribe their data to kafka or use rest API to provide information.
- ❏ The operators can use GUI to visualize the data and take action on data.



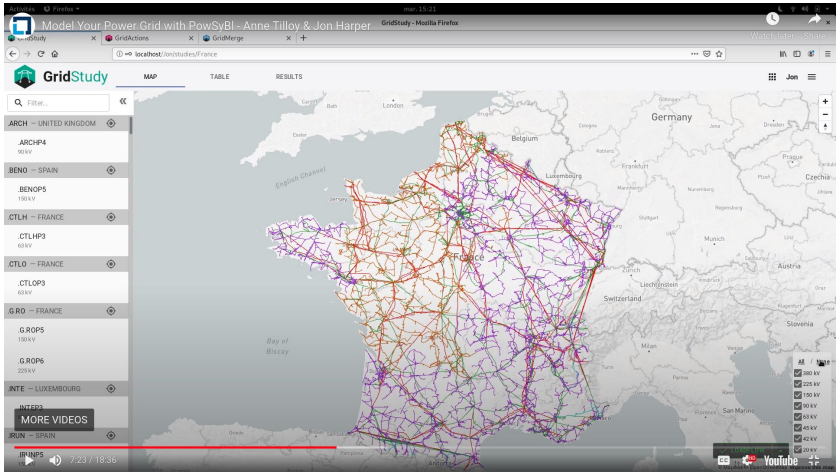
PowSyBL

https://www.powsybl.org/pages/documentation/

- ❏ PowSyBl (**Pow**er **Sy**stem **Bl**ocks) is an open source library dedicated to electrical grid modeling and simulation.
- ❏ PowSyBl is written in Java and licensed under the Mozilla Public License 2.0.
- ❏ PowSyBl provides a complete internal model of the electrical grid, complete with substations, voltage levels, AC and DC lines, two- and three- winding transformers, batteries, generators, loads, shunt and static VAR compensators, and other related equipment.

PowSyBl as a library provides several APIs for power system simulation and analysis, including

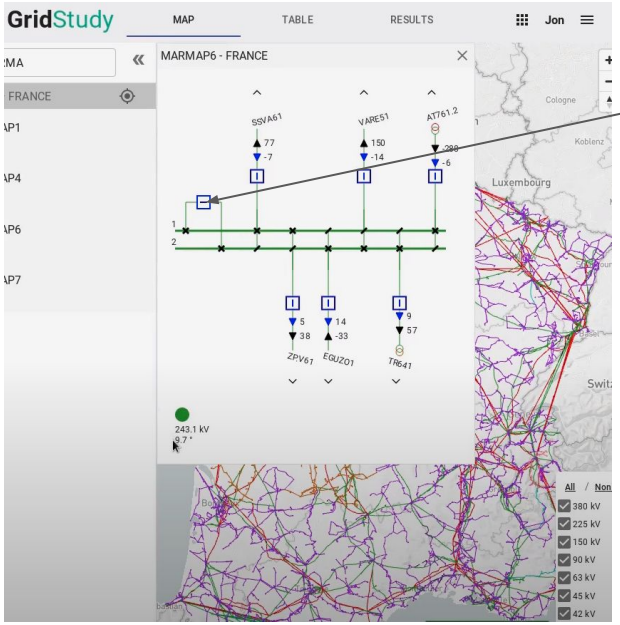
- power flow computation,
- security analysis,
- remedial action simulation,
- sensitivity analysis,
- time domain simulation etc.



Grid Suite; A tool to simulate and analysis power flow computation based on Powsybl. (https://github.com/gridsuite/gridsuite.github.io)

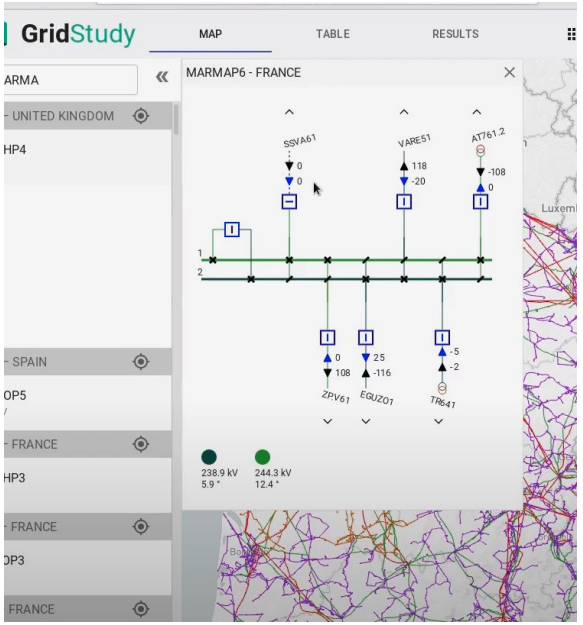
- ❏ PowSyBl is contributed by RTE and in early adoption stage.
- ❏ PowSyBl is a set of Java library which could be used by applications for multiple purpose including analytics, computation, simulation etc. It makes it easy to write complex software for power systems' simulations and analysis.
- ❏ It is among top 3 active project in LF Energy
- ❏ As its a library integration with EdgeGallery may not be useful.

PowSyBL: Grid Suite Example Calculation



Circuit breaker

After switch off the circuit breaker power flow has been calculated



- The Data for the application need to be manually feed (Using files etc.). Data format has standard specification. Powsybl supports CIM-CGMES, UCTE-DEF, XIIDM, Matpower etc.
- This app use for power simulation, calculation and analysis. It can run anywhere and doesn't have any edge specific requirement.

Other

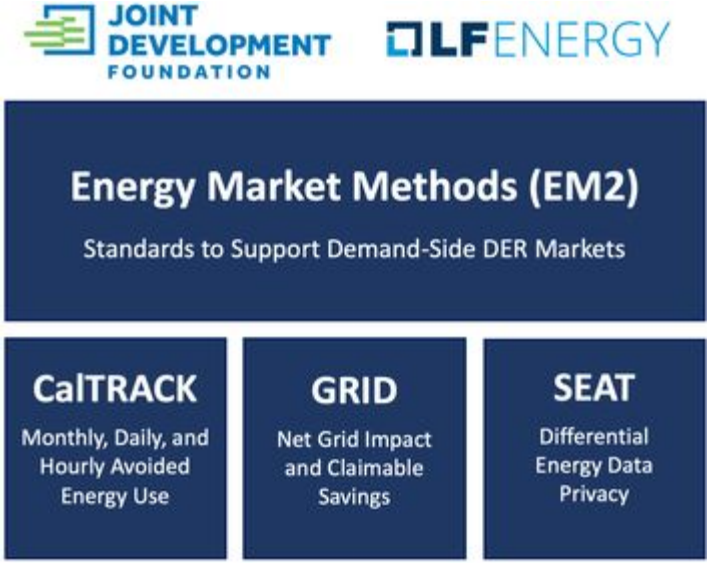
EM2

The Energy Market Methods Consortium (EM2) is an energy industry collaboration to create and curate market methods and algorithms, with a focus on distributed energy resource grid impacts, regulatory planning, and data privacy. It is made up of industry stakeholders committed to collaboration to reduce the costs of scaling demand-side energy programs and procurements.

It is maintaining and improving standardized methods, linked to open source code, to enable demand flexibility as a resource, supporting energy programs and distributed energy resource (DER) markets.

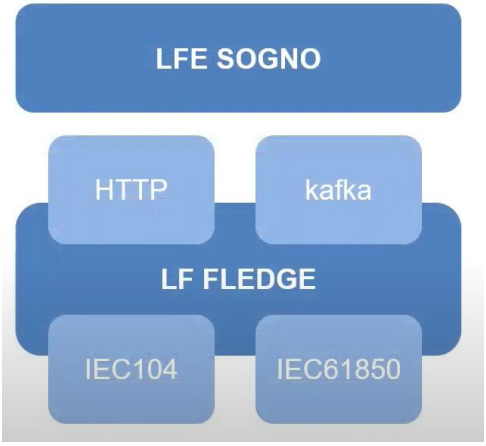
The methods development process is split into three working groups, each representing a core challenge in developing scalable energy markets on the demand side.

- CalTRACK - calculating avoided energy use
- GRID - adjustments to avoided energy use for grid integration
- SEAT - enabling secure data sharing



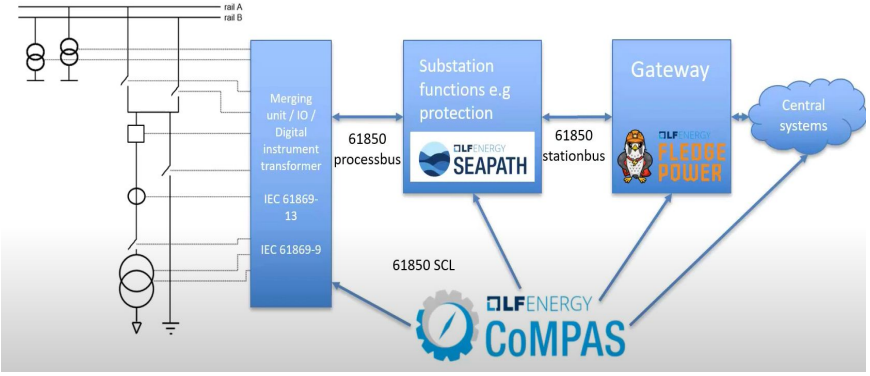
EM2 is a consortium of companies, experts to define standardized methods/algorithm for energy usage, data security etc.

