



**GRID**  
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# Grid Architecture Glossary

July 2016



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## Foreward

For the terms listed here, this document provides the grid architecture definition only. Some terms in this glossary also may have a definition in the power systems domain. In such cases, this document provides the grid architecture definition only. For the power systems definition, and other power systems terms and definitions, please see the *GMLC Grid Architecture Power Systems Glossary* (LLNL-MI-723064).





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# 1.0 Glossary

**Abstraction:** The process of eliminating, hiding, or ignoring characteristics or aspects of a concept unrelated to a given purpose. An abstraction represents the essential characteristics of an entity that distinguishes it from all other kinds of entities; it defines a boundary relative to the perspective of the viewer.

**Actor:** A coherent set of roles that users of use cases play when interacting with the use cases.

**Adaptability:** Generally, the ease with which a system or component can be modified for use in environments other than those for which it was specifically designed. Adaptable grid systems or components should be flexible (susceptible to modification), versatile (having or capable of many uses), and extensible (able to be increased in scope).

**Adapts (quality):** An example of a grid quality. Notionally defined as adjusting to changing conditions on both fast (parametric) and slow (structural) time scales.

**Affordability:** The extent to which something is affordable, as measured by its cost relative to the amount that the purchaser is able to pay.

**Aggregation:** A special form of association that specifies a whole-part relationship between the aggregate (the whole) and a component (the part).

**Algorithm:** A prescribed set of well-defined rules or processes for the solution of a problem in a finite number of steps; for example, a full statement of an arithmetic procedure for evaluating  $\sin(x)$  to a stated precision.

**Architectural Element:** An element of a particular architecture. Examples of grid architectural elements are buildings, microgrids, storage, whole grid coordination, distribution system operators, and flexible distribution circuits.

**Architectural View:** A view of a **System** from the standpoint of a particular stakeholder.

**Architecture:** The set of significant decisions about the organization of a software system, including the following elements and their interfaces, their collaborations, and their composition: the selection of the structural elements and their interfaces by which the system is composed, together with their behavior as specified in the collaborations among those elements; the composition of these structural and behavioral elements into progressively larger subsystems; and the architectural style that guides this organization. Software architecture is not only concerned with structure and behavior, but also with usage, functionality, performance, resilience, reuse, comprehensibility, economic and technology constraints and trade-offs, and aesthetic concerns.

**Architecture, Grid:** A specialization of **System Architecture** that includes additional elements from control engineering, communications/networking, data management, organizational structure, energy/power markets, and utility regulatory structure. Grid architecture provides the discipline to manage the complexity and the risk associated with changing the grid in a manner that significantly reduces the likelihood of unintended consequences.

**Architecture, System:** The conceptual model that defines the components, structure, behavior, qualities, properties, and essential limits of a system. An architecture description is a formal representation of a

system, organized in a way that supports reasoning about the structures and behaviors of the system. System architectures are written, composed, or specified. Should be the product of a single architect or small team with an identified leader.

**Architecture Map:** Architecture maps represent the structure of the architecture and as such are crucial to the development of the architecture, as well as its analysis and assessment. Maps are the basis for numerical evaluation of whole architectures, individual architectural elements of subsets, and for differential analysis of competing architectures. See also **Two-Layer Diagram** and **Three-Layer Diagram**.

**Artifact:** A quantized piece of information that is used or produced by a process or an existing system.

**Association:** A structural relationship that describes a set of links, in which a link is a connection among objects; the semantic relationship between two or more classifiers that involves the connections among their instances.

**Attribute:** A named property of a classifier that describes a range of values that instances of the property may hold.

**Behavior:** The set of processes that fulfill a specific function or purpose.

**Block Diagram:** A diagram showing in schematic form the general arrangement of parts or components of a complex system or process, such as an industrial apparatus or an electronic circuit.

**Bottom-up:** The design of a system starting with the most basic or primitive components and proceeding to higher level components that use the lower level ones.

**Boundary Deference:** The explicit recognition of system and organizational boundaries with means to accommodate rather than override such boundaries.

**Chaotic System:** A dynamic system that is highly sensitive to initial conditions.

**Characteristics:** The properties and qualities of a system.

**Class:** A description of a set of objects or components which share the same attributes, operations, relationships, and semantics.

**Complex System:** A **System** made up of a large number of parts that interact in a non-simple way. In such systems, the whole is more than the sum of the parts, and it is non-trivial to infer the properties of the whole.

