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Using Smart Energy Profile 2.0 for Residential Distributed Energy Resource Integration

An Application Guide

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EPRI Project Manager:

B. Seal

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The following organization prepared this report:

Electric Power Research Institute (EPRI)
3420 Hillview Ave
Palo Alto, CA 94304

Principal Investigators
G. Aumaugher
B. Seal
J. Bolin

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ABSTRACT

The Smart Energy Profile (SEP) is a specification set forth by the ZigBee Alliance for application layer messaging in Home Area Network (HAN) environments. Many changes and additions have been made in the 2.0 version of this specification, including a range of capabilities intended to support distributed energy resources, such as small-scale solar photovoltaic and battery storage systems that may be integrated in the residential domain.

This report is presents the results of a detailed study of the part of SEP2 intended for support of distributed energy resources, and provides an application guide for implementations that might utilize these features. The report explains what capabilities are and are-not supported, and provides recommended usage (down to the message level) for implementing a range of common functions. Areas where uncertainty or ambiguity may exist are identified.

Keywords
Distributed Energy Resources
Smart Energy Profile
Home Area Network
Smart Inverter

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1 INTRODUCTION

Report Purpose

This report presents results of an assessment of the ability of the Smart Energy Profile 2.0 (SEP2) to support open standards based integration of residential Distributed Energy Resources (DER). It may be viewed as a companion to the SEP 2.0 specification itself, and may be used to assist utilities in developing strategies and expectations for residential DER integration. It may also be used by first time users to implement the protocol. The report describes how to use SEP2 for DER integration; addressing capabilities, limitations and the current status of the protocol. The range of capabilities explored is consistent with new IEC standards[1] for smart inverter functions as described in the EPRI report: Common Functions for Smart Inverters[2].

Chapter 2 of this report provides a short explanation of why it may be beneficial for utilities to communicate with residential DER and the possible advantages of integrating it into the control system. The example architecture used for this report is described in Chapter 3. Basic syntax and common methods that apply throughout the remainder of the report are explained in Chapter 4. Chapter 5 describes the initialization procedures used to establish communications between a DER device and the SEP2 host.

Chapter 6 outlines the initialization procedures used to determine what program the DER device belongs to and the method of obtaining lists of events of which it should be aware. Each of the subsections in Chapter 7 cover a particular function, providing examples and recommendations on implementation when in a SEP2.0 environment. Example XML code is provided along with detailed instructions to aid the reader in understanding the steps required to successfully navigate the SEP2.0 specification. Chapter 8 addresses the gaps uncovered between the open standards and the draft 0.9 SEP2 specification.

There are generally multiple ways to apply the SEP 2.0 specification to achieve a given goal. The methods described within this report are not the only approach and may not be the method that the reader prefers. At the time of this report, the SEP 2.0 specification was not yet final and updates may continue until the specification is officially approved and released.

This report is based upon the 0.9 version of the AppSpec (25 Aug 2012) available at http://www.zigbee.org/Standards/ZigBeeSmartEnergy/Version20Documents.aspx. The DER section is undergoing revisions based on public comments and will continue to evolve. For example, some major changes being reviewed are splitting out connect/disconnect as a separate function, and splitting DERControl into two types: a "base" control that defines the default operation of the DER and "event" type DERControl that overrides the base control for some start time/duration. These revisions are not addressed in this report since they are not yet final and not

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[1] International Electrotechnical Commission, Technical Report, IEC 618650-90-7

[2] *Common Functions for Smart Inverters*. EPRI, Palo Alto, CA: 2011. 1023059

available in a public document. A new revision of the SEP2 specification is already in circulation with the contributors and is expected to be publically available in the first half of 2013. It is expected to address many of the issues raised in this report.

SEP2 is first and foremost a Home Area Network (HAN) standard. The resources that the utility will expose to the DER (e.g. DERProgram and DERControls) may be delivered to the Energy Services Interface (ESI) through an Advanced Metering Infrastructure (AMI) network, but it is ultimately the HTTP/HTTPS conversation between the endpoints and the ESI that SEP2 is concerned with.

Context of DER and Smart Inverters

Utilities are increasingly interested in communicating with residential inverters used for photovoltaic (PV), battery storage, plug-in electric vehicles, and even small scale wind systems in order for these resources to become beneficial assets to the distribution grid. In 2009, EPRI launched a collaborative initiative with Sandia National Laboratories, the Solar Electric Power Association, and the Department of Energy to help develop a set of common functions to support smart inverters on the distribution grid. More than 550 individuals representing more than 50 PV and storage equipment providers, over 60 utilities, and 12 national laboratories and research organizations have participated in this ongoing process.

Volunteers met by teleconference throughout 2010 and 2011, discussing, defining and documenting proposed common functions. The goal of this effort was to enable high-penetration scenarios in which a diversity of resources (for example, photovoltaic and battery storage) in varying sizes and from multiple manufacturers can be integrated into distribution circuits in a manageable and beneficial way. This requires a degree of consistency in the services and functions that these devices provide; and uniform, standards-based communication protocols for their integration with utility distribution management and communication systems.

The goal of this initiative has been to bring the industry closer to off-the-shelf interoperability and ease of system integration. A document summarizing this work (*Common Functions for Smart Inverters*) is available at no cost on the EPRI website at www.epri.com with the product ID 1023059.

Over the past three years, this initiative has defined a broad set of common functions which have been picked-up by standards organizations at several levels. In 2011, the DNP users group produced an application note mapping the common functions to DNP3. This application note describes a standard data point configuration, set of protocol services and settings (a profile) for communicating with photovoltaic generation and storage systems using DNP3. The purpose of defining this profile was to make it easier to interconnect the DNP3 masters and outstations that are used to manage distributed energy resources. It describes a DNP3 profile whose design is based on the structured data models of the International Electrotechnical Commission (IEC) 61850 protocol standards family. This application note is available to DNP members from the DNP web site at http://www.dnp.org/ as AN2011-001.

The IEC 61850 standard codifies the functions themselves and currently has a released technical report IEC TR- 61850-90-7:2011. This IEC report defines a set of standardized functions for inverter-based Distributed Energy Resource devices, including photovoltaic systems, battery storage systems, electric vehicle charging systems, and any other DER with a controllable inverter. It also defines the IEC 61850 information models to be used in the exchange of information between these inverter-based DER devices and the utilities, Energy Service Providers, or other entities which are tasked with managing the Volt, VAr, and Watt capabilities of these inverter-based devices. IEC Technical Reports are considered transitional and the models are expected to be included in IEC 61850-7-420 Edition 2. The draft document is available at http://www.iec.ch/dyn/www/f?p=103:38:0::::FSP_ORG_ID,FSP_APEX_PAGE,FSP_LANG_ID,FSP_PROJECT:1273,23,25,IEC/TR%2061850-90-7%20Ed.%201.0# for IEC members.

The recent DER additions to the SEP2 specification are built on the same common set of functions and follow suit with prior mappings to DNP3 and ModBus. It is critical that all these DER communication specifications be built on a common set of functions, so that DER in different domains (e.g. residential, commercial, industrial, utility) may be cohesively managed.

2
RESIDENTIAL DER INTEGRATION CONSIDERATIONS

Why Communicate with Distributed Energy Resources?

This research delves into great detail on how to monitor and manage DER systems using SEP2 but before, it is important to address the topic of why communication with DER devices may be desirable for utilities. The issues described here are not meant to be an all inclusive discussion of why a utility could desire to manage residential DER but to touch upon a few examples of the methods and benefits of doing so.

Know the Feeder

The utility knows in great detail how much power it is supplying, and also may know the line voltage, current, power factor, frequency and other measurements at various monitoring points along feeders. As DER becomes more prevalent, knowing the amount of power being generated by these resources becomes more important. The utility must be able to properly respond to changing weather conditions as clouds move in or out of an area or wind speeds change.

The location of the DER in relation to the feeder layout is critical to understanding the results of VAr adjustments on line voltage to prevent over or under voltage conditions and using VAr support to smooth the voltage over the length of the feeder. For example, the benefit of VArs produced far from the substation may be more significant than that of the same VAr production near the substation.

By using a model of the feeder combined with voltage information reported from AMI meters, utilities may be able to adjust the reaction of various DER spread over the length of a feeder in different ways based on specific location data. This ability to tailor each device could optimize each DER and have a positive effect on the feeder health.

Know the DER

By retrieving the nameplate data of each DER, the utility can better judge the expected reaction of the feeder to the changing conditions and commands provided by utility operators. The nameplate values can help predict the amount of power loss or gain caused by weather changes but it is only part of the picture. To complete the picture the utility needs to know the current DER configuration and status.

By comparing the nameplate capability against the inverter configuration, utilities can determine the amount of excess capacity that is available for VAr support or power factor correction capability. The current status can provide instantaneous power generation values for both immediate calculations and a view into the predicted behavior of the feeder under similar weather conditions.

Manage the DER

There are a number of options for managing DER. DER can be connected or disconnected from the grid to support emergency situations, circuit maintenance, and management of malfunctioning equipment. Another option is limiting the maximum generation level when the line voltage approaches the maximum limit and other avenues of reduction have been exhausted. Price based charging of storage systems can take advantage of times when electricity is cheap and plentiful and then be told to discharge during peak usage hours to minimize circuit load at peak times. Storage systems can also be used to absorb energy at high voltage periods reducing the need for VAr correction to control local voltages.

Not all commands need to come from the utility. Autonomous Volt/VAr and Volt/Watt functions can be used to smooth feeder voltage by downloading curves to be followed by each individual device. Decisions to use the curves are made at the utility level but the actual implementation is done by each individual DER by monitoring the voltage at the point of connection and adjusting its output or VArs based upon the reading.

The motivations to employ various management functions are diverse. Certain DER management functions may assist with voltage conservation by helping to maintain a balanced voltage over the length of the feeder and thereby maximizing opportunity to lower feeder voltage (conservation voltage reduction). Management of battery systems and EV charging times and rates can contribute to peak shifting out of critical peak periods. The question of why it is beneficial to control DER has been addressed in other EPRI reports. This report is focused on the “how” rather than the “why,” specifically how to implement DER control using SEP 2.0.

3
IMPLEMENTATION OVERVIEW

Because the exchanges discussed in the following chapters vary based on the system architecture, it is necessary to provide a specific architecture to be used as a base line for the remainder of the report. For example, whether an ESI host resides inside or outside the resident firewall will change the method of event notification. Also, visualizing how a sequence of messages travel between devices can make it easier to understand the logical messages sequence. This Chapter describes an example architecture to lay the ground work for the detailed message exchange discussions that follow.

Example System Architecture

SEP2 requires that every home area network have one or more nodes that act as a host for endpoints within a residence. This host is referred to as an Energy Services Interface (ESI) and serves as the point in the network from which utility commands to the home area network (HAN) endpoints originate. It would be possible to have one host supporting DER while a separate host supports demand response/load control activities. In the simplest form, a single host would perform all SEP2 functions for a residence.

A utility must provide some method to communicate with each ESI host which acts as SEP 2.0 server for the HAN to provide information required to link DER endpoints to the ESI and provide events to the endpoints. This utility link to the ESI is outside the scope of this report.

In this document, a simple system is assumed, with a single SEP2.0 ESI host serving an inverter endpoint. SEP2.0 is agnostic to the physical layer of the HAN, as long as it supports Internet Protocol version 6 (IPv6) at the network layer. Connections may be via Ethernet, HomePlug AV, Wi-Fi, ZigBee, or other HAN technology. This report will address the message contents assuming that a suitable physical layer has been chosen.

For this example the meter is assumed to act as the ESI host and to be joined to the residential Wi-Fi network inside the firewall. In this case, the ESI host is the SEP 2.0 server and both terms refer to the same physical entity. Figure 3-1 depicts this example architecture.

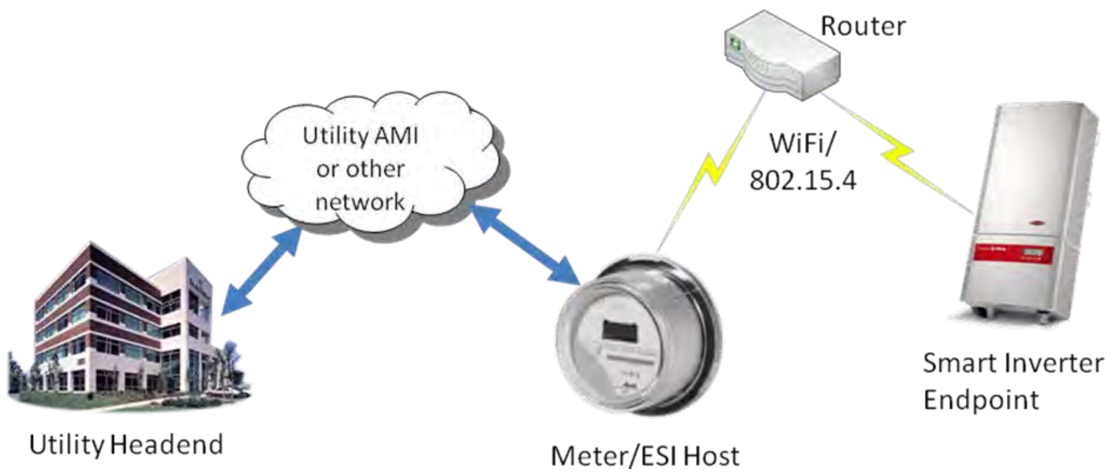

Figure 3-1
Example System Architecture

Example Message Exchange

Before DER endpoints can be effectively managed using SEP2.0, certain tasks must be completed. Figure 3-2 shows the typical sequence of exchanges required to establish a connection between a DER endpoint and a server in a SEP2.0 environment:

1. The utility informs the DER server of a new device to be serviced.
2. The DER client performs discovery to identify the DER server where the endpoint is registered.
3. The DER endpoint establishes a secure connection with the DER server using TLS.
4. The client device issues a GET EndDevice request to identify the topics that the client device and server can communicate about.
5. The client device performs the Registration step with the server or meter. This speeds the future communication process.
6. The endpoint will provide the Nameplate values to communicate its capabilities to the DER server
7. The endpoint will provide the current setting to the DER server
8. The endpoint will then determine the program ID in which it is enrolled.
9. The endpoint will obtain the DERControlList
10. If the Subscribe/Notify method is chosen, the endpoint will need to subscribe to desired DER controls.
11. The DER server will notify the endpoint of new events and existing events that have been updated.
12. If the poll method is chosen, or if the endpoint has been notified of new or changed events, the endpoint will request updated information for DERControl events.

While not part of the implementation process, the endpoint should perform time synchronization with the DER server as soon as possible to ensure it is in sync when performing time-based events.

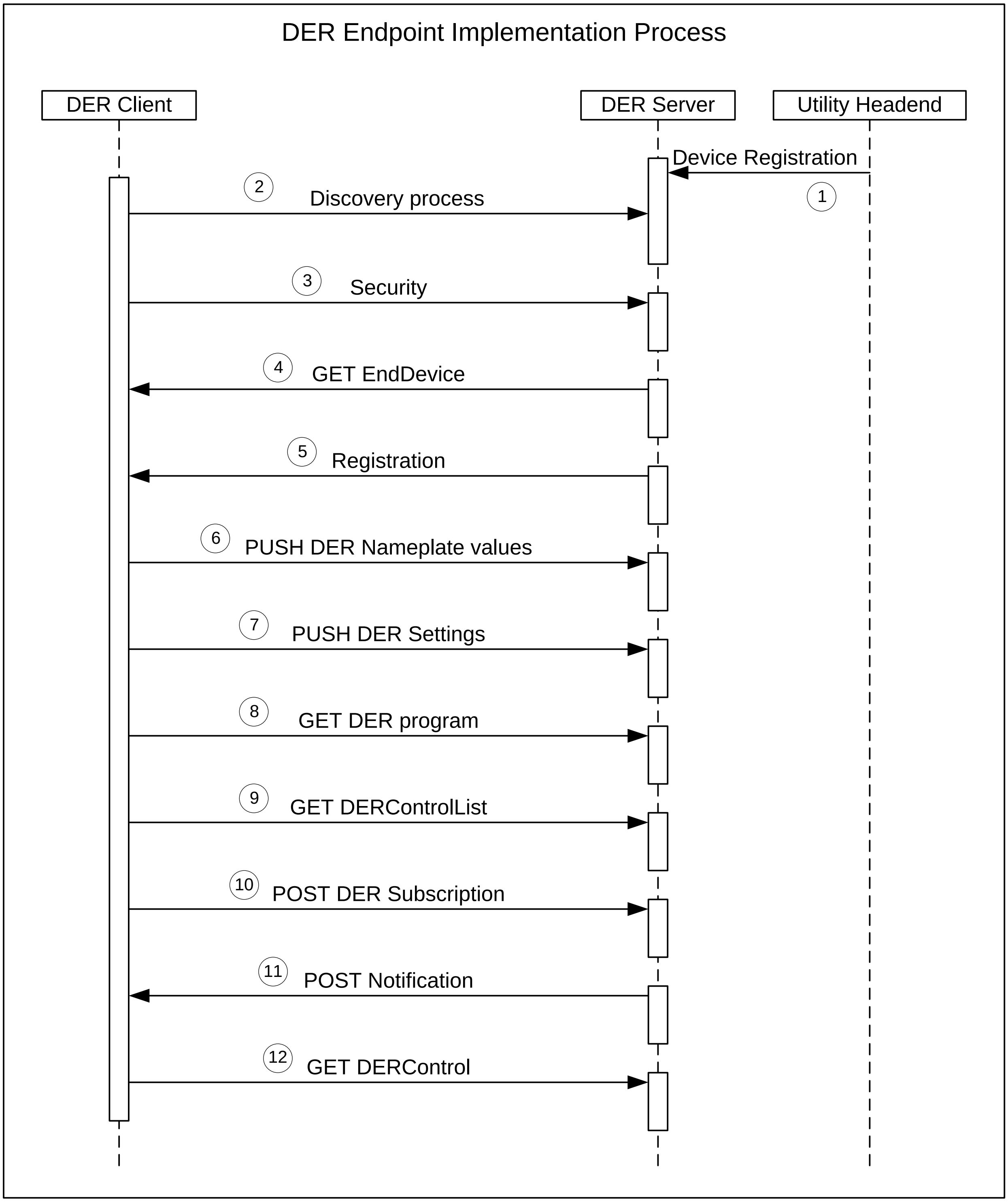

Figure 3-2
Flow Diagram of SEP2 Initialization and DERC Data Exchange

Subscribe/Notify versus Poll

There are two different approaches to implementing an endpoint in order to collect DER event information. The endpoint can **subscribe** to be notified of new events and updates to existing events, or the endpoint can **poll** for this information.

The poll method works best for battery powered devices that sleep most of the time and wake occasionally to collect any updates. In this case, the endpoints must poll at least every day but no more than once an hour. Polling is also useful if the DER server is outside a residential firewall.

To use the subscribe method, the current design requires SEP2 clients to implement a web server in order to receive notifications. Since it can be problematic for a remote server to cross the residential firewall polling is the preferred method for communication with a remote ESI host.

If the subscribe method is used with a remote ESI, the home owner will typically need to open a port for the utility DER server to use to send unsolicited messages to the endpoint. This means that if the router configuration is changed or the router is replaced, the owner will need to open the port for the utility. This is not necessary if the endpoint polls for the data. In that case the endpoint initiates all requests making changes to the configuration of the router unnecessary.