LFEnergy project Integration



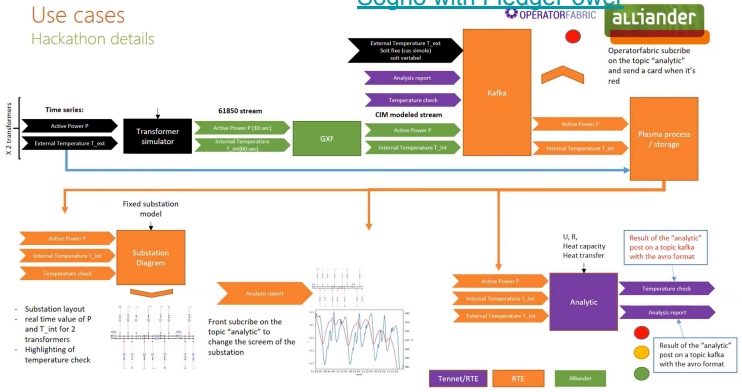
Most of the Projects in LFEnergy started well before LFEnergy launched. So they developed as end to end. And there is no interaction between them.The work has been started to established a common data architecture so that they can communicate with each other reduce similar functionality development.
Status: Initial Draft
(https://docs.google.com/document/d/1QcHqPRSmUUJQlJnfygGDkOpDPIId6U1V22pBuvZvDYk/edit?pli=1#)

The LF Energy data architecture provides development and architectural guidelines for:
- Interoperability of data exchange between LF Energy projects
- Applications and data structures
- Defining high-level information flows between LF Energy functional categories



Compas interaction with other LFEnergy Projects and system

Sogno with FledgePower

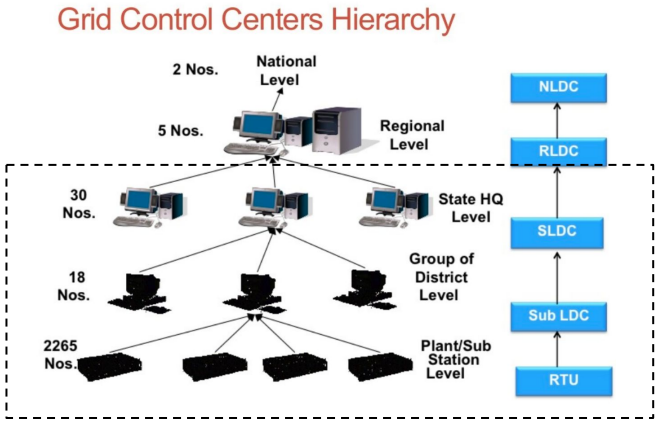


GXF with operator Fabric

Currently there is no interaction between LFEnergy Projects. The work/thought process is in very initial state

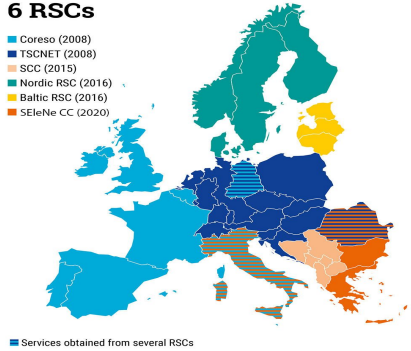
EG-LFEnergy
Integration Solution

Background: Role of Edge in Power Sector



Power system hierarchy in india. NLDC(National Load Despatch Centre) to SLDC generally control generation and transmission, SLDC to below may have generation, transmission and distribution.

Each control center (a.k.a Load despatch centre in india) operates by multiple operators and stakeholders.



https://etap.com/solutions/substation-automation-system
https://www.capgemini.com/in-en/wp-content/uploads/sites/6/2020/11/The-Smart-Substation-solution-brochure_2020.pdf

Power system hierarchy Europe:
DSO: Distribution system operators. More than 3K Distributors.
TSO: Transmission system operators. 42 TSOs from 35 countries
RSC: Cross border Grid security analysis. 6 RSCs

Control center operates by DSOs, TSOs and RSCs(For cross border operation and security).

Control Centre (District/Province) Edges: SCADA/EMS/GMS supervises, controls, optimizes and manages generation and transmission systems. SCADA/DMS Distribution Management systems performs the same functions for power distribution networks. Both systems enable utilities to collect, store and analyze data from hundreds of thousands of data points in national or regional networks, perform network modeling, simulate power operation, pinpoint faults, preempt outages, and participate in energy trading markets.
Control centre needs data as fast as possible to fast response to faults, quick rectifications, thus increase network resilience. Also control centre deals with large amount of data comes from substation. So being on edge reduce the data traffic towards cloud.

Substation Level Edge: Substation runs applications like protection, control, automation, equipment and other critical data monitoring, and communication related. A smart substation can also run applications like video surveillance, Edge Analytics & Asset Monitoring etc. [Capgemini and Intel provide such solution]

Background: Role of Edge

SOGNO and Ericsson 5g Edge field trials

SOGNO aims at facilitating the transition to a modular microservices based control center software solution for distribution system operators. The initiative was established to address the growing need for distribution system operators (DSOs) to have real-time insights into network operation, as well as to remotely optimize their processes for a cost-efficient, seamless and secure power supply for customers.

Ericsson, RWTH achen university and some **power system operators** did a field trial of an automation solution based on Sogno

Solution:

System awareness services

- State estimation for monitoring the grid in real time
- Power quality evaluation to monitor particular parameters and evaluate the grid's health
- Power control solutions to manage distributed generation
- Load and generation forecasting

Autonomous self-healing services

- Fault location, isolation and service restoration; an automated solution that manages emergency conditions triggered by a fault, identifies its location, isolates the faulty grid section and restores the power supply in non-faulty segments

Ericsson provided 5G infrastructure to drive the initiative. 5G enabled low-latency and high-reliability communications for measurement and control devices used in near real-time virtualized applications, which were hosted in the Ericsson 5G Edge solution.

The benefits observed:

The benefits of 5G and Edge as part of SOGNO: The initiative verified that 5G networks can more than meet the ICT requirements for operating full-scale power network monitoring. 5G Edge infrastructure capabilities can support local hosting of SOGNO distribution network automation services, increasing power network resilience and minimizing the communications latency.

The operational benefits: The SOGNO platform architecture facilitates flexible software and hardware component integration from multiple vendors, data exchange, parallel operation, seamless integration with utility legacy systems and rapid deployment of new services

The financial benefits The initiative showed that testing and procuring new services using a software-as-a-service approach carries a low investment risk and requires no upfront capital costs. Finally, automation services reduce penalties for lost minutes of customer service through faster reconnection of customers affected by outages, as well as increased rewards for continuity of power supply.

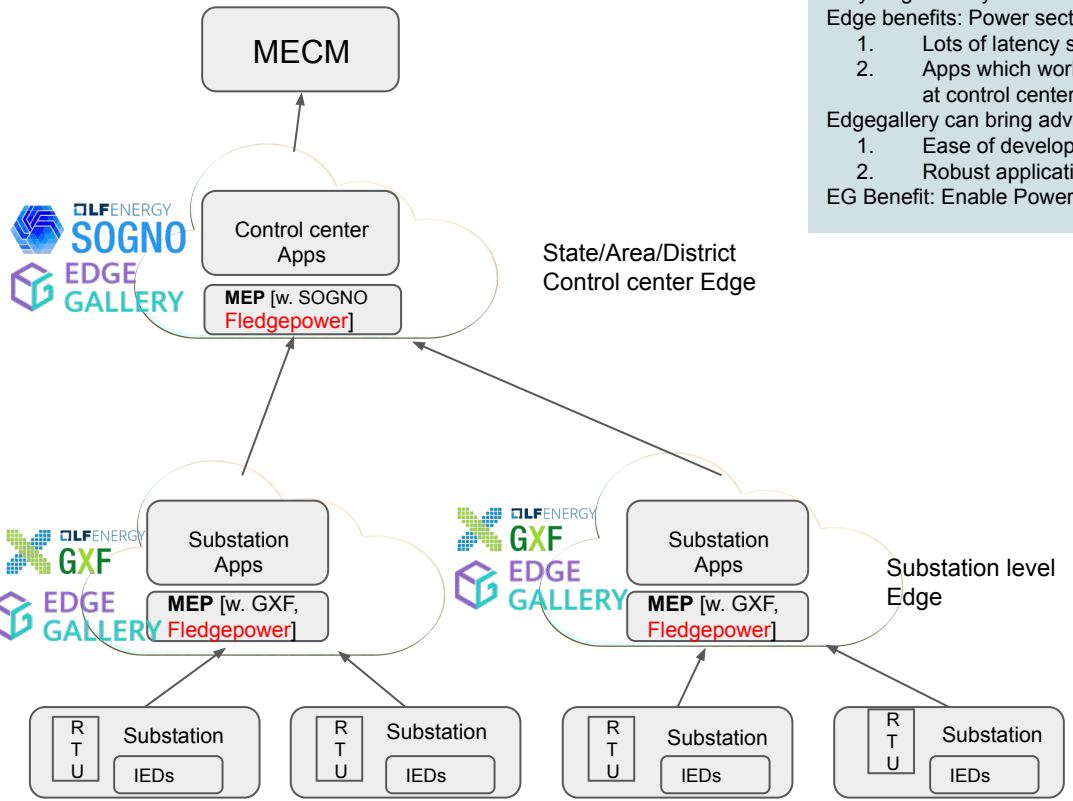
https://www.ericsson.com/4a970a/assets/local/cases/customer-cases/2020/intelligent-energy-distribution-with-5g.pdf