**Components:** Uniquely identifiable, non-trivial, nearly independent devices, individuals, organizations, organisms, elements, building blocks, parts or sub-assemblies that may be collected together to cooperate or to serve a common purpose.

**Composability:** Composability is a system-design principle that deals with the interrelationships of components. A highly composable system provides recombinant components that can be selected and assembled in various combinations to satisfy specific user requirements.

**Composition:** A form of aggregation with strong ownership and coincident lifetime of the parts by the whole; parts with non-fixed multiplicity may be created after the composite itself, but once created they live and die with it. Such parts can also be explicitly removed before the death of the composite.

**Conceptual Integrity:** A property of a **System Architecture** that minimally denotes being intellectually clean of unnecessary complexities or “exceptions”, and having solved similar problems in similar ways (see **Patterns**).

**Connectivity:** The state of being linked or joined together to enable some form of exchange. Connectivity is a basic form of structure.

**Conserves (quality):** An example of a grid quality. Notionally defined as using all resources sparingly, especially those resources that are not replaceable.

**Constraint:** An externally imposed limitation on system requirements, design, or implementation or on the process used to develop or modify a system.

**Context:** A set of related elements for a particular purpose, such as to specify an operation.

**Control Engineering:** An engineering discipline that applies control theory to the design of systems with desired behaviors.

**Control Loop:** An arrangement of control system components (for example, sensors, actuators, and control algorithms) with the intent of regulating a controlled variable at a set point. Control loops can be open or closed. An open-loop system is one whose output is a function of only the inputs to the system; a closed-loop system is one in which the output is fed back and compared to the input to generate an error signal, which is then used to generate a new output signal.

**Decomposition:** A type of modular decomposition in which a system is broken down into a hierarchy of components through a series of top-down refinements. See also **Top-down**.

**Delivers (quality):** An example of a grid quality. Notionally defined as the grid providing the amount of energy customers want, when they want it, and in the form they want.

**Dependency:** A semantic relationship between two things in which a change to one thing (the independent thing) may affect the semantics of the other thing (the dependent thing).

**Domain:** An area of knowledge of activity characterized by a set of concepts and terminology understood by practitioners in that area.

**Dynamic Interaction Model:** A model that describes the dynamic interactions between elements of the model. Such models can be used to explore and illustrate the dynamic impacts of coupled components in a system.

**Element:** An atomic constituent of a model.

**Enables (quality):** An example of a grid quality. Notionally defined as providing broad access and support for energy innovation and value realization.

**Entity:** A thing that can be distinctly identified. A specific person, company, or event is an example of an entity.

**Entity-Relationship Diagram:** A diagram that visually expresses a particular **Entity-Relationship Model**.

**Entity-Relationship Model:** The entity-relationship model is a data model that expresses the real world in terms of entities and relationships. It adopts aspects of the network, relational, and entity set models.

**Extensibility:** A system design principle in which implementation takes future growth into consideration. It is a systemic measure of the ability to extend a system and the level of effort required to implement the extension.

**Feature:** A property, such as an operation or an attribute, that is encapsulated within another entity, such as an interface, a class, or a datatype.

**Flexibility:** The ability of the generation fleet to change its output (ramp) rapidly, start and stop with short notice, and achieve a low minimum-turn-down level.

**Framework:** An architectural pattern that provides an extensible template for applications within a domain.

**Graph:** A set  $V$  of vertices and a set  $E$  of unordered and ordered pairs of vertices; denoted by  $G(V,E)$ . The concept of a graph is employed in defining mathematical ideas such as a control system, in certain definitions of an algorithm, of a grammar, etc. Graphs are also widely employed in the formulation and description of various mathematical models in economics, biology, etc.

**Interaction Model:** A **Model** of the interactivity of components of a system. The interaction model indicates the physical or information exchange phenomena that occur at the component interfaces.

**Interaction:** A class of behavior that comprises a set of mutual or reciprocal influences among a set of objects within a particular context to accomplish a purpose. Influences may take the form of conversation, transaction, or closed-loop (feedback) control.

**Interface:** A collection of operations that are used to specify a service of a class or component.

**Interoperability:** The capability of two or more networks, systems, devices, applications, or components to share and readily use information securely and effectively with little or no inconvenience to the user.

