AMI 1.2 Product Description

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Contents

Figures

Tables

Revision History

Revision	Release Date	Change Description
A	September 18, 2015	Initial release.

1 AMI System Overview

1.1 On-Ramp Wireless AMI System

Advanced Metering Infrastructure (AMI) is an integrated system of smart meters, communication networks, and data management systems that enables bi-directional communication between utilities and customer systems. These systems enable measurement of detailed, time-based information and frequent collection and transmittal of such information to various parties. The chief goals of an AMI system are to:

- Provide utilities with real-time data about power consumption and quality, and remote meter programming capabilities.
- Enable customers to make informed choices about energy usage based on the price at the time of use.

Utilities are applying AMI systems for time-based rate programs, customer billing, power outage detection and response, tamper and theft detection, remote service connection and disconnection, load forecasting, and generation capacity planning. Utilities also plan to utilize the AMI data to target customers for energy efficiency and demand response programs.

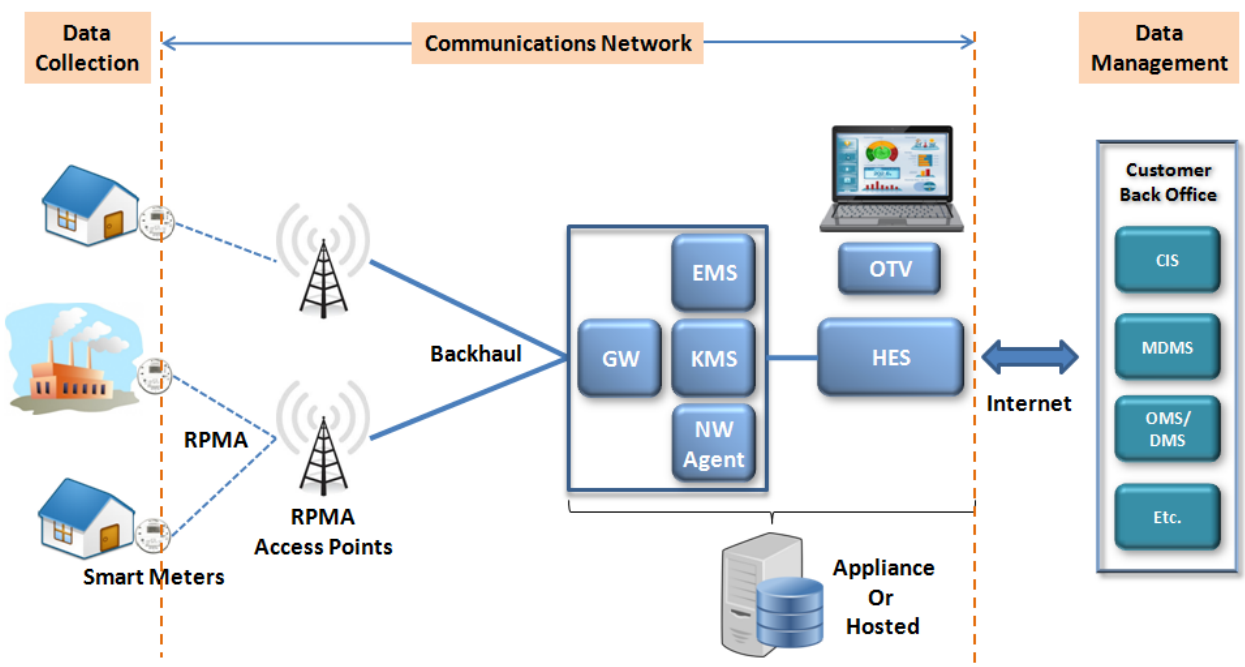


Figure 1. AMI System Components

Figure above shows the building blocks of an On-Ramp Wireless AMI system. Customers are equipped with GE's smart electric meters that collect time-based power consumption data.

Smart Meter: A smart meter is an electronic device that is able to record consumption of electricity in intervals and communicate this information back to utilities for monitoring & billing. They also possess bi-directional communication capabilities including the ability to be remotely programmed. GE smart meters consists of advanced electronic hardware such as metrology analog front-end, metrology sensors, meter microprocessors, electronic meter communication module (eMCM), etc.

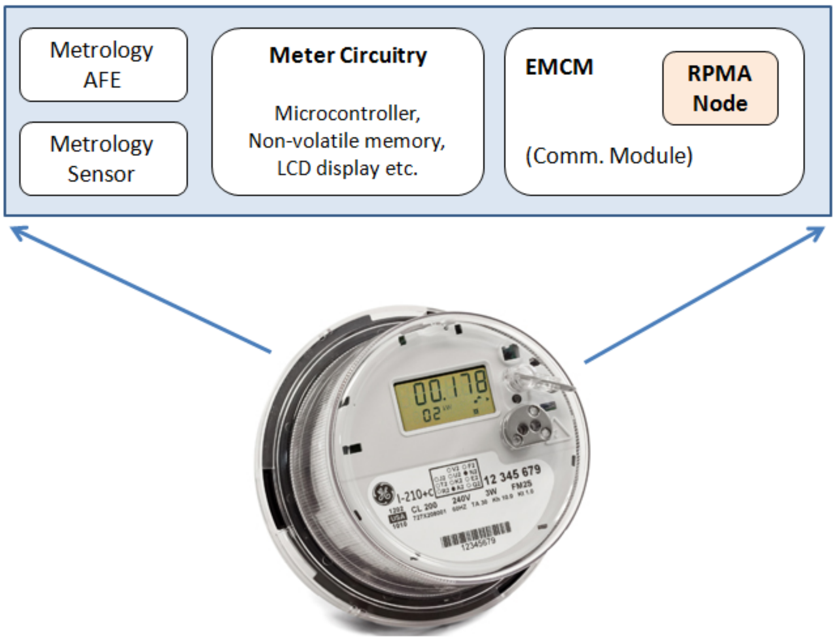


Figure 2. Components of a Smart Meter

Metrology sensors and meter circuitry measures and stores many instantaneous and cumulative electricity parameters, including billing related parameters. The eMCM in the smart meters reads the stored meter data and transmit the collected data over an RPMA® network. The eMCM provides the means for back office systems to configure and control the meter to perform the desired tasks. It speaks protocols such as C12.19 with the meter. The RPMA node in the eMCM is responsible for receive and transmit functionality.

RPMA: RPMA stands for Random Phase Multiple Access. It is a revolutionary, next generation wireless communications technology developed and patented by On-Ramp Wireless. It is designed ground up with high capacity and large coverage specifically for low data rate applications such as AMI.

Communications Network: The communication network facilitates bi-directional communication of data and commands between the smart meters and utilities' back office systems. The On-Ramp Wireless AMI communications network consists of eMCM installed in the smart meters, Access Points (APs), Gateway (GW), Element Management System (EMS), Key Management System (KMS), Network Agent, Head End System (HES) and On-Ramp Total View (OTV) web services and visualization interface.

Meter data from a large number of meters is received by Access Points. The AP is responsible for management of the RPMA communication channel to the meters. It is also responsible for the collection of meter data and relaying the data to the Gateway via a backhaul such as fiber, DSL, cellular, etc. An AP resides on high vantage locations such as communication towers, pole-tops, hill-tops, etc.

The high capacity, high availability Gateway manages network security and AP connections with back office management applications. EMS manages network elements with intuitive interfaces for monitoring network performance, managing device configuration and firmware updates. The Network Agent provides network diagnostic and database services.

The Head End System receives the meter data from the AMI system. It also manages the control and communication from back office systems to the meters. It performs limited amount of data validation and it parses and manages meter data and interactions. The HES has the intelligence to abstract the details of the underlying AMI system and communication network from external systems and end users. It includes a database that acts as a short time repository for meter data. The OTV interfaces with HES to provide end users an intuitive graphical interface for visualization of meter data and meter alarms, and execution of meter control commands.

Data Management: Parsed meter data from HES and OTV is sent over Internet to back office systems such as Meter Data Management System (MDMS), Customer Information System (CIS), and Outage Management System (OMS). Various industry standard interfaces, such as IEC-CIM, MultiSpeak, etc., are employed for this communication over Internet.

Bi-directional communication capabilities of AMI system enable it to relay data and control commands from back office to the meter.

1.2 Functional Classification

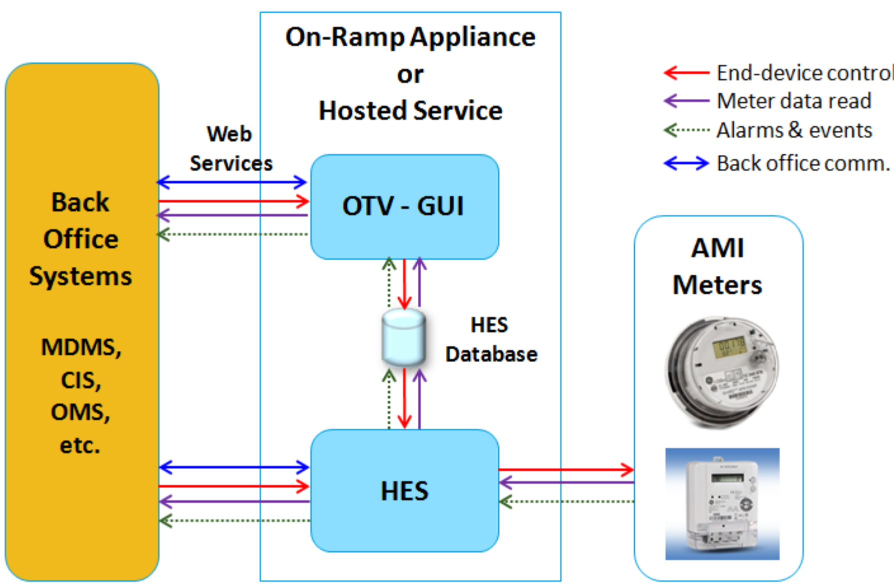


Figure 3. Flow of data and control in ORW's AMI system

From an operation and management perspective, the AMI system can be classified into four main categories.

1. **Meter data reads**
   Primary function of an AMI system is to record and report meter data. Scheduled and on-demand readings of meter's billing data, interval data, power quality metrics, and logged events constitute meter reads. These readings are generated at the meter and flow to back office systems.
2. **Events and alarms**
   It is vital to have the ability to monitor and manage the health of the AMI systems easily and remotely. This function deals with handling and reporting of events and alarms generated by smart meters in the network. Events are generated and logged by a meter when a metric exceeds a certain configured threshold. High priority events are called "alarms" and relayed immediately to back office systems.
3. **Over-the-air meter (end-device) control**
   AMI system enables utilities to configure and control smart meters remotely. These include remote connect and disconnect of meters, demand reset, over-the-air configuration of meters for real-time pricing, etc. Control data originates from either back office systems or OTV and flows to the meters.
4. **Back office communication**
   Constitutes two-way communication between AMI's HES and back office systems. In addition to relaying of meter data, alarms, events, and meter control commands, this function deals with the synchronization of customer information between back office systems and HES.

1.3 Deployment of Meters in AMI

The key function of an AMI system is to collect and report regularly customers' usage of over intervals. The process of collection of power consumption begins with smart meters.

Factory provisioning: GE's smart meters are provisioned at GE's factories. This process involves programming of firmware in eMCM of the smart meters, applying network specific configurations, and generating device specific security keys and their programming in the device. Two files are generated as a result of provisioning. A security file contains the encrypted keys provisioned into the eMCM and should be ingested into a Key Management Server (KMS) before the meters can join and communicate with the network (Refer Appendix "A.3 Key Exchange during Provisioning"). A marriage file generated during provisioning specifies the association between eMCM MAC address (also called Node Id) and manufacturer's meter serial number. Ingesting a marriage file into HES is required before eMCM is authorized and communicates meter data to the HES.

Factory provisioned smart meters are delivered to Utility company when the meters are purchased. These meters are placed in stock at the Utility. Information pertaining to the meters, such as the manufacturer's meter serial number and Utility's meter number, are stored in back office systems like Customer Information System (CIS) and asset management database. The marriage file generated at the time of provisioning of the meters is also delivered to the Utility.

Marriage file import: Utility's or ORW's personnel import the marriage file in OTV. The import allows HES and OTV to identify legit pairs of manufacturer's meter serial number and node ID for any given meter. This is required for authentication of meters to join the AMI network. It is required to import marriage file in OTV before the meters are installed.

CIS - HES synchronization: After meter technicians install new meters or replace existing meters, the customer information related to the meters is communicated to the CIS by the meter technicians. The CIS links customer account info (name, address, GPS coordinates, etc.), meter serial number, Utility's meter number, node ID, and Service Delivery Point (SDP) ID. CIS synchronizes relevant portions of the customer information with MDMS and HES.

Different synchronization points of interest are:

- Utility's meter number also called "Customer meter number": Customer meter number is updated via marriage file ingestion. If customer meter number was not available during factory provisioning, a second marriage file needs to be generated post CIS update and ingested via XML import if communication via customer meter number is desired. In absence of customer meter number in the marriage file, HES/OTV would communicate with backend via manufacturer's meter serial number.
- Operational State: Meters once installed must be placed in "operational" mode before event notifications are enabled by OTV. Operational state is an attribute that can be updated directly via REST web service interface.
- Billing cycle: If the demand reset task manager is being used to reset demand aligned to a billing cycle, this attribute could be used to group the meters that have their demand reset scheduled aligned.
- Data Reporting Config Name: Meters report data to the HES based on a reporting schedule. If different reporting schedules are desired, then this attribute indicates the associated reporting schedule. If there is no metadata associated with this attribute, then all meters corresponding to a meter model will be assigned a default reporting schedule.

Meter authentication: After meter installation, meter attempt to join the network by scanning the network, connecting to an available AP and sending an authentication request. Meter is authenticated by Gateway using the keys stored in KMS. Only after successful authentication, a data session with HES is established during which meter serial number is communicated to HES. If the marriage file is ingested and includes the MAC address of the eMCM, then HES authorizes eMCM to report the information being recorded in the meter to HES. For GE SGM meters, where hot swap is a possibility, authorization step also requires that the meter serial number reported by eMCM matches the meter serial number associated with the MAC address in marriage file. If the authorization fails, then eMCM is informed and it reattempts authorization from HES within an hour approximately. This process continues till a valid marriage file is ingested. Refer Appendex "A.4 Meter Boot Process."

Meter data reporting: There are two aspects to meter data reporting. eMCM in the meter reads and reports meter data to HES as per the reading and reporting schedule configured in "data_orders.properties" file installed in HES. When eMCM is authorized, HES installs the schedule into the eMCM. The config file shall contain reporting schedule per meter model. If different reporting schedules per meter model is desired for different groups of meters, then multiple reporting schedules should be created corresponding to different values taken by “Data Reporting Config Name.” The HES receives meter data, which it stores in the OTV database on a short term basis. HES also forwards meter data to back office systems, such as MDMS, OMS, etc.