DELL:

Dell Technologies provides the analytical capabilities and complete edge-to-core-to-cloud infrastructure to develop holistic solutions to manage smart grid functionality and automate operations, understand energy demand, and deploy resources efficiently. Utility organizations can deploy the AI model to any device on the Edge, providing a distributed analytical capability to summarize data before bringing it back to a centralized data repository. Dell use Edgexfoundry as IOT platform.

https://www.delltechnologies.com/asset/fr-mg/solutions/industry-solutions/industry-market/h18048-utilities-at-the-edge-intelligent-management-through-strategic-modernization.pdf

Solution: Sogno & GXF Integration with EG



Why EdgeGallery:
Edge benefits: Power sector can benefits from edge for two reasons:

1. Lots of latency sensitive apps (both in substation and control center)
2. Apps which works on huge of amount data should be processed on edge. (Simulation/Analytical apps at control center)

Edgegallery can bring advantages of edge in power sector. Also provide a platform which provides

1. Ease of development. (Apps can reuse many other capabilities like location, AI)
2. Robust application lifecycle management. (Which is not there in many of platforms or very basic)

EG Benefit: Enable Power sector protocols, capabilities in Edge Gallery. Also can leverage sample applications.

State/Area/District control centre edge : Generally operate by transmission/distribution operators or other stakeholders. EMS/DMS applications like state estimation, load prediction, voltage controls, fault management, analytical application runs here.

SOGNO based solutions:

- State estimation
- Load prediction
- Voltage control
- Other EMS applications

Substation level Edge: Generally operate by Distribution operators and other stakeholders. Runs SAS applications eg. protection, control, automation, monitoring, and communication capabilities as a part of a comprehensive substation control and monitoring solution.

GXF based solutions:

- Public lighting
- Distribution automation (To monitor substation equipments)
- Smart meter

Fledgepower is for future integration, since code base is not available yet.

Solution Details Profile based IIOT (Power Sector)

Total 4 Profiles from GXF+SOGNO*

GXF Profiles

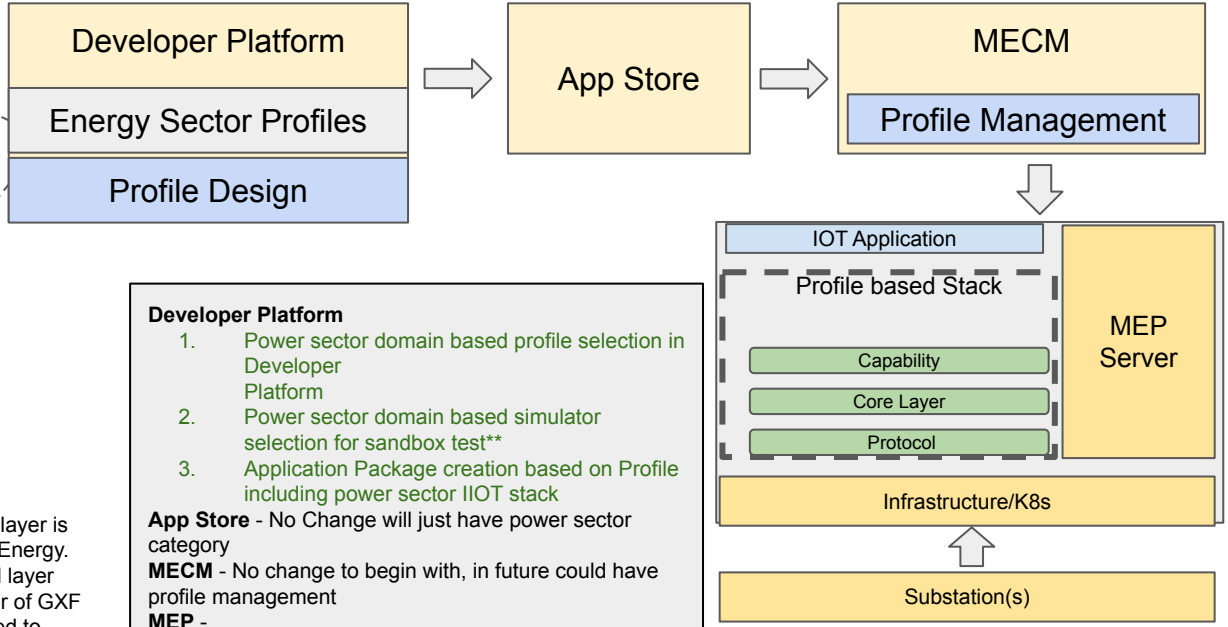
- Public Lighting profile
  - Public Lighting WebService
  - Public Lighting Domain
  - OSLP Protocol
- Smart Metering
  - Smart metering WebService
  - Smart meter domain
  - DLMS Protocol
- Micro Grid
  - Micro-grid webservice
  - Microgrid domain
  - Iec61850 protocol

SOGNO Profiles

- Power system awareness
  - State estimation
  - Voltage control
  - Load prediction
  + Core services
  + Protocol adapter

SOGNO Protocol adapter layer is not open source under LFEnergy. Options to have a protocol layer

- Modified Protocol adapter of GXF (JMS to MQTT). Also need to separate all protocol layer in GXF.
- Villasframework (GPL3.0) which has been developed by RWTH Achen university and used in real time field trial.



Developer Platform

1. Power sector domain based profile selection in Developer Platform
2. Power sector domain based simulator selection for sandbox test**
3. Application Package creation based on Profile including power sector IIOT stack

App Store - No Change will just have power sector category

MECM - No change to begin with, in future could have profile management

MEP -

1. GXF has end to end stack to run an application. Currently layers interact with other with JMS, they are not containerized. Need to separate them and containerized.
2. Protocol stack for SOGNO (either of 2 option)

Note:

Ones marked in blue would need new development and can be planned for future.

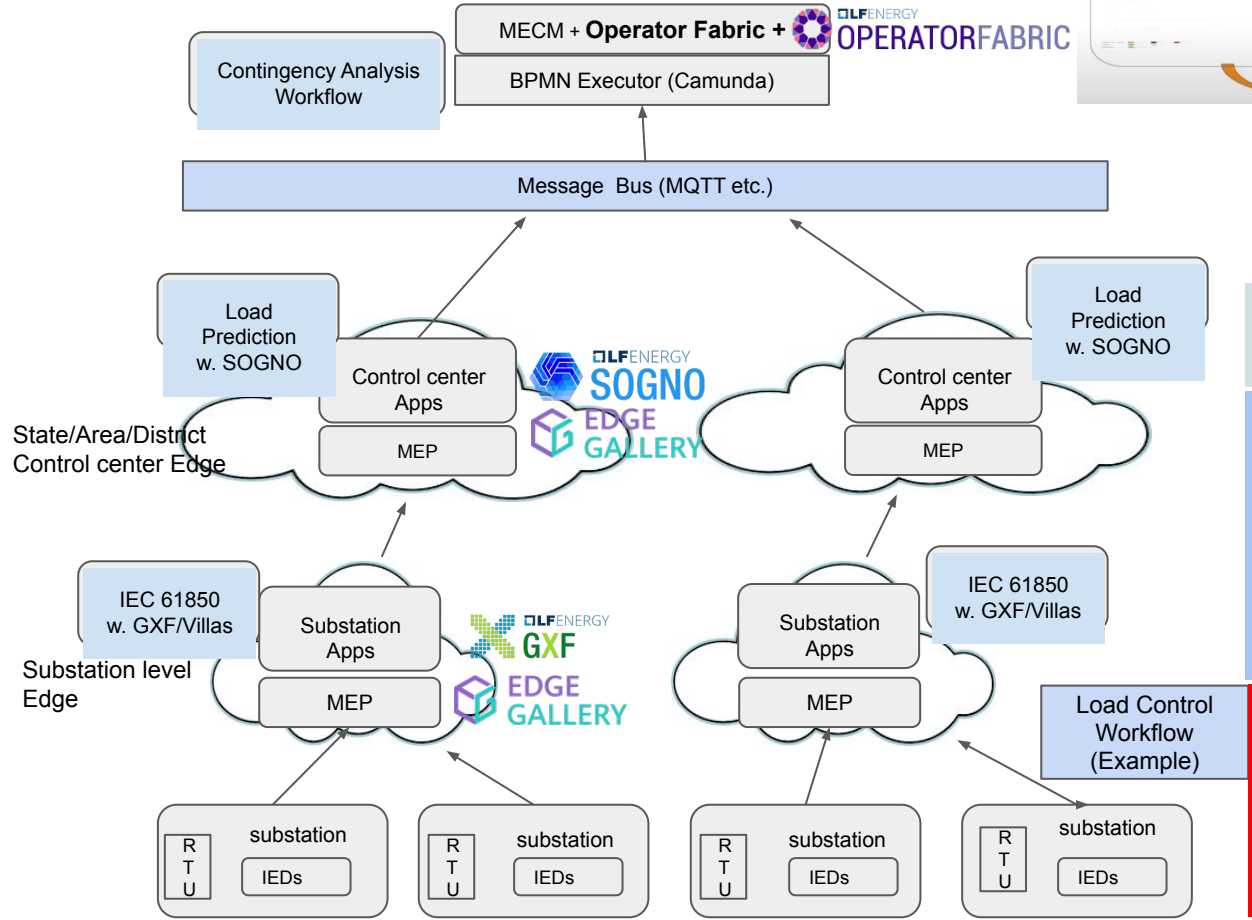
This Solution is in-line with Profile based solution already discussed for IIOT platform wherein based on IIOT use case need profile would be selected in Developer Platform and same would be deployed to edge.

