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Optimum Load Shaping for Electric Vehicle and Battery Charging

Document Types and Tags

Document Type: Specification

Document Tags:

☒ Test or Measurement	☐ Checklist	☐ Facility
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Table of Contents

Title **Page Number**

Document Types and Tags 2
1. Introduction 5
 1.1. Executive Summary 5
 1.2. Scope 5
 1.3. Benefits 5
 1.4. Intended Audience 5
 1.5. Areas for Further Investigation or to be Added in Future Versions 5
2. Normative References 6
 2.1. SCTE References 6
 2.2. Standards from Other Organizations 6
 2.3. Published Materials 6
3. Informative References 6
 3.1. SCTE References 6
 3.2. Standards from Other Organizations 6
  3.2.1. PV Generation and Related Standards 6
  3.2.2. Electric Energy Storage and Related Standards 7
  3.2.3. Electric Vehicles and Related Standards 7
  3.2.4. Responsive Loads and Related Standards 7
  3.2.5. Grid-Connected Microgrids and Related Standards 8
 3.3. Published Materials 8
4. Compliance Notation 9
5. Abbreviations and Definitions 9
 5.1. Abbreviations 9
 5.2. Definitions 10
6. Requirements 10
 6.1. Generation-to-load optimum load shaping 10
 6.2. The OLS Producer/Consumer 11
 6.3. An electric vehicle charger as an OLS Consumer-enabled smart load 11
 6.4. Example use of an OLS to manage the charging of an electric vehicle 11
 6.5. Measurement and Monitoring 11
7. OLS Protocol 12
 7.1. UML Information Model Representation 12
 7.2. YANG Data Model 12
8. Transport Protocols 12
 8.1. OpenAPI Interface Specification 12

List of Figures

Title **Page Number**

Figure 1 - Creating, transmitting, and acting upon an Optimum Load Shape 10
Figure 2 - Example Use of an OLS to manage charging of an EV 12

1. Introduction

1.1. Executive Summary

This standard defines in simplistic terms how to create, transmit, and act upon a forecast optimum load shape (OLS) that may be used to manage the charging of electric vehicles (EVs) and facility batteries, or otherwise used to manage electrical load. This OLS standard provides for end-to-end, generation to load control of the electric power grid towards the goals of reducing energy costs, maximizing the use of renewable energy, and accelerating the adoption, monetization, resiliency, and societal benefits of microgrids, EVs, and batteries.

1.2. Scope

An OLS provides grid control with a set of numbers, such as the target load for hours 1-24, that forecast the cleanest, most efficient, and least cost electrical supply in grids, microgrids, and nanogrids, so that all stakeholders: generation entities, utilities, distributors, retailers, and consumers—can reduce their electricity costs and carbon emissions.

A number of topics are addressed herein: 1) A generation-to-load OLS architecture is specified. 2) Based on inputs of forecast load and forecast generation from renewables, a method for producing an OLS is specified. 3) A method for managing the charging of electric vehicles is specified as an example of how any smart load can autonomously interpret and take local actions based on an OLS. In addition to electric vehicles, smart loads may include batteries, and other devices such as Internet-connected thermostats that control space and water heating/cooling.

1.3. Benefits

This OLS standard is needed because existing siloed standards do not provide for generation to load control of the electric power grid. With OLS, stakeholders including cable companies can reduce their electricity costs and carbon emissions by having their smart loads follow the lowest cost forms of supply. If not implemented, Cable companies will have less control over the rising cost of procuring electric power. Short-term benefits include the ability to create and distribute a far-reaching OLS quickly and easily that allows smart devices that implement the standard to participate. Benefits accrue in the short and long-term as more smart devices implement the standard resulting in a greater benefit for all stakeholders in the electricity value chain. The potential impact on the broadband industry is a reducing energy procurements costs and creating new revenue generating units based on managing the charging of cable customer's vehicles and batteries.