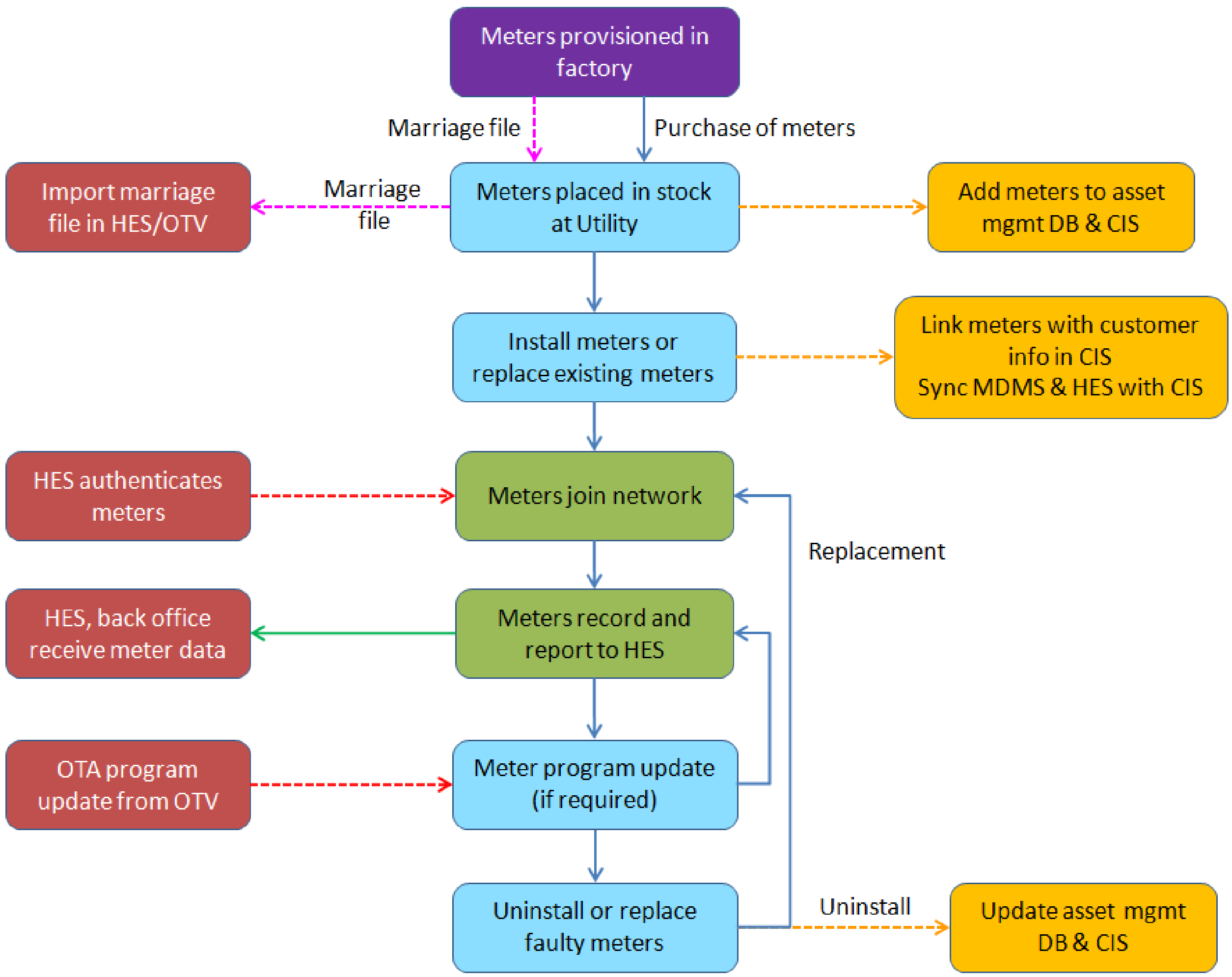


Figure 4. Meter deployment process in ORW’s AMI

OTA meter program update: Meter recording and reporting configurations can be changed remotely, over-the-air in an AMI system. This is done from the OTV. GE MeterMate™ is required to create the new program that specifies, among other things, what quantities the meter has to record and how frequently. Once the meter program is created in an XML format, it is sent OTA to the relevant meters from the OTV’s GUI. OTV is also used to update the “data_order.config” file, which specifies the meter data reading and reporting schedules.

Meter uninstall: If a meter has to be uninstalled or replaced, then the back office systems such as CIS and asset management database are updated to reflect the changes. The changes are then synchronized by CIS with MDMS and HES.

Hot swapping: Marriage file contains association between eMCM MAC address and meter serial number. If eMCM inside a meter is swapped by a new eMCM, or a meter is replaced but old eMCM is used, then before communication can be restored, marriage file needs to be ingested and should explicitly divorce the first association and create the new association.

1.4 Types of Smart Meters

There are primarily two categories of two-way communication capable smart meters – Residential and Commercial & Industrial (C&I).

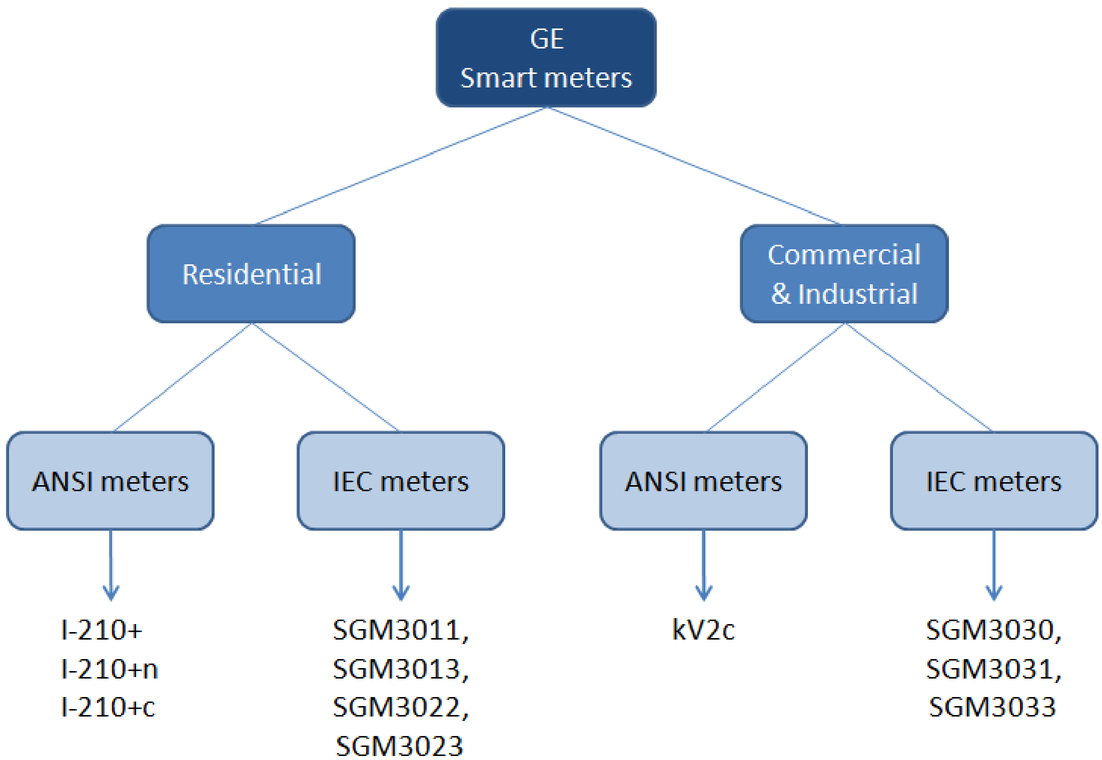


Figure 5. GE smart meter family

NOTE: Consult GE Digital Energy for latest information on their smart meter product line.

1.4.1 Residential Meters

These smart meters are designed for use on low-voltage grid at residential (and some commercial) locations. They are known for their accuracy, reliability, and simplicity. They feature a wide range of functionality such as billing, prepay, profiling, remote connect and disconnect, outage notifications, basic quality-of-service analysis, etc. They operate on single phase circuits.

ORW's AMI applications operates with both ANSI and IEC smart meters and have been integrated in GE's ANSI meters family (I-210+, I-210+c) and SGM3000 IEC meter family (SGM3011, SGM3013, SGM3022, SGM3023).

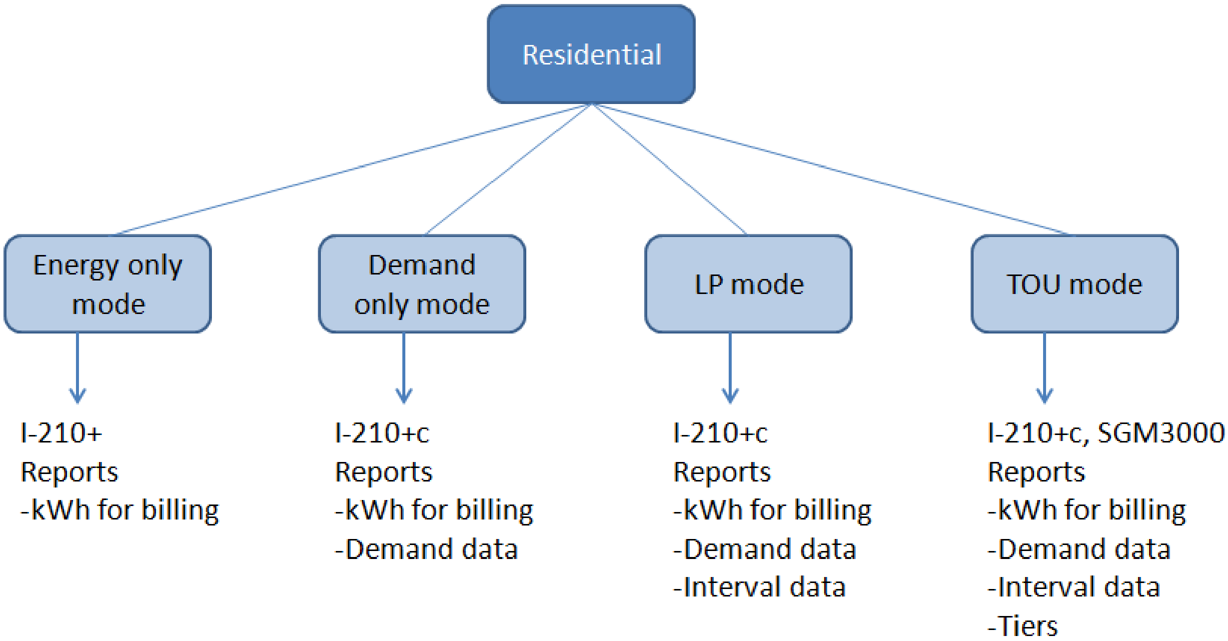


Figure 6. Modes of operation for GE residential smart meters

GE's residential smart meters, ANSI and IEC, can operate in four different kinds of mode.

Energy only mode: This is the most basic mode of operation where the meter reports only the energy (delivered, received, net, total kWh) for use of billing. GE's I-210+ meter can operate in only this mode. Note that energy quantities are part of bulk data reporting in other meters.

Demand only mode: In addition to bulk data reporting, demand data is also reported in this mode of operation. GE's I-210+c meter can operate in this mode. To enable demand reporting, I-210+c requires GE's "N_2 soft switch" software package to be loaded and enabled in the meter.

Load Profile (LP) mode: GE's I-210+c meter can also operate in LP mode where it reports the interval data in addition to what is reported in demand only mode. To operate in this mode, I-210+c requires GE's "R_2 soft switch" software package to be loaded and enabled in the meter.

Time-of-Use (TOU) mode: I-210+c meters reports time-of-use data when "T_2 soft switch" software package is loaded and enabled in the meter. This enables tiered billing based on time of use. No soft switches are required to operateSGM3000 family of meters. SGM3000 family of meters operate, by default, in TOU mode and record bulk, demand as well as tiered data. Meters can be configured to record only the data of interest and AMI system can be configured report only the data of interest.

NOTE 1: Addition of Q_2 soft switch activates power quality recording (minimum, average and max voltage) in I-210+c meters.

NOTE 2: Addition of V_2 soft switch activates sag/swell monitoring and recording in I-210+c meters.

NOTE 3: SGM3000 family of meters does not require any soft switches.

NOTE 4: Refer "A.10 Soft Switches in GE Smart Meter" for list of soft switches for GE meters.

1.4.2 C&I Meters

These versatile smart meters move beyond revenue metering to real-time instrumentation, true power quality monitoring, and real cost-of-service measurements. They are capable of high precision smart metering and perform everything from simple energy rating to quality-of-service and load analysis to power outage notifications on both single and polyphase circuits. These meters are typically polyphase meters, capable of recording usage and power quality on all three phases and can operate at higher voltage and current ratings.

ORW's AMI applications operates with both ANSI and IEC smart meters and have been integrated in GE's ANSI meters family (kV2c) and SGM3000 IEC meter family (SGM3030, SGM3031, SGM3033).

Like the I-210+c, the kV2c meters operate in energy only mode, demand mode, LP mode and TOU mode dependent on the soft switches loaded and the meter recording configuration. SGM3000 meters do not require any soft switches.

C&I meters are usually configured to record more data and report more frequently than residential meters. More data consists of more billing data UOMS, more channels and load profile sets, and more power quality metrics.

Based on usage model, they can be classified into two categories: regular usage and high usage (aka bellwether meters).

1.4.3 Bellwether Meters

Utilities may designate some of the deployed C&I meters as bellwether meters. The bellwether meters are configured to report more measurement quantities and at a faster rate than a normal meter. They provide near real-time feedback to the utilities on the quality of power distribution, which enables utilities to quickly address potential issues on the electric grid. Meters classified as bellwether meters are usually installed at high-priority or strategically located sites such as hospitals, fire stations, end of a distribution line, etc.

1.5 Typical Meter Configurations

A smart meter is very versatile and can be configured to perform number of functions. The meter's configuration determines the electrical quantities a meter records and how frequently or over which time periods the meter records. The meter configuration is determined by the meter's use case and mode of operation.

Listed below are typical meter configurations, based on their mode of operation, for recording and reporting of meter data such as billing, interval and power quality. These meter configurations reflect real world deployments of smart meters. They represent real examples of meters generating small to large amounts of frequent and infrequent billing and interval data. These are basically the fundamental parameters that impact the load on the AMI system and provide a measure of performance – what types, how much and how often are measurements reported from the meter to the back office systems.

Disclaimer: The numbers represented in the tables below are typical expected sizes and likely to vary due to encoding of the payload during transmission.

1.5.1 Energy & Demand Only Modes

The I-210+ meter is an energy only meter. It can report limited set of quantities. The kV2c meter is configurable to operate in demand only mode.

Table 1. Reading & reporting configuration for energy and demand only modes

Typical Settings	I-210+ (Energy only)	kV2c (Demand only)
Billing Data		
Measurements	4 active energies (Delivered, received, net, total)	5 summations 5 demands 10 coincidents
Reads	15 min	24 hr local midnight
Reporting window	60 min	5 hours
Interval Data		
Measurements	NA	NA
Reads	NA	NA
Reporting window	NA	NA
Power Quality		
Measurements	3	11
Reads	15 min	Every 24 hrs
Reporting window	60 min	0 – 5 min

1.5.2 TOU/LP Mode

Meters operating in LP and TOU modes are capable of reporting interval data and tier data (TOU mode). This is the most common configuration of residential and C&I meters.

Table 2. Reading & reporting configuration for LP & TOU modes

Typical Settings	I-210+c	kV2c	SGM301X/302X
Billing Data			
Measurements	4 summations 2 demands 1 tier (LP) 4 tiers (TOU)	5 summations 5 demands 10 coincidents 1 tier (LP) 4 tiers (TOU)	4 summations 4 demands 10 tiers
Reads	24 hr local midnight	24 hr local midnight	24 hr local midnight
Reporting window	5 hours	5 hours	5 hours

Typical Settings	I-210+c	kV2c	SGM301X/302X
Interval Data			
Measurements	4 channels	4 channels	4 channels
Reads	15 min intervals	15 min intervals	15 min intervals
Reporting window	1 hour	1 hour	1 hour
Power Quality			
Measurements	3	11	6
Reads	Every 24 hrs	Every 24 hrs	Every 24 hrs
Reporting window	0 – 5 min	0 – 5 min	0 – 5 min

1.5.3 High Utilization Mode

Bellwether meters are usually configured to read and report data in this mode. This mode involves frequent reading and reporting of large numbers of electrical parameters. This amount of information is reported by meters placed at strategic locations such as beginning, middle and end of a distribution line. Since a large amount of data has to be reported, which stresses the AMI network for almost no gains, most meters are not configured in this mode.