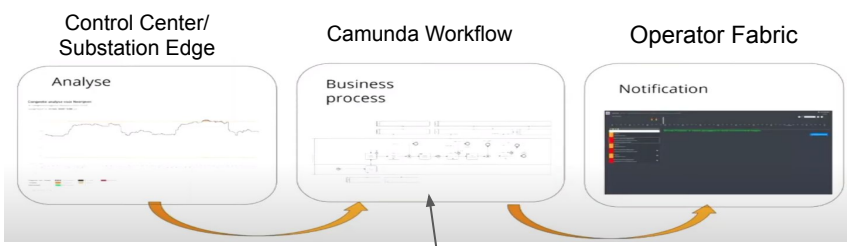
Note: GXF Domain/Capabilities tightly coupled with Protocol. Ability selection alone is not sufficient

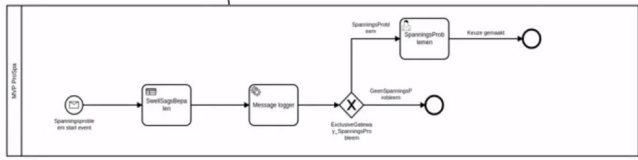
*More profiles could be added based on progress of GXF and SOGNO

**Simulators are domain specific

Solution : Operator Fabric







EG Benefit: Utility sector business process model execution & monitoring via EG.

Why Operator Fabric at Center: To perform their duties, an operator has to interact with multiple applications (perform actions, watch for alerts, etc.), which can prove difficult if there are too many of them.

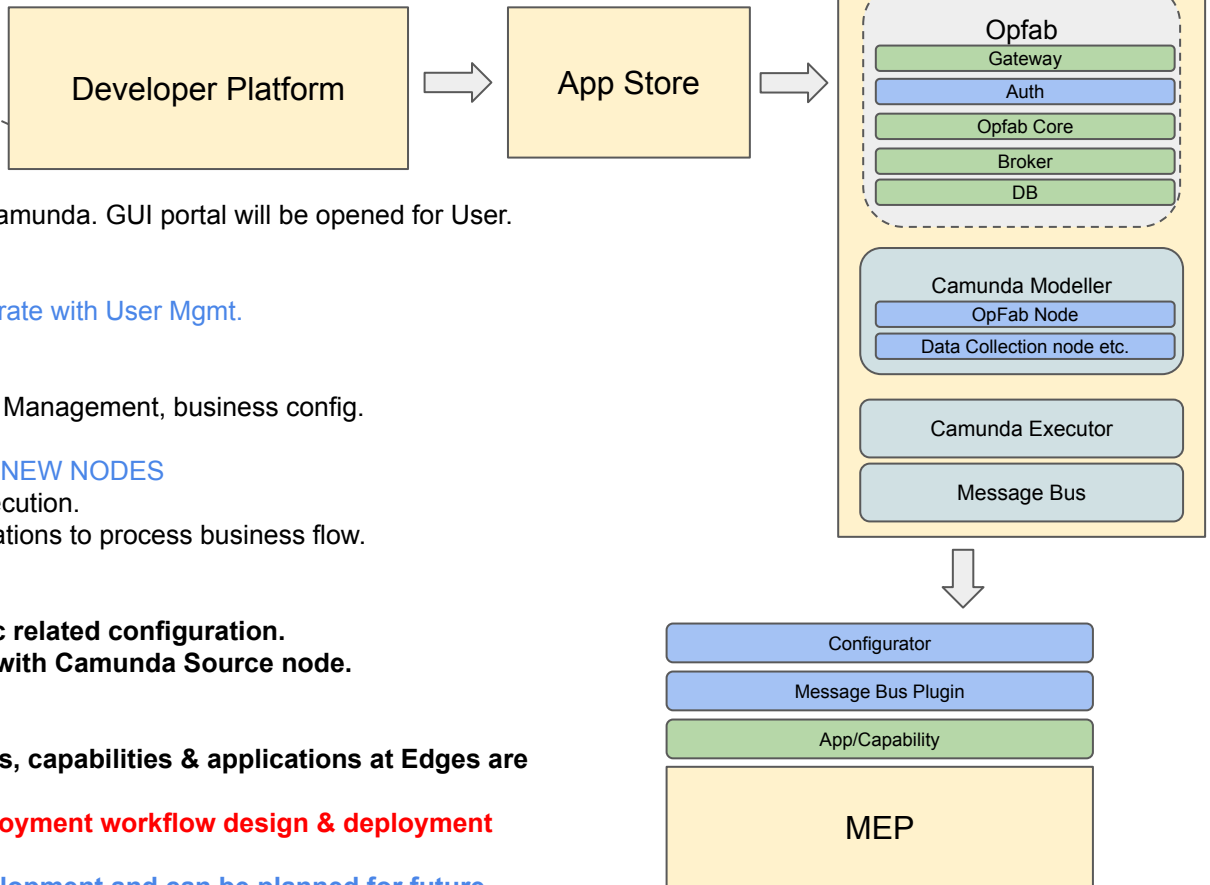
- Operator fabric aggregate all the notifications from all these applications into a single screen, and to allow the operator to act on them if needed.
- Operator fabric can coordinate task between multiple control centers(distributed control center under same TSO/DSO).
- Share information in real time, as pre-formatted cards that can be sent either manually by operators or automatically by external solutions.

From the usage of opFab looks like the best place of operator fabric deployment should be in cloud.
Also we can extend the scope of MECM and deploy it on MECM level, but MECM meant for app lifecycle and management, and MECM control may or may not be with the power operator.

Business Workflow Deployment & Execution

Utility sectors where Operator fabric can be useful

- Power, Water, Gas



Developer Platform : No Change
App Store - No change
MECM - MECM prepackaged with operator fabric & Camunda. GUI portal will be opened for User.
Operator fabric components:

- Gateway : Opfab gateway.
- Authentication: Opfab use keycloak, can integrate with User Mgmt.
- Broker: RabbitMQ
- DB: MongoDB
- Opfab core: UI, publication, consultation, user Management, business config.

Camunda :

- Camunda modeller with power sector specific NEW NODES
- Camunda executor for business work flow execution.

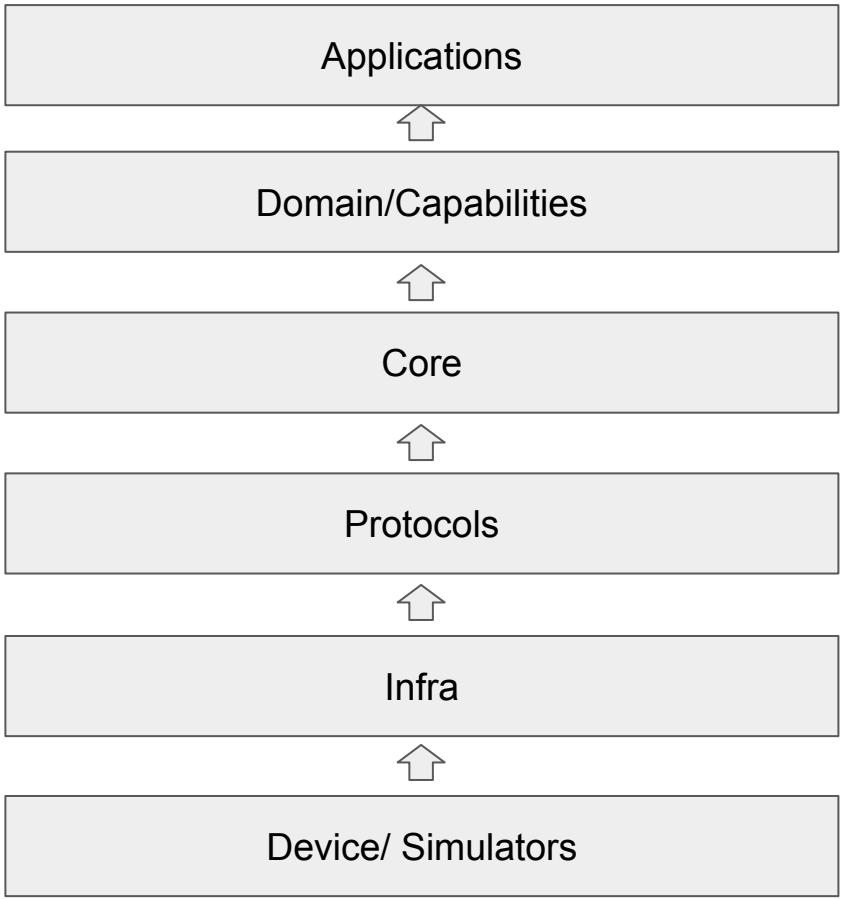
Message Bus: To receive messages from edge applications to process business flow.

MEP
IIOT profile Configurator to add Message Bus topic related configuration.
Message bus plugin to have unified message bus with Camunda Source node.