If the DER server is inside the resident firewall, such as a utility meter that joins the resident Wi-Fi network, then the firewall issue is eliminated and the choice is now solely based on the endpoint's waking pattern. If the endpoint sleeps for the majority of the time, polling is a logical solution. If the endpoint is always awake, subscribe/notify may be the best solution. The actual process of subscription and polling will be discussed later. For this example architecture, it is assumed that the DER server and the endpoint are inside the same firewall and will use Subscribe/Notify for the example exchanges.

4

MESSAGE BASICS

There are some basics that apply to all functions or methods in this document. This chapter describes those items. The most commonly used methods and DER Uniform Resource Identifiers (URI) are described. The basics for all the message headers are described along with how to use the query string parameters. Some of the items described here are common standards such as HTML while other items are specific to SEP 2.0.

Example Code

In the SEP 2.0 draft the term {hostname} is used in the XML examples as a placeholder for the ESI host address. In the example XML code blocks in this report an example ESI host address (fe80::2012:eff:fe41:a66b) is used throughout. This is an example only and could be any valid IPv6 address. For these examples it is assumed that the host is on the same local network as the DER device, thus the use of fe80 as first element of the IPv6 address.

Message Setup

Client Request

Once a discovery query has been done, links discovered, and the client cleared through security (described in the following chapter), then the client can start to communicate to the server. In general, each message has a consistent set up. The first part of the message tells the server what action to take. The four methods are:

- GET– This tells the server to go out and get whatever information the client is looking for and provide it in the response.
- PUT – This tells the server to take whatever information the client inputs and put it into the location that is specified.
- POST – This tells the server to go out and create what information the client wants to make whether it is a new instance or end device.
- DELETE – This tells the server to delete whatever list, instance, information, or subscription the client tells it to.

Uniform Resource Identifier (URI)

After a method is specified, the client inputs a URI. URIs are short in nature (usually from three to four letters). Each URI represents a function set such as the metering function set or the pricing function set. Inside each function set, there are more URIs to find out additional information about a specific instance, device, or list. URIs are separated by a forward slash character (/). See Appendix B in the Smart Energy Profile 2.0 Application Protocol Specification for an explanation of every URI used by SEP2. The following is a list of DER URIs:

Table 4-1
DER URI Descriptions

URI	Description
/derp	List of all the DER Programs.
/derp/{id1}	A specific DER Program.
/derp/{id1}/actderc	List of all active DER controls on a specific DER Program.
/derp/{id1}/derc	List of all DER controls on a specific DER Program.
/derp/{id1}/derc/{id2}	A specific DER control on a specific DER Program.
/derp/{id1}/dcg	List of DER curve groups
/derp/{id1}/dcg/{id2}	A specific DER curve group.
/derp/{id1}/dcg/{id2}/dc	List of DER curves.
/derp/{id1}/dcg/{id2}/dc/{id3}	A specific DER curve.
/der	A list of Distributed Energy Resources.
/sdev/der	Information on the host's Distributed Energy Resource.
/edev/{id1}/der	Information on a specific Distributed Energy Resource.
/edev/{id1}/der/ders	DER's status of the end device.
/edev/{id1}/der/dera	DER's availability of the end device.
/edev/{id1}/der/dercap	Capabilities of the DER.

HTTP/1.1

The term “HTTP/1.1” follows the URI to show the application data exchange protocol in use. HTTP/1.1 is the transport protocol and was chosen because of its operability and use of TCP. Once the HTTP/1.1 is added, that completes the first line of the client’s request. The first line reads: action/ URI HTTP/1.1. For example:

```
GET /derp/1/derc/2 HTTP/1.1
```

Each new‘/’ starts a new URI. “/derp”, “/1”, “/derc”, and “/2” are all separate URIs. In this case the reference is to DERControl ID 2 of DERProgram ID 1.

Host

The second line of the client’s request deals with the host it is requesting to. The client first inputs host:. Next, the client will input the host’s IP address. SEP 2.0 was made with the recent release of IPv6 in mind. It is preferred that an IPv6 address is used, but SEP 2.0 should work with an Ipv4 address. The IP address is found during the discovery process. Once the IP address is inputted, the second line of the request is finished. For PUT, POST, and sometimes DELETE, extra lines of code have to be added so the server will know what information to add, change, or delete.

Accept

For GET requests, an additional line must be added. The client must notify the server if it is able to receive XML or EXI messages or not. EXI stands for Efficient XML Interchange and is a binary version of XML. ‘Accept:’ is first added. Next, the client has to tell the server what kind code it will accept back from the server. If the client accepts XML, ‘application/sep+xml;’ is added.

```
Accept: application/sep+xml; level=+S0
```

If the client accepts EXI, ‘application/sep-exi;’ is added.

```
Accept: application/sep-exi; level=+S0
```

If the client accepts both EXI and XML, ‘application/sep-exi;level=+S0, application/sep+xml;level=+S0’ is added.

```
Accept: application/sep-exi;level=+S0, application/sep+xml;level=+S0
```

Depending on whether a client can or cannot receive the attributes associated with XML or EXI, `level=+S0` or `level=-S0` is added. The term `level=+S0` is added to show that is able, and `level=-S0` shows that it isn’t. The example below is a typical complete GET message. See section 7.8.1 in the SEP 2.0 specification.

```
GET /derp/1/derc/2 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

Host Response

The host’s response starts with HTTP/1.1 to show application data exchange protocol in use.

HTTP Response Codes

With every request that is sent to a host, there is a three digit HTTP code followed by a short one to two word description returned from the host after the initial HTTP/1.1. The following shows the initial request and the start of the host response that is consistent in every message.

The client would send:

```
GET /edev/1 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/xml
Content-Length: 366
```

This three digit code tells the client if the message was successful or not. The three most common codes are 200,400, and 404. `200 OK` is sent to the client to show a successful transaction took place. `400 Bad Request` is sent to the client when there is a client-side error and when no other 4xx response code is appropriate. `404 Not Found` is sent to the client to show that no resource can be found at the specified URI. Please refer to page 34, line 997, section 7.5 in the Smart Energy Profile 2.0 Application Protocol Specification to find out more information about other HTTP Response Codes.

Content

After the first line in the response, the host responds with Content-Type: application/xml. This tells the client that the server's response will be in XML. The third line shows the amount of characters that are used in the response below. See above for an example for an initial setup. Once the content length is displayed, the host will respond with whatever the client requested for.

Query String Parameters

Whenever the host responds with a list of information, it can be quite lengthy. For example, if the client device asks for the list of DER Controls, the host could respond with up to eleven controls with individual information on each control. When searching for a specific control it is inefficient return the entire set. SEP 2.0 allows the use of query string parameters to efficiently find a specific control instance. The command setup for query parameters is:

{URI}?s={x}&a={y}&l={z}

After the URI, a question mark is added to initialize the query string parameters. Without the question mark, the parameters will not be added, and the message will be sent unsuccessfully. 's'(start), 'a'(after) and 'l'(limit) are all different query string parameters. 'x', 'y' and 'z' are all values for the parameters. 's' gives the parameter for what position and instance the query starts. The first position or instance that can be entered is '0'. 'a' gives the query a parameter to start including items after a certain time. 'l' is a limit parameter that tells the host how many different results or instances that can be sent to a client. If the limit is higher than the actual amount of instances, the query will result in the actual number of instances. All three parameters don't have to be used as inputs when query string parameters are used. See page 27 line 766 for more information about query string parameters.

The client would send:

```
GET /upt/0/mr/0/rs/0/r?s=3&l=1 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 347

<?xml version="1.0" encoding="UTF-8" standalone="no" ?>
<ReadingList xmlns="http://zigbee.org/sep" all="5"
href="/upt/0/mr/0/rs/0/r" results="1"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://zigbee.org/sep sep.xsd">
   <Reading href="/upt/0/mr/0/rs/0/r/3">
      <value>361231</value>
   </Reading>
</ReadingList>
```

5

SEP 2.0 NETWORK INITIALIZATION FUNCTIONS

A DER endpoint needs to perform several steps to establish itself with the DER server before it becomes an active component within the SEP2 network. Figure 5-1 depicts the registration remote process.

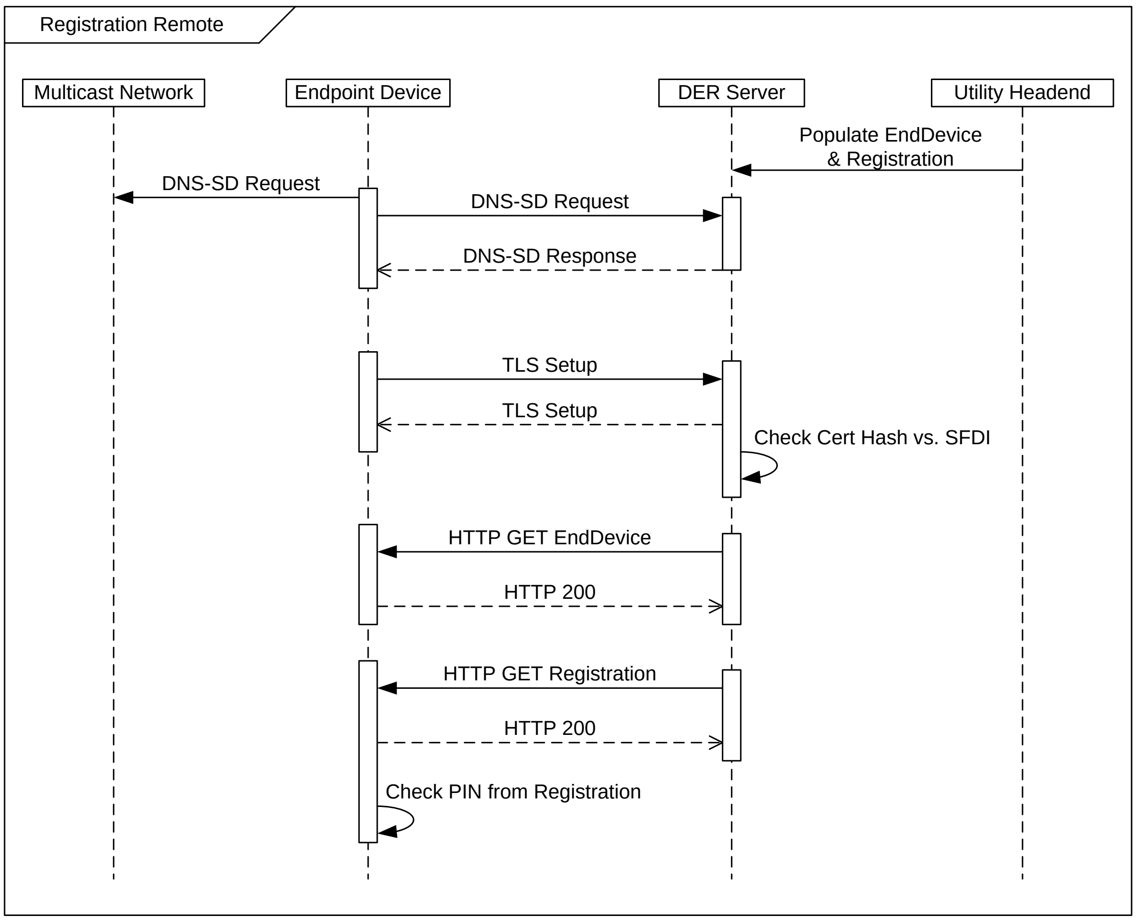

Figure 5-1
Registration Remote Flow Diagram

Device Registration

The first step in the process would be to register the device or inverter with the customer's service provider or utility. The service provider will then configure a DER server to support this endpoint device. This process is particular to the individual utility and is outside the scope of this report. It is assumed that this action has been performed.

Discovery

Discovery is the process that identifies what DER server has been assigned to service a particular endpoint. Without this process, the endpoint will not be able to receive instructions from the utility or provide feedback. This is the first step shown in Figure 3-2 describing the endpoint initialization process.

In the discovery phase, the client endpoint must identify the server that is configured to handle its actions. The utility should preload the server with the device ID of all devices that it is to service. The server assigns a unique <Instance> label each DNS SRV/TXT record pair that it advertises. This should begin with a meaningful label followed by a hyphen '-' and end with the device's SFDI or other unique substring such as the low-order bits of an EUI-64 in text form (e.g., "device-1111111111111").

This must be in decimal digits so it can easily be entered from a numeric keypad such as a phone. In this way an end user could dial an automated system, identify their product and enter the device ID. The utility could then download a message to their server assigned to support the residence whose phone number made the call and enable the appropriate device.

Example Discovery

Figure 5-1 shows the discovery process using Function Set Assignment (FSA). In the first step, the client issues a domain name server service discovery (DNS-SD) request to locate its DER server based on the endpoint's SFDI as a key.

In this example, the client device uses the Linux dig command to perform this step of the discovery process.

The client would send:

```
dig -p 5353 @224.0.0.251 _derp-123456789014._sub._smartenergy._tcp.sit PTR
```

One or more servers provide a DNS a response with a URL to a client's EndDevice resource. An EndDevice resource is used to provide an interface to exchange information related to a particular client device. See 11.2 of [4] for additional details. If no server replies then this device is not registered with any servers on this network.

In this example a server has the end device registered and provides a response.

The server would respond:

```
; <<>> DiG 9.7.3 <<>> -p 5353 @224.0.0.251 _derp-
1234567890123._sub._smartenergy._tcp.site PTR
; (1 server found)
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 6639
;; flags: qr aa; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 4

;; QUESTION SECTION:
;_derp._tcp.local.                IN        PTR

;; ANSWER SECTION:
_derp._tcp.local.     10         IN         PTR     derp-
1234567890123._derp._tcp.local.

;; ADDITIONAL SECTION:
derp-1234567890123._derp._tcp.local. 10 IN SRV 0 0 515 Foo1000.local.
derp-1234567890123._derp._tcp.local. 10 IN TXT "txtvers=1" "dcap=/dcap"
"description=Inverter" "product=Foo 1000" "path=/upt" "scheme=https"
"Level=-S0".
Foo1000.local.                  10         IN         A         192.168.1.31
Foo1000.local.                  10         IN         AAAA
fe80::dad3:85ff:fe4c:ea4

;; Query time: 1 msec
;; SERVER: 192.168.1.31#5353(224.0.0.251)
;; WHEN: Wed Nov 23 15:28:24 2011
;; MSG SIZE  rcvd: 333
```

A good reference to understand the service record (or DNS SRV record) can be found at: http://blog.lithiumblue.com/2007/07/understanding-dns-srv-records-and-sip.html

Security

The initial security process in SEP 2.0 can be lengthy and difficult to understand. It is in place so that the server can decide how secure it is or how fast quick communications can take place. It also has checks inside of the process, so if any unwanted visitors get access, they will be detected. For more information on the security process, see Chapter 9 in the specification.

Common Terms

Before the security process can truly be understood, a few terms need to be defined.

- Device Identifier – A unique combination of numbers and letters derived from the SHA256 certificate fingerprint that is a nonconfidential identifier to the device. Here is an example of a device identifier: 3E4F-45AB-31ED-FE5B-67E3-43E5-E456-2E31-984E-23E5-349E-2AD7-4567-2ED1-45EE-213A. See line 1472 section 9.3.1 page 50 in the specification for more information.
- Short Form Device Identifier (SFDI) – A MSB truncated form of the device identifier to 36 bits. The SFDI is expressed in an 11 digit decimal form plus a 10 - sum of first 11 digits mod 10 checksum digit, such as 167261211391. See line 1479 section 9.3.2 page 50 in the specification for more information.

- Long Form Device Identifier (LFDI) – A truncated form of the device identifier to 160 bits. It is used when a unique identifier is needed. Here is a LFDI example: 3E4F-45AB-31ED-FE5B-67E3-43E5-E456-2E31-984E-1495 23E5. See line 1492 section 9.3.3 page 50 in the specification for more information.
- 6-digit PIN Code – A 6 digit number added onto the device identifier for extra security. Here is an example: 123-455. See line 1498 section 9.3.4 page 50 in the specification for more information.
- Registration Code – In certain situations, a single registration code is needed. This is the PIN added to the end of the SFDI. Here is an example: 67-261-211-391-123-455. See line 1509 section 9.3.5 page 51 in the specification for more information.
- TLS Handshake Protocol – A series of messages sent from a client device to a server when they first start communicating to ensure the security for the server. See the document RFC5246 for more information or see the TLS Handshake Protocol later on in the document.
- Access Control List (ACL) – A list that shows how much access particular resources have. See section 9.2 in the specification.

Authorization

See sections 9.4, 9.5, and 9.6 in the SEP 2.0 Application Specification for more information.

TLS Handshake Protocol

A TLS handshake happens between the client device and the server. See the document RFC5246 for more information on the TLS Handshake Protocol.

Access Control List

See section 9.2 in the specification for more information.

GET EndDevice

The client device's function sets are found by sending a GET edev command to the server. This identifies the topics that the client device and server can communicate about. Here is an example:

The client would send:

```
GET /edev/3 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 435

<EndDevice subscribable="0" href="/edev/3" xmlns="http://zigbee.org/sep">
  <ConfigurationLink href="/edev/3/cfg" />
  <DeviceInformationLink href="/edev/3/di" />
  <DeviceStatusLink href="/edev/3/ds" />
  <FileStatusLink href="/edev/3/fs" />
  <PowerStatusLink href="/edev/3/ps" />
  <sFDI>98765432100</sFDI>
  <FunctionSetAssignmentsListLink all="3" href="/edev/3/fsal" />
  <RegistrationLink href="/edev/3/reg" />
  <SubscriptionListLink all="0" href="/edev/3/subl" />
</EndDevice>
```

Table 5-1 describes the attributes of the DER EndDevice response.

Table 5-1
DER EndDevice Attributes

Attribute Name	Description	Req'd
EndDevice	Container for EndDevice attributes	Yes
ConfigurationLink	A Link to an instance of Configuration.	
DeviceInformationLink	A Link to an instance of DeviceInformation.	
DeviceStatusLink	A Link to an instance of DeviceStatus.	Yes
FileStatusLink	A Link to an instance of FileStatus.	
PowerStatusLink	A Link to an instance of PowerStatus.	
sFDI	Short form of device identifier. 12 decimal digits. See the Security section for additional details.	Yes
FunctionSetAssignmentsListLink	A Link to a List of FunctionSetAssignments instances.	Yes
RegistrationLink	A Link to an instance of Registration.	Yes
SubscriptionListLink	A Link to a List of Subscription instances.	Yes

Registration

After the client device verifies that everything is correct again, it will register itself to the ESI server. This allows the device to not have to go through the entire process once it tries to communicate to server/meter once again. Also, the registration will speed up the security process because the client will already be authenticated.

The client would send:

```
GET /edev/3/reg HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 92

<Registration href="/edev/3/reg" xmlns="http://zigbee.org/sep">
  <pIN>12345</pIN>
</Registration>
```

See section 9.9 in the specification for more information.

PUSH DER Nameplate Values

The capabilities of a specific Distributed Energy Resource are often referred to as the nameplate ratings and limit settings.

Nameplate ratings are read only values set by the manufacturer's configuration. These values could represent the continuous active power rating in watts, continuous positive and negative reactive power ratings in VArs, and scale factors. These values are also used as the default values for the basic settings. A DER server should check with the client's DER resource to see if its settings are within the settings in the device's capabilities before making a DER control.

To see the nameplate ratings, a user has to use the URI for DER capabilities. The URI is /edec/{id1}/der/dercap. This will return the DER type, the DER control type, active power, apparent power, and the maximum AC current capability. It can also return different ratings depending on the configuration from the utility and the manufacturer. For further information on extra nameplate ratings, see Figure 16-34: DER Info Types on page 225, the DER Capability section on page 229, or page 119 in the specification.

The client would send:

```
GET /edec/2/der/dercap HTTP/1.1
Host: (Host name)
```

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 1110

&lt;?xml version="1.0" encoding="UTF-8"?&gt;
<DERCapability xsi:schemaLocation="http://zigbee.org/sep
file:///Z:/Documents/Business/SSN/Interop6/docs-10-6049-51-seed-sep-2-0-
uml-model/sep.xsd" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
href="/edev/3/dercap" xmlns="http://zigbee.org/sep">
   &lt;modesSupported&gt;00001FFF&lt;/modesSupported&gt;
   &lt;rateMaxCharge&gt;
      &lt;multiplier&gt;3&lt;/multiplier&gt;
      &lt;value&gt;5&lt;/value&gt;
   &lt;/rateMaxCharge&gt;
   &lt;rateMaxDischarge&gt;
      &lt;multiplier&gt;3&lt;/multiplier&gt;
      &lt;value&gt;5&lt;/value&gt;
   &lt;/rateMaxDischarge&gt;
   &lt;rtgA&gt;
      &lt;multiplier&gt;1&lt;/multiplier&gt;
      &lt;value&gt;6&lt;/value&gt;
   &lt;/rtgA&gt;
   &lt;rtgAh&gt;
      &lt;multiplier&gt;-2&lt;/multiplier&gt;
      &lt;value&gt;16667&lt;/value&gt;
   &lt;/rtgAh&gt;
   &lt;rtgMinPFCap&gt;
      &lt;multiplier&gt;-1&lt;/multiplier&gt;
      &lt;value&gt;7&lt;/value&gt;
   &lt;/rtgMinPFCap&gt;
   &lt;rtgMinPFInd&gt;
      &lt;multiplier&gt;-1&lt;/multiplier&gt;
      &lt;value&gt;7&lt;/value&gt;
   &lt;/rtgMinPFInd&gt;
   &lt;rtgPFSign&gt;true&lt;/rtgPFSign&gt;
   &lt;rtgVA&gt;
      &lt;multiplier&gt;3&lt;/multiplier&gt;
      &lt;value&gt;12&lt;/value&gt;
   &lt;/rtgVA&gt;
   &lt;rtgVArNeg&gt;
      &lt;multiplier&gt;1&lt;/multiplier&gt;
      &lt;value&gt;632&lt;/value&gt;
   &lt;/rtgVArNeg&gt;
   &lt;rtgVArPos&gt;
      &lt;multiplier&gt;1&lt;/multiplier&gt;
      &lt;value&gt;632&lt;/value&gt;
   &lt;/rtgVArPos&gt;
   &lt;rtgW&gt;
      &lt;multiplier&gt;2&lt;/multiplier&gt;
      &lt;value&gt;102&lt;/value&gt;
   &lt;/rtgW&gt;
   &lt;rtgWh&gt;
      &lt;multiplier&gt;4&lt;/multiplier&gt;
      &lt;value&gt;2&lt;/value&gt;
   &lt;/rtgWh&gt;
   &lt;type&gt;1&lt;/type&gt;
&lt;/DERCapability&gt;
```

Table 5-2
DER Nameplate Attributes

Attribute Name	Description	Req'd
DERCapability	Distributed energy resource type and nameplate ratings	Yes
modesSupported	Bitmap indicating the DER Controls implemented by the device	Yes
rateMaxCharge	Maximum rate of energy transfer received by the storage device, in Watts.	No
rateMaxDischarge	Maximum rate of energy transfer delivered by the storage device, in Watts.	No
rtgA	Maximum AC current capability of the DER, in Amperes (RMS).	Yes
rtgAh	Usable energy storage capacity of the DER battery, in AmpHours.	No
rtgMinPFCap	Minimum Power Factor (capacitive/over-excited) capability of the DER; unsigned value between 0.0 and 1.0.	No
rtgMinPFInd	Minimum Power Factor (inductive/under-excited) capability of the DER; unsigned value between 0.0 and 1.0.	No
rtgPFSign	True if PF sign is interpreted according to IEC convention: positive PF means DER is delivering active power (P+). False if PF sign is interpreted according to IEEE/EEI convention: negative (PF lagging) means active and reactive power flows in the same direction. SHALL be true by default; overridden by setPFSign.	No
rtgVA	Maximum apparent power capability of the DER, in VA.	Yes
rtgVArNeg	Maximum reactive power received by the DER, in VAr.	No
rtgVArPos	Maximum reactive power delivered by the DER, in VAr.	No
rtgW	Maximum active power capability of the DER, in Watts.	Yes
rtgWh	Maximum energy storage capacity of the DER, in WattHours.	No
type	Type of DER	Yes

PUSH DER Settings

The DER basic settings are in place so that the default settings made by the nameplate ratings can be changed. The basic settings also include the configuration settings from installation such as setMaxW, the maximum active power setting of the DER, setMaxVArPos, the setpoint for maximum reactive power delivered by the DER, and setMaxChargeRate, the maximum rate of energy transfer received by the storage device. Similar to the nameplate ratings, two values each are provided for the maximum VAr and minimum Power Factor settings.

The URI to see the basic settings is /edev/{id1}/der. This will reveal the maximum active power setting, the nominal AC voltage at the utility's point of common coupling, and the nominal AC voltage offset between the DER's electrical connection point and the utility's point of common coupling. It can also return different setting depending on the configuration from the utility and the manufacturer. For further information on extra basic settings, see Figure 16-33: DER Info Types on page 224 or the DER Object section on page 228 in the specification.

The client would send:

```
GET /edev/{id1}/der HTTP/1.1
Host: (host name)
```

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 1115

<?xml version="1.0" encoding="UTF-8"?>
<DER xsi:schemaLocation="http://zigbee.org/sep
file:///Z:/Documents/Business/SSN/Interop6/docs-10-6049-51-seed-sep-2-0-
uml-model/sep.xsd" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
href="/edev/3/der" xmlns="http://zigbee.org/sep">
   <setGradW>200</setGradW>
   <setMaxChargeRate>
      <multiplier>3</multiplier>
      <value>2</value>
   </setMaxChargeRate>
   <setMaxDischargeRate>
      <multiplier>3</multiplier>
      <value>2</value>
   </setMaxDischargeRate>
   <setMaxVA>
      <multiplier>3</multiplier>
      <value>12</value>
   </setMaxVA>
   <setMaxVArNeg>
      <multiplier>1</multiplier>
      <value>632</value>
   </setMaxVArNeg>
   <setMaxVArPos>
      <multiplier>1</multiplier>
      <value>632</value>
   </setMaxVArPos>
   <setMaxW>
      <multiplier>2</multiplier>
      <value>102</value>
   </setMaxW>
   <setMinPFCap>
      <multiplier>-1</multiplier>
      <value>7</value>
   </setMinPFCap>
   <setMinPFInd>
      <multiplier>-1</multiplier>
      <value>7</value>
   </setMinPFInd>
      <setPFSign>true</setPFSign>
   <setVRef>
      <multiplier>1</multiplier>
      <value>24</value>
   </setVRef>
   <setVRefOfs>
      <multiplier>-1</multiplier>
      <value>12</value>
   </setVRefOfs>
   <updatedTime>1341446390</updatedTime>
   <UsagePointLink href="/upt/3"/>
</DER>
```

Table 5-3
DER Settings Attributes

Attribute Name	Description	Req'd
DER	Distributed energy resource information	Yes
multiplier		
value		
setGradW		
setMaxChargeRate	Maximum rate of energy transfer received by the storage device, in Watts.	No
setMaxDischargeRate	Maximum rate of energy transfer delivered by the storage device, in Watts.	No
setMaxVA	Setpoint for maximum apparent power (in VA). Default to rtgVA.	No
setMaxVArNeg	Setpoint for maximum reactive power received by the DER (in VAr). Default to rtgVArNeg.	No
scheduledInterval		
setMaxVArPos	Setpoint for maximum reactive power delivered by the DER (in VAr). Default to rtgVArPos.	No
setMaxW	Maximum active power setting of the DER, in Watts.	Yes
setMinPFCap	Minimum Power Factor (capacitive/over-excited) setpoint of the DER; unsigned value between 0.0 and 1.0. Defaults to rtgMinPFCap.	No
setMinPFInd	Minimum Power Factor (inductive/under-excited) setpoint of the DER; unsigned value between 0.0 and 1.0. Defaults to rtgMinPFInd.	No
setPFSign	True if PF sign is interpreted according to IEC convention: positive means DER is delivering active power (P+). False if PF sign is interpreted according to IEEE/EEI convention: positive means P & Q have the same sign. Defaults to rtgPFSign (true).	No
setVRef	The nominal AC voltage (RMS) at the utility's point of common coupling.	Yes
setVRefOfs	The nominal AC voltage (RMS) offset between the DER's electrical connection point and the utility's point of common coupling.	Yes
updatedTime		

6
DER INITIALIZATION EXCHANGES

This chapter addresses the basic DER interactions that do not concern DER monitoring or management. These interactions are concerned with identifying the DER program that the endpoint is part of, obtaining a list of the DER management functions that the device can support, the subscription/notification exchanges and posting of status information. Figure 6-1 provides a graphical depiction of the exchanges and the order in which they typically occur to complete a DER initialization process.

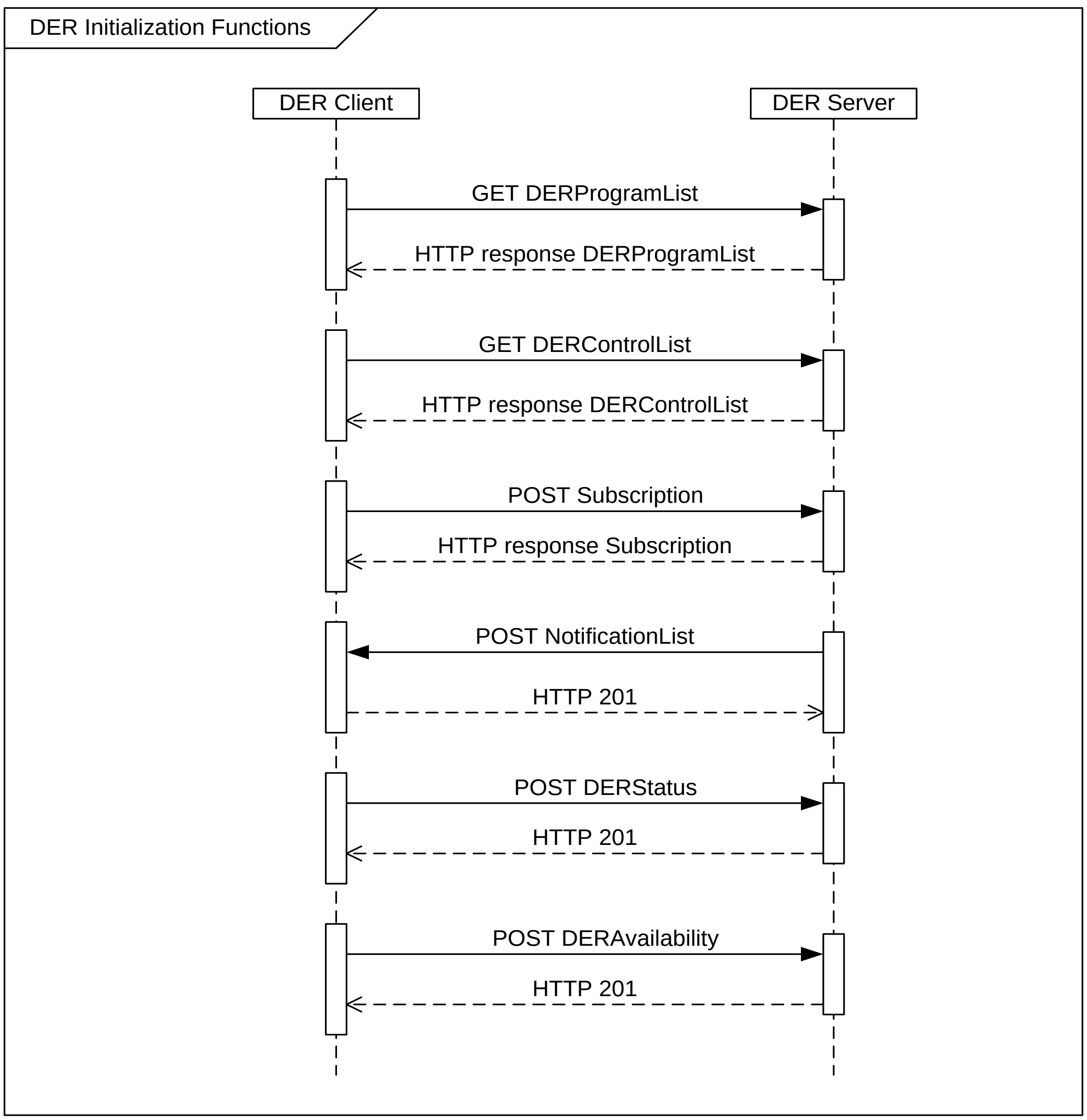

Figure 6-1
DER Initialization Functions Flow Diagram

GET DER Program

This function provides a list of DER programs that the requesting device is enrolled in. The following is an example of a derp request.

The client would send:

```
GET /derp HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The GET /derp command requests a full list of all programs the endpoint is enrolled in. The IPv6 address of the host is provided in the second line following “Host: ”.

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 377

<DERProgramList xmlns="http://zigbee.org/sep" href="/derp" all="1"
results="1">
   <DERProgram href="/derp/0">
      <mRID>0000000000000000000000001BE7A7E57</mRID>
      <description>Example DER Program</description>
      <DERControlListLink all="2" href="/derp/0/derc"/>
      <DERCurveGroupListLink all="1" href="/derp/0/dcg"/>
      <primacy>2</primacy>
   </DERProgram>
</DERProgramList>
```

Table 6-1
DERP Function Attributes

Attribute Name	Description	Req’d
DERProgramList	A List element to hold DERProgram objects.	Yes
DERProgram	Distributed Energy Resource program.	Yes
mRID	128 bit (32 hex digit) attribute with the 32 LSBs (lower 8 hex characters) being the IANA PEN provider ID and the remaining bits (upper 24 hex characters) identifying the objects created by that provider. Leading zeros are not required.	Yes
description	A text description.	No
DERControlListLink	A List element to hold DERControl objects.	No
DERCurveGroupListLink	A List element to hold DERCurveGroup objects.	No

GET Active DERControlList

This function provides a list of DERControls that are currently active. In this case, active means that the current time falls within the range for the event. To obtain a list of all DERC events, use derc instead. The following is an example of an actderc request.

The client would send:

```
GET /derp/0/actderc HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The program number is specified by the digits following /derp/, which is 0 for this example. The term actderc tells the ESI to return the list of currently active DERC events. The IPv6 address of the host is provided in the second line following “Host:

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 834

<?xml version="1.0"?>
<ActiveDERControlList href="/derp/0/actderc" all="2" results="2">
   <DERControl href="/derp/0/actderc/0">
      <mRID>0000000000000000000000002BE7A7E57</mRID>
      <creationTime>1338544800</creationTime>
      <interval>
            <start>1338904593 </start>
            <duration>300</duration>
      </interval>
      <randomizeStart>0</randomizeStart>
      <randomizeDuration>0</randomizeDuration>
      <opModGenConnect>false</opModConnect>
   </DERControl>
   <DERControl href="/derp/0/actderc/1">
      <mRID>0000000000000000000000003BE7A7E57</mRID>
      <creationTime>1338544800</creationTime>
      <interval>
            <start>1338904593</start>
            <duration>300</duration>
      </interval>
      <randomizeStart>0</randomizeStart>
      <randomizeDuration>0</randomizeDuration>
      <opModGenConnect>false</opModConnect>
   </DERControl>
</ActiveDERControlList>
```

Table 6-2
ACTDERC Function Attributes

Attribute Name	Description	Req'd
ActiveDERControlList	Container for the DERControls	Yes
DERControl	Container for the DERControl elements. Two controls are identified in this example, numbers 0 and 1 as identified by the digits following "/actderc/".	Yes
mRID	128 bit (32 hex digit) attribute with the 32 LSBs being the Internet Assigned Numbers Authority (IANA) Private Enterprise Number (PEN) provider ID and the remaining bits identifying the objects created by that provider. In this case the value is empty and must be recorded as such.	Yes
creationTime	The time this control was created in UTC. Note that this is not local time.	Yes
interval	Container for the start, and duration values	Yes
start	The time to start the event in UTC. Note that this is not local time.	
duration	Number seconds past the start time to end the event	
randomizeDuration	A random number between 0 and this number to be added to the duration to calculate the actual end time of the event. When this number is negative the end time will be earlier than the duration value.	Yes
randomizeStart	A random number between 0 and this number to be added to the start time to calculate the actual start time of the event. When this number is negative the start time will be earlier than the start value.	Yes
opModGenConnect	Set generator DER as connected (true) or disconnected (false)	

POST DER Subscription

Polling

There are two different ways for a device to update its information. The first way is to make the device poll for information every so often. To poll, the device inputs a request for every device or resource of interest. A device should not poll more than once an hour, but it must poll every 24 hours. Polling is useful because it works without modification to a residence firewall if the ESI server is located outside the residence network. Polling, however, has two drawbacks. First, polling takes up a more bandwidth since the client must check for changes versus being notified when an event changes. Second, polling will not have the most up to date information. If an event alters right after a poll or a grid emergency occurs, a client might not find out about the event for up to 24 hours. One important advantage is that polling supports battery powered devices that sleep for the majority of their operational life and only wake to support events and check for new events.

Subscription

The subscription resource does not suffer from the drawbacks of polling. Client devices have the ability to be able subscribe to many resources. Once they are subscribed to a resource, the server will send the client notifications about changes to the resource. Changes that alter how an endpoint handles an event will trigger a notification, such as adding a new event, changing a value or start/stop times for an event, terminating an event early, or deleting an event. Using subscription eliminates the need to continuously poll throughout the day for events and event changes, reducing network traffic.

The primary drawback to subscription is that if the ESI host is located outside the residence firewall it requires opening ports for communication through the firewall. This configuration must be done and can be lost when the router is changed or modified. Subscription does not work with devices that sleep to save battery life because they will miss the notifications. To see which events, function sets, and attributes are subscribable, see Appendix B starting on page 149 line 4305 in the specification.

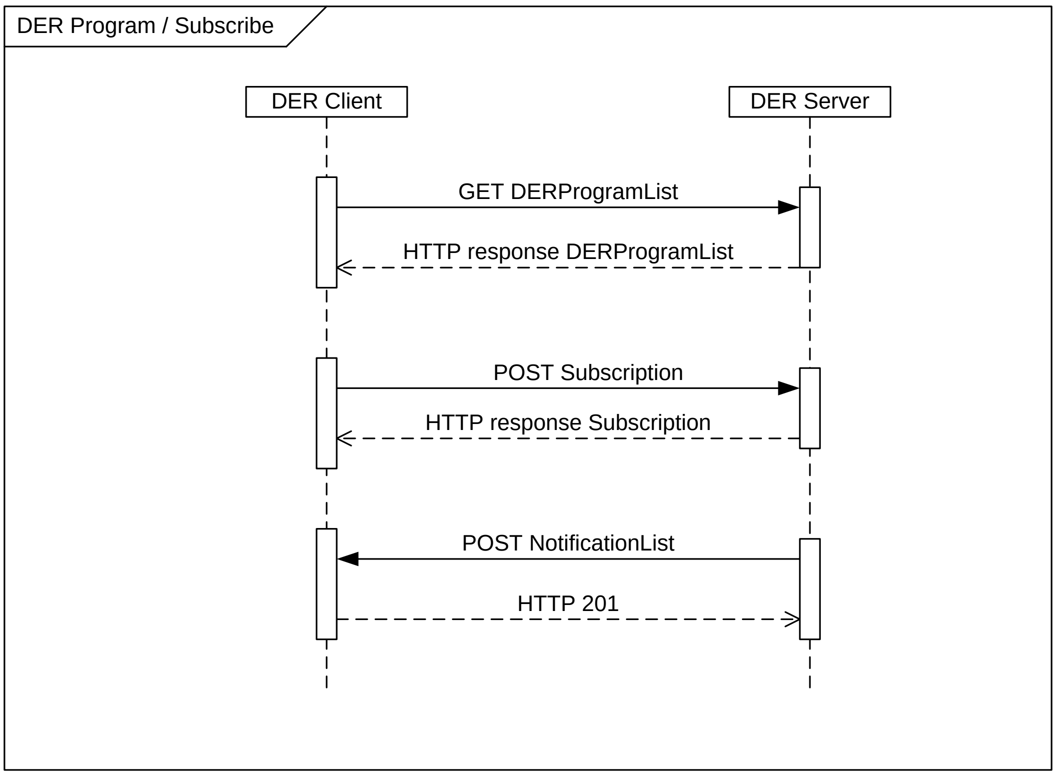

Figure 6-2
Subscribe/Notify Flow Diagram

Figure 6-2 shows the process of subscription and notification.

Subscribable Resources

Subscription Rules

Located below are the rules and requirements for subscriptions from the specification. They also specify when a notification is sent.

- [Sub-A]: Clients shall send subscription renewals every 24 hours, and no more often than every 1 hour.
- [Sub-B]: Servers may remove subscriptions at any time.

- [Sub-C]: Servers should remove subscriptions if a client has not renewed in 36 hours.
- [Sub-D]: Subscriptions shall be maintained on servers through power loss.
- [Sub-E]: Servers shall use the subscription parameters from the latest subscription renewal.
- [Sub-F]: Clients should poll after perceived loss of connectivity.
- [Sub-G]: If the URI of a resource changes, then subscriptions to that resource shall be terminated.
- [Sub-H]: For subscriptions to non-list resources, a notification shall be sent whenever the representation of the non-list resource changes.
- [Sub-I]: For subscriptions to list resources, a notification shall be sent whenever any subordinate resources are added to or removed from the list, or if the representation of those subordinate resources change. See Section 6.5 in the specification for more information.
- [Sub-J]: To prevent overwhelming network resources, notifications should be sent to a given client for a given resource no more than once every 30 seconds. Notifications for conditional subscriptions should only be sent once within this time period for a given client for a given resource and any additional notifications should not be queued. All devices need to be considerate of network resources.
- [Sub-K]: Servers implementing the subscription resource shall be capable of maintaining a minimum of 1 subscription and servers implementing the subscription resource should support at least 1 subscription per device per subscribable resource.
- [Sub-L]: If a server implementing the subscription resource is unable to accept a subscription, the server shall return an error representation indicating the specific error (e.g., element does not support conditional subscription).
- [Sub-M]: When a server removes or terminates a subscription, it shall send the client a terminate subscription. The server shall send a *Notification* to the client's "Post URI" for the affected subscription. The *Resource* contained in the *Notification* shall be a *Subscription,* containing a *Status* element identifying the reason for terminating the subscription. When a subscription is terminated because the subscribed resource has moved, servers may include *newResourceURI* in the subscription termination message, indicating the resource's new location.
- [Sub-N]: If a client receives a notification for a subscription of which it is unaware, the client shall return an HTTP 5xx error.
- [Sub-O]: Servers should allow only the end device that corresponds to a given EndDevice resource to modify the subscriptions within that resource.
- [Sub-P]: The default recommended policy is that subscription management should be performed using TLS.

How to Subscribe

The process of subscribing is relatively simple. It first starts out with a Post call from the client to the server. Next, the desired instance, list, or device's URIs are entered after the Post with "/sub" added to the end of it. The host and IP address is added to the next line, followed by the content length of the EXI that will be located below the initial request. The content type is also added after the content length. The EXI will be under the first four lines of whatever subscribed instance, list, or device. To see what is subscribable, see Appendix B in the specification.

The client would send:

```
POST /edev/0/sub HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Content-Type: application/sep+xml
Content-Length: 277

<Subscription xmlns="http://zigbee.org/sep">
   <subscribedResource>http://server.example.com/derp/0/derc</subscribedRe
source>
   <encoding>0</encoding>
   <level>+S0</level>
   <limit>1</limit>
   <notificationURI>http://client.example.com/ntfy</notificationURI>
</Subscription>
```

The fields in the Subscription request are described in Table 6-2. See the SEP 2.0 v0.9 specification for additional detail.

Table 6-3
Subscription Function Attributes

Attribute Name	Description	Req'd
Subscription	Container for the subscription attributes	Yes
encoding	0 - application/sep+xml, 1 - application/sep-exi	Yes
level	Contains the preferred schema and extensibility level indication such as "+S0"	Yes
limit	This element is used to indicate the maximum number of items that should be included in a notification when the subscribed resource changes.	Yes
notificationURI	The resource to which to post the notifications about the requested subscribed resource.	Yes

The <limit>1</limit> attribute will cause one list item (the newest one according to the sort order defined in Table 13-11 on page 139 of the SEP2 specification) to be returned each time the list changes.

If new subscription entries are created the DER server responds with Status 201 Created.

The server would respond:

```
HTTP/1.1 201 CREATED
Location: /edev/0/sub/1
```

If entries were not created but modified the DER server responds with Status 204.

The server would respond:

```
HTTP/1.1 204 No Content
```

From that point forward, the DER server will "PUSH" DERControlList updates to the client.

DER Subscriptions

The DER Control function lets the user subscribe to at least 4 DER Controls. Client devices can subscribe to a specific DER Control instance such as the Watt Hour control to stay up to date with the DER Control. Whenever a new DERControl is discovered, the client will have the option to subscribe to that device or not.

POST Notification

When a subscribed resource changes or a subscribed event happens, the notification resource is used to notify the client device. The location of the notification resource is passed to the subscription server in the body of the subscription. A client device may have one notification that represents many different notifications or may have a different notification resource for each type of notifications. The notification should resemble a server's response to a GET request from a client device. View the subscription rules above to see when notifications are sent.

Below are the two URIs associated with the Notification resource. For more information on what actions they are compatible with, see page 128, line 3517 in the specification.

/ntfy shows the list of notifications.

/ntfy/{id1} shows a specific notification.

The server would send:

```
POST /ntfy HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Content-Type: application/sep+xml
Content-Length: 966

<?xml version="1.0" encoding="UTF-8"?>
<Notification xmlns="http://zigbee.org/sep">
   <subscribedResource>/derp/0/derc</subscribedResource>
   <Resource xsi:type="DERControlList" xmlns="http://zigbee.org/sep"
all="2" href="/derp/0/derc" results="1" subscribable="1">
      <DERControl>
         <mRID>0000000000000000000000002BE7A7E57</mRID>
         <description>Example DERControl 1</description>
         <creationTime>1341446390</creationTime>
         <EventStatus>
            <dateTime>1341532800</dateTime>
            <potentiallySuperseded>false</potentiallySuperseded>
            <type>1</type>
         </EventStatus>
         <interval>
            <duration>86400</duration>
            <start>1341446400</start>
         </interval>
         <randomizeDuration>180</randomizeDuration>
         <randomizeStart>180</randomizeStart>
         <opModGenConnect>true</opModGenConnect>
         <opModVoltWatt>1</opModVoltWatt>
      </DERControl>
   </Resource>
   <status>0</status>
   <subscriptionURI>/edev/0/sub/1</subscriptionURI>
</Notification>
```

The fields in the Notification are described in Table 6-3.

Table 6-4
Notification Function Attributes

Attribute Name	Description	Req'd
Notification	Container for the DERControls	Yes
DERControl	Container for the DERControl elements. Two controls are identified in this example, numbers 0 and 1 as identified by the digits following "/actderc/".	Yes
mRID	128 bit (32 hex digit) attribute with the 32 LSBs being the IANA PEN provider ID and the remaining bits identifying the objects created by that provider. In this case the value is empty and must be recorded as such.	Yes
creationTime	The time this control was created in UTC. Note that this is not local time.	Yes
EventStatus	Container for the EventStatus elements	Yes

Attribute Name	Description	Req'd
dateTime	A timestamp of when the current status was defined.	Yes
potentiallySuperseded	Set to true by a server of this event if there are events that may overlap this event in time.	Yes
type	Field representing the current status type. 0 = Scheduled, 1 = Active, 2 = Cancelled, 3 = Cancelled with Randomization, 4 = Superseded.	Yes
interval	Container for the start and duration values. The period during which the Event applies.	Yes
duration	Number seconds past the start time to end the disconnect event	Yes
start	The time to disconnect in UTC. Note that this is not local time.	Yes
randomizeDuration	A random number between 0 and this number to be added to the duration to calculate the actual end time of the event. When this number is negative the end time will be earlier than the duration value.	Yes
randomizeStart	A random number between 0 and this number to be added to the start time to calculate the actual start time of the event. When this number is negative the start time will be earlier than the start value.	Yes
opModGenConnect	Set generator DER as connected (true) or disconnected (false)	Yes
opModVoltWatt	Specify curve Id for curve type = 4.	Yes

This example shows two modes being set: connected and Volt-Watt mode with a curveID of 1. If a utility wishes to update an existing curveID with new data, it would first update the curve and then issue a new DERControl that referenced it.

Note that the <subscribedResource>/derp/0/derc</subscribedResource> does not provide the complete path. It defaults to the location set previously so the full path would be:

<subscribedResource>http://server.example.com/derp/0/derc</subscribedResource>

The client would respond:

```
HTTP/1.1 201 Created
```

GET DERAvailability

The DERAvailability object is used by client devices to report their current generation status and their availability to deliver reserve active and reactive power. It can also be exposed instead by devices that are able to report this information on behalf of other devices. The availabilityDuration attribute may be provided to indicate how long the generation can be sustained. The DERAvailability resource is optional on DER devices.

Currently the ESI cannot subscribe to the end device availability so the end device cannot PUT its availability to the ESI. The ESI must perform a GET of the availability to stay current on its current condition. DER resource shows the capability of a DER device. The URI for the DERStatus resource is /edev/{id1}/der/ders. For further information on the DER resource and what it returns, see Figure 16-33: DER Info Types on page 224 or the DERStatus Object on page 230 in the specification.

The server would send:

```
GET /edev/3/DERAvailabilityLink HTTP/1.1
Host: fe80::2012:eff:fe41:a66c
Accept: application/sep+xml; level=+S0
```

The client would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 1043

<?xml version="1.0" encoding="UTF-8"?>
<DERAvailability xmlns="http://zigbee.org/sep">
   <availabilityDuration>0</availabilityDuration>
   <DERProgramLink href="/derp/0"/>
   <reservePercent>65535</reservePercent>
   <statVArAvail>
      <multiplier>127</multiplier>
      <value>65535</value>
   </statVArAvail>
   <statWAvail>
      <multiplier>127</multiplier>
      <value>4096</value>
   </statWAvail>
</DERAvailability>
```

The fields in the DERAvailability are described in Table 6-5.

Table 6-5
DERAvailability Function Attributes

Attribute Name	Description	Req'd
DERAvailability	Container for DERAvailability attributes	Yes
availabilityDuration	Indicates for how many seconds the DER will be able to deliver at the reserve active power level.	No
reservePercent	Maximum percent of continuous active power (setMaxW) that is estimated to be available in reserve.	No
statVArAvail	Estimated reserve reactive power, in VAr.	No
multiplier	Multiplier for above attribute	Yes
value	Value for above attribute	Yes
statWAvail	Estimated reserve active power, in Watts.	No
multiplier	Multiplier for above attribute	Yes
value	Value for above attribute	Yes

7
SUPPORTED DER MANAGEMENT FUNCTIONS

The 0.9 draft of the SEP 2.0 specification added DER supports that were not available in SEP 1.0. This chapter examines the supported functions in detail that are included in the specification, providing flow diagrams of the exchanges, function descriptions, potential interoperability issues, and sample XML exchanges. Note that the examples provided are one way of implementing a function and not necessarily the only or best method.

Degree of Support

There is a close but not perfect alignment between EPRI Common Functions for Smart Inverters, IEC 61850-90-7, DNP3 AN2011-001 and SEP2 DER support are closely coupled but not completely. Some functions are supported with slightly different attributes and a few functions are not supported at all within SEP2. The following chart gives an overview of the degree of support for the DER functions. The ratings are one through five where one is no or little support and five is complete support. Please see the following sections in this chapter for the details on how the SEP2 functions match up to the three standards documents.

The rating system is as follows:

Five stars are given to functions that have no compatibility issues identified with the existing standards.

Four stars are given to functions that have limited compatibility issues identified that can be overcome by a straight forward calculation or use of a default setting.

Three stars are given to functions for which the majority of the functionality is maintained but a portion is lost and could not be supported.

Two stars age given to functions for which a significant portion of the functionality is lost but some capability could be maintained.

One star is given if no aspect of the function is supported. Table 7-1 shows the ratings on the SEP2 support for the various standard DER functions.

Table 7-1
DER Function Ratings

Function Name	Chapter	Rating
DER Generation Connect/Disconnect	7	★★★★
Max Generation Level Control	7	★★★★
Volt-Watt Function	7	★★★★
Intelligent Volt-VAr Function	7	★★★★
Frequency-Watt Function	7	★★★★
Low/High Voltage Ride-Through	7	★★★★★
Direct Storage Management	7	★★★★
Fixed Power Factor Control	7	★★★★★
State/Status Monitoring	7	★★★★
Event Logging	7	★★
Time Adjustment	7	★★★★★
Fixed VAr Control	7	★★★★★
Curve List Retrieval Process	7	n/a
Curve Retrieval Process	7	n/a
Priced-Based Storage Management	8	★★
Dynamic Reactive Current Support Function	8	★
Real Power Smoothing	8	★
Dynamic Volt-Watt Function	8	★
Peak Power Limiting	8	★
Load and Generation Following	8	★

DERControl Data Exchange

Figure 7-1 shows a typical DERControl data exchange. This example would be for a Connect/Disconnect function or control of the maximum generation level. Note the addition of the Response server to the flow diagram. The server which handles the response is not necessarily the same server which handles the DER request. This is specified using the "replyTo=" attribute in the DERControl line as shown in the XML examples.

Example DERControl Data Exchange

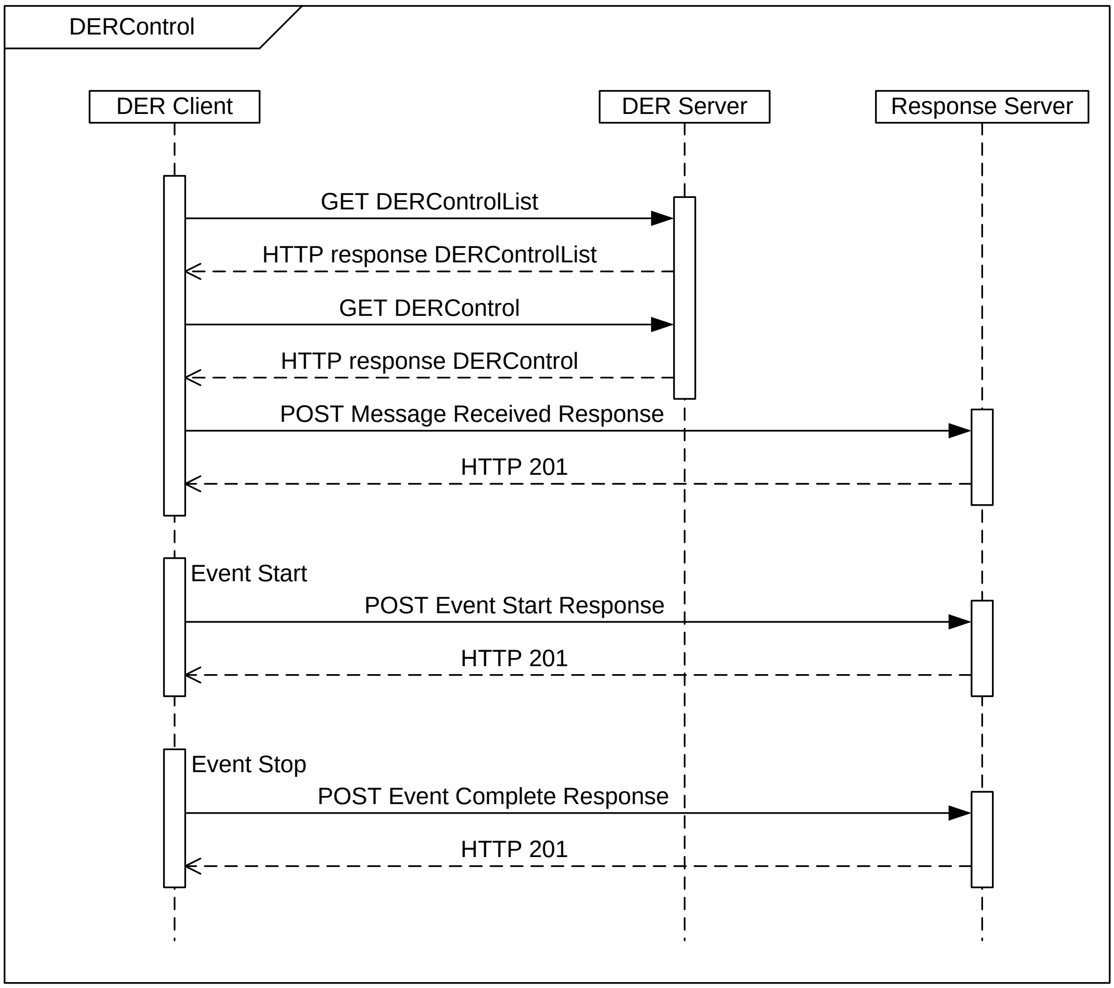

Figure 7-1
DERControl Flow Diagram

The first step is to get the DERControl list. This can be tailored to the needs of the device by getting only active, pending or all DERControl objects in the list. This is followed by getting a specific instance of a DERControl. Responses are then generated for receipt of the DERControl, initiating a DERControl event and terminating a DERControl event.

DER Generation Connect/Disconnect

Function Description

This function is used to connect/disconnect a DER device to/from the grid. Setting the power output to zero does not satisfy this function. It specifically refers to the operation of a switch device that would completely isolate the DER from the grid. Example uses of this function include:

- Removing a misbehaving DER device from the grid
- Removing possible voltage sources during maintenance.

The connect/disconnect function is not related to intentional islanding, and refers to the management of a switch that separates at the DER, leaving customers connected to the grid. Figure 7-2 from the EPRI report: Common Functions for Smart Inverters[3] depicts a possible implementation of DER system with both PV and storage capability. This function relates to the operation of the "DER Connect/Disconnect Switch," not the "Utility Switch."

