Industry IoT Consortium

Three Tier IoT Distributed Energy Resource System Pattern

An Industry IoT Consortium Design Pattern

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Authors

Alan McGibney (Munster Technological University), Eddie Lee (Moxa).

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1 GENERAL INFORMATION

1.1 NAME

A three-tiered architecture pattern for IoT Distributed Energy Resource Forecasting and Condition Monitoring Systems.

1.2 PATTERN TYPE

System Pattern.

1.3 DESCRIPTION

A three-tier architecture for the continuous monitoring of energy-generating field systems and assets. The system comprises an edge tier consisting of multiple IoT sensors, controllers and advanced metering infrastructure (AMI) that are attached to energy-generating assets (e.g. solar panel). These IoT devices monitor performance metrics and parameters (e.g. solar radiation, angle, temperature, wind speed and watt output).

The edge tier is connected via the internet to the platform tier where data services (data processing, storage, distribution) and analytic capabilities (e.g. modelling & machine learning) are provided. These data services are accessible via open application programming interfaces (APIs) e.g. REST. The APIs provides a mechanism to facilitate data services to be used by decision-support tools and applications for the end user situated within the enterprise tier.

This pattern is based on a Three-Tier Architecture pattern Using similar principles allows for a simple functional partitioning across tiers without restricting the specific implementation of functions implemented in a real system governed by specific use case needs or requirements. For example, the IIRA allows for functions to be implemented across all tiers, for example application logic and control conditions could be implemented at the edge tier to enable intelligent management of assets at the edge (e.g. for diagnostics, prognostics and optimization on the assets). In addition, services from all tiers can be leveraged in others to support and share data, context and information forming an end-to-end system

2 CONTEXT

With a shift towards local generation and maximizing the use of renewable technologies, the stability, reliability and resilience of such systems is becoming increasingly critical. IIoT can play an important role to provide capabilities to dynamically monitor, coordinate and control distributed energy resources and systems with particular emphasis on its operating state relative to maintain local stability. To achieve a higher level of operational efficiency, the system shall continuously sense and forecast local power generation and conditions.

Given the complexity and diverse set of energy resource equipment, loads and dynamic nature of operation such systems must be managed with real-time distributed control.

The goal of this system pattern is to define the key functional components that enable the monitoring of a set of properties and parameters of distributed energy generating assets that can in turn be used to predict future energy availability. This information can then be used as an input to provide decision support and promoting the optimization and efficient use of energy resources. Assets can be monitored remotely and proactively supported by advanced models and data management tools.

Such systems involve the sensing, collection, aggregation and processing of large amounts of data, interpreting these data sets to obtain operational intelligence and providing decision support to create and implement operational plans (could also support semi-autonomous or autonomous behaviors in such systems).

The three-tiered approach establishes a conceptual common architecture that can be used as a higher-level starting point for conceptualizing and designing IIoT systems for Distributed Energy Resource Forecasting and Condition Monitoring systems. This will offer a guide for the specification of interoperable architecture building blocks and collating implementation specific components that when assembled form a complete system.

This architectural pattern is applicable across other application areas that involves energy generation and consumption (e.g. smart grid, smart buildings, asset and facilities management).

2.1 Typical/Known Scenarios

Real-time/Continuous monitoring of:

- operational performance.

Asset tracking and condition-based monitoring to:

- provide a historical record of energy generation and system performance.

Implementation of data driven services (analytics) that enables:

- forecasting of generation and demand loads and
- detect anomalies and predict potential failures.

2.2 Typical/Known Problems Addressed

The following outlines the domain-specific challenges that have been identified in the context of the distributed energy asset management:

- integration & interoperability of heterogenous data,
- scalability and distributed data management for energy performance monitoring,
- enabling operators to monitor energy assets remotely and in “real time”,

- enabling the collection of data over long periods to inform operational optimization,
- enabling the aggregation, processing and structuring of large data sets to support the creation of reliable models for predictive analysis and forecasting, and
- data-driven coordination and management of DER.

3 Model

3.1 Model

The architecture model comprises a set of components that can be distributed across three architectural tiers, edge, platform and enterprise as shown in Figure 3-1.