Note:

1. **Power sector IIOT stack including protocols, capabilities & applications at Edges are pre-deployed using previous solution.**
2. **Future can consider profile design for deployment workflow design & deployment automation.**
3. **Ones marked in blue would need new development and can be planned for future.**

Layer wise Mapping of All relevant LFEnergy Project in Stack



GXF, SOGNO
Openeemeter (Library), PowSyBl (Library)

GXF, SOGNO, OperatorFabric

GXF, FledgePower, **EdgeGallery,**
RIAPS

GXF, FledgePower(Not ready)
OpenLeADR (Libraray)

EdgeGallery (Openstack/ Kubernetes), Seapath

SOGNO
GXF (specific usecase)

Note: GXF/SOGNO looks to be good starting point

Thanks

Glossary

SCADA	supervisory control and data acquisition (SCADA) is a control system architecture comprising computers, networked data communications and graphical user interfaces (GUI) for high-level process supervisory management, while also comprising other peripheral devices like programmable logic controllers (PLC) and discrete proportional-integral-derivative (PID) controllers to interface with process plant or machinery.
IED	Intelligent electronic devices
SA	substation automation (SA) system
RTUs	A remote terminal unit is a microprocessor-controlled electronic device that interfaces objects in the physical world to a distributed control system or SCADA system by transmitting telemetry data to a master system, and by using messages from the master supervisory system to control connected objects.
ADR	Automatic Demand Response
VTN	Virtual Top Nodes (VTNs) are Demand response service provider
VEN	Virtual End Node are Demand Response customer
IEC	International Electrotechnical Commission (IEC)

Glossary

CIM	common information model
DER	Distributed Energy Resources
DSO	Distribution system Operators; DSOs connected new loads and ensured that the distribution network was reinforced and maintained to be able to deliver power to consumers all year round
TSO	Transmission system operators; TSOs connected the generators needed to supply those consumers with power, and managed the real-time flows on the network
RSC	RSCs are companies owned by their clients, the TSOs. They perform services for the TSOs, such as providing a regional model of the grid or advanced calculations to tell TSOs which remedial actions are the most cost-efficient, without being constrained to national borders.
ENSTO-E	The European Network of Transmission System Operators, represents 42 electricity transmission system operators (TSOs) from 35 countries across Europe,

SCADA : Introduction

SCADA stands for Supervisory Control And Data Acquisition. SCADA is a system of different hardware and software elements that come together to enable a plant or facility operator to supervise and control processes.

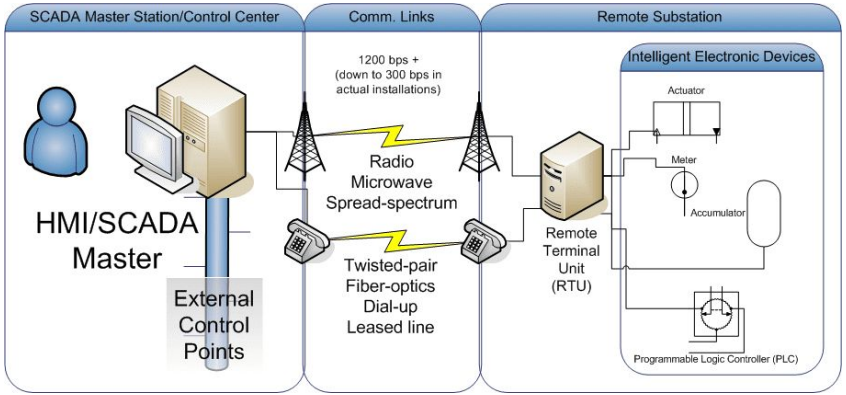
Key features
Supervision:
Computers process the data and let personnel in charge to oversee and direct the status of the power system using the acquired data. Personnel in charge were often operators and engineers who monitor the information remotely or locally. Now, the master station is tasked to supervise most of the system.
Control:
Control in SCADA refers to sending command messages to a device to operate the Instrumentation and Controls system (I&C) and power-system devices.
Data collection:
Instead of collecting data and filling datasheets by hand, SCADA automatically compiles information in real-time. SCADA gathers data from hundreds or even thousands of sensors at a given time. It also generates backlogs for later analysis.

- Data communication:

SCADA delivers information to a central hub. A communication network transport all the data gathered from sensors. Earlier systems had radio or modem. Today, SCADA data is transferred over internet protocol (IP) and Ethernet.

- Data presentation:

SCADA interacts with human operators through work-station computers that deploy the human-machine interface (HMI). The master station presents a widespread view of the whole system and alerts the operator by visual display or alarm sound.



A typical scada architecture

https://www.allumiax.com/blog/scada-and-its-application-in-electrical-power-systems

Power Industry: Miscellaneous Concepts

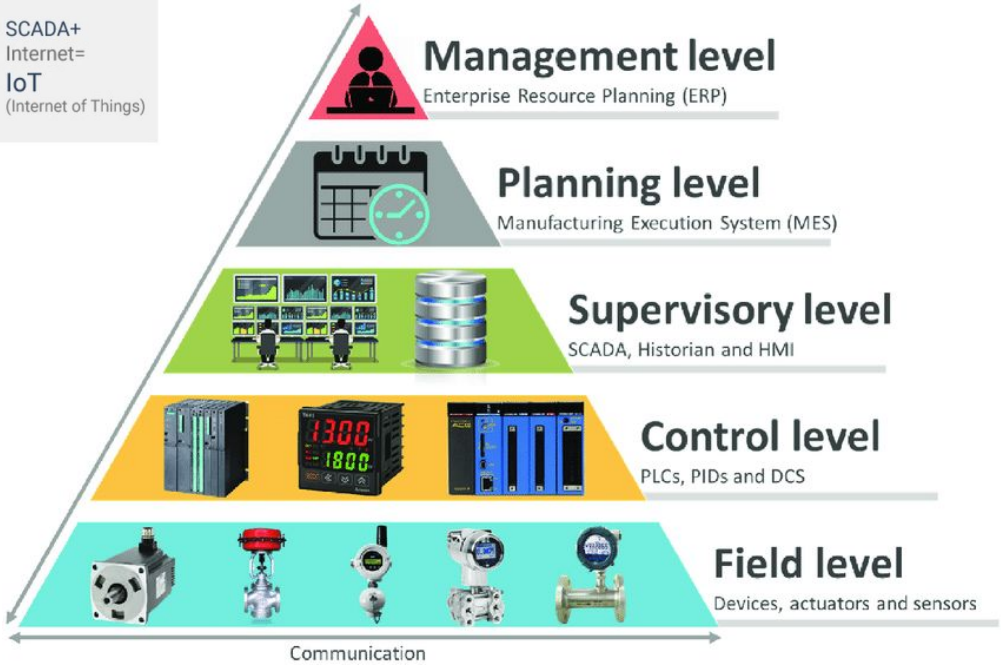
Industrial Automation

Industry 1.0
Manual Production+
Steam Power=
Industry

Industry 2.0
Industry+
Electricity=
Mass Production

Industry 3.0
Mass Production+
Computers=
SCADA
(Supervisor Control and Data Acquisition)

Industry 4.0
SCADA+
Internet=
IoT
(Internet of Things)



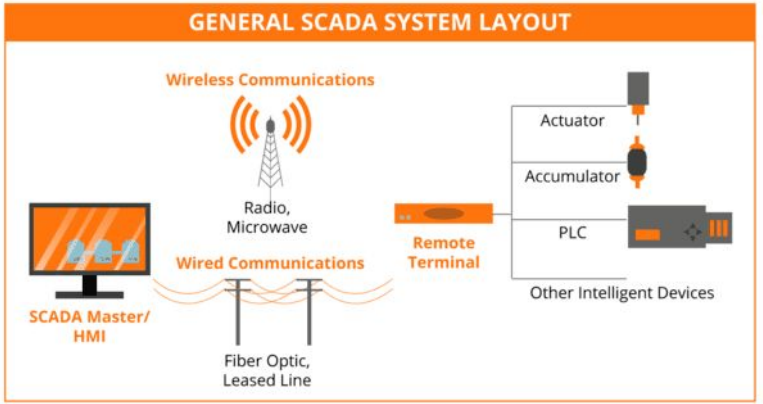
SCADA Components and its functions

Sensors:
Field instruments are an array of transmitters, monitors, and sensors. Sensors help its users to measure and collect data from various locations.

Conversion units:
Conversion units are the computerized units deployed at a specific location in the field to receive and interpret the data from sensors. They convert the information they receive into digital format, which is then sent to the centralized system to display. The two most common types of conversion units used in a SCADA system are PLCs and RTUs.

Programmable logic controllers (PLCs): The programmable logic controller is an industrial digital computer designed for output arrangements and multiple inputs. PLC is used sometimes in place of other conversion units due to their versatility, flexibility, affordability, and configuration. However, one may need good programming skills to make the most out of it.

Remote terminal units (RTU): The RTU is a microprocessor-controlled electronic device that interfaces objects in the physical world to a distributed control system or SCADA system by transmitting telemetry data to the system and/or altering the state of connected objects based on control messages received from the system.



Communication network:
The main function of a communication network within a SCADA system is to connect the Conversion units with the SCADA master station. The data can be transmitted through various communication platforms such as ethernet, telephone line, wifi etc.

Master unit:
The master unit is considered to be the supervisory computer system because they serve as the SCADA system centralized processing unit. Generally speaking, Human Machine Interface (HMI) is a user interface or dashboard that allows the operator to view and interact with collected and processed data. This interface is usually used to perform tasks like collecting data, creating maps, diagrams, sending out notifications, and making reports.