Table 3. Reading & reporting configuration for high utilization mode

Typical Settings	kV2c	SGM3000
Billing Data		
Measurements	5 summations 5 demands 10 coincidents 4 tiers	8 summations 8 demands 10 tiers
Reads	24 hr local midnight	24 hr local midnight
Reporting window	5 hours	5 hours
Interval Data		
Measurements	20 channels	24 channels (4 LP sets, 6 channels each)
Reads	15 min intervals	LP set #1: 15 min LP set #2: 30 or 60 min LP set #3 & #4 (if needed): 60 min
Reporting window	1 hour	LP set #1: 15 min LP set #2: 60 min LP set #3 & #4: 60 min
Power Quality		
Measurements	17	6
Reads	Every 60 min	Every 60 min
Reporting window	0 – 5 min	0 – 5 min

2 Register or Billing Data

Smart meters are capable of recording electricity consumption data in different dimensions that enables utilities to easily bill their customers based on customers energy use patterns. This consumption data is termed as register or billing data, the latter being GE's preferred vernacular. GE's smart meters record billing data under four categories.

2.1 Types of Billing Data

Summation Data: Total cumulative consumption a meter has recorded for any Unit of Measurement (UOM) is termed as summation. This is a running counter of the meter that cannot be reset unless meter is reprogrammed with explicit instructions to clear meter data. Summation data for a period can be obtained by subtracting the summation readings at the beginning of the period from readings at the end of the period. A smart meter is capable of recording multiple UOMs, and the UOMs to record summation data for can be configured via GE's MeterMate® tool. Summation data consists of the latest summation readings for all the UOMs. It is also known as bulk data or register data.

Demand Data: Demand is the defined as the average consumption (eg active, reactive, apparent power) over a recorded interval. Demand register latches to the highest or peak demand until a reset is issued. This reset is termed as "demand reset." Only peak demand is recorded and reported as demand.

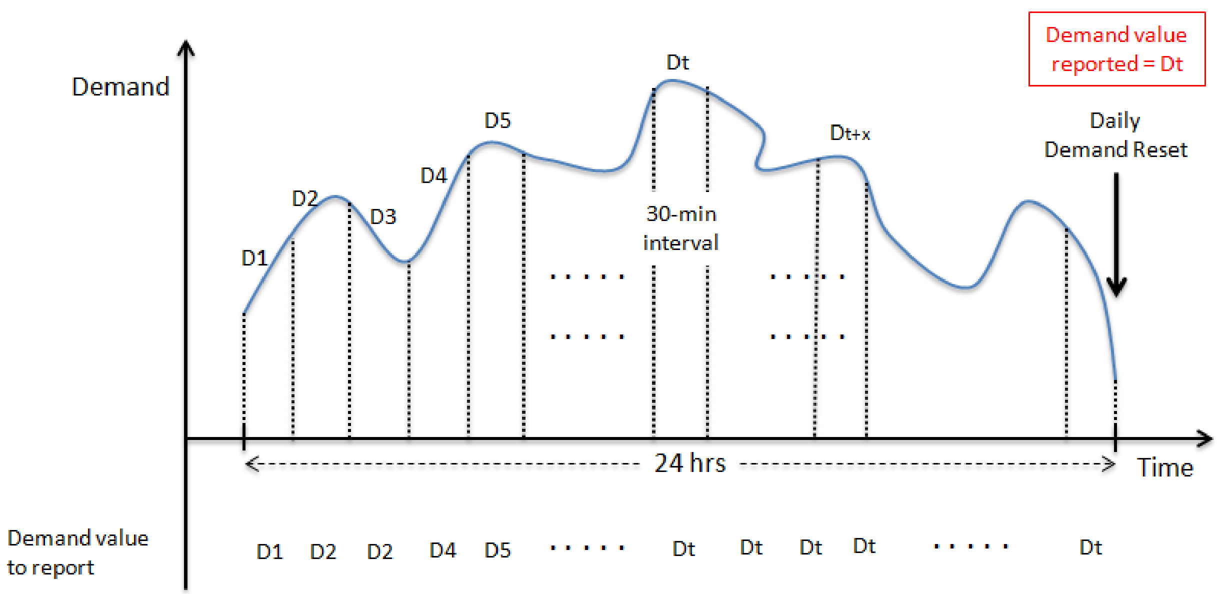


Figure 7. Peak demand latches in registers until reset

In the figure above, demand is computed on 30-min intervals but reported only once every 24 hours. The peak demand, Dt in this case, is read from the registers before the reset, and Dt is reported as the demand value. The time interval over which demand has to be computed by the meter is a configurable setting and can be set via GE's MeterMate® tool. Demand reset is scheduled either by OTV (based on a schedule) or by MDMS via IEC-CIM interface.

Coincident Data: Values of different measurement quantities at the time of meter's peak demand are latched into registers as coincident values. For e.g., the values of voltage, current, frequency, etc., at the time of peak demand is recorded as coincident data. Only GE kV2c meter supports coincidents.

Tier Data: GE's smart meters are capable of recording power consumption in "tiers." Recording in tiers could be set as time-based or consumption-based. In time-based tiers, the meter automatically records consumption into appropriate tier based on time and/or season of the day. In consumption based tiers, the meter records blocks of usage under different tiers. E.g., First 300kWh usage is recorded under Tier-1, the next 300kWh is recorded under Tier-2, and so forth.

Tier settings are configurable via GE MeterMate® tool. An example of time based consumption is represented below.

Table 4. Example of tiers in a smart meter

Time of Day	06:00 – 11:00	11:00 – 17:00	17:00 – 21:00	21:00 – 06:00
Recording Tier	Tier 1	Tier 2	Tier 3	Tier 1

2.2 List of Billing Data UOMs

Smart meters can record data for a number of electrical parameters, called Units-of-Measurements or UOMs. Billing data is recorded for some of these UOMs. The number of UOMs a meter records data for vary by meter type and capabilities. Below is a condensed list of commonly used billing data UOMs. Refer Appendix "A.5 List of UOMs" for a detailed list of billing data UOMs.

Table 5. Commonly used UOMs for recording billing data

Quantity	ANSI ID_CODE	I210+	I210+c	kV2C	SGM3000
Delivered energy (kWh)*	0	✓	✓	✓	✓
Received Energy (kWh)*	0	✓	✓	✓	✓
Total Energy (kWh)*	0	✓	✓	✓	✓
Net Energy (kWh)*	0	✓	✓	✓	✓
Reactive energy (kVArh)*	1		✓	✓	✓

Grey colored blank = Meter does not support
X = Meter supports but AMI 1.2 does not support
*Includes both energy and power
*Multi-quadrant measurements supported

2.3 Billing Data Recording

Configuration of billing data related parameters in the meters is part of the meter program which is created and/or modified using GE's MeterMate® tool. The OTV and AMI system is capable of updating meter program remotely. This process is described elaborately in section 8.6.1 Meter Program Update.

Table 6. Billing data recording capabilities by meter type

Billing Data Recording		I210+	I210+c	kV2C	SGM3000
Summation (Bulk or Register data)	Number of UOMs recorded	4	2	5	8
	Bytes recorded per UOM per tier *Available in R&P guide*	6	6	6	6
Demand	Number of UOMs recorded	NA	2	5	8
	Cumulative demand supported	NA	Yes	Yes	Yes
	Count of number of demand resets	NA	Yes	Yes	Yes
	Bytes recorded per UOM (Includes demand, coincident demand, event timestamp) *Available in R&P guide*	NA	14	14	14
Coincident Values	Number of UOMs recorded	NA	NA	10	NA
	Bytes recorded per UOM *Available in R&P guide*	NA	NA	4	NA
Tiers	Number of Tiers	None	4	4	10
Meter tables used for reading recorded values		ST85	ST23	ST23	ST23
Max number of bytes recorded[1]		24	261	701	1761
Number of typical reads stored at eMCM		96	2 reads	2 reads	2 reads
Tool for configuring Billing Data Recording		GE's MeterMate® tool			

[1]Note that maximum number of bytes recorded is not the same as number of bytes transmitted. There is overhead of security, transport and application headers and read timestamp. Further encoding the data may change the size of the raw data.

2.4 Billing Data Reading and Reporting

The eMCM reads the meter and reports the meter data to back office systems. Meter readings are performed either on a preconfigured schedule or in response to an on-demand read request. It is also possible to have two preconfigured billing schedules that are installed on the eMCM when eMCM first communicates with HES. The schedules are termed as "Billing Order 1" and "Billing Order 2" and are listed in data_orders.properties file. These schedules can be changed by updating the data_orders.properties file as described in Section 1.3 and requesting "eMCM Device Configuration Set" change via OTV UI.

2.4.1 Primary Reporting Schedule

In primary reporting schedule (default), eMCM reads all the billing data from the meter tables at read time, stores it in its persistent memory and reports it at some random time within the reporting window. This allows all reads to be at specified time (say local midnight) while randomization helps distribute network usage over reporting period. Since data is stored in persistent memory, data is not lost if power outage occurs in between read and reporting times. Once the billing data in queued for transmission, AMI system has an end-to-end reliable transport protocol that ensures reliable delivery of billing data even with network connectivity issues. Note that sustained power outage and device reset (user/watchdog triggered) during transport might still result in data loss. Primary reporting schedule is specified in “Billing Orders 1” section of data_orders.properties file at HES.

2.4.2 Secondary Reporting Schedule

In addition to default read and reporting schedule, a secondary reporting schedule is provided for frequent reporting of bulk/register data (i.e. for summations of total tier). Demand, coincident and tier data cannot be included in frequent reporting. Further, frequently reported bulk data is not stored in persistent memory and hence it cannot be retrieved if lost due to long term connectivity loss. Secondary reporting schedule is specified in “Billing Orders 2” section of data_orders.properties file at HES. Refer “A.8 Sample of data_orders.properties File.”

2.4.3 Scheduled Reading and Reporting

The dexterity of an AMI system lies in its ability to control and configure the time and frequency at which meter reads and their reporting is performed.

Table 7. Reading and reporting of billing data

Billing Data Reading & Reporting	I-210+	I-210+c	kV2C	SGM3000
Typical read frequency on primary schedule	15 min	24 hrs	24 hrs	24 hrs
Lowest possible read frequency on primary schedule	15 mins	8 hrs	8 hrs	8 hrs
Lowest recommended read frequency on secondary schedule: bulk data only (recommended use: absence of interval data)	NA	15 mins	15 mins	15 mins
Time of read (typical) *Configurable*	Aligned to hour	Local Midnight	Local Midnight	Local Midnight
Billing data reporting frequency	15 min	24 hrs	24 hrs	24 hrs
Typical billing data reporting window on primary schedule	0 – 1 hour	0 – 5 hours	0 – 5 hours	0 – 5 hours
Billing data reporting frequency on secondary schedule	NA	Less than or equal to Read Period		
Tool for configuration of Billing Data Read and Reporting	data_orders.properties file at HES			

Reporting of scheduled billing data reads from the meters deployed in the field is randomized across "reporting window." This is done to prevent collisions of packets that would result from large number of simultaneous transmissions.

"data_orders.properties" is one of the HES configuration files that define the reading and reporting schedules for different kinds of readings supported by AMI. One can specify default configuration per meter type (I210+c, kV2c, SGM3000). Customers can also specify non-default configuration for a group of meters of same type. However this requires that attribute "Meter Data Reporting Config Name" is updated before the schedule associated with that attribute can be installed. The HES Config file is modified by ORW or the entity that hosts the AMI system.

If a billing data read is lost due to device reset during the time of transport or lack of connectivity for extended period of time, then those readings are lost and cannot be retrieved by back office. For readings reported under primary schedule, the possibility of such a loss should be rare and loss of connectivity has to extend for days before the data is lost. For secondary schedule, however such a loss is highly likely if there is sustained power fail or connectivity loss exceeds short read period (~30 mins).

Only summations for total tier can be reported at a higher frequency (up to 15 minutes). Smaller amount of billing data reported results in lesser system capacity usage as well as reduced reporting latency. As eMCM does not store the more frequent billing data reads in flash, there is no flash wear leveling due to these reads. Configuration of UOMs to read and report, and the frequency at which to report are configured in "Billing_Orders2" section in data_order.properties file. Refer "A.8 Sample of data_orders.properties File."

Billing data from HES can be reported to back office systems over IEC-CIM or MultiSpeak interfaces. It can also be exported in California Metering Exchange Protocol (CMEP) or comma separated values (CSV) file formats.

2.4.4 On-Demand Reading and Reporting

Instantaneous reading and reporting of billing data occurs in response to "on-demand reads" from either back office systems or OTV. The latest meter readings are reported. It is not possible to retrieve past recordings of billing data from the meter. On-demand reads can be performed for a single meter or a group of meters.

- There are three types of on-demand reads of billing data.
- Entire billing data: All recorded summation quantities, demand and coincident values, for all TOU tiers is reported
- Only summations: Only total tier summations for all recorded UOMs is reported. This is also known as bulk data. It reduces reporting latency
- Only summation for record kWh: Only total tier summations of UOMs that record kWh are reported. These are bulk kWh readings. This has the lowest reporting latency.

Typical latency for items (a) and (b) is approximately 40 seconds. Latency in retrieving entire billing data can take variable amount of time ranging from a minute to few minutes depending on coverage, data size (highly variable based on configuration and meter type) and network deployment (deployed meters/AP). When latency is of concern, it is recommended that only bulk kWh readings are requested.

Back office can request AMI for on-demand billing data reads through IEC-CIM and MultiSpeak interfaces. AMI system reports the requested data through IEC-CIM and MultiSpeak interfaces as well.

2.5 Interval Data from Energy Only Mode

Energy-only meters, such as GE's I-210+, are capable of recording only billing data for delivered, received, total and net energy. These meters are very simplistic with limited features. They do not have the ability to measure interval data on their own.

Energy-only meters and smart meters configured in demand-only mode could record billing data on 15-minute windows. The AMI system could report the billing data every 15 or 60 minutes (4 billing periods in the report). From this billing data, an approximation of interval data for 15-minute intervals can be constructed at the back office. This process is termed as Virtual Metering.

Since billing data is stored in flash memory, frequent reading of billing data for construction of an interval data profile would result in flash-wear leveling, which translates to shorter flash memory life. An alternative to this is to use secondary reporting schedule, which does not store the billing data in flash memory. This approach has a risk of data loss as it is “best-effort” delivery only.

2.6 Pricing in AMI Systems

Smart meters and AMI systems are powerful and proficient in gathering, at a very granular level, customer's power consumption data based on their usage patterns. This has capacitated utility companies to create new and innovative pricing programs that reflect over time the customer's usage and utility company's cost to produce electricity over time.

The pricing programs reward customers who reduce their energy use during peak periods by shifting their energy use to off-peak periods. These programs also penalize, with high pricing, those customers who use more energy during peak periods. Peak periods are defined as those times of day or year when electricity consumption and the associated costs to supply the electricity are at their highest levels.

Flat Pricing: All electricity usage during a given period of time (e.g., 30-day billing cycle) is charged the same rate.

Tiered Pricing: Charge different prices based on blocks of usage (e.g., first 300 kWh vs. next 300 kWh) during a given period of time (e.g., 30-day billing cycle).

Time of Use Pricing (TOU): Electricity prices are set for broad blocks of hours on in advance or forward basis, typically not changing more often than twice a year. Prices paid for energy consumed during these periods are pre-established and known to consumers in advance, allowing them to vary their usage in response to such prices and manage their energy costs. For example, summer on-peak = 12pm – 7pm, summer off-peak = rest of the hours.

Real-Time Pricing (RTP): Electricity prices may change as often as hourly (exceptionally more often). Price signal is provided to the user on an advanced or forward basis, reflecting the utility's cost of generating and/or purchasing electricity at the wholesale level.

Variable Peak Pricing (VPP): Hybrid of TOU and RTP where the different periods of pricing are defined in advance but the price established for on-peak periods varies by utility and market conditions.

Critical Peak Pricing (CPP): When utilities observe or anticipate high wholesale market prices or power system emergency conditions, they may call critical events during a specified time period (e.g., 3 p.m.—6 p.m. on a hot summer weekday), the price for electricity during these time periods is substantially raised. Two variants of this type of rate design exist: one where the time and duration of the price increase are predetermined when events are called and another where the time and duration of the price increase may vary based on the electric grid’s need to have loads reduced.