**Laminar Coordination Framework:** A coordination framework for distributed systems that keeps the individual elements aligned on solving a common problem. The Laminar approach uses structure derived from the layered decomposition/network utility maximization approach to provide a formal basis for network architectures. See also **Whole Grid Coordination**.

**Laminar Network:** A communication structure that can be viewed as a combination of multi-layer hub-and-spoke and peer-to-peer forms arranged in a hierarchical, self-similar structure.

**Local Optimization Inside Global Coordination:** A means for control coordination across system and organizational boundaries; a mix of centralized and distributed control which has control federation and disaggregation, boundary deference, and local selfish optimization properties.

**Local Selfish Optimization:** The means to enable local optimization goals and constraints within the global coordination framework.

**Mapping:** An assigned correspondence between the elements of one set and the elements of another set. For example, in grid architecture, a two-layer diagram expresses a mapping between system properties and qualities.

**Merits (quality):** An example of a grid quality. Notionally defined as providing sufficient useful capability and public good to support continued public and private investment.

**Model:** An approximation, representation, or idealization of selected aspects of the structure, behavior, operation, or other characteristics of a real-world process, concept, or system. A model is sometimes constructed to better understand the system being created.

**Modularity:** The degree to which a system's components may be separated and recombined.

**Multipartite Graph:** Formally, a graph whose set  $V$  of vertices can be partitioned into  $k$  disjoint sets, so that each edge connects vertices belonging to different subsets. A specialization of a multipartite graph is the bipartite graph (with two disjoint sets). Grid architecture uses two-layer (bipartite) graphs to express the mapping of system qualities to system properties.

**N-ary association:** An association among three or more classes.

**Network:** An arrangement of components, or nodes, and interconnecting branches.

**Network Utility Maximization (NUM):** The aggregate maximization of the utilities of all the nodes subject to physical and economic constraints in the network. Network utility maximization is a method used in network design. Network structure derived from layered decomposition and NUM is used by laminar coordination to provide a formal basis for network architectures.

**Object:** A concrete manifestation of an abstraction; an entity with a well-defined boundary and identity that encapsulates state and behavior; an instance of a class.

**Orthogonality:** Mathematically, the relation of two lines at right angles (perpendicular) to one another, and the generalization of this relation into infinite-dimensional vector spaces (Hilbert Spaces). Informally, it refers to the concept of non-overlapping, uncorrelated, or independent objects of some kind.

**Pattern:** A common solution to a common problem in a given context.

**Preserves (quality):** An example of a grid quality. Notionally defined as minimizing wastes and emissions.

**Problem Domain:** The area or environment that encompasses real-world things and concepts related to the problem that a system is being designed to solve.

**Protects (quality):** An example of a grid quality. Notionally defined as providing safety for itself, users, utility workers, and the public in general.

**Receding Horizon Control:** A general purpose control scheme that involves repeatedly solving a constrained optimization problem, using predictions of future costs, disturbances, and constraints over a moving time horizon to choose the control action. Also known as model predictive control (MPC).

**Reference Architecture:** A reference model mapped onto elements that implements the functionality defined in the reference model.

**Reference Model:** A division of functionality into elements together with the data flow among those elements.

**Relationship:** The means by which two entities, consisting of collections of component behaviors, are affiliated. Architectural relationships consist of two classes of behaviors: **Interactions** and **Transfers**.

**Relationship:** A semantic connection among elements.

**Reliability:** The probability that a system will perform its intended functions without failure, within design parameters, under specific operating conditions, and for a specific period of time. In the utility industry, reliability is often expressed as system reliability indices, for example Customer Average Interruption Duration Index (CAIDI), Average Service Unavailability Index (ASUI), and many others.

**Requirement:** A desired feature, property, or behavior of a system.

**Resilience:** The capacity of a grid system to maintain state awareness and to proactively maintain a safe level of operational normalcy in response to anomalies, including threats of a malicious and unexpected nature. Synonymous with **Robustness**.

**Robustness:** The degree to which a system or component can function correctly in the presence of invalid inputs, stressful environmental conditions, or other unexpected perturbations. Synonymous with **Resilience**.

**Scalability:** The ability of a system to accommodate an increasing number of elements or objects; the ability to expand in a chosen dimension without major modifications to its architecture. The characteristics that undermine scalability are usually only apparent in context; for example, number of distributed energy resource market participants, or number of communication endpoints.

