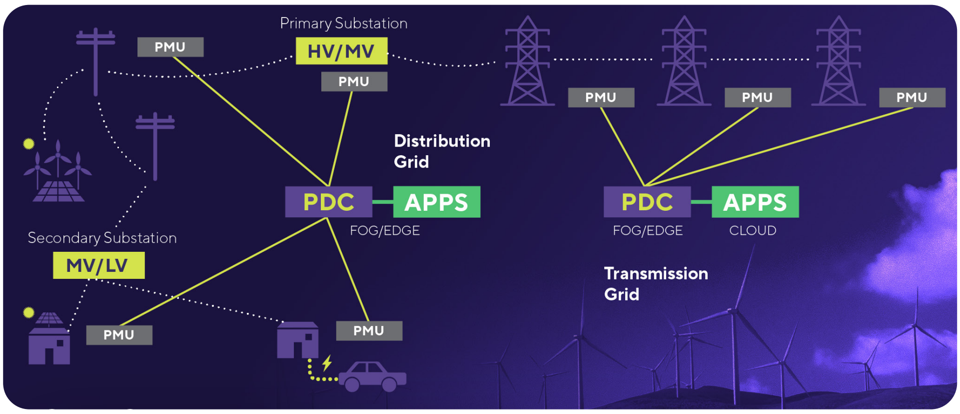
Intelligent Power Grid

The introduction of a massive number of renewable energy sources requires a highly monitored distribution grid that can coordinate energy producers and consumers in real-time. The emerging power grid architecture will rely on a large number of measuring devices such as PMUs (Phasor Measurement Units) strategically positioned on the power grid to measure electrical quantities, with real-time data collection and synchronization carried out by PDCs (Phasor Data Concentrators).
The synchronized data collected by PMUs and managed by PDCs serves as crucial input for the Grid State Estimation algorithm, which is the basis for real-time applications such as monitoring, control and protection of the grid, and offline applications such as archiving and offline analysis. Traditionally, PMUs have been deployed within the transmission grid. However, the evolving power grid demands a more comprehensive monitoring approach, including the distribution grid.



PROBLEM

The introduction of PMUs into the distribution network brings about various challenges, including:

- **Scalability:** The number of PMUs required for the power grid to be observable is significantly higher for the distribution case. While hundreds of PMUs are needed for the transmission network to be observable, the distribution network will require a number of the order of thousands. This implies the need to manage a massive number of distributed devices and their corresponding data flows.

- **Resilience:** With thousands of devices in play, enhancing the resilience of the ICT infrastructure for data collection is crucial. For instance, managing faults or planned maintenance should be automated, as well as the possibility for the above devices when disconnected from the network and/or unable to access companion services running in the cloud.

- **Latency:** The system must support large-scale data processing in real-time, meeting the specific latency constraints of the targeted applications (of the order of tens of milliseconds for control applications)
- **Cybersecurity:** The power grid is a critical infrastructure for the country and, as such, must be protected from any malicious attack, including the ones targeting monitoring and control services.

CURRENT APPROACH

While the transmission grid already hosts PMUs typically managed centrally by a single or few PDCs, the introduction of PMUs in the distribution grid is still at an experimental level. Nevertheless, the massive number of PMUs and PDCs in the future grid makes this centralized approach (a) hardly scalable, (b) not resilient to network failures or forced disconnections (e.g., to preserve a portion of the network from an ongoing attack).

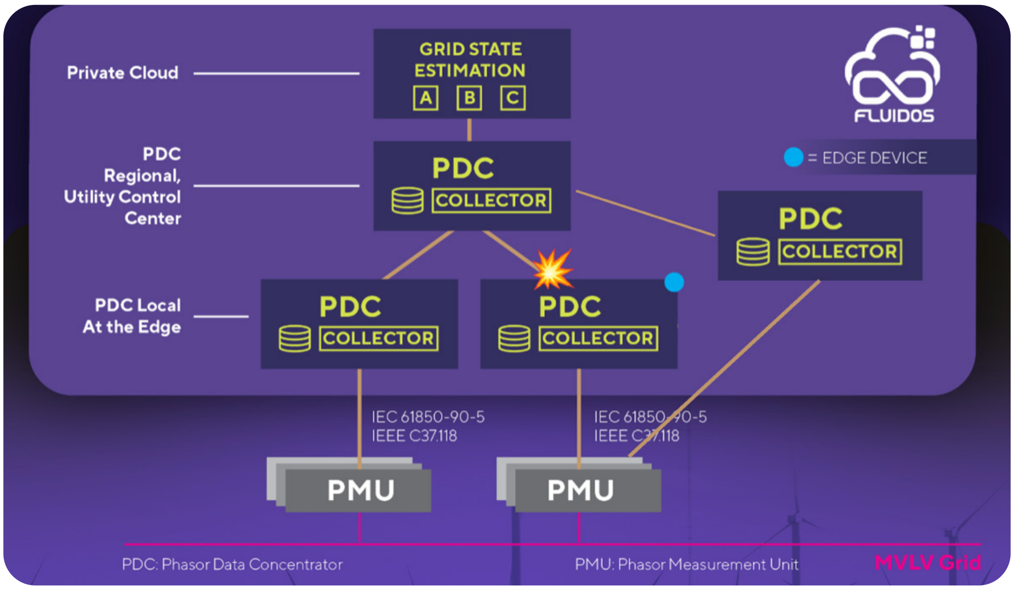
FLUIDOS APPROACH

Traditionally, PDCs were monolithic applications running on dedicated hardware; however, with the increasing computational power available at lower costs, this is changing in recent years. Experimental efforts are underway to virtualize applications and utilize Kubernetes for orchestrating the deployment of PDCs and real-time analysis applications at the edge. This is aimed at reducing latency issues and improving resiliency, avoiding the need of operator physical assistance in case of outages, and paves the way for their usage within a FLUIDOS-based environment.
In fact, FLUIDOS creates a continuum of resources from the edge to the cloud and enables the displacement of workloads, such as data collection and analysis processes, based on specific scenarios (faults, reconfiguration, maintenance). The main features of the approach enabled by FLUIDOS are:

COMPUTING CONTINUUM FLUIDOS would enable PDCs and analysis applications to continue functioning even if communication with control centers is interrupted by migrating PDC services to an adjacent node in case of fault.

CYBERSECURITY FLUIDOS ensures service isolation from other applications on the hosting node with different usage permissions. It also leverages logging and anomaly detection capabilities, and provides survival capabilities in case a portion of the grid is disconnected from the main network, hence preserving its operations in case of a cyber attack.

INTENT-BASED ORCHESTRATION FLUIDOS can automatically orchestrate PDCs based on the latency between the node and PMUs, thereby improving the power grid state estimate or responding to faults.



FLUIDOS ADVANTAGES

- **Scalability**: Effectively managing a high number of PMUs.
- **Resilience:** The capacity to tolerate and respond to faults, forced disconnections, and (planned) maintenance.
- **Application Performance:** Improved performance by satisfying the application requirements.
- **Cybersecurity:** Enhanced security measures.

KEY PERFORMANCE INDICATORS (KPI'S)

Reduction of software update time on N geographically distributed devices: from O(N) duration to O(1)

Support for time-sensitive services also on nodes without GPS hardware: synchronization error < 32us

Scalability of phasor data processing at local grid distribution level: >= 1K secondary stations

No electrical downtime in presence of an ICT fault

Reduction of phasor data loss after a processing chain reconfiguration: >= 80%.