Critical Peak Rebates (CPR): When utilities observe or anticipate high wholesale market prices or power system emergency conditions, they may call critical events during pre-specified time periods (e.g., 3 p.m.—6 p.m. summer weekday afternoons), the price for electricity during these time periods remains the same but the customer is refunded at a single, predetermined value for any reduction in consumption relative to what the utility deemed the customer was expected to consume.

AMI and Pricing Programs: The AMI system operates similarly for all the pricing programs. The onus of accumulating data into “tiered bins” according to the pricing program lies on GE’s smart meters. The AMI system reads all required meter tables to report necessary data to back office systems. Some of the above pricing programs can be supported only with interval data.

2.7 Scenarios

2.7.1 Power outage at schedule read time

Meter data is not recorded during a power failure and eMCM cannot read during a power failure. Hence, billing data read is never performed during power failure and it can be considered to be “lost.” HES is not informed by meter of this lost reading. There is no “make up read” and billing data is read only at the next scheduled time.

AMI system has resilience built in against momentary outages that end within certain duration of the billing read time. For e.g., if the billing read is scheduled for local midnight and a momentary power outage occurs. If the power is restored within a bounded duration (configurable parameter whose default value is 45 seconds) after midnight, then the AMI system successfully performs the scheduled read.

2.7.2 Communication link loss at reporting time

Even if there is communication link loss at the time of reporting, it does not affect eMCM’s reading capabilities. Hence billing data is read at the scheduled read time. The billing data is stored in eMCM’s persistent memory for up to 2 read intervals (typically, an interval is set for 24 hours) and queued for transmission. This allows a maximum of 3 billing data reads to be stored at eMCM for reporting. The billing data is transmitted when the communication link is restored. If the link is not restored before the fourth billing read, the oldest billing read is “lost” for it is replaced in the eMCM’s buffers.

2.7.3 Back Filling

The process of identifying and fetching missing data reads is termed as back filling. This activity is typically undertaken by back office system, such as an MDMS.

With AMI 1.2, any missing data within the last 96 reads is retrievable for I-210+ meters. Thus, for an I-210+ meter configured to read every 15 minutes, 24 hours of gap filling data is available for retrieval. Only 3 billing reads is available for retrieval for all meter types, which is kV2c, I-210+c, and SGM3000 meter family.

3 Interval Data

Smart meters are capable of tracking not just the amount of electricity used in a billing period but also precisely when electricity was used. This is a core capability of an AMI system and is termed as interval data or load profiling. Thus, interval data is time-based information about a customer's energy use. Data is collected typically every 15 minutes or on hourly intervals.

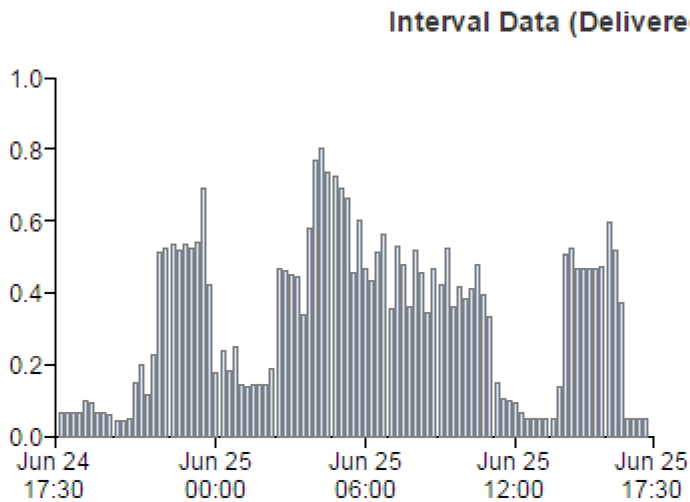


Figure 8. Sample representation of interval data usage in OTV

Interval data can be used to improve operational efficiencies and reduce costs for both utilities and customers.

- Interval data provides means to identify customers that have significant potential for demand response and/or energy efficiency programs
- Using interval data, utility companies have the ability to link the time of consumption with an appropriate price for that time period that accurately reflects the wholesale power market conditions and relative scarcity of electricity at that time

3.1 List of Interval Data UOMs

List of interval data UOMs supported by meter is available in Appendix "A.5 List of UOMs."

3.2 Interval Data Recording

The meter stores interval data as "load profile sets." A load profile set contains multiple channels or UOMs. Unlike billing data, interval data is stored in the persistent memory of the meter. The number of days of meter data that can be stored is configurable via GE's MeterMate® tool. eMCM only retrieves this data and transmits it to back office system.

Table 8. Interval data recording capabilities by meter type

List of UOMs	I210+	I210+c	kV2C	SGM3000
Number of load profile sets	NA	1	1	4
Number of channels per load profile set	NA	4	20	6
Meter tables in which data is recorded	NA	ST64	ST64	ST64, ST65, ST66, ST67
Bytes per interval per set (typical)	NA	12	44	16
Allowed recording intervals (minutes)	NA	1,2,3,4,5, 6,10,12,15, 30,60	1,2,3,4,5, 6,10,12,15, 30,60	5,10,15, 20,30,60
Zero filling by meter during power outage	NA	Yes	Yes	No
Tool for configuring interval data records	GE’s MeterMate® tool			

While the meter allows for granular recording of interval data (e.g., 1 or 2 minutes), there could be AMI system capacity limitations with reporting the large amount of data associated with very small intervals. The tradeoffs in interval size and reporting have to be conducted as a part of network planning exercise.

3.3 Interval Data Reporting

3.3.1 Scheduled Read and Reporting

Interval data is typically recorded on 15 or 60 minute intervals. It is also read by the eMCM from the meter’s tables on the same cycle. The reporting frequency could be larger than the recording frequency. For example, four 15-min intervals of data could be reported in a single report every 60 minutes. Less frequent reporting has the advantage of reduced traffic on the network, which builds latent capacity and allows for more applications to be deployed.

AMI 1.2 supports 5-min reporting of interval data for applications, such as bellwether meters, that require near real-time reporting. Only a subset of total population of meters can be configured to report every 5 minutes. This determination has to be performed during network planning.

A report can carry a maximum of 16 intervals only. Reporting of scheduled load profile data reads is randomized across “reporting window” to prevent collisions of packets that would result from large number of simultaneous transmissions.

Table 9. Reading and reporting of interval data

	I-210+	I-210+c	kV2C	SGM3000
Typical reporting frequency (minutes)	NA	15, 60	15	15, 60

	I-210+	I-210+c	kV2C	SGM3000
Minimum allowed reporting frequency (minutes)*	NA	5	5	5
Maximum intervals per report	NA	16	16	16
Reporting window	NA	0 – 2 times reporting interval		
Tool for configuration of interval data reporting	data_orders.properties file at HES			

*Dependant on meter's flash-wear leveling

3.3.2 On-Demand Read and Reporting

Instantaneous reading and reporting of interval or load profile data occurs in response to "on-demand reads" from either back office systems or OTV.

- Can read only one load profile set per on-demand request
- Start and end time, aligned on interval boundaries, have to be specified in the
- Maximum of 16 intervals can be reported per request
- Can fetch interval data of completed intervals only
- Can fetch interval data from any point of time (typically less than 3 months) as long as the meter has the data
- Multiple on-demand read requests might have to be issued to fetch interval data spread over a time range
- Reporting latency varies – Depends on the number of channels per load profile set and the number of intervals to be reported.
- On-demand reads can be performed for a single meter or a group of meters. In AMI 1.2, the groups are created via OTV only

3.4 Interfaces to Back Office

3.4.1 Scheduled Reads

Interval data from scheduled reads is reported via IEC-CIM or MultiSpeak interfaces from HES to back office systems.

Interval data can also be exported in California Metering Exchange Protocol (CMEP) or comma separated values (CSV) file formats. While automated exports of interval data in CMEP file format can be scheduled from OTV, only manual exports are possible (from OTV) in CSV file format.

"data_orders.properties" file is the tool used to set or change the frequency of reading and reporting of interval data from the meter. This file is managed by ORW or HES/OTV operator.

3.4.2 On-Demand Reads

On-demand read requests are issued from back office systems to HES on either IEC-CIM or MultiSpeak interfaces. Interval data reports for on-demand read requests are sent via IEC-CIM or MultiSpeak from HES to back office systems. On-demand read requests can also be issued from OTV. The responses are visible on OTV's GUI.

3.5 Scenarios

3.5.1 Power outage at schedule read time

Meter data is not recorded during a power failure and eMCM cannot read during a power outage. eMCM reads interval data at the first scheduled time after power restoration and after successfully joining the network. The meter if programmed to do so, can automatically fills zeroes for intervals in which power was not recorded. Quality flags associated with zero filled interval data reads during power outage are marked as "Power Fail" by the meter.

eMCM can blindly fetch data for up to 16 most recent recorded intervals (default of 4) at first schedule after the power restoration. Default of 4 was chosen to avoid sudden increase in capacity use after mass power outage. Increase to 16 is recommended only if a few interval quantities are being recorded. If the power outage is longer than 16 intervals, then back office systems would have to issue an on-demand read requests to obtain missing interval data.

3.5.2 Communication link loss at reporting time

In the event of a communication link loss, the eMCM buffers interval reads for transmission. Post communication failure, eMCM allows buffering of up to 10 interval data reports in its internal buffer. A variety of factors, such as reporting frequency of billing data, periodic power quality reports and number of load profile sets, determine the amount of interval data that is buffered.

If the communication link is not restored when the buffers are full, the oldest reading in the buffer is "dropped" and replaced with most recent interval read. The meter, however, keeps recording interval data irrespective of eMCM's buffering capabilities. Up to 16 most recent intervals of data are read from the meter and buffered into eMCM after communication link restoration.

Interval data reporting delay during communication link failure is dependent on the duration of the link failure plus time it would take to transmit buffered data in eMCM. Recovery time is typically small except for mass outage scenario. Interval data is lost and not automatically reported if communication link is not restored within 16 interval durations plus the time it takes for eMCM buffer to get full. Back office systems will then have to initiate on-demand reads to fetch missing interval data.

3.5.3 Back Filling

The process of identifying and fetching missing data reads is termed as back filling. This is an activity typically undertaken by back office system, such as an MDMS.

There is no auto-back filling support for interval data in AMI 1.2 release. Back office systems like MDMS will have to identify missing interval data and fetch them from the AMI system. Missing data can be fetched by issuing on-demand read requests. How far the MDMS can go to fetch past data depends on meter storage. Since an on-demand interval read request can fetch only 16 contiguous intervals, the MDMS will have to manage and issue multiple on-demand interval read requests to fetch data for more than 16 contiguous intervals.

4 Power Quality Data

Power quality refers to the electricity that consistently meets the agreed upon specifications for optimal and efficient use in home electronics. In an AMI system, it is a view of the quality of electricity at the edge of the grid where smart meters are located. Power quality data is collected and reported by an AMI system as readings and/or events.

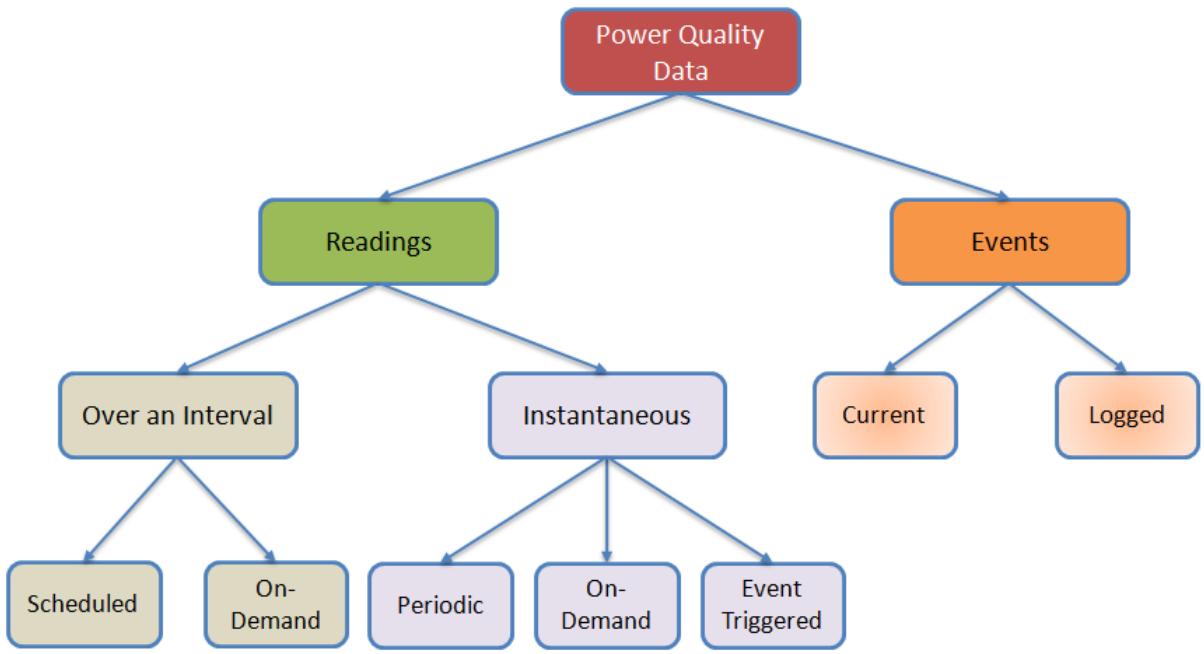


Figure 9. Classification of power quality data

Power quality data in AMI system consists of two categories – readings and events. Explicit reads of power quality metrics recorded by the smart meter constitutes power quality readings. Reporting of instances of power quality metrics exceeding specified thresholds constitutes power quality events.

4.1 Power Quality Readings

Smart meters measure and record power quality metrics continuously. These measurements could be an instantaneous view or over an interval. The AMI system can be setup to read and report these metrics.

- Instantaneous power quality metrics are accessible in registers of the smart meter. Like billing data, they cannot be retrieved from the meter at a later point of time
- Power quality metrics measured over a time interval are part of interval data. This data is stored in meter tables and up to three months of interval data is stored in smart meters

4.1.1 Periodic Reads of Instantaneous Power Quality

AMI system performs periodic reading of instantaneous power quality metrics. The time of reading and the frequency of reading are configurable. Default reporting setting for power quality metrics is once every twenty four hours. Table below lists the power quality metrics recorded by meter that can be read and reported periodically.

Table 10. Power quality metrics for on-demand and periodic readings

Quantity[1]	Filter1 bit#	Filter2 bit#	I-210+[2]	I-210+c[3]	kV2c	SGM3K
Line-to-line Voltage	1				✓	
Line-to-neutral Voltage	2		✓	✓	✓	✓
Current	3				✓	✓
Momentary Power Factor	4			✓	✓	✓
Running Avg Power Factor	5				✓	
ITHD	6				✓	
VTHD	7				✓	
TDD	8				✓	
Distortion Power Factor	9				✓	
Temperature	10		✓	✓	✓	
Frequency	11				✓	
Active Power	12		✓		✓	✓
Reactive Power	13				✓	✓
Distortion Volt Ampere	14				✓	
Apparent Power		1			✓	✓
Voltage Angle		2			✓	
Current Angle		3			✓	

[1] Reported quantities may have per phase values (if meter is 3 phase), F or F+H or both depending on meter

[2] I210+ reporting is not affected by filtering

[3] I210+c FW release 5.x is expected to contain instantaneous active Power. It is not supported currently

Power quality metrics are reported immediately after reading. To avoid large message traffic, the reading and reporting time of power quality metrics at different meters is randomized over a reporting interval or window. The quantities for which power quality has to be reported, the frequency of their reporting, and the reporting interval are all configurable in data_orderes.properties file, that resides at HES/OTV.