**Securability:** The degree to which the protection of computer hardware and software from accidental or malicious access, use, modification, destruction, or disclosure, can be achieved. Also pertains to personnel, data, communications, and the physical protection of computer installations.

**Solution Domain:** The domain of the things (as manifested by system properties) that are implemented to meet a set of requirements (in the problem domain) of a system.

**Specification:** A textual statement of the syntax and semantics of a specific building block; a declarative description of what something is or does.

**Structure:** An arrangement or pattern of interlinkages of components; organization of a system; the form; the "shape" of a system.

**Structural Model:** A model of the physical or logical structure of a system; for example, a model that represents a computer network as a set of boxes connected by communication lines.

**Subsystem:** A grouping of elements of which some constitute a specification of the behavior offered by the other contained elements.

**System:** A set of allied or interdependent elements forming an integrated whole. Elements are organized to accomplish a specific purpose, and described by a set of models, possibly from different viewpoints. A system has components, structure, behavior, qualities, and properties, and is often decomposed into a set of subsystems.



**System Architecture:** System architecture is a discipline for describing, analyzing, and communicating structural representations of complex systems. Colloquially, a system architecture is a model of a (complex) system, the purpose of which is to help think about the overall shape of the system, its attributes, and how the parts interact. In the development of complex systems, the creation of architecture precedes system design.

**System Performance Measure (Metric, Key Performance Indicator):** Performance measures, often called key performance indicators in the business analytics world, are data-driven mathematical formulae that are intended to provide insights into various aspects of the operation of complex systems.

**System Property:** System properties are characteristics of the system as a whole as seen by “insiders” (developers and operators of the system). System properties emerge from system components and structures, each of which has its own set of properties. In practice, a complex system will have a large number of desired properties.

**System Quality:** System qualities are desired features or characteristics of the system as seen by end users and other stakeholders with “outsider” perspectives. They can be thought of as high-level requirements that may be expressed qualitatively or quantitatively. Generally, the number of qualities selected for a system is small, and one of the challenges is to choose a set that is comprehensive in nature despite the limited number. Qualities that are mutually orthogonal, quantifiable (with associated relative weighting factors to support prioritization), and expressed with specificity, are highly desirable.

**System of Systems:** A system comprising independent, self-contained systems that, taken as a whole, satisfy a specified need.

**Systems Analysis:** The process of studying an activity, typically by mathematical means, to define its goals or purposes and to discover operations and procedures for accomplishing them most efficiently.

**Three-Layer Diagram:** A diagram, typically in the form of a multipartite graph. In grid architecture, a three-layer diagram expresses the mapping between system components, properties, and qualities. Such a diagram can be extended using graph theory and matrix methods to analyze and reason about a system in an objective manner. See also **Architecture Map**.

**Top-down:** Deriving a hierarchical structure by successive subdivision from the top. Also known as stepwise refinement.

**Topology:** The interconnection pattern of nodes in a network. With respect to the grid, it is the interconnection pattern of entities that facilitate power generation, transmission, distribution and consumption.

**Transfer:** A class of behavior that comprises a set of conveyances from one entity to another. Conveyances may take the form of transmission, broadcast, narrowcast, grants/takings, and open-loop command and control.

**Two-Layer Diagram:** A diagram, typically in the form of a multipartite graph. In grid architecture, a two-layer diagram is used to express the mapping of system qualities to system properties. Such a diagram can be used to analyze and reason about a system. See also **Architecture Map**.

**Ultra-Large-Scale System (ULSS):** A system in which at least one of whose dimensions is of such large scale that constructing the system using development processes and techniques prevailing at the start of the 21st century is problematic. ULSS exhibit the following characteristics: decentralization; conflicting,

unknowable, and diverse requirements; continuous evolution and deployment; heterogeneous and changing elements; erosion of the people/system boundary; and normal failures of parts of the system. The electric grid is an example of a ULSS.

**Use Case:** A description of a set of sequences of actions, including variants, that a system performs which yields an observable result of value to an actor.

**User:** The person or persons operating or interacting directly with the system.

**Validation:** The process of evaluating a system or component during or at the end of the development process to determine whether a system or component satisfies specified requirements.

**Value Stream:** The sequence of activities required to design, produce, and provide a specific good or service, and along which information, materials, and worth flows.

**Whole Grid Coordination:** The means by which distributed grid elements are made to cooperate to solve a common problem—in this case, grid control. See also **Laminar Coordination Framework**.





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