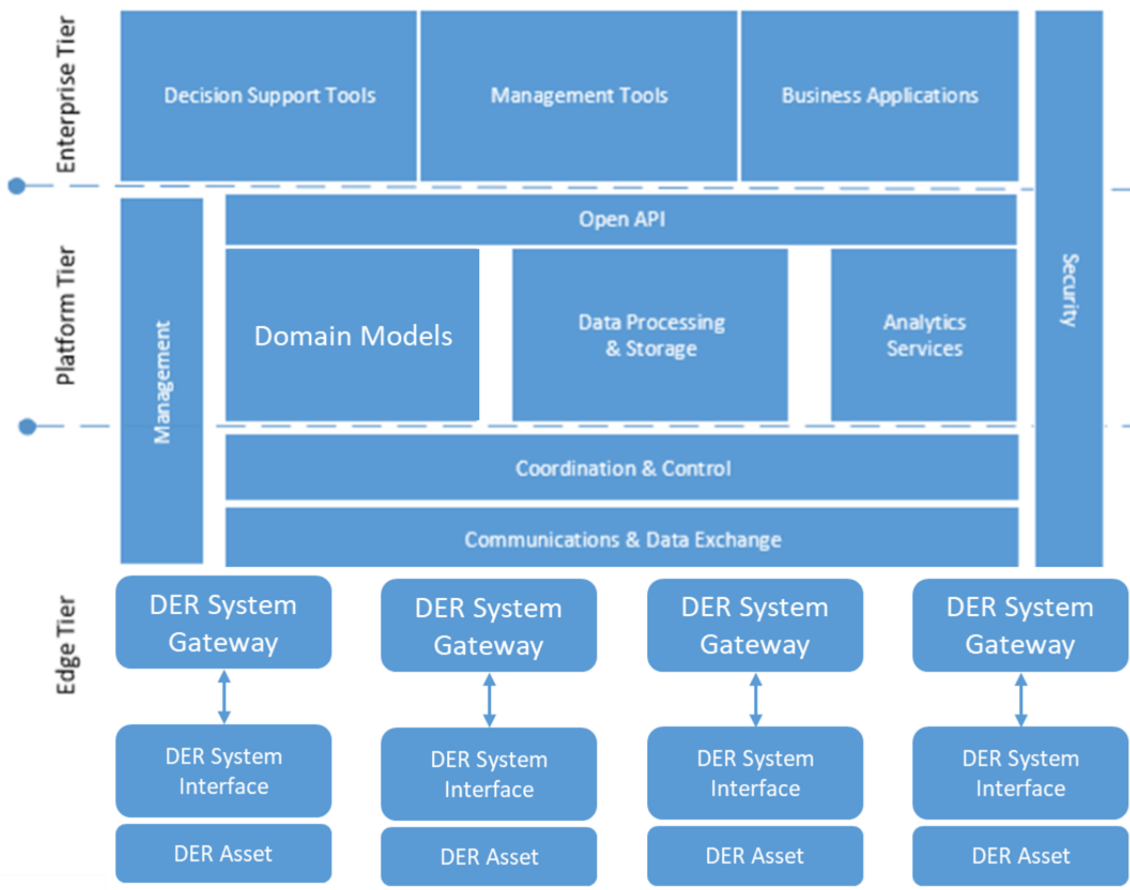

Figure 3-1. Three-tier Architectural System Pattern for DER forecasting and condition monitoring.

Required components:

- [edge] one or more sensor connections (components with sensing capabilities, e.g. meters) that connect to a DER asset (e.g. solar panel, electricity meter),
- [edge] one or more IoT protocol interface (e.g. OPC, Modbus, MQTT),
- [edge] one or more edge gateways that act as a secure connection between edge and data services, enabling secure edge communications (Wired, WiFi, LTE, 5G),
- [platform] one or more data processing/distributing services,
- [platform] data-management services (storage, historian, backups),
- [platform] data-security services (e.g. encryption, compliance, GDPR),
- [enterprise] secure application programming interface (API) for data access and
- [enterprise] decision-support tool (user interface).

Optional components:

- [edge] additional system connectors and interfaces
- [edge] external service integration (e.g. weather service)
- [platform] domain-specific models
- [platform] operational dashboards and analytics services (e.g. visualization)
- [platform] historical data archiving and interaction traceability
- [platform] control action (provide feedback/control actions to edge)
- [enterprise] data-management tools (e.g. data sharing governance)

The following provides a brief summary of the architectural components:
Edge components:

- DER asset: Any asset of a DER system (e.g. solar panel, wind turbine, generator) that has IoT sensors attached or embedded (e.g. energy meters, accelerometers, irradiance sensors).
- DER system interface: IoT protocols and connectivity interfaces to sensors.
- DER system gateway: edge-mediated connectivity to cloud services (e.g. Edge gateway devices or software application interface). This can support real-time analytics at edge.
- Communications and data exchange: data distribution service, data protection mechanisms (e.g. encryption, validation and data quality checks).
- Coordination and control: manage interaction of decisions made within upper tiers to the physical assets via edge tier.