4.1.2 On-demand Read of Instantaneous Power Quality

Instantaneous power quality metrics can be read on-demand as well. The same list of power metrics available for periodic readings (section 4.1.1) are also available for on-demand reads.

Since there are a number of power quality metrics, and not all of them might be required, a subset of power quality metrics can be read in an on-demand read request. Thus, there are four options for on-demand power quality metric readings.

- All power quality readings
- Distortion (VTHD, ITHD, TDD/THD, distortion power factor, distortion kVA)
- Instantaneous demand readings (only kW, kVAR)
- Diagnostics (L2N voltage, current, voltage angle, current angle)

Table 11. On-demand power quality read options

Quantity	All	Distortion only	Instantaneous demand only	Diagnostics
Line-to-line Voltage	✓			
Line-to-neutral Voltage	✓			✓
Current	✓			✓
Momentary Power Factor	✓			
Running Avg Power Factor	✓			
ITHD	✓	✓		
VTHD	✓	✓		
TDD	✓	✓		
Distortion Power Factor	✓	✓		
Temperature	✓			
Frequency	✓			
Active Power	✓		✓	
Reactive Power	✓		✓	
Distortion Volt Ampere	✓	✓		
Apparent Power	✓		✓	
Voltage Angle	✓			✓
Current Angle	✓			✓

The above table summarizes the four options for on-demand power quality reads. Following examples best illustrate on-demand PQ read capabilities of a given meter.

Example 1: On-demand “Instantaneous demand only” PQ read of a kV2c or SGM3000 meter returns the active power, reactive power and apparent power only.

Example 2: On-demand “Diagnostics only” PQ read of a SGM3000 meter returns only L2N voltage and current readings since SGM3000 meters do not provide voltage angle and current angle measurements.

Example 3: On-demand “Distortion only” PQ read of an I-210+c meter does not return any readings because I-210+c meter does not support VTHD, ITHD, TDD, distortion power factor, or distortion Volt Ampere.

On-demand PQ readings can be performed from OTV or from back office that is integrated with HES/OTV. The interface for request and responses is IEC-CIM. Separate CIM codes distinguish on-demand PQ read requests for the four different option groups. The four options groups are configurable via modifying IEC-CIM-HTTP.properties file located in HES. Please refer “HES/OTV AMI Interface Guide” for further details on the interfaces.

4.1.3 Event Triggered Instantaneous Power Quality Reads

When a metric exceeds a certain configured threshold, the meter sets its internal flags. These flags trigger events at the HES. They are also recorded and logged in the meter. The meter records readings associated with some of these flags. These readings are reported when logged power quality events are reported. Since the readings have the same time stamp as the logged power quality events, the two can be correlated to the same occurrence. Table below lists the power quality reads that are triggered by events.

Table 12. Power quality quantities read when triggered by events

Quantity	I-210+	I-210+c[1]	kV2C[1]	SGM3000
Sag / Swell Current*		✓	✓	X
Sag / Swell Voltage*		✓	✓	X
Sag / Swell Duration		✓	✓	X
Sag / Swell Event Count		✓	✓	X
Cumulative sag/swell event count	X	✓	✓	X
Momentary Event Count	✓	✓	✓	✓
Momentary Cumulative Count	✓	✓	✓	✓
Momentary Interrupt Count	✓	✓	✓	✓

[1]V2 (I210+c) or V (kV2C) soft switches are required

X = Meter records but AMI does not read and report

4.1.4 Reads of Power Quality over Intervals

A smart meter is capable of measuring and recording power quality metrics over an interval and not just the instantaneous values. These power quality metrics form part of the interval data. Hence, they are stored in the meter tables for 60 to 180 days.

- Refer chapter “3 Interval Data” for details regarding reading and reporting of power quality metrics as well as interfaces to back office systems
- Both scheduled and on-demand reads of power quality over intervals can be performed
- Power quality metrics that can be read over an interval are listed in Appendix “A.5 List of UOMs”

4.2 Power Quality Events

Refer section “5.1 Events” for definition and categorization of events. Power quality events are a subset of meter events.

4.2.1 Current Events

Current events that occur when power quality metrics exceed stipulated thresholds are reported as current PQ events.

Table 13. List of current PQ events for I-210+c and kV2c meters

METER EVENT	DESCRIPTION	I-210+c	kV2c
Polarity, Cross Phase, Rev. Alert	Cross Phase Alert		✓
Voltage Imbalance Alert	Voltage Imbalance Alert		✓
Inactive Current Alert	Inactive Current Alert		✓
Current Phase Angle Alert	Current Phase Angle Limit Alert		✓
Distortion Alert	High Distortion Alert		✓
Under Voltage Alert	Low Voltage Alert	✓	✓
Over Voltage Alert	High Voltage Alert	✓	✓
High Neutral Current Alert	High Neutral Current Alert		✓

- Refer section “5.1.1.5 Generic Meter Events” for details on all I-210+ meter events.
- AMI system does not report any current power quality events for SGM3000 meters. It only reports logged power quality events for SGM3000 meters. Refer section “4.2.2 Logged Events” for details on logged power quality events.

4.2.2 Logged Events

Some power quality events are logged by meter in a meter table. These PQ events are logged by the meter after they have finished occurring. The logged events meter table is circular and has a fixed depth; therefore it has the risk of events getting overwritten if they are not read in a timely manner.

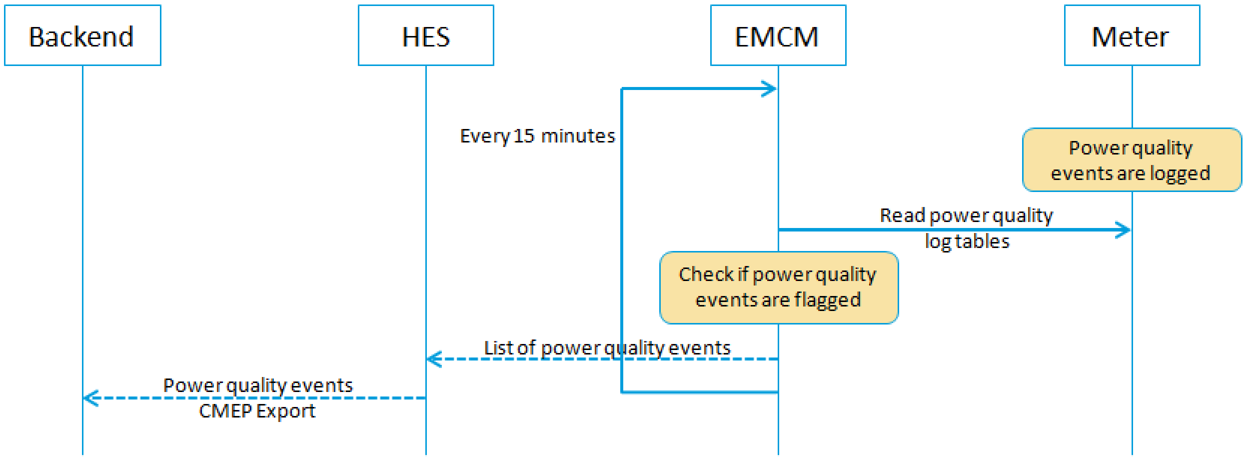


Figure 10. Reporting of logged power quality events

The list of logged events is mutually exclusive from current events. Information logged includes event type, time of the event occurrence, number of occurrences of the event since last eMCM read, duration of the event, actual value of the measure that triggered the event, etc. SGM and I-210+ meters do not record the duration of the event and the actual value of the measure that triggered the event.

Table 14. List of power quality events logged by the meter

	I-210+		I-210+c		kV2C		SGM3000	
	Event	Event triggered PQ read	Event	Event triggered PQ read	Event	Event triggered PQ read	Event	Event triggered PQ read
Sag	✓		✓	✓	✓	✓	✓	X
Swell	✓		✓	✓	✓	✓	✓	X
Voltage imbalance							✓	X
Under frequency							✓	X
Over frequency							✓	X
Momentary Outage	✓	✓	✓	✓	✓	✓	✓	✓

eMCM reads the logged events table in the meter every fifteen minutes. This is a configurable setting. eMCM reads and reports both the logged event and its associated metric or value for I-210+, I-210+c, and kV2c meters. In AMI 1.2, only logged events are reported for SGM3000 meters. The measure or value associated with the logged event is not read and reported for SGM3000 meters.

"E" soft switch has to be enabled in GE smart meters to perform event log recording (typically most recent 200 events). MeterMate™ Program Manager can be used to select the event types to be logged. Refer GE's smart meter documentation for exact and specific information regarding the required soft switches.

5 Events and Alarms

5.1 Events

Smart meter have a number of status indicators. These status indicators are typically set whenever a certain threshold is exceeded. For example, if the line voltage drops 10% below its expected value, the meter sets a status indicator to indicate the voltage drop. Whenever eMCM detects change in status indicators, at poll time, it communicates the status indicators to HES/OTV, which in turn generates events. Changes in status indicators between poll times are not detected by eMCM.

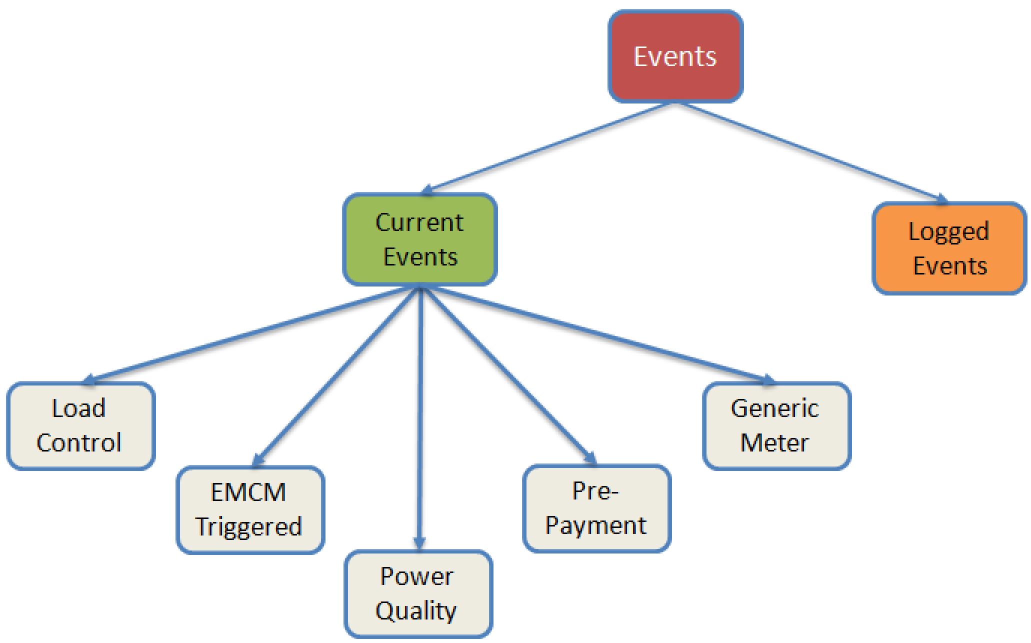


Figure 11. Types of meter events

There are two types of AMI events – current events and logged events. Current events are those events that are active at the time of eMCM polling. Meter events that are recorded and logged in meter's tables are termed as logged events.

5.1.1 Current Events

Events that are active or occurring in the meter at the time of eMCM poll are termed as current events. The meter latches all current events and stores them in a table. The values associated with the event are not stored in the table. For e.g. over-voltage event is latched but the value of the over-voltage is not stored.

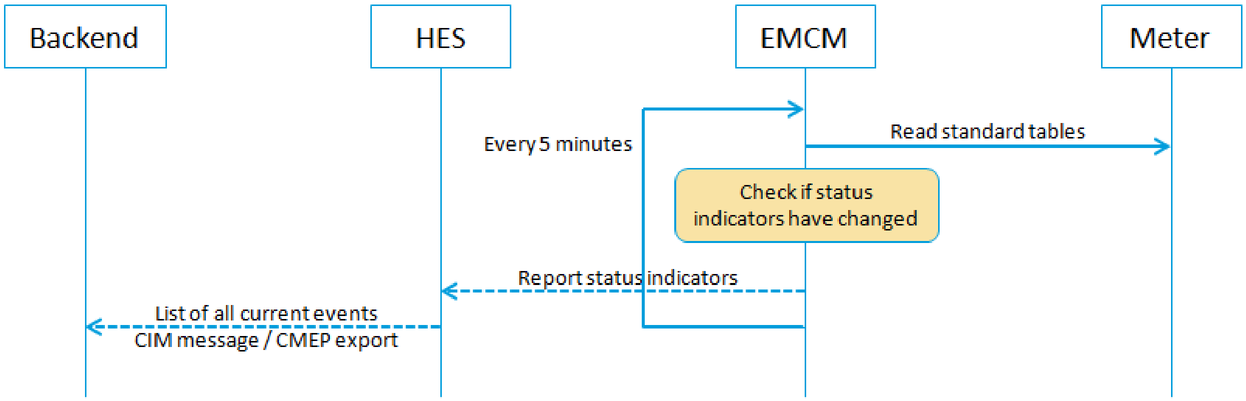


Figure 12. Monitoring and reporting of events happening at poll time (current events)

The eMCM polls the meter for current events every time a five minute timer expires. The time of poll for current events is configurable. If the status flag for latched current events is set, then the eMCM reads and reports the entire meter table of current events. The event report is time stamped with local time and sent to HES. The HES sends the current events to back office systems via IEC-CIM messages.

The meter latches events as they are occurring. The meter clears the latch when the event occurrence ends. Thus, if a current event occurs between eMCM polls, it is lost since the meter does not store them.

5.1.1.1 Load Control Events

Refer the following section for list of relay and control point related events.

- 8.3.1 Remote Connect & Disconnect
- 8.3.2.1 Relay connect/disconnect and Load Control in I-210+c
- 8.3.2.2 Relay connect/disconnect and Load Control in SGM3000 meters
- 8.3.3 Event Driven Connect & Disconnect
- 8.3.4 Events Associated with Control Points

5.1.1.2 eMCM Triggered Events

Listed below are events that are generated by the eMCM when it performs certain actions.

Table 15. List of eMCM triggered current events in AMI system

eMCM Triggered Event	Description
Meter time corrected	eMCM corrects and aligns the meter's time (local time)
Meter communication error	eMCM is unable to communicate with meter
Meter power fail	Meter loses electrical power
Meter power fail clear	RPMA node in meter rejoins network after power restoration

eMCM Triggered Event	Description
Meter power restore	Reports time stamp of actual power restoration
MCM FW configuration error	eMCM performs CRC check on firmware
MCM FW self-test error	eMCM performs self-check
Device FW attributes changed	Whenever eMCM attributes changed
Updated attributes reported	When meter attributes are updated
Meter metrology configuration change	When eMCM detects that the meter is reprogrammed (program update)
Meter serial number changed	eMCM swapped from one meter to another

5.1.1.3 Power Quality Events

Refer to section “4.2 Power Quality Events.”

5.1.1.4 Prepayment Events

There are two ways in which AMI systems implement prepayment.

- Prepayment rests entirely in back office system like CIS

  In this scenario, all the logic and controls required to implement prepayment resides with the back office system. The back office keeps track of payments made, balance remaining, credit expiry, etc. When credits expire, the back office system issues a remote relay disconnect command to the meter (typically after a small grace period) to disconnect electric supply. A remote relay connect command is issued to meter when payments are made and the credit is positive.

  The AMI system only generates “Relay connected” and “Relay disconnected” events in response to the RC-DC commands from back office system.

- Meter enabled prepayment

  In this scenario, the back office receives customer payments and it programs the meters (remote program update) with the credit amounts. The meter keeps track of credit balances and it disconnects the relay when credit expires. Relays are reconnected when credit balance turns positive after a meter program update, which accompanies customer payments.

  The AMI system generates two events when the balance is updated in the meter:

  - Relay connected
  - Prepayment balance positive

  Similarly, the AMI system generates following events when the balance expires in the meter:

  - Prepayment balance expired
  - Balance over-draft (only in SGM3000 meters, not in I-210+c)
  - Relay disconnect

NOTE: Meter program update is possible via OTV-UI (remote update) or directly at the meter.