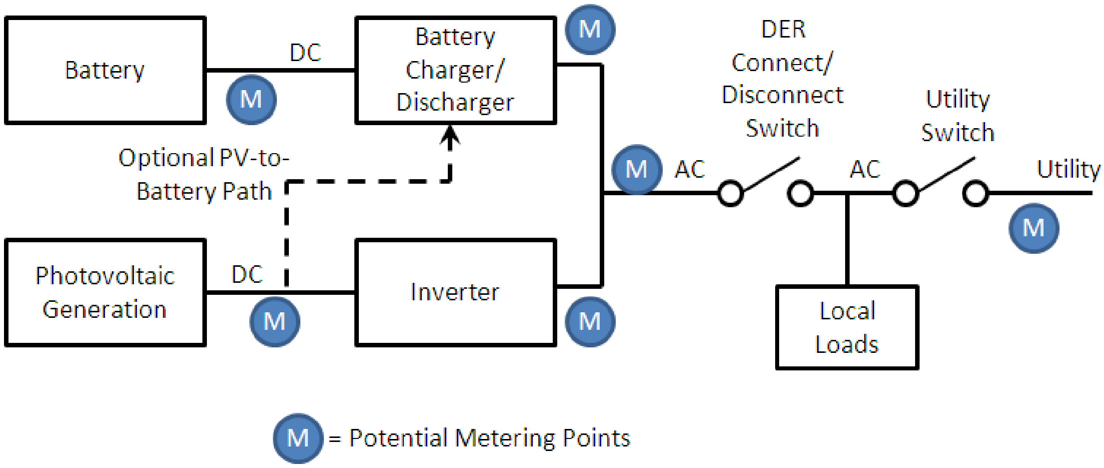

Figure 7-2
Example DER Diagram

See chapter 3 of [1] for more details on this function. This function is the equivalent of the DNP3 function INV1: Connect/Disconnect described in section 2.3.3 of [2]. Document [3] describes this function in section 7.1.1 Function INV1: connect/disconnect from grid. All of these functions achieve the same result of allowing a controller to connect/disconnect a DER inverter to/from the grid within a specified time window and receive a response.

---

[3] *Common Functions for Smart Inverters*. EPRI, Palo Alto, CA: 2011. 1023059

Function Status

EPRI has issued comments on the SEP2 0.9 public draft for this function. See the section below on challenges in achieving interoperable implementations for a description of the issues raised.

Challenges in Achieving Interoperable Implementations

SEP2 has taken the approach of defining each DERControl as a composite message, containing all desired DER operating modalities with the intent of overriding the previous ones. The difficulty with this approach is that in the case of a misbehaving inverter, the utility could send a disconnect command to the inverter in order to have it disconnect from the grid. If at a later time, another function such as a Volt-Watt event is scheduled, the opModGenConnect could be inadvertently reset to true, and there would be nothing to prevent the inverter from reconnecting.

According to the SEP2 approach, when sending a disconnect command to an inverter, it is the responsibility of the DER server to invalidate all future events until the inverter is told to reconnect by the utility. This is more complicated than having the connect/disconnect command be an independent stand alone function that is not combined with any other function.

This approach of having each message contain all elements of the DERControl also means if a Volt-VAr curve is enabled, a previously enabled Watt-frequency function will be disabled. This issue was raised during the review comment resolution meetings and is being addressed. The method of resolution was not available at the time of publication of this report.

Suggested SEP2.0 Usage to Support this Function

In this example, the endpoint requests a single element from the DERControlList on the DER server.

The client would send:

```
GET /derp/0/derc?s=0&l=1 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The above GET asks for the DERControls in DERProgram 0, starting at the first element (s=0) and return one element (l=1). The DER server responds with the first DERControl on the list. This request can return from one to many DERControl objects in a single request.

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 883

<DERControlList xmlns="http://zigbee.org/sep" all="2" href="/derp/0/derc"
results="1" subscribable="1">
   <DERControl xmlns="http://zigbee.org/sep" href="/derp/1/derc/3"
responseRequired="01" subscribable="true" replyTo="/rsp">
      <mRID>000000000000000000000002BE7A7E57</mRID>
      <description>Shutdown for testing</description>
      <creationTime> 1343761959</creationTime>
      <EventStatus>
         <dateTime>1343761959</dateTime>
         <potentiallySuperseded>true</potentiallySuperseded>
         <potentiallySupersededTime>2147483647</potentiallySupersededTime>
         <reason>Text description</reason>
         <type>0</type>
      </EventStatus>
      <interval>
         <duration>14400</duration>
         <start> 1343815200</start>
      </interval>
      <randomizeDuration>120</randomizeDuration>
      <randomizeStart>120</randomizeStart>
      <opModGenConnect>false</opModGenConnect>
   </DERControl>
</DERControlList>
```

In this case the reply tells the DER endpoint to disconnect the inverter starting between 1343815200 (August 1, 2012 10:00:00) and 1343815320 (August 1, 2012 10:02:00) UTC time and stopping between 1343829600 (August 1, 2012 14:00:00) and 1343829720 (August 1, 2012 14:02:00) UTC time.

The fields in the reply are described in Table 7-2. See the SEP 2.0 v0.9 specification for additional detail.

Table 7-2
Connect/Disconnect Function Attributes

Attribute Name	Description	Req'd
DERControlList	Container for the DERControl objects	Yes
DERControl	Container for the DERControl elements	Yes
mRID	128 bit attribute with the 32 LSBs being the IANA PEN provider ID and the remaining bits identifying the objects created by that provider.	Yes
description	A text description of the DERControl	No
creationTime	The time this DERControl was created in UTC.	Yes
EventStatus	Container for the EventStatus elements	Yes

Attribute Name	Description	Req'd
dateTime	A timestamp of when the current status was defined.	Yes
potentiallySuperseded	Set to true by a server of this event if there are events that may overlap this event in time.	Yes
potentiallySupersededTime	The time that the potentiallySuperseded flag was set.	No
reason	A textual explanation of the status.	No
type	Field representing the current status type. 0 = Scheduled, 1 = Active, 2 = Cancelled, 3 = Cancelled with Randomization, 4 = Superseded.	Yes
interval	Container for the start and duration values. The period during which the Event applies.	Yes
duration	Number seconds past the start time to end the disconnect event	Yes
start	The time to disconnect in UTC. Note that this is not local time.	Yes
randomizeDuration	A random number between 0 and this number to be added to the duration to calculate the actual end time of the event. When this number is negative the end time will be earlier than the duration value.	Yes
randomizeStart	A random number between 0 and this number to be added to the start time to calculate the actual start time of the event. When this number is negative the start time will be earlier than the start value.	Yes
opModGenConnect	Set generator DER as connected (true) or disconnected (false)	Yes

If the desired DERControl is known, asking for the DERContolList is not necessary. The following XML would be typical of a poll by the endpoint and the response returned by the ESI host for a request for a specific DERControl. This example assumes that this specific disconnect event is part of DER program 1, and is DERControl 3.

The client would send:

```
GET /derp/1/derc/3 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 781

<?xml version="1.0" encoding="UTF-8" ?>
<DERControl xmlns="http://zigbee.org/sep" href="/derp/1/derc/3"
responseRequired="01" subscribable="true" replyTo="/rsp">
   <mRID>000000000000000000000002BE7A7E57</mRID>
   <description>Shutdown for testing</description>
   <creationTime> 1343761959</creationTime>
   <EventStatus>
      <dateTime>1343761959</dateTime>
      <potentiallySuperseded>true</potentiallySuperseded>
      <potentiallySupersededTime>1343766243</potentiallySupersededTime>
      <reason>Text description</reason>
      <type>0</type>
   </EventStatus>
   <interval>
      <duration>14400</duration>
      <start> 1343815200</start>
   </interval>
   <randomizeDuration>120</randomizeDuration>
   <randomizeStart>120</randomizeStart>
   <opModGenConnect>false</opModGenConnect>
</DERControl>
```

Notice that the DERControl section is identical. The only difference is it is no longer contained in a DERControlList.

Note that SEP2 specifies a time for an event or action to take place in UTC time, not local time. Local time offsets and daylight savings time (DST) offsets must be calculated to determine local time for the events to be triggered. Maintaining time in UTC on the resource can simplify time calculations. The actual start time and end time is calculated:

ActualStart = start + random(0 to randomizeStart)

ActualEnd = start + duration + random(0 to randomizeDuration)

Responses

Three responses are generated to this event. The first is sent when the DERControl message is received. The second is sent when the event begins and the third is sent when it terminates. The response message is shown in the following code window. These responses are typical for most DERControl functions so they will not be repeated in each section.

Message Received Response

For each DERControl with ResponseRequired Bit 0 set, the Client POSTs a Response with a Status of "Message Received" to the Response resource specified by the replyTo field in the DERControl.

The client would send:

```
POST /rsp HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Content-Type: application/sep+xml
Content-Length: 252

<Response xmlns="http://zigbee.org/sep">
   <createdDateTime>1341507000</createdDateTime>
   <endDeviceLFDI>00000000000000000000000000000000C0FFEE00</endDeviceLFDI>
   <status>1</status>
   <subject>000000000000000000000002BE7A7E57</subject>
</Response>
```

The fields in the response are described in Table 7-3.

Table 7-3
DERControl Message Received Response Attributes

Attribute Name	Description	Req'd
Response	Container for the response attributes	Yes
createdDateTime	The time this response was created in UTC	No
endDeviceLFDI	Contains the LFDI of the device providing the response	Yes
status	1 = "Message Received"	No
subject	mRID of the DERControl that is being responded to	Yes

The response server would respond:

```
HTTP/1.1 201 Created
```

This message can have multiple Response sections, one for each DERControl contained in the original message.

Event Started Response

The client initiates the event at the start time or immediately if the start time is in the past. Client POSTs a Response with a Status of "Event Started" to the Response resource specified by the replyTo field in the DERControl.

The client would send:

```
POST /rsp HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Content-Type: application/sep+xml
Content-Length: 252

<Response xmlns="http://zigbee.org/sep">
   <createdDateTime>1341507010</createdDateTime>
   <endDeviceLFDI>00000000000000000000000000000000C0FFEE00</endDeviceLFDI>
   <status>2</status>
   <subject>000000000000000000000002BE7A7E57</subject>
</Response>
```

The fields in the response are described in Table 7-4.

Table 7-4
DERControl Event Started Response Attributes

Attribute Name	Description	Req'd
Response	Container for the response elements	Yes
createdDateTime	The time this response was created in UTC.	No
endDeviceLFDI	Contains the LFDI of the device providing the response	Yes
status	2 = "Event Started"	No
subject	mRID of the DERControl that is being responded to.	Yes

The response server would respond:

```
HTTP/1.1 201 Created
```

Event Completed Response

When the client completes the event it POSTs a response with a status of "Event Completed" to the Response resource specified by the replyTo field in the DERControl.

The client would send:

```
POST /rsp HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Content-Type: application/sep+xml
Content-Length: 252

<Response xmlns="http://zigbee.org/sep">
   <createdDateTime>1341532810</createdDateTime>
   <endDeviceLFDI>00000000000000000000000000000000C0FFEE00</endDeviceLFDI>
   <status>3</status>
   <subject>000000000000000000000002BE7A7E57</subject>
</Response>
```

The fields in the response are described in Table 7-5.

Table 7-5
DERControl Event Completed Response Attributes

Attribute Name	Description	Req'd
Response	Container for the response elements	Yes
createdDateTime	The time this response was created in UTC.	No
endDeviceLFDI	Contains the LFDI of the device providing the response	Yes
status	3 = "Event Completed"	No
subject	mRID of the DERControl that is being responded to.	Yes

The response server would respond:

```
HTTP/1.1 201 Created
```

DER Storage Connect/Disconnect

This is the same as DER generation connect/disconnect except it is for storage systems. The examples are the same except <opModGenConnect> is replaced with <opModStorConnect>.

Max Generation Level Control

Function Description

This function is intended to provide a flexible mechanism through which the maximum generation level of a distributed generation device might be reduced, if so desired. This could be implemented to address:

- Temporary over voltage condition on the feeder
- Any other condition in which a utility might desire to reduce the output levels of DER.

See chapter 4 of [1] for more details on this function. This function is the equivalent of the DNP3 function INV2: Adjust Maximum Generation Level Up/Down described in section 2.3.4 of [2]. Document [3] describes this function in section 7.1.2 Function INV2: adjust maximum generation level up/down. All of these functions achieve the same result: regulating the maximum output of an inverter up or down with the capability of providing a start time, duration and randomized beginning and end times.

Function Status

This function is stable and probably will not change significantly in the final release.

Challenges in Achieving Interoperable Implementations

Ramp time is not defined within the SEP2 specification so a device-specific default or user configured value will be used.

All other parameters for managing Max Generation Level Control that are defined in the Common Functions for Smart Inverters document are supported in the SEP2.0

Suggested SEP2.0 Usage to Support this Function

The following XML would be typical of a poll by the endpoint and the response returned by the ESI host. This example assumes that this specific maximum generation level control event is part of DER program 1, and is DERControl 4.

The client would send:

```
GET /derp/1/derc/4 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 772

<?xml version="1.0" encoding="UTF-8" ?>
<DERControl xmlns="http://zigbee.org/sep" href="/derp/1/derc/3"
responseRequired="01" subscribable="true" replyTo="/rsp">
   <mRID>0000000000000000000000003BE7A7E57</mRID>
   <description>Shutdown for testing</description>
   <creationTime> 1343761959</creationTime>
   <EventStatus>
      <dateTime>1343761959</dateTime>
      <potentiallySuperseded>true</potentiallySuperseded>
      <potentiallySupersededTime>2147483647</potentiallySupersededTime>
      <reason>Text description</reason>
      <type>0</type>
   </EventStatus>
   <interval>
      <duration>14400</duration>
      <start> 1343815200</start>
   </interval>
   <randomizeDuration>120</randomizeDuration>
   <randomizeStart>120</randomizeStart>
   <opModFixedW>7500</opModFixedW>
</DERControl>
```

Table 7-6 explains the attributes in the DERControl function.

Table 7-6
Max Generation Level Control Function Attributes

Attribute Name	Description	Req'd
DERControl	Container for the DERControl attributes	Yes
mRID	128 bit attribute with the 32 LSBs being the IANA PEN provider ID and the remaining bits identifying the objects created by that provider.	Yes
description	A text description of the DERControl	No

Attribute Name	Description	Req'd
creationTime	The time this DERControl was created in UTC.	Yes
EventStatus	Container for the EventStatus elements	Yes
dateTime	A timestamp of when the current status was defined.	Yes
potentiallySuperseded	Set to true by a server of this event if there are events that may overlap this event in time.	Yes
potentiallySupersededTime	The time that the potentiallySuperseded flag was set.	No
reason	A textual explanation of the status.	No
type	Field representing the current status type. 0 = Scheduled, 1 = Active, 2 = Cancelled, 3 = Cancelled with Randomization, 4 = Superseded.	Yes
interval	Container for the start and duration values. The period during which the Event applies.	Yes
duration	Number seconds past the start time to end the disconnect event	Yes
start	The time to disconnect in UTC. Note that this is not local time.	Yes
randomizeDuration	A random number between 0 and this number to be added to the duration to calculate the actual end time of the event. When this number is negative the end time will be earlier than the duration value.	Yes
randomizeStart	A random number between 0 and this number to be added to the start time to calculate the actual start time of the event. When this number is negative the start time will be earlier than the start value.	Yes
opModFixedW	Immediately limit active power output to %setMaxW. The value is an integer in hundredths of a percent. This example is 75% of maximum.	Yes

Responses

The three responses for this message are identical to the responses described in the Responses sections described above in the Connect/Disconnect DERControl. Please see those sections for XML examples and attribute definitions.

Volt-Watt Function

Volt-Watt Function Description

This function is intended to provide a flexible mechanism through which a DER may be configured to limit its maximum Watt output as a function of the local grid voltage. Utilities expressed a variety of needs for this function including:

- Circumstances where high PV output and low load is causing feeder voltage to go too high at certain times. Existing distribution controls are not able to prevent the occurrence.

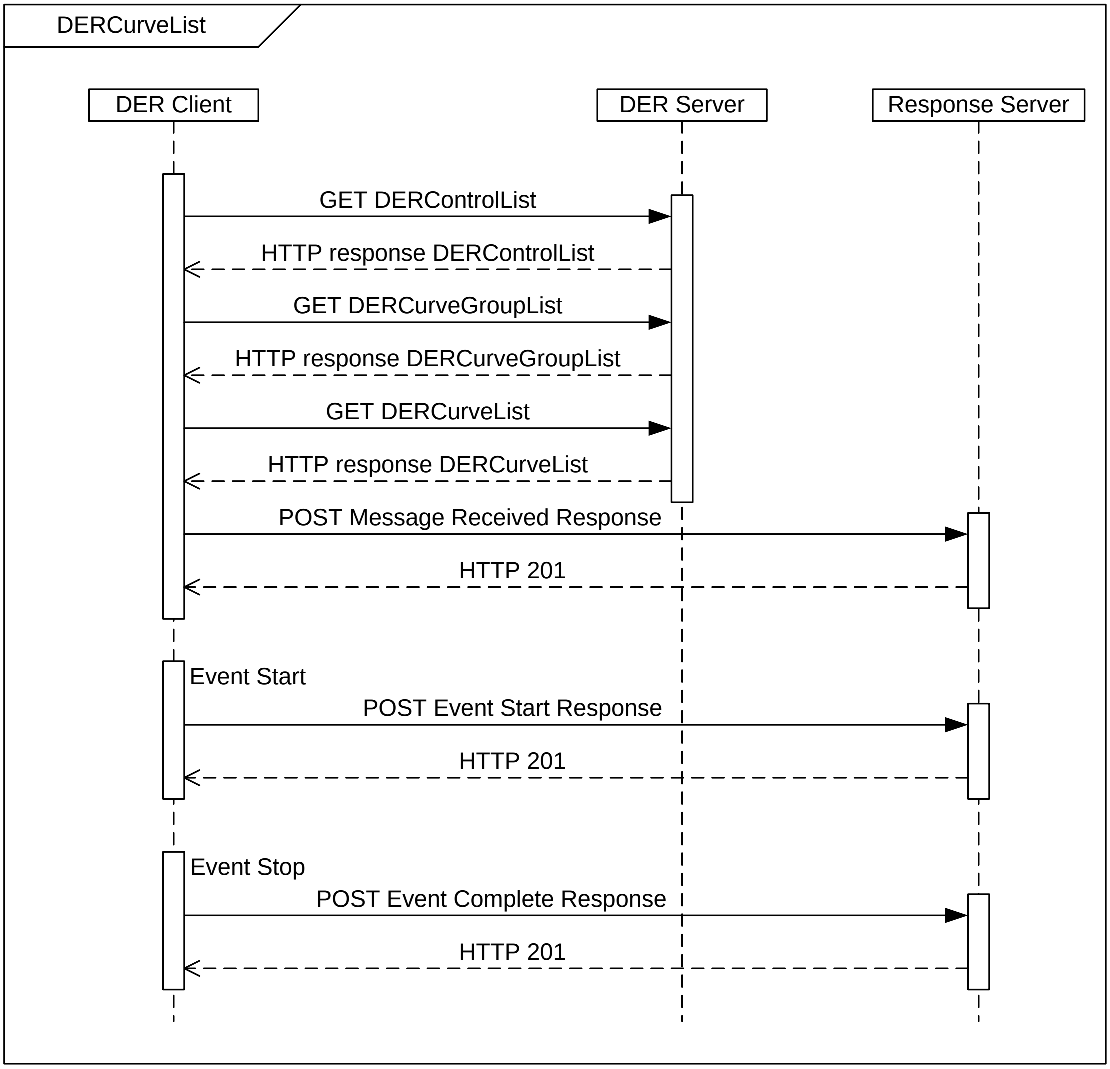

Figure 7-3
Typical Curve DERControl Flow Diagram

Figure 7-3 shows a typical implementation of first getting the DERControlList, DERCurveGroupList, followed by the specific DERCurveList that contains the actual curve data.