1.4. Intended Audience

The audience for this document is diverse. Within cable operators, the audience is electric power engineers, financial planners, and staff that purchase electricity, electric vehicles and microgrid components. Within vendors that supply the cable industry, the audience is power systems product management and engineering. Within the electric utility industry, the audience includes product management, load and generation planners.

1.5. Areas for Further Investigation or to be Added in Future Versions

The vehicle charging example herein should be supplemented with a battery charging example.

2. Normative References

The following documents contain provisions, which, through reference in this text, constitute provisions of this document. At the time of Subcommittee approval, the editions indicated were valid. All documents are subject to revision; and while parties to any agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1. SCTE References

[OLS-YANG] The OLS Data Model is defined in YANG format and is available on Github at: https://github.com/cablelabs/scte-ols/blob/main/ols%402020-12-26.yang

2.2. Standards from Other Organizations

No normative references are applicable.

2.3. Published Materials

No normative references are applicable.

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

3.1. SCTE References

[OLS-OpenAPI] A RESTful API expression of the OLS Data Model in OpenAPI (aka SwaggerDoc) format is available on Github at: https://github.com/cablelabs/scte-ols/blob/main/ols-2020-12-26.json

3.2. Standards from Other Organizations

The following standards are provided as a reference to the reader in part to represent the proliferation of standards that suggest a unifying end-to-end protocol as described in this specification would be useful.

3.2.1. PV Generation and Related Standards

[IEEE 1547] IEEE Std 1547, IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

[IEEE 1547.1] IEEE Std 1547.1, IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems

[UL 1741] The UL 1741, Standard for Safety - Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources

[IEC TR] IEC TR 61850-90-7, Communication Networks and Systems for Power Utility Automation—Part 90-7: Object Models for Power Converters in Distributed Energy Resources (DER)

[IEC 61850-7] IEC 61850-7-420, Communication Networks and Systems for Power Utility Automation—Part 7-420: Basic Communication Structure—Distributed Energy Resources Logical Nodes.
[NAESB] NAESB RMQ.26, Open Field Message Bus (OpenFMB) Model Business Practices.
[IEC Ed. 1.0] IEC 61850-7-420 Ed. 1.0 b:2009, Communication Networks and Systems for Power Utility Automation - Part 7-420: Basic Communication Structure - Distributed Energy Resources Logical Nodes
[IEEE 2030.5] IEEE 2030.5-2018, Standard for Smart Energy Profile Application Protocol
[IEE 1547.3] IEEE Std 1547.3, IEEE Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems
[IEEE 1815] IEEE Std 1815, Distributed Network Protocol (DNP3)

3.2.2. Electric Energy Storage and Related Standards

[IEEE 1547] IEEE 1547:2018, California's Utility DER Electric Rule 21 Interconnection
[IEEE 2030.2] IEEE 2030.2, IEEE Guide for the Interoperability of Energy Storage Systems Integrated with the Electric Power Infrastructure
[IEEE P1547.9] IEEE P1547.9, Guide to Using IEEE Standard 1547 for Interconnection of Energy Storage Distributed Energy Resources with Electric Power Systems

3.2.3. Electric Vehicles and Related Standards

[SAE J3072] SAE J3072, Interconnection Requirements for Onboard, Utility-Interactive Inverter Systems
[SAE J2836] SAE J2836/0, Instructions for Using Plug-In Electric Vehicle (PEV) Communications, Interoperability and Security Documents
[SAE J2836-3] SAE J2836/3_201301, Use Cases for Plug-in Vehicle Communication as a Distributed Energy Resource
[SAE J2847] SAE J2847/2_201504, Communication Between Plug-In Vehicles and Off-Board DC Chargers
[SAE J3847-3] SAE J2847/3, Communication for Plug-in Vehicles as a Distributed Energy Resource
[SAE J2894] SAE J2894/1/2, Power Quality Test Procedures for Plug-In Electric Vehicle Chargers
[SAE J29531] SAE J29531_201310, PEV-EVSE, Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)
[IEC 63110] IEC 63110-1 ED1, Protocol for Management of Electric Vehicles charging and discharging infrastructures - Part 1: Basic Definitions, Use Cases and architectures