SCADA and IIOT

Scada and IIOT both does the below job

- Plant and process system monitoring
- Industrial process and machine control (manual and automated)
- Data collection and analysis
- Alarm monitoring and notification
- Reporting

	SCADA	Industrial IoT
Sensors	Wired connection to a PLC	Wireless connection to a database via the internet
Data collection & storage	On premises	Cloud-based
System type	Proprietary system, often by PLC & sensor manufacturers	Open standards system that collects data from many sources (e.g. MQTT)
Scalability	Costly to add sensors and make modifications	Easy to add sensors and make modifications
Interoperability	Limited interoperability, OPC often used for data gathering	Open standards enable diverse systems to interoperate
Integration	Poor integration across vendors	Strong integration across vendors

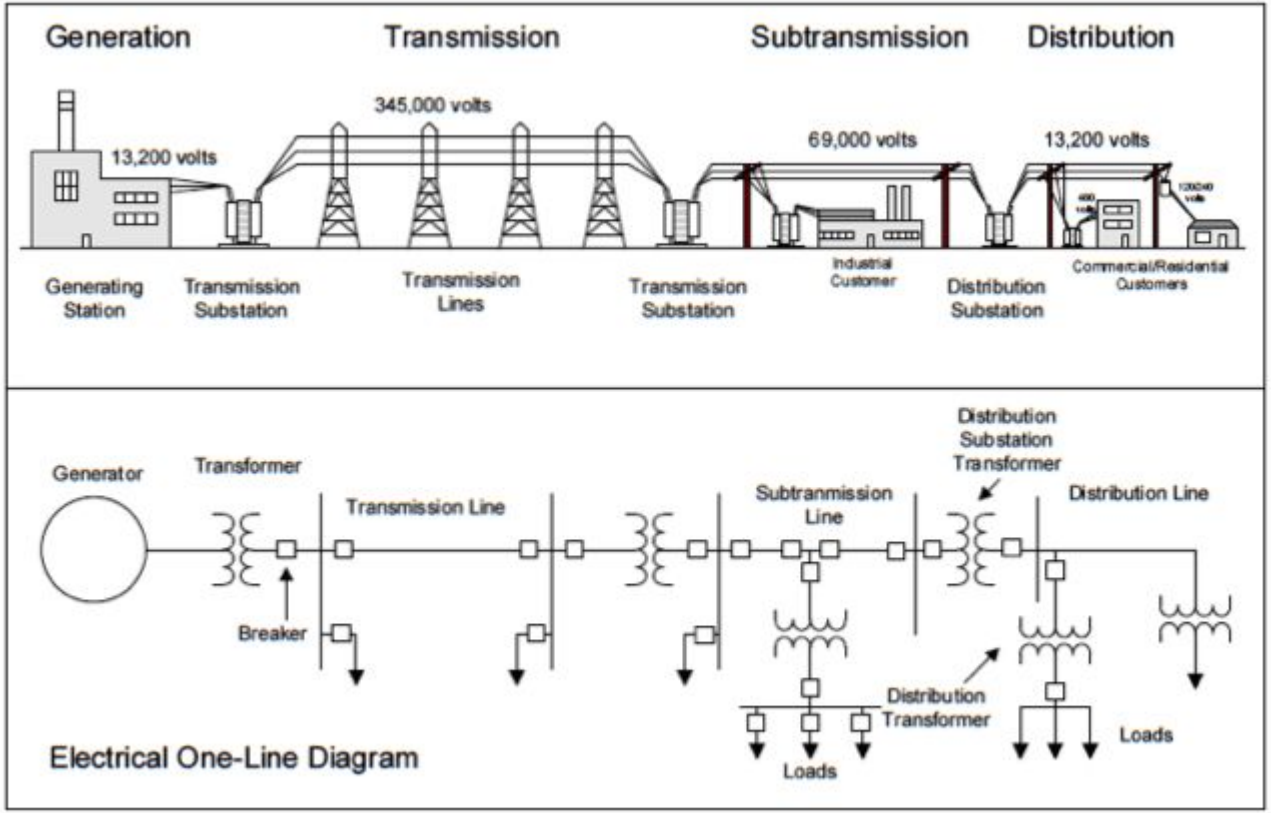
So are we going to replace SCADA with IOT

Companies will still need control systems to monitor and manage their equipment; however, the tools with which they do this will become more internet-based, more cloud-based, and capable of managing even more data. The underlying business case for legacy SCADA systems established decades ago still applies, but the way they are implemented will change with IoT.

https://www.biz4intellia.com/blog/industrial-iot-vs-scada-which-is-more-powerful/

https://www.3agsystems.com/blog/iot-vs-scada

Electrical Grid



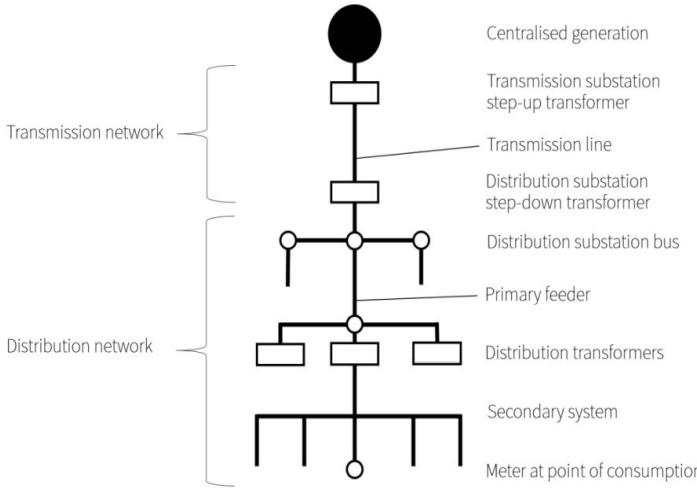
Electrical Grid

An electrical grid is an interconnected network for electricity delivery from producers to consumers. Electrical grids vary in size and can cover whole countries or continents. It consists of:

power stations: often located near energy and away from heavily populated areas. Nuclear, thermal, hydro power plant.
Substation: electrical substations to step voltage up or down.

- **Step up transformer/Transmission substation:** Step voltage up to carry long distance.
- **Distribution substation:** transfers power from the transmission system to the distribution system of an area. Step Down transformers reduces the voltage to suitable for local use.

Apart from these substation does
Switching and isolating the circuits for maintenance. Switching is also an important function of substations. Closing down a feeder circuit when the load demands are high needs to be done for the safety of the generating plants.
Load shedding: When the power demand is more than the supply, the substations do load shedding on distribution circuits to maintain balance across the electrical network.
Correction of power factors circuits: The power factor has to be kept at the correct value when reactive loads are there to protect the generating plant and increase efficiency. Read this link for more information on how power factor correction saves power.
Safety devices like circuit breakers and fuses: These safety devices are provided for protecting the machinery on the distribution circuit as well as in the substation against high short circuit currents.
Busbars: It contains bus bars for splitting the power for distribution: Thick bars of copper to which various distributing circuits are connected by nuts and bolts are known as bus bars.



Transmission Line: High voltage transmission lines deliver electricity over long distances. The high voltage is required to reduce the amount of energy lost during the distance.
electric power distribution: Distribution to individual customers, where voltage is stepped down again to the required service voltage(s)
control centre: The substation control system is complete system by which all the events , measurements operation and control of the substation is achieved from the local PC as well as the Remote control centre ..

Smart Grids

Currently it is still very difficult for consumers to see how much electricity they are using, but smart grid devices are quickly being developed. It is hoped that by being able to monitor how much electricity they are using, consumers will use less of it, subsequently cutting energy bills and, moreover, pinpointing off-peak hours to run their energy-intensive machines.

Optimises assets and operates efficiently
A Smart Grid will be able to generate more power through the existing systems by optimising them, allowing the reduction of power-flow waste and maximising the distribution of lowest-costgeneration sources. The harmonisation of local distribution with interregional energy flows will improve thecurrent use of grid assests, reducing grid congestion and potentially outages / disruptions.

Variety of Generation Options
With CO2 emissions on the increase and primary sources of energy running out it is imperative that new sources are found and integrated into the grid system. The current electricity grid cannot facilitate energy being drawn seamlessly from a variety of energy sources via a number of distributed technologies, but this is the aim of the Smart Grid.

Accommodates all generation and storage options
All sources will be interconnected allowing consumers to access a general and renewable generated sourceof energy. Energy storage will also be available ensuring none is wasted, and that energy can be tapped at a late date should the need arise.

Demand Response
Consumers are changing what they need from a power supplier and are moving towards flexible energy, cheaper alternatives and the option for microgeneration, all of which are not currently facilitated by the electricity grid. The development of the Smart Grid and associated "smart" technologies and devices will allow users to have a more direct control over the energy they use on a day-to-day basis.

Self-healing
Automatically detects and responds to grid problems, ensuring quick recovery after disturbances. The incorporation of microgrids also means that affected areas can be isolated from the main network as to cause minimal disruption to services

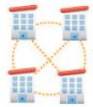
Power for 21st Century Needs
Power outages and quality issues cost businesses billions every year. A Smart Grid will reduce downtimes issues ensuring everyone can obtain power when they need it with solutions at both a system and consumer level

Electricity Market
Creating an open market where alternative energy sources can be sold to customers regardless of location. Microgeneration of electricity will also be a viable source of energy and will potentially contribute a good source of income to local economies.