See chapter 9 of [1] for more details on this function. Document [3] describes this function in section 7.7.1 Voltage-watt mode VW51: voltage-watt management. All of these functions achieve the same result: adjusting the watt output of an inverter based on the voltage at the point of connection.

Function Status

This function is implemented in the SEP 2.0 Draft 0.9 specification for direct control of the curve ID to be used. Support has not been included for some attributes that control how this function is implemented, such as Fall_Limit, Rise_Limit, and Low Pass Filter Time. Per the IEC standard, these attributes manage the time-characteristics of the inverter relative to the Volt-Watt function.

Challenges in Achieving Interoperable Implementations

Because of the lack of support for some of the parameters, it is assumed that default values would be used by the inverter and any specified values would be ignored during a protocol translation.

Suggested SEP2.0 Usage to Support this Function

The process begins when the client GETs the list of DERControls from the DER server.

The client would send:

```
GET /derp/0/derc?s=0&l=1 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The above GET asks for the DERControls in DERProgram 0, starting at the first element (s=0) and return one element (l=1). The DER server responds with the first DERControl on the list.

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 700

<DERControlList xmlns="http://zigbee.org/sep" all="2" href="/derp/0/derc"
results="1" subscribable="1">
   <DERControl>
      <mRID>000000000000000000000002BE7A7E57</mRID>
      <description>Example DERControl 1</description>
      <creationTime>1341446390</creationTime>
      <EventStatus>
            <dateTime>1341532800</dateTime>
            <potentiallySuperseded>false</potentiallySuperseded>
            <type>1</type>
      </EventStatus>
      <interval>
            <duration>86400</duration>
            <start>1341446400</start>
      </interval>
      <randomizeDuration>180</randomizeDuration>
      <randomizeStart>180</randomizeStart>
      <opModGenConnect>true</opModGenConnect>
      <opModVoltWatt>1</opModVoltWatt>
   </DERControl>
</DERControlList>
```

In this case the reply tells the DER endpoint to use Volt-Watt curve #1 starting between 1341446400 and 1341446580 UTC time and stopping between 1341532800 and 1341532980 UTC time.

The fields in the reply are described in Table 7-7. See the SEP 2.0 v0.9 specification for additional detail.

Table 7-7
Volt-Watt Function Attributes

Attribute Name	Description	Req'd
DERControlList	Container for the DERControl objects	
DERControl	Container for the DERControl elements	
mRID	128 bit attribute with the 32 LSBs being the IANA PEN provider ID and the remaining bits identifying the objects created by that provider. In this example it is item 2 of provider id BE7A7E57.	
description	A text description of the DERControl	
creationTime	The time this DERControl was created in UTC.	
EventStatus	Container for the EventStatus elements	
dateTime	A timestamp of when the current status was defined.	
potentiallySuperseded	Set to true by a server of this event if there are events that may overlap this event in time.	
type	Field representing the current status type. 0 = Scheduled, 1 = Active, 2 = Cancelled, 3 = Cancelled with Randomization, 4 = Superseded.	
interval	Container for the start and duration values. The period during which the Event applies.	
duration	Number seconds past the start time to end the disconnect event	
randomizeDuration	A random number between 0 and this number to be added to the duration to calculate the actual end time of the event. When this number is negative the end time will be earlier than the duration value.	
randomizeStart	A random number between 0 and this number to be added to the start time to calculate the actual start time of the event. When this number is negative the start time will be earlier than the start value.	
opModGenConnect	Set generator DER as connected (true) or disconnected (false).	
opModVoltWatt	Specify curve Id for curve type = 4.	

Curve Retrieval Process

This function uses the curve list retrieval process and the curve retrieval process described at the end of this chapter. The curve list retrieval process obtains a list of available curves that can be retrieved from the server. The curve retrieval process obtains the curve data for a specific curve.

Intelligent Volt-VAr Function

Volt-VAr Function Description

This function is intended to provide a mechanism through which a DER may be configured to manage its own VAr output in response to the local service voltage. This function can be used by utilities for a variety of purposes, including:

- Support of conservation voltage reduction stabilization of the voltage on a feeder
- Minimizing the voltage variation along the length of a feeder.

This is a curve-based function and is handled the same way in SEP2 as other curve-based DER functions. See Figure 7-3 for an applicable flow diagram describing this process.

See chapter 8 of [1] for more details on this function. Section 2.3.12 Volt-VAR Array Modes of [2] covers this function. Document [3] describes this function in section 7.2 Modes for volt-var management. All of these functions achieve the same result: regulating the VAr generation as a result of the voltage at the inverter point of connection.

Function Status

This function is implemented in the SEP 2.0 Draft 0.9 specification for direct control of the curve ID to be used. Support for multiple modes is via the curve ID being altered. Volt-VAr schedules are supported as another curve type.

Ramp rates are specified in the EPRI Common Functions for Smart Inverters report as well as in DNP Application Note AN2011-001. The IEC 61850-90-7 document uses both ramp rate and ramp time but implies that ramp time optional and will default to the ramp rate if the parameter is not included. In SEP2 ramp rates have not been included but has been replaced with ramp time. Ramp rate can be calculated from a requested ramp time and it is assumed the inverter would operate at a default maximum defined by the manufacturer if the calculated value exceeds the default maximum.

Challenges in Achieving Interoperable Implementations

It is assumed there would be default values for the missing parameters which would be used in their place. This could result in unexpected results if translation from another protocol that supports the parameters to SEP2 occurs.

Suggested SEP2.0 Usage to Support this Function

The process begins when the client GETs the list of DERControls from the DER server. This process is exactly the same as the Volt-Watt function with the exception that the response from the DER server would contain <opModVoltVAr> instead of <opModVoltWatt>.

The client would send:

```
GET /derp/0/derc?s=0&l=1 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The above GET asks for the DERControls in DERProgram 0, starting at the first element (s=0) and return one element (l=1). The DER server responds with the first DERControl on the list.

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 698

<DERControlList xmlns="http://zigbee.org/sep" all="2" href="/derp/0/derc"
results="1" subscribable="1">
   <DERControl>
      <mRID>0000000000000000000000002BE7A7E57</mRID>
      <description>Example DERControl 1</description>
      <creationTime>1341446390</creationTime>
      <EventStatus>
            <dateTime>1341532800</dateTime>
            <potentiallySuperseded>false</potentiallySuperseded>
            <type>1</type>
      </EventStatus>
      <interval>
            <duration>86400</duration>
            <start>1341446400</start>
      </interval>
      <randomizeDuration>180</randomizeDuration>
      <randomizeStart>180</randomizeStart>
      <opModGenConnect>true</opModGenConnect>
      <opModVoltVAr>2</opModVoltVAr>
   </DERControl>
</DERControlList>
```

In this case the reply tells the DER endpoint to use Volt-VAr curve ID 1 starting between 1341446400 and 1341446580 UTC time and stopping between 1341532800 and 1341532980 UTC time.

The fields in the reply are described in Table 7-8. See the SEP 2.0 v0.9 specification for additional detail.

Table 7-8
Intelligent Volt-VAr Function Attributes

Attribute Name	Description	Req’d
DERControlList	Container for the DERControl objects	
DERControl	Container for the DERControl elements	
mRID	128 bit attribute with the 32 LSBs being the IANA PEN provider ID and the remaining bits identifying the objects created by that provider. In this example it is item 2 of provider id BE7A7E57.	
Description	A text description of the DERControl	
creationTime	The time this DERControl was created in UTC.	
EventStatus	Container for the EventStatus elements	
dateTime	A timestamp of when the current status was defined.	
potentiallySuperseded	Set to true by a server of this event if there are events that may overlap this event in time.	

Attribute Name	Description	Req'd
Type	Field representing the current status type. 0 = Scheduled, 1 = Active, 2 = Cancelled, 3 = Cancelled with Randomization, 4 = Superseded.	
Interval	Container for the start and duration values. The period during which the Event applies.	
Duration	Number seconds past the start time to end the disconnect event	
randomizeDuration	A random number between 0 and this number to be added to the duration to calculate the actual end time of the event. When this number is negative the end time will be earlier than the duration value.	
randomizeStart	A random number between 0 and this number to be added to the start time to calculate the actual start time of the event. When this number is negative the start time will be earlier than the start value.	
opModGenConnect	Set generator DER as connected (true) or disconnected (false).	
opModVoltVAr	Specify curve Id for curve type = 1.	

Curve Retrieval Process

This function uses the curve list retrieval process and the curve retrieval process described at the end of this chapter. The curve list retrieval process obtains a list of available curves that can be retrieved from the server. The curve retrieval process obtains the curve data for a specific curve.

Frequency-Watt Function

Frequency-Watt Function Description

This function provides a flexible mechanism through which a DER may be configured to manage its maximum Watt input/output in response to the local grid frequency. Two examples of uses for this function are:

- Short-Term (Transient) Frequency Deviations. Under certain circumstances, system frequency may dip suddenly. Autonomous responses to such events are desirable because response must be fast to be of benefit.
- Long-Term Frequency Deviations or Oscillations. Particularly in smaller systems or during islanded conditions, frequency deviations may be longer in duration and indicative of system generation shortfalls or excesses relative to load.

This is a curve based function and is handled the same way in SEP2 as other curve based DER functions. See Figure 7-3 for an applicable flow diagram describing this process. As with other curve based functions, this one commands the DER to use a particular curve, in this case of the Frequency-Watt type, and provides additional attributes such as start times and durations.

See chapter 10 of EPRI Technical Update Common Functions for Smart Inverters, publication number 1023059, for more details on this function. The IEC specification IEC 61850-90-7 describes this function in section 7.3 Modes for frequency-related behaviors. All of these functions achieve the same result: regulating the watt generation as a result of the voltage at the inverter point of connection.

Function Status

While the basic Frequency-Watt function is supported with the ability to select a specific curve to implement and the ability to download specific curve points, a number of configuration parameters needed to fully support this function have not been included, such as:

- The frequency deviation from nominal frequency (ECPNomHz) at which a snapshot of the instantaneous power output is taken as a maximum power output reference level (Pref) and above which reduction in power output occurs (Hz)
- The frequency deviation from nominal frequency (ECPNomHz) at which curtailed power output may return to normal and the snapshot value is released (Hz)
- The maximum time rate of change at which power output returns to normal after having been curtailed by an over frequency event (Hz)
- The frequency at which the power reference point is to be captured if in snapshop mode (Hz)
- The frequency at which the power reference point is to be released if in snapshop mode (Hz)

Challenges in Achieving Interoperable Implementations

It is assumed there would be default values for the missing parameters. This could result in unexpected results if translation from another protocol that supports the parameters to SEP2 occurs.

Suggested SEP2.0 Usage to Support this Function

This curve based function is typical of the previously defined functions. The difference being the use of the opModFreqWatt attribute within the DERControl resource.

Curve Retrieval Process

This function uses the curve list retrieval process and the curve retrieval process described at the end of this chapter. The curve list retrieval process obtains a list of available curves that can be retrieved from the server. The curve retrieval process obtains the curve data for a specific curve.

Low/High Voltage Ride-Through

★★★★★

Function Description

This function provides a flexible mechanism through which general Low/High Voltage Ride-Through (L/HVRT) behavior may be configured, if so desired. In this context, L/HVRT refers to the trip behavior of the DER, essentially defining the voltage conditions under which the DER may and must connect and disconnect.

This function defines only the mechanism through which the L/HVRT settings may be made and does NOT define the settings that would be used. Various countries, states, or other organizations such as the IEEE may issue specific L/HVRT requirements. The intention is that this function will be sufficiently flexible to support all requirements.

See chapter 11 of [1] for more details on this function. Document [3] describes this function in section 7.5 Functions for “must disconnect” and “must stay connected” zones. All of these functions achieve the same result of defining the low/high voltage ride-through behavior.

Function Status

This function is fully implemented in the SEP 2.0 Draft 0.9 specification. Sections 13.9.5.4.2.5 and 6 of the SEP 2.0 specification describe how the curves are intended to be implemented.

Challenges in Achieving Interoperable Implementations

There are no identified issues with this function to affect interoperable implementations.

Suggested SEP2.0 Usage to Support this Function

In this example, it is assumed that the client has been notified of a new DERControl (DERProgram 0, ID 7) via the notification process described earlier in this document. The process begins when the client GETs the new DERControl from the DER server.

The client would send:

```
GET /derp/0/derc/7 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The above GET asks for the DERControl in DERProgram 0, identified by ID 7. The DER server responds with the matching DERControl.

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 828

<?xml version="1.0" encoding="UTF-8" ?>
<DERControl xmlns="http://zigbee.org/sep" href="/derp/0/derc/7"
responseRequired="01" subscribable="true" replyTo="/rsp">
   <mRID>0000000000000000000000003BE7A7E57</mRID>
   <description>LVRT curve for testing</description>
   <creationTime> 1343761959</creationTime>
   <EventStatus>
      <dateTime>1343761959</dateTime>
      <potentiallySuperseded>true</potentiallySuperseded>
      <potentiallySupersededTime>2147483647</potentiallySupersededTime>
      <reason>Text description</reason>
      <type>0</type>
   </EventStatus>
   <interval>
      <duration>31536000</duration>
      <start> 1343815200</start>
   </interval>
   <randomizeDuration>0</randomizeDuration>
   <randomizeStart>0</randomizeStart>
   <opModLVRT>
      <lowerLimit>1</lowerLimit>
      <upperLimit>2</upperLimit>
   </opModLVRT>
</DERControl>
```

In this case the reply tells the DER endpoint to use LVRT curve 1 as the “Must Disconnect” curve and to use LVRT curve 2 as the “Must Remain Connected” starting at 1341446400 UTC time and stopping one year later.

The fields in the reply are described in Table 7-9. See the SEP 2.0 v0.9 specification for additional detail.

Table 7-9
Low/High Voltage Ride-Through Attributes

Attribute Name	Description	Req’d
DERControl	Container for the DERControl elements	Yes
mRID	128 bit attribute with the 32 LSBs being the IANA PEN provider ID and the remaining bits identifying the objects created by that provider. In this example it is item 2 of provider id BE7A7E57.	Yes
description	A text description of the DERControl	
creationTime	The time this DERControl was created in UTC.	
EventStatus	Container for the EventStatus elements	Yes
dateTime	A timestamp of when the current status was defined.	Yes

Attribute Name	Description	Req’d
potentiallySuperseded	Set to true by a server of this event if there are events that may overlap this event in time.	Yes
potentiallySupersededTime	The time that the potentiallySuperseded flag was set.	No
reason	A textual explanation of the status.	No
type	Field representing the current status type. 0 = Scheduled, 1 = Active, 2 = Cancelled, 3 = Cancelled with Randomization, 4 = Superseded.	Yes
interval	Container for the start and duration values. The period during which the Event applies.	Yes
duration	Number seconds past the start time to end the disconnect event	Yes
start	The time to disconnect in UTC. Note that this is not local time.	Yes
randomizeDuration	A random number between 0 and this number to be added to the duration to calculate the actual end time of the event. When this number is negative the end time will be earlier than the duration value.	Yes
randomizeStart	A random number between 0 and this number to be added to the start time to calculate the actual start time of the event. When this number is negative the start time will be earlier than the start value.	Yes
opModLVRT or opModHVRT	Container for the opModLVRT attributes, specify curveId pair for curve type 5 or for the opModHVRT attributes, specify curveId pair for curve type 6	Yes for LVRT
lowerLimit	CurveId for lower bound of operating region, in this case the “must disconnect” region.	Yes
upperLimit	CurveId for upper bound of operating region, in this case the “must remain connected” region.	No

Curve Retrieval Process

This function uses the curve list retrieval process and the curve retrieval process described at the end of this chapter. The curve list retrieval process obtains a list of available curves that can be retrieved from the server. The curve retrieval process obtains the curve data for a specific curve.

Direct Storage Management

Function Description

This function allows the charge or discharge rate of a storage system to be manually set to a percentage of the unit’s maximum charge and discharge rate. This charge/discharge function assumes that the intelligence which determines when charging or discharging resides outside the storage system, and that the storage system follows the requests it is given while operating within its functional constraints.

It sets the rate in the attribute opModFixedFlow as a percentage of the maximum rate. The refType attribute tells the DER if the provided percentage is charging (%setMaxChargingRate) or discharging (%setMaxDischargingRate). This function is only valid if opModStorConnect is true.

See chapter 5 of [1] for more details on this function. This function is the equivalent of the DNP3 function Modify PV/Storage Settings described in section 2.3.8 of [2]. Document [3] describes this function in section 7.1.4 Function INV4: request real power (charge or discharge storage). All of these functions achieve the same result directly managing the charge/discharge processes of battery storage systems.

Function Status

This function is stable and is not likely to change significantly in the final release.

Challenges in Achieving Interoperable Implementations

No ramp rate specification is defined so a manufacturer’s default value would be used.

No minimum reserve for storage is defined so a user defined configuration value would be used.

Suggested SEP2.0 Usage to Support this Function

It is assumed that a prior notification informed the resource that this control has been added or updated based on a subscription. The following XML would be typical of a poll from an endpoint of a request for this DERControl.

The client would send:

```
GET /derp/1/derc/5 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The following example is for setting the maximum storage charge rate.

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 824

<?xml version="1.0" encoding="UTF-8" ?>
<DERControl xmlns="http://zigbee.org/sep" href="/derp/1/derc/5"
responseRequired="01" subscribable="true" replyTo="/rsp">
   <mRID>0000000000000000000000002BE7A7E57</mRID>
   <description>Shutdown for testing</description>
   <creationTime> 1343761959</creationTime>
   <EventStatus>
      <dateTime>1343761959</dateTime>
      <potentiallySuperseded>true</potentiallySuperseded>
      <potentiallySupersededTime>2147483647</potentiallySupersededTime>
      <reason>Text description</reason>
      <type>0</type>
   </EventStatus>
   <interval>
      <duration>14400</duration>
      <start> 1343815200</start>
   </interval>
   <randomizeDuration>120</randomizeDuration>
   <randomizeStart>120</randomizeStart>
   <opModFixedFlow>
      <refType>5</refType>
      <value>8000</value>
   </opModFixedFlow>
</DERControl>
```

Table 7-10 explains the attributes in the DERControl function.