3.2.4. Responsive Loads and Related Standards

[IEC 624746] IEC 62746-10-1:2018 (OpenADR 2.0), Systems interface between customer energy management system and the power management system - Part 10-1: Open automated demand response
[ASHRAE 135] ANSI/ASHRAE 135, (BACnet), A Data Communication Protocol for Building Automation and Control Networks

[ASHRAE 201] ANSI/ASHRAE/NEMA Standard 201 (FSGIM), Facility Smart Grid Information Model
[ISO 14908] ISO/IEC 14908-1:2012, Information technology — Control network protocol — Part 1: Protocol stack
[ISO 14908-2] ISO/IEC 14908-2:2012, Information technology — Control network protocol — Part 2: Twisted pair communication
[ISO 14908-3] ISO/IEC 14908-3:2012, Information Technology — Control Network Protocol — Part 3: Power Line Channel Specification
[CTA 245] ANSI CTA 245/CEA 2045, Modular Communication Interface

3.2.5. Grid-Connected Microgrids and Related Standards

[IEEE 1547.4] IEEE Std 1547.4, Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems
[IEEE 2030.7] IEEE 2030.7-2017, Standard for the Specification of Microgrid Controllers
[IEEE 2030.8] IEEE Std 2030.8, Standard for the Testing of Microgrid Controllers
[IEEE 2030.9] IEEE P2030.9, Recommended Practice for the Planning and Design of the Microgrid

3.3. Published Materials

[Cruickshank] The Value of Optimum Electric Load Shaping: A Guide for Procurement and Policy Decision Makers, R.F. Cruickshank, L. F. Asperas, Society of Cable Telecom Engineers, Journal of Energy Management, Vol. 5, No, 1, Mar 2020
[NREL] GMLC Survey of Distributed Energy Resource Interconnection and Interoperability Standards, National Renewable Energy Laboratory et al., Draft December 2019
[OLS-YANGTOOLS] http://www.yang-central.org/twiki/bin/view/Main/YangTools

4. Compliance Notation

shall	This word or the adjective "***required***" means that the item is an absolute requirement of this document.
shall not	This phrase means that the item is an absolute prohibition of this document.
forbidden	This word means the value specified shall never be used.
should	This word or the adjective "*recommended*" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
should not	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
may	This word or the adjective "*optional*" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.
deprecated	Use is permissible for legacy purposes only. Deprecated features may be removed from future versions of this document. Implementations should avoid use of deprecated features.

5. Abbreviations and Definitions

5.1. Abbreviations

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BACnet	data communication protocol for building automation and control networks
DER	distributed energy resource
DNP3	distributed network protocol
EV	electric vehicle
EVSE	electric vehicle supply equipment
ISBE	International Society of Broadband Experts
NEMA	National Electrical Manufacturers Association
OFMB	open field message bus

OLS	optimum load shape
OpenADR	open demand response
PEV	plug-in electric vehicle
SCTE	Society of Cable Telecommunications Engineers

5.2. Definitions

microgrid	A microgrid is an electrical system that connects multiple sources and loads that is controllable by the user to allow independent operational choices.
nanogrid	Single instance of a microgrid with single owner involved in the consumption of the power provided by the system. The system may have a localized optimum load shape.
OLS	Optimum Load Shape that maximizes the use of renewable energy and the efficiency of all types of conventional thermal generation.
OLS Consumer	A smart electric device that is internet connected and able to modulate load based on optimal load shape.
OLS Producer	Energy provider software that is associated with an electricity supply or control system, such as a utility or microgrid energy supplier, able to forecast lowest cost of energy supply over a given time periods.

6. Requirements

6.1. Generation-to-load optimum load shaping

An OLS is created, transmitted, and acted upon as shown in Figure 1. An OLS *Producer,* typically an entity that is associated with an electricity supply or control system, such as a utility, makes OLS data available to any number of OLS *Consumers,* typically entities that manage or consume electricity.