Energy seamlessly drawn from a variety of sources

Microgeneration
Energy obtained on a small scale can reduce demand on the grid

Smart Meters
These record usage in real-time for the purpose of billing and monitoring and can also choose periods of the day from which to draw power i.e. during off-peak to save money



Larger Network (Offices etc)
Can generate own power through solar panels, wind turbines and in turn can supply energy back to the central network grid

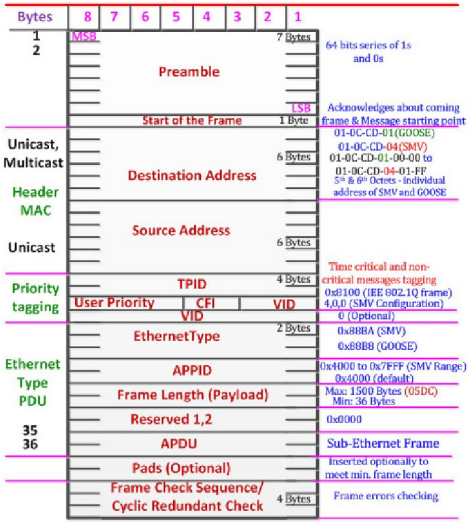
Isolated Microgrids
If there is a disturbance in the grid the affected microgrids can be isolated from the central grid to ensure minimal disruption to services

Power Storage
Energy that is generated during non-peak times can be stored for potential future usage, to ensure minimal wastage

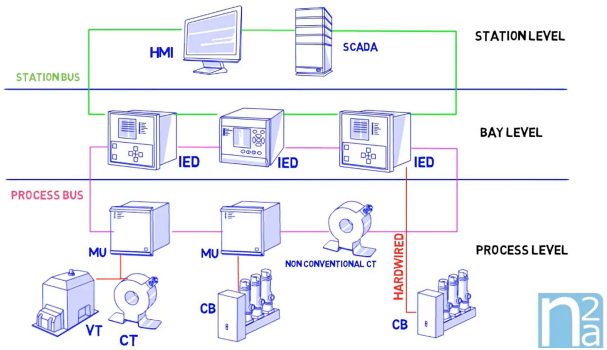
Sources: Office of Electricity and Energy Reliability and European SmartGrids Technology Platform

IEC 61850

The power industry today has a number of unique protocols, many proprietary. The need for IEC 61850 as a way to provide a single, open, object-oriented protocol. The protocol is object-oriented and implemented by using a producer/consumer model, incorporating Quality Of Service (QOS) and multicast to allow any unit to communicate with other units. IEC 61850 also takes advantage of the Manufacturing Message Specification (MMS) an international standard (ISO 9506) dealing with messaging system for transferring real time process data and supervisory control information between networked devices and/or computer applications.



Goose message header



Demand Response

What is Demand Response?

Demand response is a strategy used by electric utility companies to reduce or shift energy consumption from peak hours of the day, when the demand for electricity is thegreatest to leaner demand periods. It involves allowing customers to choose non-essential loads, which can be shed by the customers themselves or by the utility, at peak times. It is a pre-arranged agreement between the Utility or intermediate agencies like aggregators with the consumer with specific conditions of load, price and time intervals. Since power plants and transmission systems are designed to respond to the highest potential demand, lowering peak demand during demand intensive times of the day helps utilities reduce overall installation costs, operating costs and mitigate potential grid failures.

There are three main types of demand response which includes emergency demand response, economic demand response, and ancillary services demand response.Each addresses critical system needs.

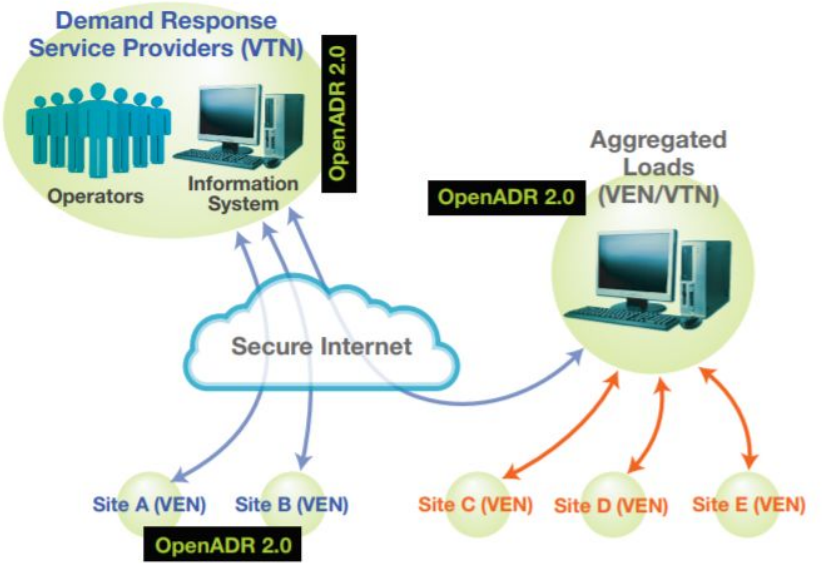
- ***Emergency Demand Response*** is used to mitigate the potential for blackouts or brownouts during times when demand threatens to exceed supply resources. This typically occurs on days of extreme hot or cold temperatures when heating and cooling systems are causing greater demand on the grid.

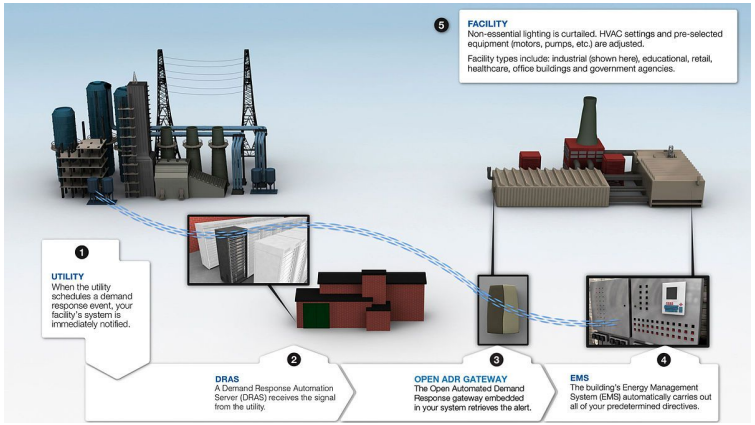
- ***Economic Demand Response*** is employed by utilities to avoid the significantly higher costs of producing energy during peak demand times of the day that is associated with ramping up "peaking" power plants to meet higher than expected demand.

- ***Ancillary Service Demand Response*** is used to support the transmission of electricity to loads in a manner consistent with reliability requirements that are imposed on utility companies by industry regulators.

Open ADR

Open Automated Demand Response (OpenADR) provides a non-proprietary, open, standardized and secure demand response (DR) interface that allows electricity providers to communicate DR signals directly to existing customers using a common language and existing communications such as the Internet.
The key services
Event Service (EiEvent) - Used by OpenADR servers or VTNs to send demand response events to clients or VENs, and used by VENs to indicate whether resources are going to participate in the event. Events can contain one or many different segments (intervals) for different prices, curtailment levels, or other signals pertinent to the DR program.
Report Service (EiReport) - Used by VENs and VTNs to exchange historical, telemetry, and forecast reports. Resources can report their status, availability, and forecasts, but also real time energy and curtailment readings. The report service also has a placeholder for GreenButton data.
Opt Service (EiOpt) - Used by VENs to communicate temporary availability schedule to VTNs or to qualify the resources participating in an event. This helps both the DR program operators and the participants to better plan their resources.
Registration Service (EiRegisterParty) - Initiated by the VEN, and used by both VEN and VTN to exchange information required to ensure interoperable exchange of payloads.
Poll Service (OadrPoll) - Used by VENs to poll the VTN for payloads from any of the other services. This is specifically important for simpler devices that cannot fully support additional messaging.





Micro Grid

A microgrid is a self-sufficient energy system that serves a discrete geographic footprint, such as a college campus, hospital complex, business center, or neighborhood.

Within microgrids are one or more kinds of distributed energy (solar panels, wind turbines, combined heat & power, generators) that produce its power.

In addition, many newer microgrids contain energy storage, typically from batteries.

Interconnected to nearby buildings, the microgrid provides electricity and possibly heat and cooling for its customers, delivered via sophisticated software and control systems.