Table 7-10
Direct Storage Management Function Attributes

Attribute Name	Description	Req'd
DERControl	Container for the DERControl attributes	Yes
mRID	128 bit attribute with the 32 LSBs being the IANA PEN provider ID and the remaining bits identifying the objects created by that provider.	Yes
description	A text description of the DERControl	No
creationTime	The time this DERControl was created in UTC.	Yes
EventStatus	Container for the EventStatus elements	Yes
dateTime	A timestamp of when the current status was defined.	Yes
potentiallySuperseded	Set to true by a server of this event if there are events that may overlap this event in time.	Yes
potentiallySupersededTime	The time that the potentiallySuperseded flag was set.	No
reason	A textual explanation of the status.	No
type	Field representing the current status type. 0 = Scheduled, 1 = Active, 2 =	Yes

Attribute Name	Description	Req’d
	Cancelled, 3 = Cancelled with Randomization, 4 = Superseded.	
interval	Container for the start and duration values. The period during which the Event applies.	Yes
duration	Number seconds past the start time to end the disconnect event	Yes
start	The time to disconnect in UTC. Note that this is not local time.	Yes
randomizeDuration	A random number between 0 and this number to be added to the duration to calculate the actual end time of the event. When this number is negative the end time will be earlier than the duration value.	Yes
randomizeStart	A random number between 0 and this number to be added to the start time to calculate the actual start time of the event. When this number is negative the start time will be earlier than the start value.	Yes
opModFixedFlow	FixedFlowType - Valid only of opModStorConnect is true.	Yes
refType	Specifies how values specified in Percent are to be interpreted: 0 - N/A 1 - %setMaxW 2 - %setMaxVAr 3 - %statVArAvail 4 - %setVRef 5 - %setMaxChargingRate 6 - %setMaxDischargingRate	Yes
value	Limit charge/discharge power to a percentage of %setMaxChargingRate or %setMaxDischargingRate. This is an integer value in hundredths of a percent, 0 – 10000 so 10000 = 100%.	Yes
opModGenConnect	Set generator DER as connected (true) or disconnected (false)	Yes

Responses

The three responses for this message are identical to the responses described in the Responses sections described above in the Connect/Disconnect DERControl. Please see those sections for XML examples and attribute definitions.

Fixed Power Factor Control

★★★★★

Function Description

This function is intended to provide a simple mechanism through which the power factor of a DER may be set to a fixed value.

See chapter 7 of [1] for more details on this function. This function is the equivalent of the DNP3 function INV1: Connect/Disconnect described in section 2.3.3 of [2]. Document [3] describes this function in section 7.1.1 Function INV1: connect/disconnect from grid. All of these functions achieve the same result of allowing a controller to connect/disconnect a DER inverter to/from the grid within a specified time window and receive a response.

See chapter 7 of [1] for more details on this function. This function is the equivalent of the DNP3 function INV3: Adjust Power Factor described in section 2.3.5 of [2]. Document [3] describes this function in section 7.1.3 Function INV3: adjust power factor. All of these functions achieve the same result directly managing the power factor of smart inverter systems.

Function Status

This function is stable and probably will not change significantly in the final release.

Challenges in Achieving Interoperable Implementations

The sign of the power factor is a possible point of contention. Care must be taken while translating one protocol to another to be sure that the power factor is expressed in the correct sign.

Suggested SEP2.0 Usage to Support this Function

The following XML would be typical of a poll by the endpoint and the response returned by the ESI host for a request for a specific DERControl. This example assumes that this specific fixed power factor control event is part of DER program 1, and is DERControl 3.

The client would send:

```
GET /derp/1/derc/3 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 873

<?xml version="1.0" encoding="UTF-8" ?>
<DERControl xmlns="http://zigbee.org/sep" href="/derp/1/derc/3"
responseRequired="01" subscribable="true" replyTo="/rsp">
   <mRID>000000000000000000000002BE7A7E57</mRID>
   <description>Shutdown for testing</description>
   <creationTime> 1343761959</creationTime>
   <EventStatus>
      <dateTime>1343761959</dateTime>
      <potentiallySuperseded>true</potentiallySuperseded>
      <potentiallySupersededTime>1343766243</potentiallySupersededTime>
      <reason>Text description</reason>
      <type>0</type>
   </EventStatus>
   <interval>
      <duration>14400</duration>
      <start> 1343815200</start>
   </interval>
   <randomizeDuration>120</randomizeDuration>
   <randomizeStart>120</randomizeStart>
   <opModFixedPF>
      <displacement>900</displacement>
      <excitation>true</excitation>
      <multiplier>-3</multiplier>
   </opModFixedPF>
</DERControl>
```

Table 7-11 explains the attributes in the DERControl function.

Table 7-11
Fixed Power Factor Control Attributes

Attribute Name	Description	Req'd
DERControl	Container for the DERControl attributes	Yes
mRID	128 bit attribute with the 32 LSBs being the IANA PEN provider ID and the remaining bits identifying the objects created by that provider.	Yes
description	A text description of the DERControl	
creationTime	The time this DERControl was created in UTC.	Yes
EventStatus	Container for the EventStatus elements	Yes
dateTime	A timestamp of when the current status was defined.	Yes
potentiallySuperseded	Set to true by a server of this event if there are events that may overlap this event in time.	Yes
potentiallySupersededTime	The time that the potentiallySuperseded flag was set.	
reason	A textual explanation of the status.	

Attribute Name	Description	Req'd
type	Field representing the current status type. 0 = Scheduled, 1 = Active, 2 = Cancelled, 3 = Cancelled with Randomization, 4 = Superseded.	Yes
interval	Container for the start and duration values. The period during which the Event applies.	Yes
duration	Number seconds past the start time to end the disconnect event	Yes
start	The time to disconnect in UTC. Note that this is not local time.	Yes
randomizeDuration	A random number between 0 and this number to be added to the duration to calculate the actual end time of the event. When this number is negative the end time will be earlier than the duration value.	Yes
randomizeStart	A random number between 0 and this number to be added to the start time to calculate the actual start time of the event. When this number is negative the start time will be earlier than the start value.	Yes
opModFixedPF	Container for the FixedPF objects	Yes
displacement	Specify signed value of cos(theta), between -1.0 and 1.0. Sign is interpreted according to convention specified in setPFSign.	Yes
excitation	True for capacitive/over-excited (reactive power delivered by the DER (or Q+)); false for inductive/under-excited (reactive power received by the DER (or Q-)).	Yes
multiplier	Specifies the power of ten multiplier for the displacement. 0 = None (default, if not specified) 1 = deca=x10 2 = hecto=x100 -3 = mili=x10^-3 3 = kilo=x1000 6 = Mega=x10^6 -6 = micro=x10^-3 9 = Giga=x10^9	No

Responses

The three responses for this message are identical to the responses described in the Responses sections described above in the Connect/Disconnect DERControl. Please see those sections for XML examples and attribute definitions.

State/Status Monitoring

Function Description

Many functions require the status of the inverter either periodically, on significant change of a value, or upon request. SEP2 provides reporting status upon request via the DERStatus Resource.

See chapter 19 of [1] for more details on this function. This function is the equivalent of the DNP3 function INV8: “Status” Reporting described in section 2.3.10 of [2]. Document [3] describes this function in section 7.9.3 Reporting status DS93: selecting status points, establishing reporting mechanisms. All of these functions achieve the same result of obtaining the current state/status information for the inverter/storage system.

Function Status

In draft 0.9 the ESI cannot subscribe to the end device status so the end device cannot POST its status to the ESI. The ESI must poll the DER (perform a GET) to obtain the status to stay current on its current condition. It does not allow for the DER to subscribe and update the ESI host when a value goes outside a specified range. This does not satisfy the needs laid out in the standards to be notified on an out of range value. However in the latest unreleased model, DERStatus is a subscribable resource, so the ESI can set up a subscription to be notified when the resource changes. Only in this scenario can the DER client pass the resource to the ESI along with the notification.

DERStatus resource returns the basic operational status of DER device. It contains a link to the active DERProgram, which contains links to the active DERControl and DERCurveGroups.

The DERStatus resource is optional for DER devices. The URI for the DERStatus resource is /edev/{id1}/der/ders. For further information on the DERStatus resource and what it returns, see Figure 16-33: DER Info Types on page 224 or the DERStatus Object on page 230 in the specification.

Challenges in Achieving Interoperable Implementations

While the DERStatus has a collection of attributes that match with a few of the values from the IEC standard, the vast majority of the IEC data values are not available from within the SEP2 DERStatus function. However many of them are available from other sources in SEP2. Some of the values in the IEC status function are nameplate values that are available in SEP2 via the nameplate function (see Table 5-2) and others are setting values (see table 5-3).

Suggested SEP2.0 Usage to Support this Function

The following XML would be typical of a poll by the server requesting an event log list and the response returned by the endpoint.

The server would send:

```
GET /edev/3/DERStatusLink HTTP/1.1
Host: fe80::2012:eff:fe41:a66c
Accept: application/sep+xml; level=+S0
```

The client would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 1551

<?xml version="1.0" encoding="UTF-8"?>
<DERStatus xmlns="http://zigbee.org/sep">
   <DERProgramLink href="/derp/0"/>
   <genConnectStatus>
      <dateTime>1348483647</dateTime>
      <quality>Good</quality>
      <value>255</value>
   </genConnectStatus>
   <inverterStatus>
      <dateTime>1348483647</dateTime>
      <quality>Good</quality>
      <value>255</value>
   </inverterStatus>
   <localControlModeStatus>
      <dateTime>1348483647</dateTime>
      <quality>Good</quality>
      <value>255</value>
   </localControlModeStatus>
   <manufacturerStatus>
      <dateTime>1348483647</dateTime>
      <quality>Good</quality>
      <value>aaaaaa</value>
   </manufacturerStatus>
   <operationalModeStatus>
      <dateTime>1348483647</dateTime>
      <quality>Good</quality>
      <value>255</value>
   </operationalModeStatus>
   <readingTime>1348483647</readingTime>
   <stateOfChargeStatus>
      <dateTime>1348483647</dateTime>
      <quality>Good</quality>
      <value>65535</value>
   </stateOfChargeStatus>
   <storageModeStatus>
      <dateTime>1348483647</dateTime>
      <quality>Good</quality>
      <value>255</value>
   </storageModeStatus>
   <storConnectStatus>
      <dateTime>1348483647</dateTime>
      <quality>Good</quality>
      <value>255</value>
   </storConnectStatus>
</DERStatus>
```

Table 7-12 explains the attributes in the DERStatus function.

Table 7-12
State/Status Monitoring Attributes

Attribute Name	Description	Req'd
DERStatus	DER status information.	No
genConnectStatus	Connect/status value for PV DER: 0 - N/A 1 - disconnected_unavail 2 - disconnected_avail 3 - connected_unavail 4 - connected_avail 5 - connected_on 6 - test_mode	No
inverterStatus	DER InverterStatus/value: 0 - N/A 1 - off 2 - sleeping (auto-shutdown) or DER is at low output power/voltage 3 - starting up or ON but not producing power 4 - tracking MPPT power point 5 - forced power reduction/derating 6 - shutting down 7 - one or more faults exist 8 - standby (service on unit) - DER may be at high output voltage/power 9 - test mode 10- as defined in manufacturer status	No
localControlModeStatus	0 – local control 1 – remote control	No
manufacturerStatus	Manufacturer status code	No
operationalModeStatus	Operational mode currently in use	No
readingTime	A timestamp of when the current status was defined.	No
stateOfChargeStatus	State of charge status	No
storageModeStatus	0 – storage charging 1 – storage discharging 2 – storage holding	No
storConnectStatus	Connect/status value for storage DER: 0 - N/A 1 - disconnected_unavail 2 - disconnected_avail 3 - connected_unavail 4 - connected_avail 5 - connected_on 6 - test_mode	

Time Adjustment

Function Description

End point devices need to be operating on the same time as the host system in order for time based instructions to be properly synchronized. The ability to set the time in the DER device is a requirement to support the scheduling of functions and the time-stamping and logging of events.

See chapter 21 of [1] for more details on this function. This function is the equivalent of the DNP3 function INV10: Time Synchronization described in section 2.3.11 of [2]. Document [3] describes this function in section 7.9.4 Time synchronization DS94: time synchronization requirements. All of these functions achieve the same result of allowing a host system to synchronize time in DER devices to provide a unified time reference for events.

Function Status

This function is stable and probably will not change significantly in the final release.

Challenges in Achieving Interoperable Implementations

None identified.

Suggested SEP2.0 Usage to Support this Function

It is expected that the endpoint will attempt to obtain an accurate time from the ESI device soon after startup. Following that the endpoint should request the time on a regular schedule of once a day at a time of low network traffic. Typically this will be done by the client sending the following command:

```
GET /tm HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The Host would return:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 423

<?xml version="1.0" encoding="UTF-8"?>
<Time xsi:schemaLocation="http://zigbee.org/sep sep.xsd"
xmlns="http://zigbee.org/sep" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance">
   <currentTime>1321966800</currentTime>
   <dstEndTime>1351987200</dstEndTime>
   <dstOffset>0</dstOffset>
   <dstStartTime>1335052800</dstStartTime>
   <localTime>1321948800</localTime>
   <quality>3</quality>
   <tzOffset>0</tzOffset>
</Time>
```

Table 7-13 explains the attributes in the Time function.

Table 7-13
Time Adjustment Function Attributes

Attribute Name	Description	Req'd
currentTime	Seconds since 00:00:00 1/1/1970 UTC (GMT)	Yes
dstEndTime	Time at which daylight savings ends (dstOffset no longer applied).	Yes
dstOffset	Daylight savings time offset from UTC.	Yes
dstStartTime	Time at which daylight savings begins (apply dstOffset).	Yes
localTime	UTC with all local time zone and daylight savings time offsets applied.	No
Quality	Metric indicating the quality of the time source from which the service acquired time: 3 - time obtained from external authoritative source such as NTP 4 - time obtained from level 3 source 5 - time manually set or obtained from level 4 source 6 - time obtained from level 5 source 7 - time intentionally uncoordinated All other values are reserved for future use.	Yes
tzOffset	Local time zone offset from UTC. Does not include any daylight savings time offsets.	Yes

When SEP2 specifies a time for an event or action to take place it is done in UTC time, not local time. In this way, there is no issue of misinterpretation of the intended time because of time zones or daylight savings time.

Fixed VAr Control

★★★★★

Function Description

This function is very similar to the Fixed Power Factor Control except that it tells the inverter to operate at a fixed percentage of available VArs rather than a fixed power factor. Although this function is not found in standard documents [1], [2], or [3] it is simple to implement by using a flat line volt-VAr curve with the desired VAr value.

Function Status

This function is stable and probably will not change significantly in the final release.

Challenges in Achieving Interoperable Implementations

None identified

Suggested SEP2.0 Usage to Support this Function

The following XML would be typical of a poll by the endpoint and the response returned by the ESI host for a request for a specific DERControl. This example assumes that this specific fixed VAr control event is part of DER program 1, and is DERControl 3.

The client would send:

```
GET /derp/1/derc/3 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 873

<?xml version="1.0" encoding="UTF-8" ?>
<DERControl xmlns="http://zigbee.org/sep" href="/derp/1/derc/3"
responseRequired="01" subscribable="true" replyTo="/rsp">
   <mRID>00000000000000000000002BE7A7E57</mRID>
   <description>Shutdown for testing</description>
   <creationTime> 1343761959</creationTime>
   <EventStatus>
      <dateTime>1343761959</dateTime>
      <potentiallySuperseded>true</potentiallySuperseded>
      <potentiallySupersededTime>1343766243</potentiallySupersededTime>
      <reason>Text description</reason>
      <type>0</type>
   </EventStatus>
   <interval>
      <duration>14400</duration>
      <start> 1343815200</start>
   </interval>
   <randomizeDuration>120</randomizeDuration>
   <randomizeStart>120</randomizeStart>
   <opModFixedVAr>
      <refType>2</refType>
      <value>8000</value>
   </opModFixedVAr>
</DERControl>
```

Table 7-14 explains the attributes in the DERControl function.

Table 7-14
Fixed VAr Control Attributes

Attribute Name	Description	Req'd
DERControl	Container for the DERControl attributes	Yes
mRID	128 bit attribute with the 32 LSBs being the IANA PEN provider ID and the remaining bits identifying the objects created by that provider.	Yes
description	A text description of the DERControl	
creationTime	The time this DERControl was created in UTC.	Yes
EventStatus	Container for the EventStatus elements	Yes
dateTime	A timestamp of when the current status was defined.	Yes
potentiallySuperseded	Set to true by a server of this event if there are events that may overlap this event in time.	Yes
potentiallySupersededTime	The time that the potentiallySuperseded flag was set.	No
reason	A textual explanation of the status.	No

Attribute Name	Description	Req'd
type	Field representing the current status type. 0 = Scheduled, 1 = Active, 2 = Cancelled, 3 = Cancelled with Randomization, 4 = Superseded.	Yes
interval	Container for the start and duration values. The period during which the Event applies.	Yes
duration	Number seconds past the start time to end the disconnect event	Yes
start	The time to disconnect in UTC. Note that this is not local time.	Yes
randomizeDuration	A random number between 0 and this number to be added to the duration to calculate the actual end time of the event. When this number is negative the end time will be earlier than the duration value.	Yes
randomizeStart	A random number between 0 and this number to be added to the start time to calculate the actual start time of the event. When this number is negative the start time will be earlier than the start value.	Yes
opModFixedVAr	Immediately set reactive power limit.	Yes
refType	Specifies how values specified in Percent are to be interpreted: 0 - N/A 1 - %setMaxW 2 - %setMaxVAr 3 - %statVArAvail 4 - %setVRef 5 - %setMaxChargingRate 6 - %setMaxDischargingRate	Yes
Value	Sets the VAr to a percentage of %setMaxVAr . This is an integer value in hundredths of a percent, 0 – 10000 so 10000 = 100%.	Yes

Responses

The three responses for this message are identical to the responses described in the Responses sections described above in the Connect/Disconnect DERControl. Please see those sections for XML examples and attribute definitions.

Curve List Retrieval Process Description

While this is not a control function per se, it is required to support the curve based functions within SEP2. Any of the curve based functions need the ability to access new or modified curves. This process retrieves a list of existing curves for the requesting device from the DER server.

Function Status

This function is fully implemented in the SEP 2.0 Draft 0.9 specification.

Challenges in Achieving Interoperable Implementations

There are no identified issues with this function to affect interoperable implementations.

Suggested SEP2.0 Usage to Support this Function

The first step is to request a list of all curves available from the server using the GET dcg request from the DER server.

The client would send:

```
GET /derp/0/dcg HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The above GET asks for the DERCurveGroupList for DERProgram 0. The DER server responds with a list of all the curves available.

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 338

<DERCurveGroupList xmlns="http://zigbee.org/sep" all="1"
href="/derp/0/dcg" results="1">
   <DERCurveGroup>
      <mRID>0000000000000000000000003BE7A7E57</mRID>
      <description>Example Volt-Watt Curve Group</description>
      <curveType>4</curveType>
      <DERCurveListLink all="1" href="/derp/0/dcg/0"/>
   </DERCurveGroup>
</DERCurveGroupList>
```

The example reply above, the DER server only has a single curve available. It is a Volt-Watt curve (curveType 4) and is curve ID 0 (dcg/0).

The fields in the reply are described in Table 7-15. See the SEP 2.0 v0.9 specification for additional detail.

Table 7-15
DERCurveGroupList Attributes

Attribute Name	Description	Req'd
DERCurveGroupList	Container for the DERCurveGroup objects	
DERCurveGroup	Container for the DERCurveGroup elements	
mRID	128 bit attribute with the 32 LSBs being the IANA PEN provider ID and the remaining bits identifying the objects created by that provider. In this example it is item 2 of provider id BE7A7E57.	
description	A text description of the DERControl	

Attribute Name	Description	Req'd
curveType	0 - N/A 1 - Volt-VAr Mode 2 - Frequency-Watt Curve Mode 3 - Watt-PowerFactor Mode 4 - Volt-Watt Mode 5 - Low Voltage Ride Through Mode 6 - High Voltage Ride Through Mode	Yes
DERCurveListLink	Provides the list link information for this curve. In the example above it says there is one curve (all="1") and provides the URI and ID of the curve (href="/derp/0/dcg/0").	

Curve Retrieval Process Description

While this is not a control function per se, it is required to support the curve based functions within SEP2. Any of the curve based functions need the ability to access new or modified curves. This process retrieves a specific curve from the DER server.

Function Status

This function is fully implemented in the SEP 2.0 Draft 0.9 specification.

Challenges in Achieving Interoperable Implementations

There are no identified issues with this function to affect interoperable implementations.

Suggested SEP2.0 Usage to Support this Function

The client request the desired curve from the DER server by sending the following GET.

The client would send:

```
GET /derp/0/dcg/0 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The above GET asks for the curve data for dcg/0. The DER server responds with a list of data points for the specified curve.