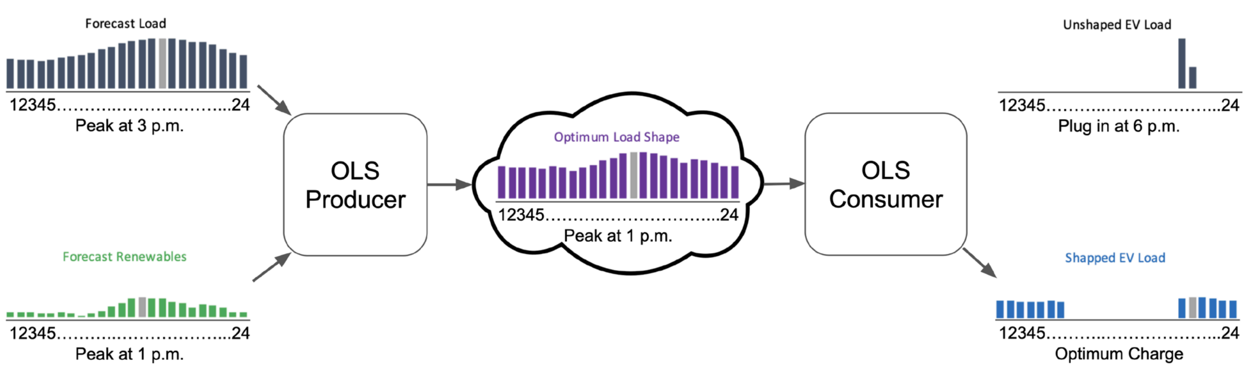

Figure 1 - Creating, transmitting, and acting upon an Optimum Load Shape

6.2. The OLS Producer/Consumer

An OLS Producer may employ any technique to create an OLS signal. An algorithm that optimizes the utilization of renewable generation is described here. As depicted at left of Figure 1, the OLS Producer is a processor which obtains time-series signals indicative of a forecasts of load and renewable generation. The OLS Producer: 1) subtracts the forecast renewable generation from the forecast load to produce a net generation shape, 2) flattens the net generation to maximize the efficiency of the mix of thermal generators, and 3) adds the forecast renewable generation and the flattened net generation to achieve the OLS. These steps are further detailed in Figure 2.

An OLS Consumer may make any use of the OLS data, e.g. it may use it to time-shift/modulate load or perform any action it deems appropriate.

A single entity may be a Producer and a Consumer, for example, an entity that consumes an OLS signal from an upstream Producer such as a utility may produce localized OLS signals to a number of downstream consumers. For example, a whole-home controller may consumer an OLS from a utility and send modified versions to the water heater, thermostat, and vehicle charger in order to coordinate time-shifting load and optimize the performance of the home.

6.3. An electric vehicle charger as an OLS Consumer-enabled smart load

As depicted in at the right of Figure 1, the charging of an electric vehicle can be configured as an unshaped or as a shaped load. At top right of Figure 1, and unshaped EV charging load might appear as two spikes, one at 6 PM and another at 7 PM. At bottom right of Figure 1, a shaped EV charging load follows the OLS for the portions of time that it is plugged in.

6.4. Example use of an OLS to manage the charging of an electric vehicle

As an illustrative example, as shown in Figure 2, the optimum load shape transmitted across any network is received by the EV charger which takes unavailability of a vehicle into consideration and autonomously adjusts the OLS to account for the hours the vehicle can be charged.