5.1.1.5 Generic Meter Events

Listed below are events that are generic meter events for all supported GE meters.

Table 16. List of I-210+ meter events

METER EVENT	DESCRIPTION
SERVICE_ERROR	Installation error due to Form and Service mismatch
DC_DETECTION	Meter detects DC presence
METER_INVERSION	Meter reversed for tampering
REVERSE_ENERGY_FLOW	Reverse energy flow was recorded
TEMPERATURE_CAUTION	Temperature is above the programmed threshold
METERING_PROBLEM	Metering related error
SAG	New sag event was detected
SWELL	New swell event was detected

Table 17. List of generic meter events for I-210+c, kV2c and SGM3000 meters

METER EVENT	DESCRIPTION	I-210+c	kV2c	SGM
UNPROGRAMMED_FLAG	Indicates device is in default (unprogrammed) state (0 = programmed, 1 = unprogrammed)	✓	✓	✓
CONFIGURATION_ERROR_FLAG	Config error			
SELF_CHK_ERROR_FLAG	Meter self-check error			
RAM_FAILURE_FLAG	RAM Error	✓	✓	✓
ROM_FAILURE_FLAG	ROM Error (program ROM or Flash)	✓	✓	✓
NONVOL_MEM_FAILURE_FLAG	NVRAM Error (data EEPROM or Flash)	✓	✓	✓
CLOCK_ERROR_FLAG	Clock Error	✓	✓	✓
MEASUREMENT_ERROR_FLAG	Bad voltage reference	✓	✓	✓
LOW_BATTERY_FLAG	Set when battery test shows low battery	✓	✓	✓
LOW_LOSS_POTENTIAL_FLAG	Device did/did not detect potential below predetermined value	✓	✓	✓
DEMAND_OVERLOAD_FLAG	Demand threshold overload	✓	✓	✓
TAMPER_DETECT_FLAG	Tamper Detect	✓	✓	✓
REVERSE_ROTATION_FLAG	Reverse Flow			
	Possible High Line Current		✓	
DC_DETECTION	Meter detects DC presence	✓		✓
HIGH_TEMPERATURE	Device detected a high temperature condition	✓		✓
METERING_ERROR/DSP_ERROR	Metering Error: See MT69 for cause of error	✓	✓	✓
SYSTEM_ERROR	Watchdog timer failed	✓	✓	✓
RECEIVED_KWH	Detected received kWh	✓	✓	✓
LEADING_KVARH	Detected leading kVAh	✓	✓	✓

METER EVENT	DESCRIPTION	I-210+c	kV2c	SGM
LOSS_OF_PROGRAM	Device was interrupted during programming; the new program was lost	✓	✓	✓
TIME_CHANGED	Set whenever time/date is set in the device. Applies only to external events, not DST time changes		✓	
FLASH_CODE_ERROR	Detected an error in the code section of flash memory		✓	
FLASH_DATA_ERROR	Device did/did not detect a checksum error in the data section of flash		✓	
RELAY_STATE_CHANGE	State of one of the relays changed			✓
COMMUNICATION_ERROR	Flag is set when the meter detects a communication error from AMI			✓
FIRMWARE_UPGRADE_ERROR	Firmware upgrade error			✓
LOW_TEMPERATURE	Device detected a low temperature condition			✓

5.1.2 Logged Events

The meter logs a host of events that happens in the meter. However, AMI 1.2 reads and reports only logged power quality events. Refer section “4.2.2 Logged Events” for details.

5.2 Alarms

In ORW’s AMI system, alarms are current events with higher priority. OTV pre-specifies a list of events as candidates for alarms. A utility company can select from this list what it deems as important for high priority reporting. Selection of alarms for reporting can be performed from OTV. An email notification is sent whenever an alarm occurs. List of email addresses to receive alarm notifications is also configured in OTV.

6 Power Outage Management

Loss of electric power is termed as power outage or simply an outage. In the event of an outage, the line voltage level drops well below the normal operating level. Household electrical appliances would fail to operate when an outage occurs. The utility company determines the voltage level drop that would constitute as an outage. For a poly-phase system, service outage detection corresponds to the phase that power the poly-phase meter.

There are two kinds of power outages – momentary and sustained power outages. Momentary outages last for a very brief duration, typically less than two minutes. Sustained outages are longer duration outages. These are described in detail in the following sections.

Quick and reliable detection of sustained power outages is of paramount importance to utility companies. In the event of large scale power outage, most AMI systems are challenged when it comes to reporting of sustained outages to the utilities. Inherent limitations in their networks inhibit their ability to handle the large traffic of simultaneous power outage notifications. As a result, only 15% to 30% of last gasp notifications successfully reach the utility company. Without proper knowledge of most, if not all, locations of outages, the utility company's ability to effectively resolve issues is significantly curtailed.

Utility companies can overcome these challenges with ORW's AMI system, thanks to its structural strengths. These include

- Direct communication link between meter and Access Point, which reduces the time required to get a message out
- Consistent coverage of the RF channel
- Excess system capacity to handle large number of outage notifications

All these advantages translate into successful transmission of upward of 90% of last gasp reporting during a large scale power outage. The same strengths come into play for quick reporting of power restoration. Almost all power restoration notifications are received at the utility company within an hour on an ORW AMI system, unlike many hours or even days required for other AMI systems.

6.1 Meter Communication Module in an Outage

The eMCM hardware module has an RPMA node and a super capacitor (super-cap). In the event of a sustained power outage, the eMCM module depends on the current from the super-cap for operation. As the super-cap can provide current for a very limited time, the eMCM module has to conserve the current by executing only the most critical operation – send the "last gasp" power outage notification to the utility company's Outage Management System (OMS).

When a power fail occurs, the eMCM notifies the RPMA node, which saves the power fail timestamp and enter into a power save mode. The eMCM then stops all its activities and enters momentary versus sustained outage detection phase. If power is not restored and a sustained outage is detected, the eMCM confirms the power fail to the node before entering power save mode itself. The node then wakes up from its low power mode and prepares for transmission of the last gasp message.

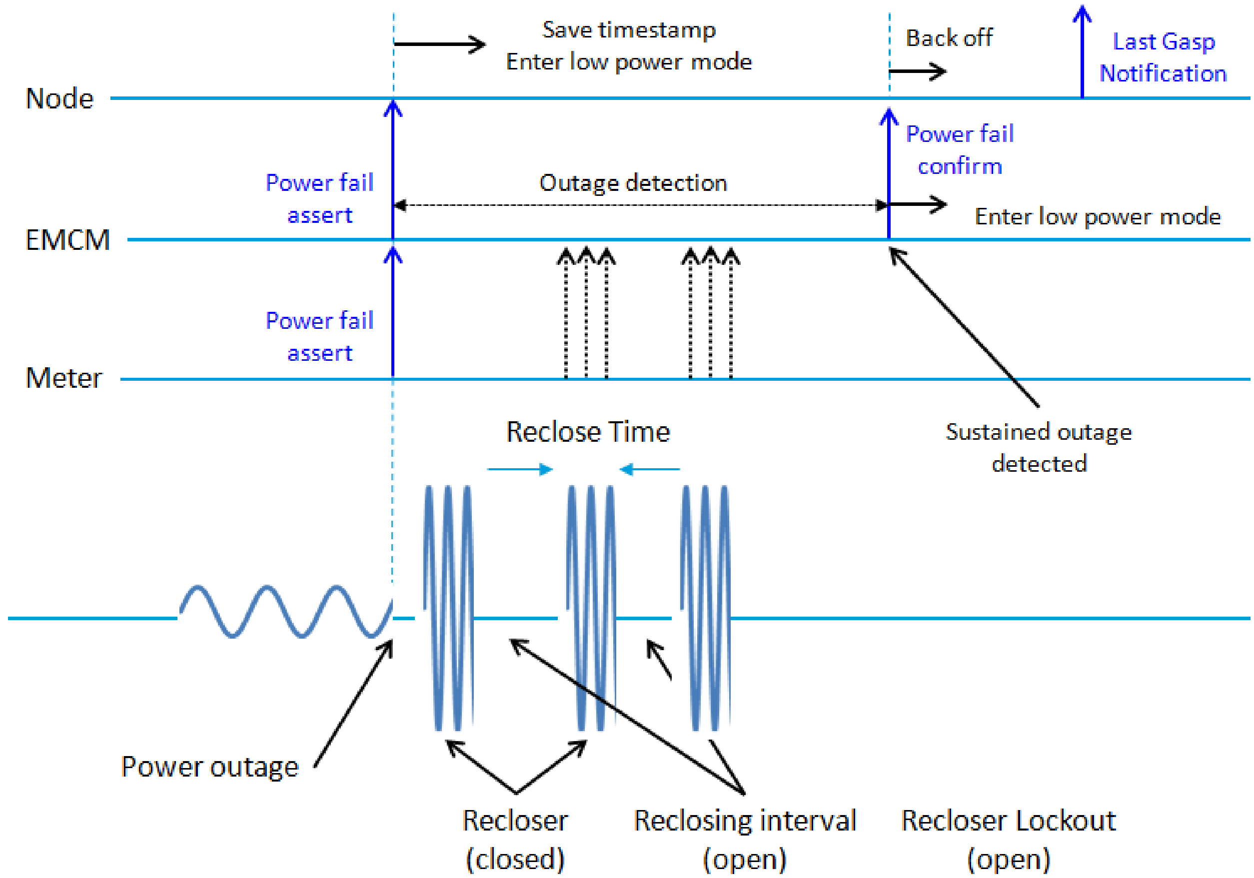


Figure 13. Outage Reporting by eMCM

In the event of a large scale power outage, many meters would be trying to send the power outage notifications at the same time causing heavy traffic on the network. To avoid collisions between messages and the resultant retransmissions, and increase the probability of messages reaching the OMS, the RPMA nodes in the meter randomize the time at which they transmit the messages. All these activities allow the node to utilize most of the energy available from the super-cap; and ensure that most of the outage notifications from the meters successfully reach the OMS.

6.2 Momentary Power Outage

Power loss of a short duration, i.e. less than the minimum duration of power loss that constitutes a sustained outage, is classified as momentary outage or simply a momentary. Typically, a momentary outage lasts for less than two minutes. A momentary is caused by interference, such as a falling branch or a dead animal, on the power lines. Electrical power lines are equipped with "automatic reclosers", which try to revive power when the interference clears out.

6.2.1 Momentary Detection

When a power line trips, the recloser automatically tries to close and restore electric power after two to five seconds. If the power is not restored, the reclosers make a second attempt to restore the connection. The second attempt could be made anywhere from five seconds to forty five seconds after the first attempt, depending on the recloser settings. The duration between each reclosing attempt is known as reclosing interval. The recloser's closing attempt lasts for a very brief period – order of tens of milliseconds to few hundred milliseconds. Reclosers make two to three attempts to review power loss. If there is a third recloser attempt, it is made 20 to 60 seconds after the second attempt. The last recloser attempt could last longer than the previous attempts but it is still in the order of few hundred milliseconds.

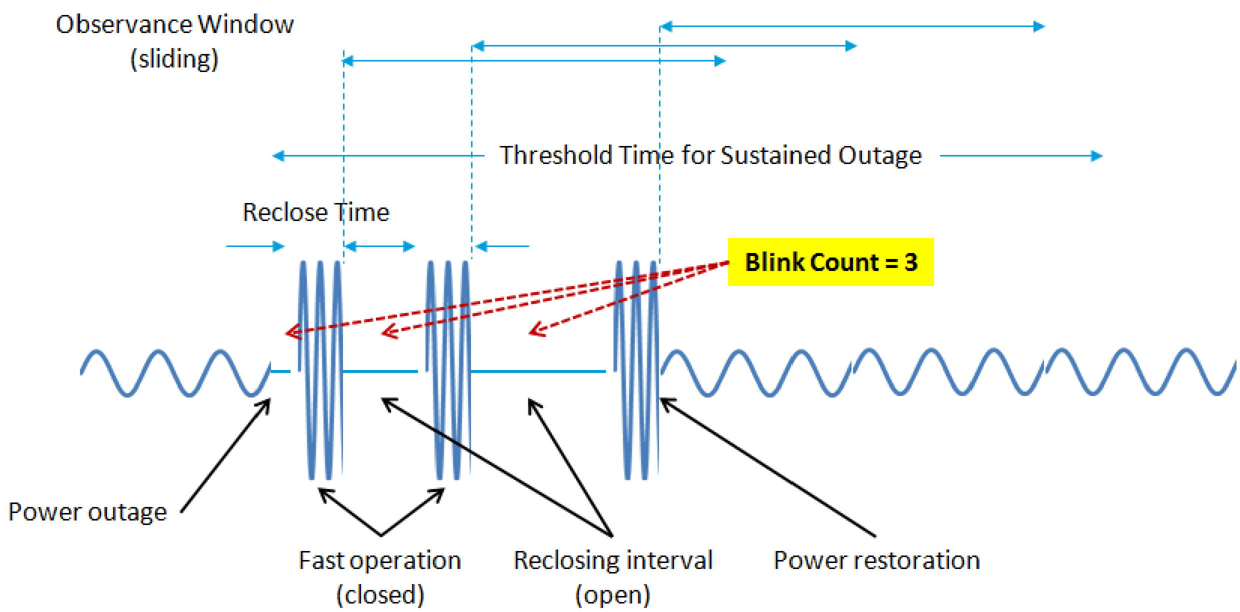


Figure 14. Momentary outage detection

Different utility companies could have different settings for operation of reclosers and determining sustained outage. The AMI system is designed with enough flexibility to accommodate these differences. There are primarily three configurable parameters in the AMI system that enables the AMI to operate and meet outage detection requirements.

Threshold time for sustained outage: A sustained power outage notification is sent by the AMI system if power loss lasts longer than this parameter. The default value for this parameter is 120 seconds. The maximum value that could be supported, at the expense of loss of notifications, is 300 seconds.

Observance window of power restoration activity: This parameter aids in early detection and notification of sustained outage, which in turn enables higher number of outage notifications to reach utility company's OMS. The default value for this configurable parameter is sixty seconds.

After each recloser attempt, the eMCM waits sixty seconds to observe if power is restored or if the recloser makes another attempt. If both of these conditions are not met at the end of sixty seconds, the eMCM declares a sustained outage without waiting for the "threshold time for sustained outage" to expire.

The early detection of sustained outage enables early reporting of outage notification, which is highly desired by utility companies. It also increases the probability of more outage notifications from the meters to be transmitted to the OMS as the eMCM has more time (i.e. super-cap charge availability) to transmit the notifications.

Minimum duration of steady power required: The eMCM detects power restoration only if the meter detects steady voltage in an acceptable voltage level range for a duration specified by this configurable parameter. The default value of this parameter is three thousand (3000) seconds. If power is restored before the expiry of both “threshold time for a sustained outage” and “observance windows for power restoration activity”, then the power loss is classified by AMI as a momentary outage.

Table 18. Configurable Parameters for Outage Detection

Outage Detection Parameter	Requirement
Threshold time for sustained outage	The value for this parameter must be greater than sum of all the reclosing intervals Must be less than five minutes to enable eMCMs transmit last gasp messages
Observance window of power restoration activity	This parameter should have a value greater than the largest reclosing interval of the re-closer
Minimum duration of steady power required	The value of this parameter should be greater than the time of the longest re-closure attempt

6.2.2 Momentary Reporting

Power is restored quickly in the event of occurrence of a momentary power outage. Since the problem is already fixed, the utility companies are not interested in being alerted/alarmed (via email notifications) of the occurrence of a momentary. Hence, the eMCM logs the occurrence of the momentary in power quality logs.