Platform components:

- Domain models: Domain-specific models can be semantic models, simulation or mathematical models used for DER management (e.g. energy models, weather models and simulation).

- Data processing and storage: Scalable data processing and storage supporting flexibility for increasing data volumes. Include data annotation, tagging and validation.
- Analytics services: Data-driven analytics and modelling services, can include support for machine learning pipelines, e.g. data preparation, normalisation, validation, model training and deployment.
- Open API: Provides common interface for interaction between platform and enterprise tiers.

Enterprise components

- Decision-support tools – Any end-user tools that offers insight and decision support (e.g. energy forecasting, control parameter optimisation)
- Management tools – cross vendor management, data administration, policy specification, backup and disaster recovery.
- Business applications–integration with existing business processes.

Cross-cutting components

- Management: This component facilitates data management and orchestration of platform services. This supports data governance, access control and audit trails.
- Security: This incorporates security for network, communications, software systems, compliance, security and zero trust provisioning of IoT devices and services to ensure resilience and robust operation.

4 GUIDANCE

The three-tier pattern for IoT enabled Distributed Energy Resource Forecasting and Condition Monitoring can be used initially to align use case requirements to specific functional components required. This should inform a mapping of vender specific tools and services that can be utilized to enable the required functionality.

Each architecture component can be expanded with concrete implementation details with the reference architecture providing a level of abstraction to represent the IoT system functions.

4.1 ADVANTAGES

The following general advantages can be achieved using the proposed model:

- end-to-end system from data to insight,
- can leverage existing components across all tiers and
- avoid vendor lock-in through use of modular components across all architectural tiers.

Table 4-1 provides an overview of how the model addresses the specific domain challenges identified:

Domain Challenges	How System Pattern Addresses Challenge
Integration & interoperability of heterogenous data	DER system gateway allows to interchange connectivity to heterogenous data sources or end points. This aligns with the gateway mediated architecture pattern.
Scalability and distributed data management for energy performance monitoring	Three-tiered architecture allows for the deployment of data services across different tiers (edge, platform and enterprise) supporting scalability
Enabling operators to monitor energy assets remotely and in "real-time"	Open APIs provide access to data collected from the gateway devices to end user applications. Processed in platform tier for computationally intensive analytics and predictive capabilities.
Enabling the collection of data over long periods to inform operational optimization	Architecture proposes continuous data streaming enabled by gateway-mediated interaction with energy assets. Domain-specific models offer opportunities to build digital twins that become richer with more data received.
Enabling the aggregation, processing and structuring of large data sets to support the creation of reliable models for predictive analysis and forecasting	Platform tier allows for the deployment of data-driven services, domain specific models and data management capabilities. This can scale based on available compute infrastructure and also integrate with external services and capabilities where appropriate in a secure and trusted manner. Control strategies can also be deployed at this tier
Data driven coordination and management of DER	Primary focus is placed on monitoring and forecasting. However the proposed architecture facilitates the deployment of coordination and control functionality across the edge and platform tiers.

Table 4-1. Specific domain challenges identified by the proposed model.

4.2 Disadvantages

- three-tier pattern involves complex interaction across tiers,
- domain-model complexity and
- heterogeneous edge-system connectors and protocols.

4.3 Examples

Figure 4-1 shows a use case scenario with IoT-enabled condition-based monitoring for a solar farm.