6.5. Measurement and Monitoring

It may become important for an OLS Consumer to record and report on actions taken in response to an OLS. While mechanisms and systems to calculate the consumption of electricity and actions taken by OLS Consumers are out of scope, it is expected that existing electric utility interval-based metering infrastructure remains suitable for recording consumption and performing billing operations and that customers ’bills will be reduced when load shaping is implemented. Other, complementary mechanisms, such as blockchain audits, could be developed, but are out of scope of this standard,

	Supply-side uses forecasts [GWh] and Optimum Load Shape (OLS) Creator					Demand-side loads [kWh] have OLS Interpreter		
	Forecast Load -	Forecast Renewables =	Net Generation →	Flat Net Generation →	Optimum Load Shape →	EV Optimum Load Shape →	Shaped EV Load	Unshaped EV Load
Midnight	36.1	6.0	30.1	35.2	3.7%	7.3%	0.73	-
1	34.6	5.8	28.8	35.2	3.6%	7.3%	0.73	-
2	33.7	5.4	28.3	35.2	3.6%	7.2%	0.72	-
3	33.4	4.6	28.8	35.2	3.5%	7.1%	0.71	-
4	34.7	4.3	30.4	35.2	3.5%	7.0%	0.70	-
5	37.5	6.7	30.8	35.2	3.7%	7.5%	0.75	-
6	38.2	4.6	33.6	35.2	3.5%	7.1%	0.71	-
7	40.0	0.4	39.6	35.2	3.2%			
8	43.2	4.5	38.7	35.2	3.5%			
9	47.0	7.8	39.2	35.2	3.8%			
10	50.7	14.2	36.5	35.2	4.4%			
11	53.8	18.0	35.8	35.2	4.7%			
Noon	56.5	23.6	32.9	35.2	5.2%			
13	58.4	25.0	33.4	35.2	5.3%			
14	59.7	24.7	35.0	35.2	5.3%			
15	60.2	23.5	36.7	35.2	5.2%			
16	59.7	20.0	39.7	35.2	4.9%			
17	58.0	17.8	40.3	35.2	4.7%			
18	55.9	11.6	44.4	35.2	4.1%	8.3%	0.83	7.00
19	55.0	16.7	38.3	35.2	4.6%	9.2%	0.92	3.00
20	52.3	14.8	37.4	35.2	4.4%	8.9%	0.89	-
21	47.5	11.5	36.1	35.2	4.1%	8.3%	0.83	-
22	43.0	6.2	36.7	35.2	3.7%	7.4%	0.74	-
23	39.5	6.0	33.6	35.2	3.6%	7.3%	0.73	-
Totals →	1,128.7	283.6	845.1	845.1	100%	100%	10.00	10.00
	GWh	GWh	GWh	GWh	Unitless	Unitless	kWh	kWh

Deliver Optimum Load Shape over any network

The vehicle is in use and unavailable for charging from 0700 - 1800 hours.

The charger takes unavailability into consideration and autonomously adjusts the Optimum Load Shape that it received from the supply-side.

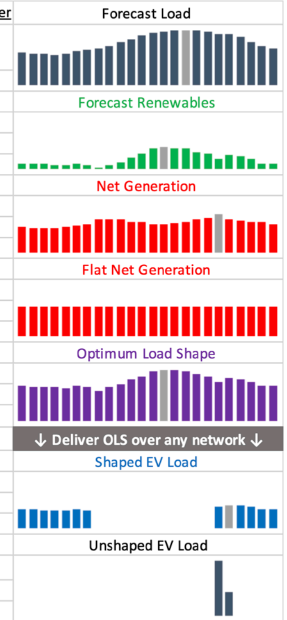

Figure 2 - Example Use of an OLS to manage charging of an EV

7. OLS Protocol

Every OLS Producer ***shall*** support at least one programmatic mechanism to transmit OLS data in the format conformant to [OLS-YANG] in either push or pull mode to OLS Consumers, e.g., HTTP REST.

7.1. UML Information Model Representation

A UML Information Model has not been defined

7.2. YANG Data Model

A YANG model is defined at [OLS-YANG]. Tools exist to generate REST, NETCONF, and Protobuf definitions and code stubs from YANG models. See [OLS-YANGTOOLS].

8. Transport Protocols

Many transport protocols might be used for OLS, we offer a REST definition as an example.

8.1. OpenAPI Interface Specification

A REST API is defined at [OLS-OpenAPI].