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 795

<DERCurveList xmlns="http://zigbee.org/sep" all="1" href="/derp/0/dcg/0"
results="1">
   <DERCurve>
      <mRID>000000000000000000000004BE7A7E57</mRID>
      <description>An example Volt-Watt curve</description>
      <creationTime>1341446380</creationTime>
      <CurveData>
         <xvalue>0</xvalue>
         <y1value>100</y1value>
      </CurveData>
      <CurveData>
         <xvalue>105</xvalue>
         <y1value>100</y1value>
      </CurveData>
      <CurveData>
         <xvalue>115</xvalue>
         <y1value>0</y1value>
      </CurveData>
      <CurveData>
         <xvalue>200</xvalue>
         <y1value>0</y1value>
      </CurveData>
      <curveId>1</curveId>
      <rampTime>10</rampTime>
      <xMultiplier>0</xMultiplier>
      <xUnit>0</xUnit>
      <y1Multiplier>0</y1Multiplier>
      <y1RefType>0</y1RefType>
      <y1Unit>0</y1Unit>
   </DERCurve>
</DERCurveList>
```

The example reply above, the DER server only has a single curve available. It is a Volt-Watt curve (curveType 4) and is curve ID 0 (dcg/0).

The fields in the reply are described in Table 7-16. See the SEP 2.0 v0.9 specification for additional detail.

Table 7-16
DERCurveList Attributes

Attribute Name	Description	Req'd
DERCurveList	Container for the DERCurve objects	Yes
DERCurve	Container for the curve definitions	Yes
mRID	128 bit attribute with the 32 LSBs being the IANA PEN provider ID and the remaining bits identifying the objects created by that provider. In this example it is item 2 of provider id BE7A7E57.	Yes
description	A text description of the DERControl	No
creationTime	The time this control was created in UTC. Note that this is not local time.	Yes
CurveData	Container for the x, y values for the curve	Yes
xvalue	The data value of the X-axis variable, depending on the X-axis units	Yes
y1value	The data value of the first Y-axis variable, depending on the Y-axis units	Yes
curveId	Contains the curve identifier assigned to this curve definition.	Yes
rampTime	Ramp time for moving from current setpoint to new setpoint, in seconds.	Yes
xMultiplier	Multiplier for X-axis.	Yes
y1Multiplier	Multiplier for Y1-axis	Yes
y1RefType	The Y1-axis units context.	Yes
y1Unit	The Y1-axis units of measure.	Yes

Curve Retrieval Function Description

This process retrieves a specific curve from the DER server for curveType 5 (LVRT) or curveType 6 (HVRT).

Function Status

This function is fully implemented in the SEP 2.0 Draft 0.9 specification.

Challenges in Achieving Interoperable Implementations

There are no identified issues with this function to affect interoperable implementations.

Suggested SEP2.0 Usage to Support this Function

The client request the desired curve from the DER server by sending the following GET.

The client would send:

```
GET /derp/0/dcg/5/dc/1 HTTP/1.1
Host: fe80::2012:eff:fe41:a66b
Accept: application/sep+xml; level=+S0
```

The above GET asks for the curve data for dcg/0. The DER server responds with a list of data points for the specified curve.

The server would respond:

```
HTTP/1.1 200 OK
Content-Type: application/sep+xml
Content-Length: 1000

<?xml version="1.0" encoding="UTF-8" ?>
<DERCurveList xmlns="http://zigbee.org/sep" all="1" href="/derp/0/dcg/0"
results="1">
   <DERCurve>
      <mRID>0000000000000000000000004BE7A7E57</mRID>
      <description>An example Volt-Watt curve</description>
      <creationTime>1341446380</creationTime>
      <CurveData>
         <xvalue>0</xvalue>
         <y1value>0</y1value>
      </CurveData>
      <CurveData>
         <xvalue>10</xvalue>
         <y1value>0</y1value>
      </CurveData>
      <CurveData>
         <xvalue>10</xvalue>
         <y1value>85</y1value>
      </CurveData>
      <CurveData>
         <xvalue>30</xvalue>
         <y1value>85</y1value>
      </CurveData>
      <CurveData>
         <xvalue>30</xvalue>
         <y1value>95</y1value>
      </CurveData>
      <CurveData>
         <xvalue>10000</xvalue>
         <y1value>95</y1value>
      </CurveData>
      <curveId>1</curveId>
      <rampTime>10</rampTime>
      <xMultiplier>0</xMultiplier>
      <xUnit>0</xUnit>
      <y1Multiplier>0</y1Multiplier>
      <y1RefType>0</y1RefType>
      <y1Unit>0</y1Unit>
   </DERCurve>
</DERCurveList>
```

The example reply above, the DER server only has a single curve available. It is a Volt-Watt curve (curveType 4) and is curve ID 0 (dcg/0).

The fields in the reply are described in Table 7-17. See the SEP 2.0 v0.9 specification for additional detail.

Table 7-17
DER Curve Retrieval Attributes

Attribute Name	Description	Req'd
DERCurveList	Container for the DERCurve objects	Yes
DERCurve	Container for the curve definitions	Yes
mRID	128 bit attribute with the 32 LSBs being the IANA PEN provider ID and the remaining bits identifying the objects created by that provider. In this example it is item 2 of provider id BE7A7E57.	Yes
description	A text description of the DERControl	No
creationTime	The time this control was created in UTC. Note that this is not local time.	Yes
CurveData	Container for the x, y values for the curve	Yes
xvalue	The data value of the X-axis variable, depending on the X-axis units	Yes
y1value	The data value of the first Y-axis variable, depending on the Y-axis units	Yes
curveId	Contains the curve identifier assigned to this curve definition.	Yes
rampTime	Ramp time for moving from current setpoint to new setpoint, in seconds.	Yes
xMultiplier	Multiplier for X-axis.	Yes
y1Multiplier	Multiplier for Y1-axis	Yes
y1RefType	The Y1-axis units context.	Yes
y1Unit	The Y1-axis units of measure.	Yes

8
UNSUPPORTED DER MANAGEMENT FUNCTIONS

There are eight DER functions identified that do not have support within the SEP 2.0 specification. This chapter examines each function with an eye to workaround methods that may available.

Priced-Based Storage Management

★★

Function Description

This function is intended to provide a mechanism through which the charging and discharging of battery storage systems may be managed based upon current energy price. It is intended to provide a simple mechanism through which battery storage systems may be informed of the price of energy so that they may manage charging and discharging accordingly. A direct charge/discharge function, which assumes that the storage unit is managed by a remote entity, is defined separately. This price-based function, however, assumes that the intelligence which determines charging or discharging resides within the storage system, and that the storage system manages its own affairs relative to this signal and other preferences that may be set by the storage system owner.

In addition to direct settings for charging and discharging storage, utilities and storage system providers indicated a requirement for a mode in which the storage system would manage its own charging and discharging. The idea for this function is that the storage system receives a signal indicative of the price (or value) of energy. The storage system then manages its own decisions about when to charge and discharge, and at what levels.

This kind of autonomous approach allows the storage system to take into account a range of owner preferences and settings, such as considerations of battery life expectancy, anticipation of bad weather /outage, and predictions regarding real-time energy price swings. It enables battery system providers to develop innovative learning algorithms and predictive algorithms to optimize asset value for the owner rather than leaving these algorithms to another entity that may not understand the battery system's capabilities and limitations as well.

Function Shortfalls

There are no provisions made for enabling this function within the DER functions. An inverter with this capability would not be able to be triggered to enter/exit this mode via SEP2 unless it was possible to map it to some other supported function.

Possible Workarounds

SEP2 does support a wide range of pricing methods so it could be used to provide the required information to the storage system. The feature that is missing is the capability of turning this function on or off via the protocol. This would need to be a manually controlled function performed by the customer. The SEP2 server would be capable providing energy price feed.

Event Logging

★★

Function Description

Section 15.2.5/16.1.11 of the SEP2 specification describes the LogEvents function. This function provides for an ability to perform event logging and reporting. This function is intended to provide a common mechanism for inverters to log and report a standardized set of events.

It was viewed as a high priority by the smart inverter initiative participants to provide a common method for event logging and reporting. There is a sense that there are many uncertainties and unknowns regarding smart inverter functions, and that particularly in the early years, it is important to monitor the behaviors of inverters and to flag abnormal conditions and events.

See chapter 20 of [1] for more details on this function. This function is the equivalent of the DNP3 function INV7: Event/History Logging described in section 2.3.9 of [2]. Document [3] describes this function in section 7.9.2 Event logging DS92: log alarms and events, retrieve logs. All of these functions achieve the same result of obtaining the log contents for the inverter/ storage system.

Function Shortfalls

There is not an event logging function for DER. This means the ESI host cannot request a log file of faults or other logged events from the end point inverter. This does not appear to be changing in the next revision.

The SEP 2.0 specification does not have a set of DER Log Events defined. Also missing from the LogEvent resource is a text description of the log event that is defined in both IEC 61850-90-7 and in the smart inverter initiative standards. This will make resolution of the log events difficult across multiple vendors.

Possible Workarounds

For many faults such as low line voltage, etc. these could be available from a sub-meter associated with the DER. The latest SEP2 specification (not yet publically released) contains 31 log events for the Meter Function Set. This would not handle faults coming directly from the DER device.

Behavior during Islanding

Function Description

At the time of the publication of EPRI's Common Functions for Smart Inverters report and IEC 61850-90-7, the topic of "Islanding" had not yet been addressed so it is not surprising that SEP2 also chose not to address this issue. This function, or collection of functions, remains on the list of functional topics to be resolved but as of yet has not received a consensus of opinion on how that can be accomplished.

This function has two components:

- Instruct a DER that it has become islanded, and to configure it in terms of what changes to various settings are required as a result of this new condition.
- Define the process of detecting an islanded condition, such that it could be flexible and yet autonomous.

Function Shortfalls

There are no provisions made for supporting this function within the SEP2 DER functions.

Possible Workarounds

No apparent workarounds are available within SEP2 to achieve this functionality.

Dynamic Reactive Current Support Function

Function Description

This function is intended to provide a flexible mechanism through which inverters may be configured to provide reactive current support in response to dynamic variations in voltage. This function is distinct from the existing steady-state Volt-VAr function in that the controlling parameter is the change in voltage rather than the voltage level itself. In other words, the power system voltage may be above normal, resulting in a general need for inductive VArs, but if it is also falling rapidly, this function could produce capacitive reactive current to help counteract the dropping of the voltage.

This is a type of dynamic system stabilization function. Such functions create an effect that is in some ways similar to momentum or inertia, in that it resists rapid change in the controlling parameter. The possible benefits could be:

- Power quality, such as flicker, may be improved by the implementation of functions of this type and when implemented in fast-responding solid-state inverters
- These functions may provide other (slower) grid equipment with time to respond.

Function Shortfalls

There are no provisions made for supporting this function within the SEP2 DER functions.

Possible Workarounds

No apparent workarounds are available within SEP2 to achieve this functionality. An inverter that supported this functionality would need to be enabled manually.

Real Power Smoothing

Function Description

Although this function is defined in EPRI's Common Functions for Smart Inverters report, it was not included in the IEC 61850-90-7 draft.

This function is intended to provide a flexible mechanism through which inverters, such as those associated with battery storage systems, may be configured to provide a smoothing function for loads or generation. This function involves the dynamic dispatch of energy in order to compensate for variations in the power level via a reference signal. With proper configuration, this function may be used to compensate for either variable load or variable generation.

This function was identified as a requirement by several utilities working together in EPRI's storage research program (P94). These utilities have developed a specification for a large scale Lithium Transportable Energy Storage System (Li-TESS) which includes a requirement for a Load/Generation Smoothing function.

Function Shortfalls

There are no provisions made for supporting this function within the SEP2 DER functions. As with other functions that require an external signal to be provided as an input to this function, the required sample rate may be outside the capability of SEP2 to support.

Possible Workarounds

No apparent workarounds are available within SEP2 to achieve this functionality.

Dynamic Volt-Watt Function

Function Description

This function is intended to provide a flexible mechanism through which inverters, such as those associated with battery storage systems, may be configured to dynamically provide a voltage stabilizing function. This function involves the dynamic absorption or production of real power

(Watts) in order to resist fast variations in the local voltage at the electrical connection point (ECP).

The Watt levels indicated by this function are additive – meaning that they are in addition to whatever Watt level the DER might otherwise be producing. The dynamic nature of this function stems from being driven by the change (dV/dt) in local voltage level as opposed to its absolute level to make it well suited for working in conjunction with other functions.

This function was identified as a requirement by several utilities working together in EPRI's storage research program (P94). These utilities have developed a specification for a large scale Lithium Transportable Energy Storage System (Li-TESS) which includes a requirement for a Load/Generation Smoothing function.

Function Shortfalls

There are no provisions made for supporting this function within the SEP2 DER functions.

Possible Workarounds

No apparent workarounds are available within SEP2 to achieve this functionality. An inverter that supported this functionality would need to be enabled manually.

Peak Power Limiting

Function Description

This function is intended to provide a flexible mechanism through which inverters, such as those associated with battery storage systems, may be configured to provide a peak-power limiting function. This function involves the variable dispatch of energy in order to prevent the power level at some point of reference from exceeding a given threshold.

Several battery storage system use cases have identified the requirement for this capability. For example:

- Work in the NIST PAP 07 identifies the need for peak power limiting as a use of storage systems.
- DTE Energy has developed a use case for a distributed battery storage system that identifies this function. This use case involves large-scale battery storage units that are strategically placed on distribution systems and designed to limit the power load on particular distribution system assets such as transformers. Such placement could be used to extend the useful life of products, or to defer investments in equipment upgrades.
- San Diego Gas and Electric identifies this function as a use for small pad-mount battery storage systems.
- The Li-TESS storage system specification being developed in EPRI's Program 94 Storage research requires such a function.

Function Shortfalls

There are no provisions made for supporting this function within the SEP2 DER functions. As with other functions that require an external signal to be provided as an input to this function, the required sample rate may be outside the capability of SEP2 to support.

Possible Workarounds

No apparent workarounds are available within SEP2 to achieve this functionality.

Load and Generation Following

Function Description

This function is intended to provide a flexible mechanism through which inverters, such as those associated with battery storage systems, may be configured to provide a following function for loads or generation. This function involves the variable dispatch of energy in order to maintain the power level at the DER output that tracks the level of a reference signal. In the case of load following, the output of the DER power output rises as the consumption of the reference load rises. In the case of generation following, the DER power absorbed increases as the output of the reference generation increases.

Several battery storage system use cases have identified the requirement for this capability. For example:

- San Diego Gas and Electric (SDG&E), Sacramento Municipal Utility District (SMUD), and Southern Company have each independently identified the need for a load/source following function in their specifications for small pad-mount battery storage systems. In one use case, the function is used to have energy flow in/out of the battery system to compensate for variability in the generation output of a PV system.
- Several utilities working together in EPRI’s storage research program (P94) have developed a specification for a large scale Lithium Transportable Energy Storage System (Li-TESS). This specification includes a requirement for a Load Following function.
- Several use cases compiled in the NIST PAP07 process identified the need for settings that limit the ramp rate of power variations. Also, the PAP 07 use cases identified scheduling mechanisms for managing storage system charging and discharging, one type of “schedule” uses a reference signal rather than time as the controlling signal.

Function Shortfalls

There are no provisions made for supporting this function within the SEP2 DER functions. As with other functions that require an external signal to be provided as an input to this function, the required sample rate will likely be outside the capability of SEP2 to support.

Possible Workarounds

No apparent workarounds are available within SEP2 to achieve this functionality.

9
CONCLUSIONS

The ZigBee Alliance's Smart Energy Profile 2.0 is a specification for application-layer messaging in residential home area network environments. Although it is not a standard, it is an open specification in the sense that the ZigBee Alliance has historically made it freely available to interested parties. To be considered a standard, the ownership of the specification itself and the process of maintaining and evolving it going forward would be in a Standards Development Organization (SDO) that could manage an application layer standard without ties to a particular physical-layer media or hardware. For the residential home area networking environment, SEP2 is filling an area of need that is not directly addressed by other specifications.

The 2.0 version of SEP represents a significant improvement over 1.x versions in several key areas:

- SEP2 has been more cleanly abstracted from underlying layers so that it can run over any physical media as long as IPv6 is used at the network layer
- SEP2 has been redesigned to be based on an abstract information model based on the IEC Common Information Model (CIM)
- A wide range of new capabilities have been added, including the DER controls outlined in this report

The utility, solar, and battery storage industries have made significant investments over the past few years to identify and standardize a set of grid-supportive functions that DER can provide. These functions include a range of capabilities affecting both real and reactive power, and including both steady-state and dynamic actions. This activity has moved forward with both utility and DER manufacturer support, with both groups recognizing that the advanced capabilities of DER cannot be effectively integrated with the grid unless they are implemented in a way that is consistent across multiple brands, sizes and types of DER because many may be integrated on a single feeder.

Open communication protocols are also needed, to support these common functions. While the functions themselves must be uniform, it is recognized that multiple open communication protocols may be needed, as appropriate for the domain and environment in which each DER is connected. For example, DER integrated directly into utility AMI or SCADA systems may communicate using DNP3 or IEC 61850 and industrial DER integrated into factories may communicate to a local energy management system using ModBus. For small scale DER that may be integrated into a residential consumer's home area network, the SEP 2.0 specification is an appropriate choice.

The incorporation of DER support into SEP2.0 has been done based on the set of common functions that are documented by the IEC and also supported in the DNP3 and ModBus protocols, so there is good reason to expect consistency of behavior across these domains. As described in this assessment, the DER support in SEP2 has been found to be consistent with overall industry activities in the DER area. Although not all DER functions described in the IEC

61850-90-7 are supported by the SEP2.0 specification, those that are supported represent a core set of the most useful functions.

As noted, there are several places in this specification where variables that could have been supported are omitted. For example, some function descriptions in the IEC 61850-90-7 identify “ramp-time” and “time window” parameters that allow function start times to be randomized and their initiation to be gradual. Where the SEP 2.0 specifications omits these parameters, it is assumed that devices would have a built-in default.

Also as noted in this report, there are some ambiguities in the SEP 2.0 specification that could lead to interoperability challenges. For example SEP2 has taken the approach of defining each DERControl as a composite message, containing all desired DER operating modalities with the intent of overriding the previous ones.

This approach of having each message contain all elements of the DERControl also means if a Volt-VAr curve is enabled, a previously enabled Watt-frequency function will be disabled. This issue was raised during the review/comment resolution meetings and is being addressed. The method of resolution was not available at the time of publication of this report.

While not sufficient for all uses, SEP2 represents a significant step forward in accomplishing an open standard based protocol capable of supporting residential DER.

10 REFERENCES

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Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com