The power quality logs are transmitted to HES and back office systems as “Power Quality” events. The reporting frequency of these logs, when present, is currently on a fifteen minute cycle. The frequency for reporting of the logs is configurable. The logs capture the following information with respect to a momentary outage:

- Number of momentary outages since the last log was transmitted
- Cumulative number of momentary outages
- Number of blinks that happened within the first momentary outage event since last log was transmitted
- Timestamp of the first momentary outage since last log was transmitted

Thus, details of only the first momentary outage since the last reported power quality event transmission are captured. However, the total number of momentary outages since the last power quality event transmission is captured.

6.3 Sustained Power Outage

Loss of electric power for duration longer than a utility configured setting, which is between two to five minutes, is classified as a sustained power outage. Most utilities declare a sustained outage if power is not restored for two to three minutes. A sustained power outage could occur due to accidental reasons, such as storms, equipment damage, etc., or planned reasons, such as servicing a distribution line. Typically, sustained outages require utility company's intervention to restore power. Sustained Outage Detection

6.3.1 Sustained Outage Detection

When a power line trips, the re-closer automatically makes multiple attempts to restore power. If power is not restored by "Threshold time for sustained outage", which is a configurable parameter with a default value of two minutes, the eMCM declares the occurrence of a sustained power outage and prepares to send the "last gasp" outage notification. It is important to have the "threshold time for sustained outage" detection parameter to have a value greater than the sum of all reclosing intervals. This ensures that the sustained outage is determined and declared only after failure of all power restoration attempts of the recloser.

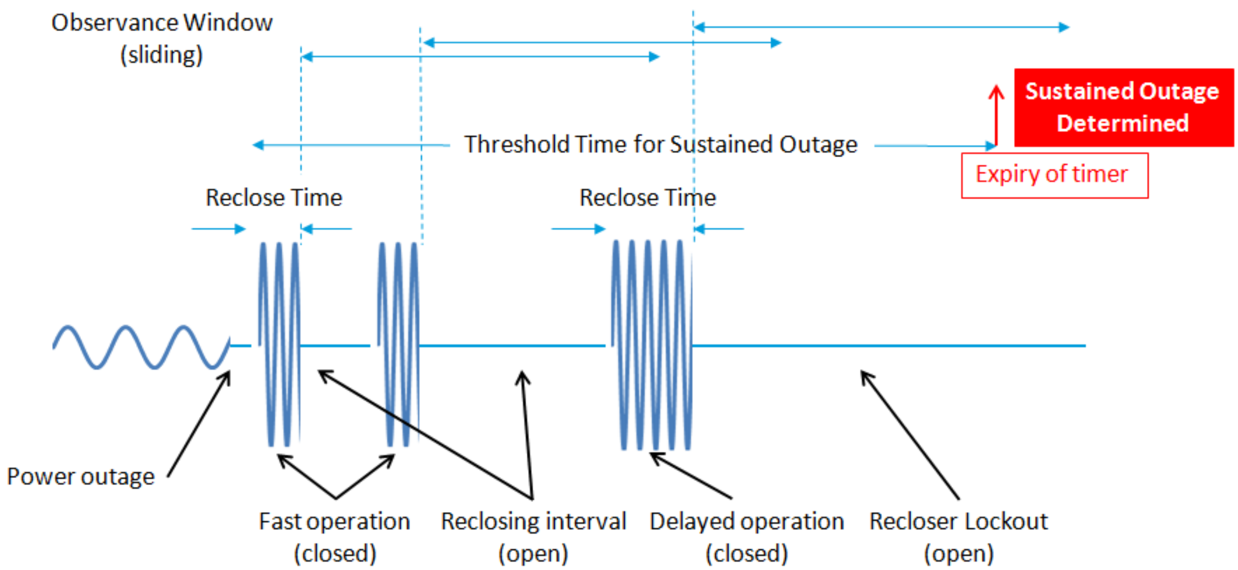


Figure 15. Sustained outage detection

Utilities are always interested in being aware of any sustained power outages on the grid and early detection of these outages. Figure below depicts how the AMI system enables early sustained outage detection.

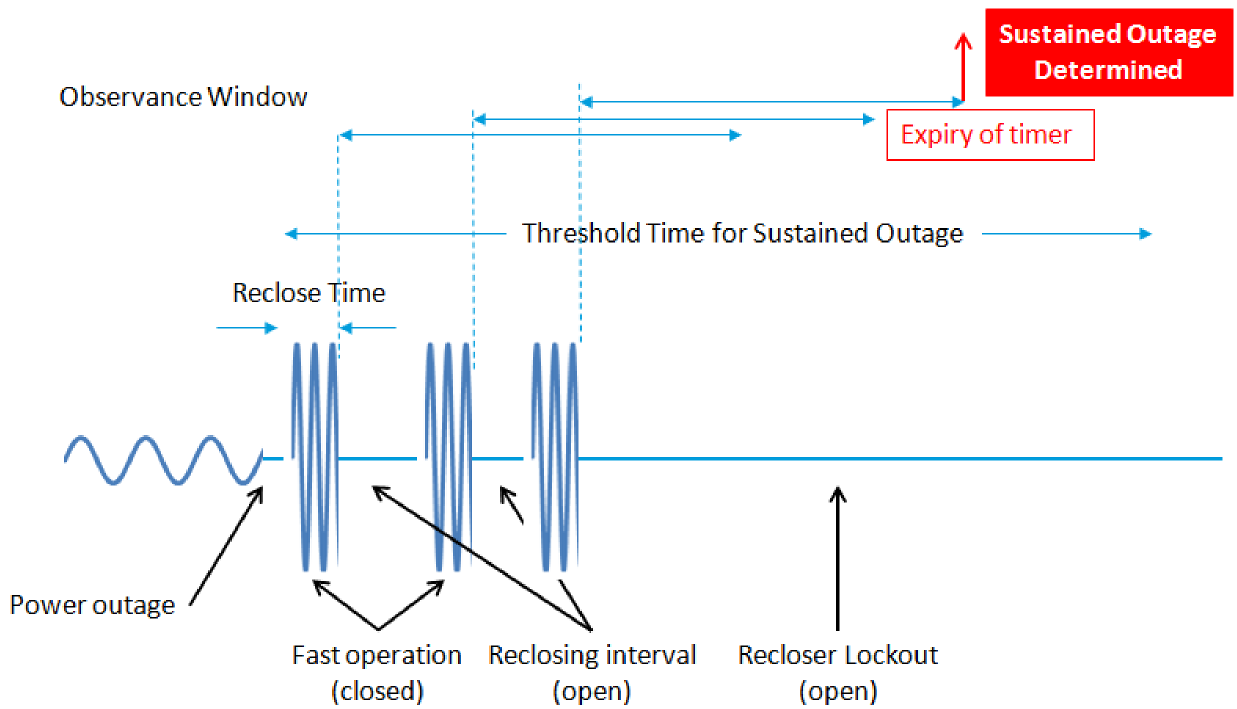


Figure 16. Early sustained outage detection

The AMI system employs a configurable sliding window parameter called “Observance window of power restoration activity” for early detection of sustained outage. After each recloser attempt, this countdown parameter is reset to its default value of sixty seconds. If power is not restored or if another recloser attempt is not made before the expiry of this countdown parameter then the eMCM would determine an early a sustained outage without waiting for the “threshold time for sustained outage” to expire. The value of this parameter should be greater than the largest reclosing interval of the recloser.

6.3.2 Sustained Outage Reporting

The outage notification is a message of highest priority. The AMI system strives to transport every outage notification from the end devices to back office systems such as OMS. In an effort to send the outage notification by conserving super-cap energy, the eMCM stops all its activities, instructs the node for transmission of a sustained outage notification, and goes into a low power sleep state.

Sustained outage notification in a large scale outage scenario gets tad bit complicated with many meters trying to transmit outage notifications simultaneously. To avoid collisions and eliminate retransmissions, and increase the probability of messages reaching the OMS, the RPMA nodes of different meters are configured to randomize the time of message transmissions. As a result, the On-Ramp Wireless AMI system successfully delivers most of the outage notifications to the OMS; a feat few AMI system can match.

Due to limited life (approximately five to six minutes) of super-cap charge and about two minutes required to determine a sustained outage, the outage notifications reach the OMS about two to six minutes after the power outage. When the outage notification from the meter reaches the HES, it creates a “power fail” event and transmits it to HES as an IEC-CIM message.

6.4 Back-to-Back Outages

When sustained power outage occurs and electric power is restored for a brief period before another sustained outage occurs, it is considered as back-to-back outages. Back-to-back outages could be two or more occurrences of sustained outages in fairly quick succession.

Reporting of back-to-back outages is a challenge for any AMI system. The eMCM drains most of the energy stored in the super-cap for last gasp reporting of the first sustained outage. Since electric power is restored only for a brief period before the next outage (in a back-to-back outage scenario), the super-caps do not charge sufficiently to provide the energy required for the eMCM to detect and report (last gasp) the next outage. As a result, often times, the AMI system is unable to report subsequent outages if they occur in quick succession after the first outage due to super-cap limitation.

- The time required for a super-cap to charge sufficiently for last gasp reporting is a function of number of factors such as the age of the super-cap, time elapsed since last outage, if the last outage was a sustained or a momentary outage, profile of the last outage, the health of the communication link, etc.
- Typically, electric power has to be restored for at least an hour before the next outage to enable super-caps to charge sufficiently for last gasp reporting.

6.5 Power Restoration Notification

When electric power is restored after either a momentary or sustained outage, the AMI system sends two events to both OTV and back office system, such as an OMS. The first event, “Power Fail Clear”, notifies the restoration of power at the meter. The second event, “Power Restore”, notifies the exact time at which power was restored.

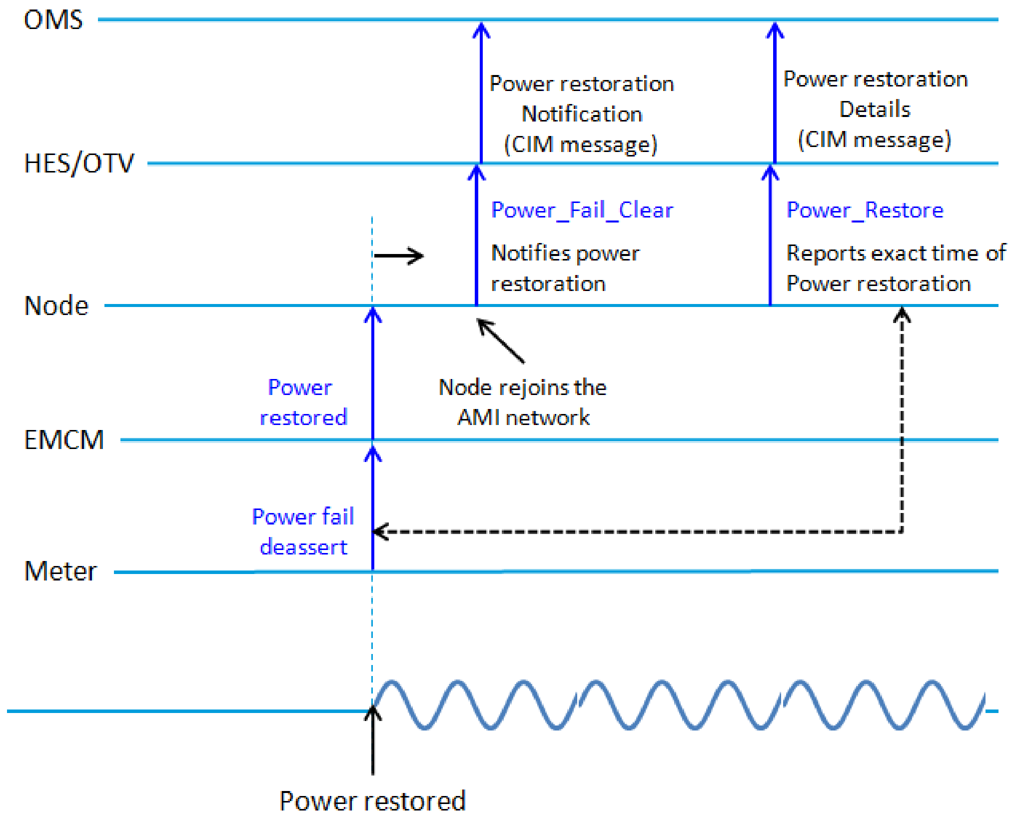


Figure 17. Notification of power restoration

6.5.1 Power Fail Clear

When power is restored the node in the meter tries to rejoin the AMI network. When the node successfully rejoins the AMI network, the HES sends a “Power Fail Clear” event notification to OTV and OMS. This event essentially notifies the OMS of power restoration at the meter. The event is sent from HES to OMS as an IEC-CIM message. Thus, the “Power Fail Clear” event notifies the OMS of power restoration, at various meters, as early as possible.

In the event of a large scale power outage, the latency associated with the “Power Fail Clear” event could be as high as thirty minutes. The OMS receives power restoration notifications from almost all the meters with in thirty minutes of power restoration, an accomplishment that few AMI vendors can match.

6.5.2 Power Restore

After the meter joins the AMI network, it transmits to HES the exact time of power restoration at the meter. The HES then sends the OMS and OTV a “Power Restore” event, which encapsulates the exact time of power restoration. The “Power Restore” event is sent as an IEC-CIM message. These messages are useful to utility companies in the computation of reliability indicators such as System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI).

7 AMI Infrastructure Outages

7.1 Data Retention in AMI System

AMI system is designed to prevent loss of meter data and ensure its reliable delivery. An important component of AMI system towards meeting these goals is uStream – a transmission control protocol that provides message reliability between meter and HES. uStream also enables flow control and delivery of quality of service (QoS).

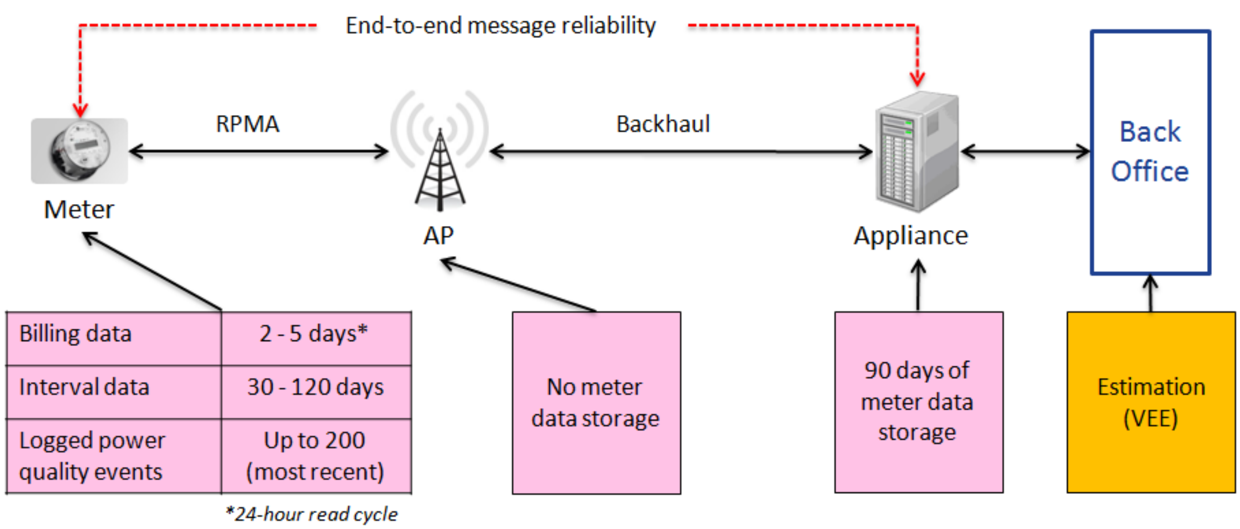


Figure 18. Data retention in AMI system

All meter data is stored at either the meter itself and/or at the HES, the two end points of uStream protocol service. The communication network is simply a transmission pipe and not a source of temporary or long term data storage.

7.2 Communication Link Outage

7.2.1 Meter-to-Access Point Link Loss

The AMI system protects meter data against RF link outages between meter and AP. They system is limited only by the meter's storage capacity.