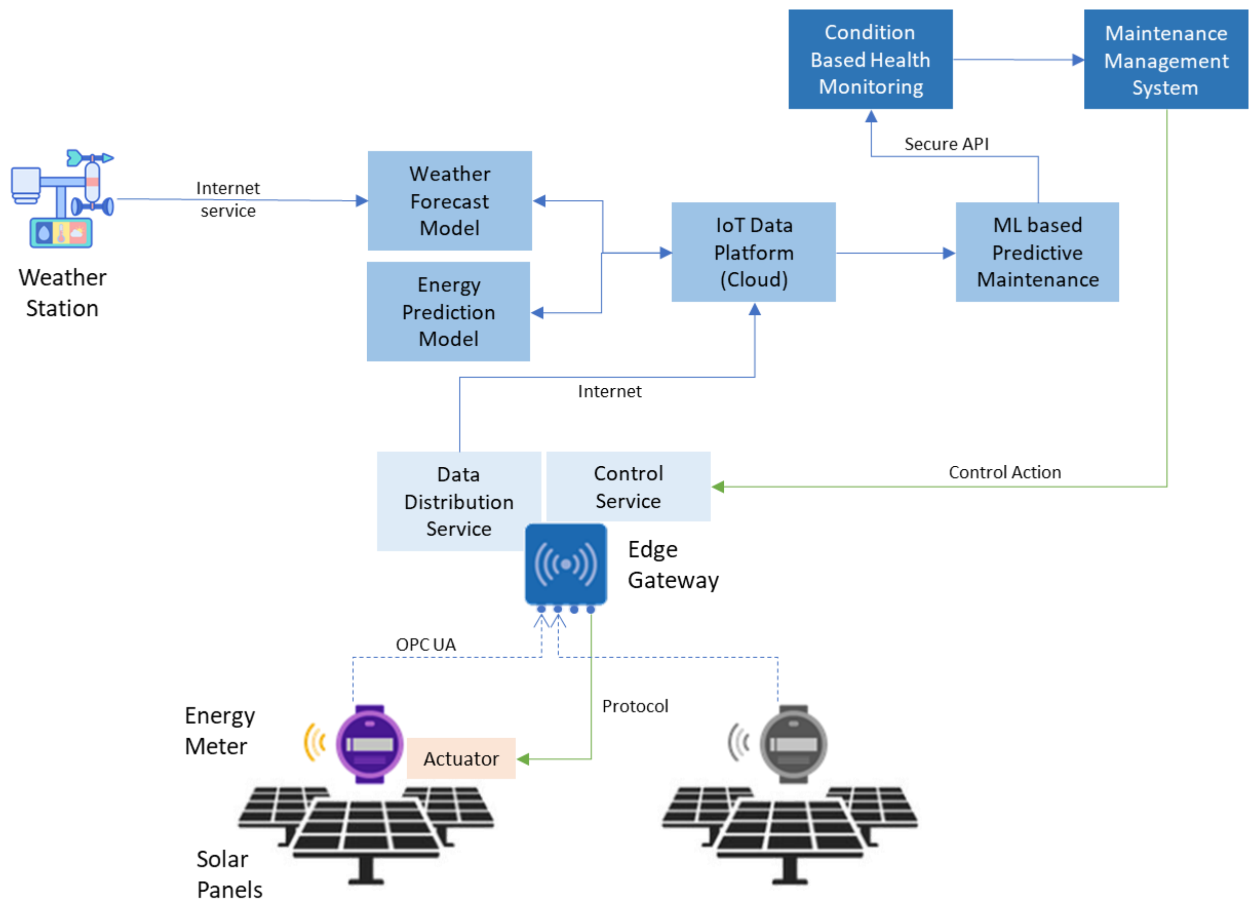

Figure 4-1: Solar farm monitoring using three-tier system pattern.

Table 4-2 provides a mapping of the solar farm components to the system pattern:

Use Case Entity	System Pattern Component	System Pattern Tier
Solar Panel	DER Asset	Edge
Wireless Energy Meter	DER Asset Interface	Edge
Tilt Actuator	DER Asset Interface	Edge
IoT Protocol	DER System Connector	Edge
Edge Gateway	DER System Connector	Edge
Data Distribution Service	Communications & Data Exchange	Edge
Control Service	Coordination & Control	Edge
IoT Data Platform		Platform
Weather Forecast Model	Domain Model	Platform
Energy Prediction Model	Domain Model	Platform
ML-based Predictive Maintenance	Analytics Service	Platform
Condition based health monitoring	Decision Support Tools	Enterprise
Maintenance Management System	Business Applications	Enterprise

Table 4-2. Mapping of solar farm components to the system pattern.

Authors & Legal Notice

This document is a work product of the Industry IoT Consortium Energy Task Group, chaired by Alan McGibney (Munster Technological University), Eddie Lee (Moxa).

Authors: The following persons contributed substantial written content to this document: Alan McGibney (Munster Technological University), Eddie Lee (Moxa).

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