1. A microgrid is local

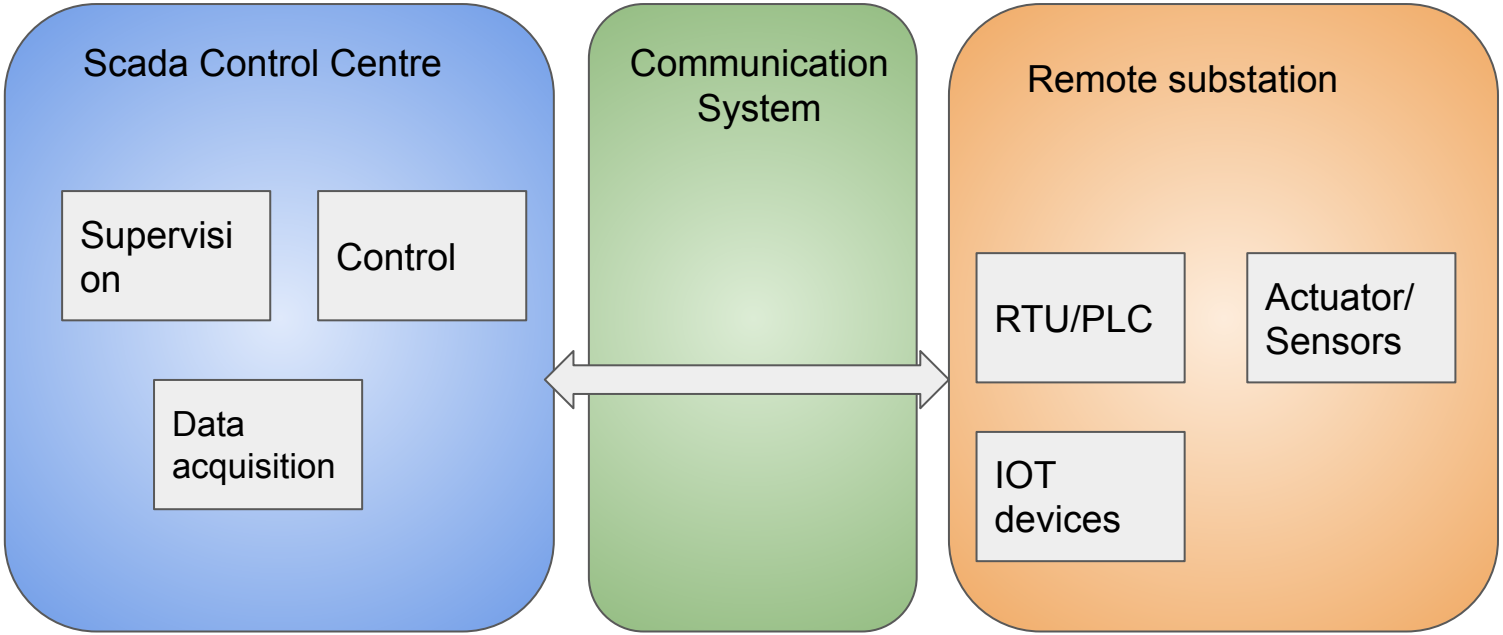
it creates energy for nearby customers.

2. A microgrid is independent

Second, a microgrid can disconnect from the central grid and operate independently. This islanding capability allows them to supply power to their customers when a storm or other calamity causes an outage on the power grid.

3. A microgrid is intelligent

Third, a microgrid – especially advanced systems – are intelligent. This intelligence emanates from what's known as the microgrid controller, the central brain of the system, which manages the generators, batteries and nearby building energy systems with a high degree of sophistication.

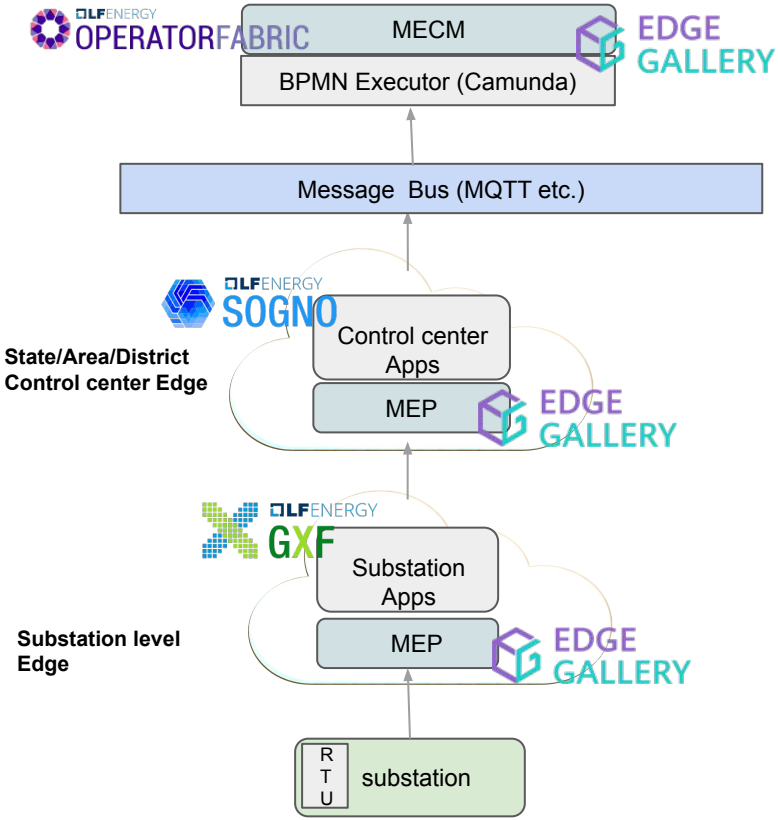


A typical SCADA architecture

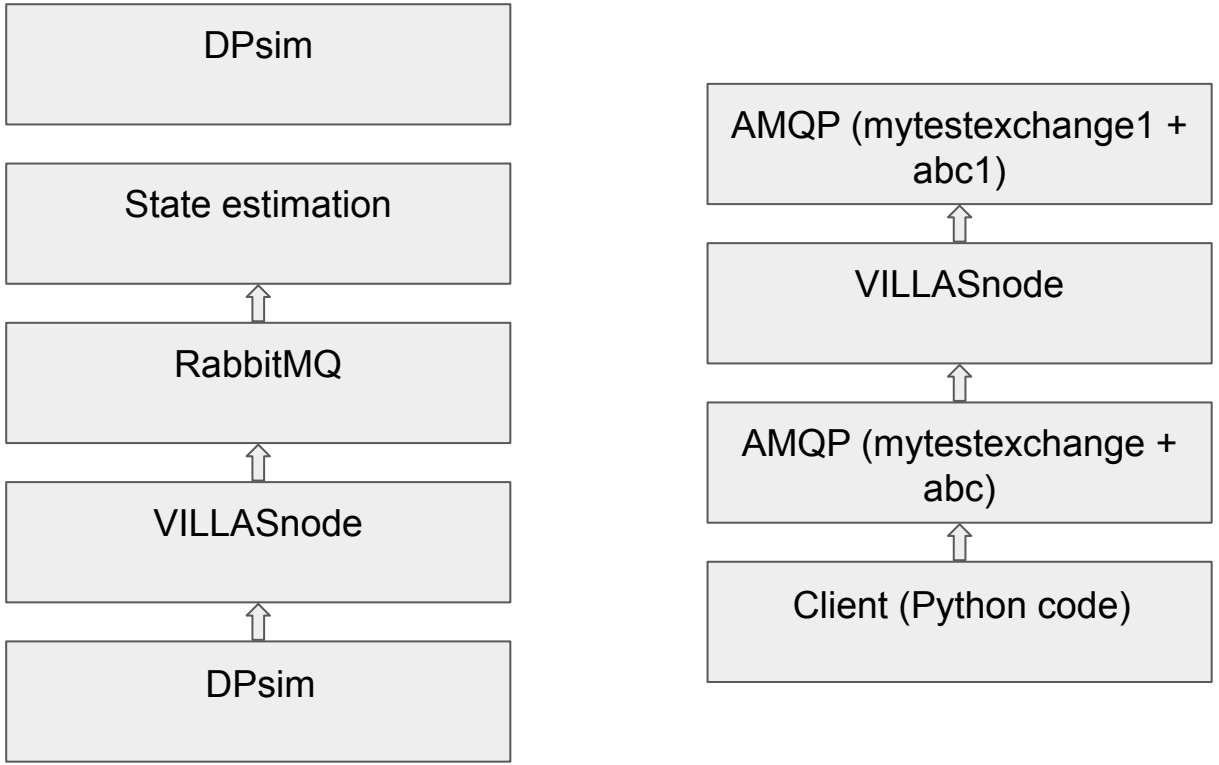
RIAPS vs EdgeGallery Comprehensive study

Feature	EdgeGallery	RIAPS
Architecture specification	Microservice Based architecture. Distributed	Component based architecture. Components talk to each other over messages. Schedules each components on thread from threadpool. Distributed Realtime [Application from different nodes talk to each other over TCP/Ip] [Can be compare to VRPv8.]
Developer portal	Generates code for capabilities App packaging design App sandbox testing design	Generate code for component framework (python or c++) based on model file App packaging
App store	Appstore App distribution etc.	NA
Orchestrator	Orchestrator App packaging App rules App distribution App deployment Dashboard	Orchestrator App packaging App distribution App deployment Simple dashboard and CLI
Platform Services	App lifecycle management Service Registry and Discovery Application can be VM or container (No language specification) Support application scalability Access hardware devices using yaml(GPU etc) API gateway Various capabilities Like AI and others	Simple app lifecycle management(start, stop, remove, fault tolerance/restart) Service registry and discovery Application should be executable/python files and adhere to RIAPS framework Can't be dynamically scalable Has device components to access hardware(actuator, circuits etc) and protocols (modbus etc) interfaces

Feature	EdgeGallery	RIAPS
Distribution	Container based	Prepackaged VM(ubutnu 18.04 based) SD card
Security		



- With GXF and SOGNO integration we can enable Power sector protocols, capabilities in EG. Also can leverage sample applications from those project like public lighting, state estimator etc.
- With operator fabric integration we can offer business process model execution & monitoring for utility sector(power, water etc) via EG.


DPsim
State estimation
RabbitMQ
VILLASnode
DPsim
AMQP (mytestexchange1 + abc1)
VILLASnode
AMQP (mytestexchange + abc)
Client (Python code)