Communication link loss between meter and AP does not affect meter's recording capabilities. The meter continues to record data normally. It however has an indirect effect on eMCM's reading capabilities. The eMCM continues to perform meter reads – register data, interval data, power quality events, etc. – and places the data for transmission in uStream's buffer that is 16 messages deep (please refer A.6 uStream Protocol for more details).

Once this message buffer fills up, the eMCM does not perform anymore meter reads except for register/billing data reads. Since eMCM stores register data reads in its flash, the contents of the stored register reads are overwritten if they are not transmitted.

Table 19. Data processing at meter in the event of communication link loss

Data Type	Meter records usage	eMCM reads meter		Retrievable after link restoration
		Before uStream buffer full	After uStream buffer full	
Register/billing data	✓	✓	✓	✓
Interval data	✓	✓	X	✓
Power quality readings	✓	✓	X	X
Current events	✓	✓	X	X
Logged events	✓	✓	X	✓

Certain meter data that was not transmitted, due to link loss, can be retrieved from the meter after the RF link between the meter and AP is restored.

- Register/billing data – This data is stored in flash and eMCM transmits them per schedule. They can also be fetched via on-demand read requests.
- Interval data – Most recent 16 interval readings are automatically transmitted by the meter. Older and missing interval readings have to be restored via on-demand read requests.
- Power quality readings – Cannot be retrieved as they are just a snapshot in time and the meter does not store them.
- Current events – Cannot be retrieved as they are just a snapshot in time and the meter does not store them.
- Logged events – Meter stores up to 200 logged events in a circular buffer. eMCM automatically transmits all the events that were not yet sent on the next scheduled transmission (after link restore). Logged power quality events can also be restored via on-demand read requests.

NOTE: If the communication link between meter and AP is not restored within 48 hours, then eMCM’s watchdog timer expires and the eMCM performs an auto hard reset. This results in loss of all the readings that were stored in uStream’s buffer. In such an event, interval data reads can retrieved from the meter via on-demand read request. However, register/billing data reads that were lost are not retrievable.

7.2.2 Access Point Backhaul Outage

AMI system architecture de-risks meter data from outages at Access Point. Meter data is protected and retrievable during or after an outage.

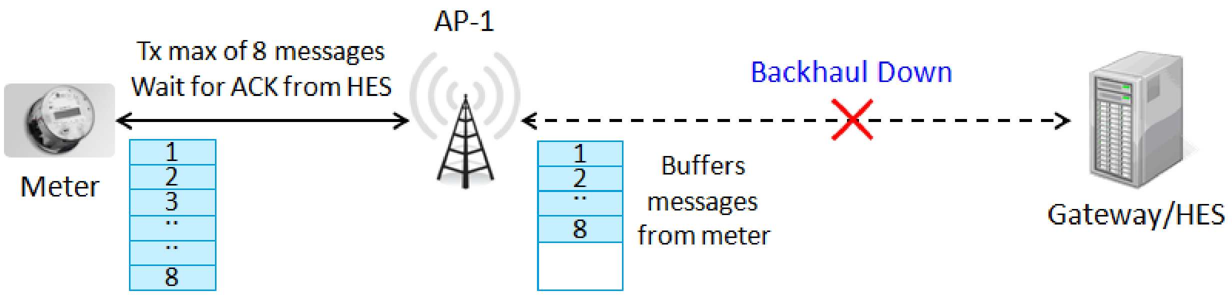


Figure 19. Backhaul between Access Point and Gateway goes down

Reliable message delivery in AMI involves HES acknowledging receipt of meter's message transmissions. The eMCM in the meter transmits up to 8 messages without waiting for acknowledgements from HES. Further transmissions from eMCM continue only after it receives acknowledgements.

When the backhaul between AP and Gateway goes down but the RF link between meter and AP exists, the eMCM continues to transmit messages to AP. However, the eMCM would transmit only up to 8 messages and wait for acknowledgements from HES.

The AP shuts down its RF link to the meters if one of the two following conditions occurs:

- The backhaul connection is not restored in four hours (configurable setting)
- The buffers at AP are 85% full

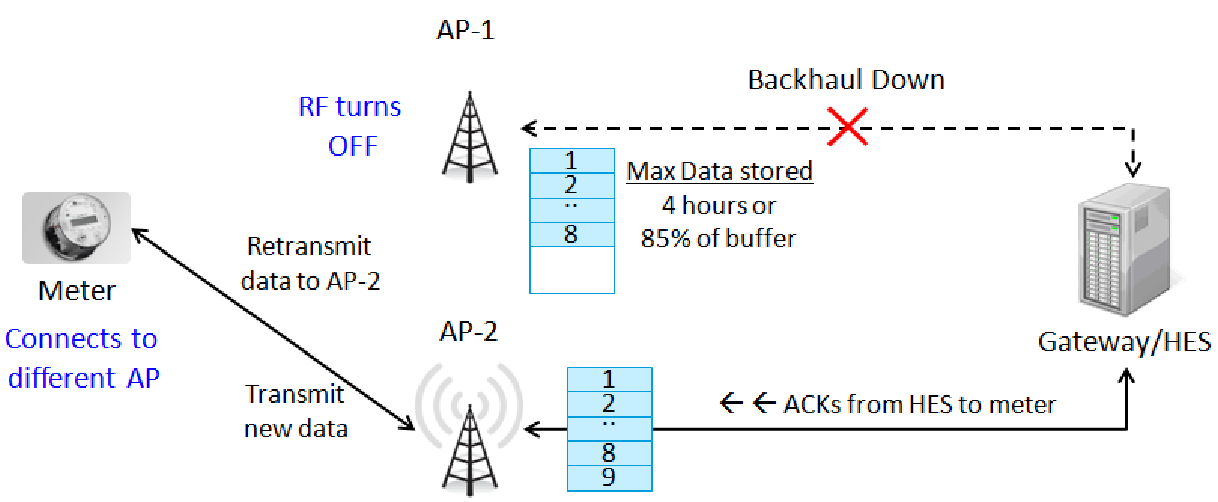


Figure 20. Meter reconnects to a different AP

When the AP turns off its RF, the meter would scan for other APs in its vicinity and tries to connect to a new AP. If the meter successfully connects to a new AP, the eMCM would flush out uStream's transmit buffer by retransmitting all messages (the messages have not yet been acknowledged by HES). Thereafter, normal mode of operation should be restored.

If the meter is unsuccessful in connecting to a new AP, then the scenario is similar to "7.2.1 Meter-to-Access Point Link Loss."

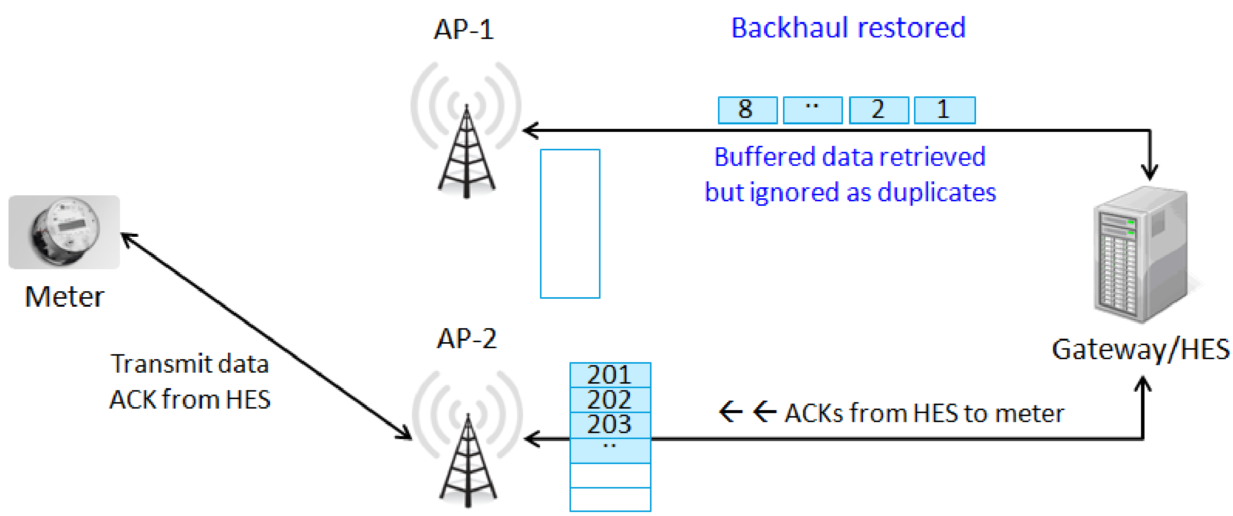


Figure 21. Backhaul between AP and Gateway is restored

When the backhaul between old AP and Gateway is restored, the old AP would flush the messages in its buffers to HES. The HES would ignore this data as duplicates if it has already received the same via retransmissions from new AP. The meter might rejoin the old AP if the signal strength of old AP is stronger than that of the new AP.

7.2.3 Appliance-to-Back Office Link Loss

Meter data is protected against communication link loss between Appliance (i.e. HES) and Back Office systems. Missing meter data can be retrieved from HES database, where it is stored, once the communication link is restored.

Ninety (90) days of meter data is stored in HES database on the appliance. Two kinds of meter data is stored – meter readings (register, interval, and power quality) and meter events (current and logged). Meter data is stored as triplets of {CIM code, value, timestamp}. AMI system architecture uses push-messaging to deliver real-time data. All meter readings and events are pushed as CIM messages to back office systems from the HES. They can also be exported in CMEP or CSV files.

When the communication link between Appliance and Back Office is down, messages to back office are queued at HES while the link is restored. This buffer is only thousand messages deep (configurable to five thousand messages). If the link is not restored before the buffer gets full, then HES starts dropping messages for transmission to back office.

In such cases, missing meter data can be restored the back office via:

- REST interface
- CMEP or CSV export

Date and time range for meter data to be fetch from HES has to be specified.

7.3 Power Outage

7.3.1 Meter Power Outage

When electrical power outage occurs at the meter, the meter does not record any data. eMCM would send the "Last Gasp" outage report to back office systems and shut itself off too. When power is restored, the meter begins recording usage. eMCM would resume its normal operation, including scheduled reading and transmitting of meter data.

The meter populates interval data tables with zeroes for the intervals during which power outage occurs. Most recent 16 such intervals are reported by the eMCM after power restoration. If the outage last longer than 16 intervals, then back office systems will have to issue on-demand reads to fetch the missing intervals.

7.3.2 Access Point Power Outage

Access Points are equipped with battery power to withstand short power outages. The duration of battery power depends on the battery deployed by the utility company. Power outage has no effect on the AMI system operation over the duration of power availability from battery.

If the battery runs out of power before power restoration, the AP will shut itself off. This results in communication link loss between meter and the Gateway/HES. The operation of the meter and the AMI system in such a situation will be similar to "7.2.2 Access Point Backhaul Outage" and "7.2.1 Meter-to-Access Point Link Loss" scenarios.

7.3.3 Appliance Power Outage

Different utility companies could deploy their Appliances/servers differently. Servers could be located in state-of-the-art data center. Or there could be two appliances, for redundancy purposes, that are located at two different locations. Or a utility might just deploy a single appliance. Power outages affect all the fore mentioned scenarios differently.

Data centers are usually built to withstand power outages. Hence, they are unlikely to be affected. Utilities deploying dual (redundant) appliances, at different locations, are also reasonably protected against power outages. Some manual intervention is required to reconfigure the system so that the APs send their data to the backup appliance in the event of power outage to the primary appliance. But order and normalcy can be restored easily.

If power outage occurs at the appliance for utility companies that have only one appliance, then the behavior of AMI system is similar to "7.2.3 Appliance-to-Back Office Link Loss." Once power for Appliance is reinstated, normal operation of AMI system is restored.

7.4 Summary

Table 20. Data Retention by Outages

AMI Entity	Power Outage	Communication Outage
Meter	Meter readings not executed	Up to 16 meter reads possible QoS reservations
Billing data	Cannot be retrieved[1]	No data loss for 2 - 5 days[2]
Interval data	16 reads auto reported after restoration Missing data retrievable with on-demand read requests	No missing data for 1 - 2 days[3] outages Missing data retrievable with on-demand read requests
Power quality events	Events since last report transmitted after power restoration	Events since last report transmitted in 1 or more reports after link restoration
Access Point	No meter data stored Meters (with power) connect to other APs	No meter data stored AP turns itself OFF after 4 hours Meters connect to other APs
HES/Appliance	All meter data stored for 90 days Can be retrieved by back office systems at any time	

[1]Billing data estimation required or Optional read after power restoration

[2]Assuming 24-hr reporting

[3]Assuming 15-min intervals and 1-hr reporting

8 End Device Control

8.1 Ping

Meter ping involves sending a ping command over the AMI network to the meter or group of meters of interest. The meter responds with an acknowledgement message if it receives the ping command. Typical round trip time is in the order of ten to twenty (14-20) seconds for a single meter. Ping can thus be used to do a quick health check on the status of meter's power and connectivity. Ping can be performed either from OTV or directly from a back office system integrated to the HES.

In the On-Ramp WirelessAMI system, ping to a group of meters consists of unicast messages to each meter in the group. As a result, the time to receive acknowledgements from all meters increases as the number of meters in a group increases. For example, it could take about five minutes to ping and receive acknowledgements from approximately 900 electric meters.

Active pinging of a meter or group of meters is used in AMR and many AMI systems to determine the extent of power outages. Mesh based AMI systems that have poor outage reporting rates have to resort exclusively on active pinging to understand the true extent of a power outage.

The On-Ramp Wireless AMI system has superior outage reporting and power restoration mechanism. Therefore, ping could have a smaller role in outage detection. Ping would however be helpful in the event of back-to-back power outages. Super-capacitors on eMCM might not charge sufficiently to enable the eMCM to report back-to-back power outages. In such cases, active pinging to a meter or group of meters can help identify the scale of power outage.

8.2 Demand Reset

Demand of the system is the maximum rate at which electrical energy is delivered. It is measured in kilowatts. Utilities configure smart meters to compute average demand over a short period, such as 15 minutes. The peak demand of the system is stored in the meter and it gets overwritten when demand exceeds the stored value. Demand is read and its value reset at the end of the billing cycle. Demand value is used by utilities in computing customer billing.

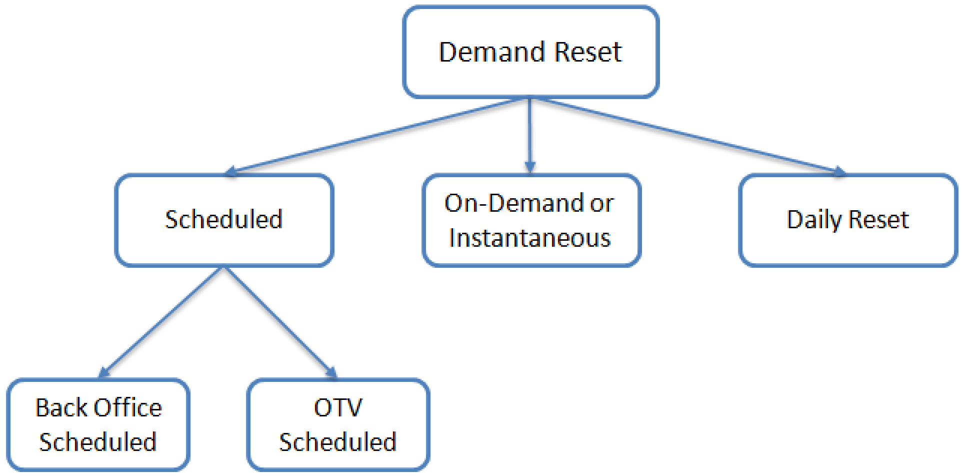


Figure 22. Demand Reset Types

Demand reset in GE meters can be:

- Performed either physically at the meter or remotely (over-the-air)
- Executed immediately or scheduled to execute at a later date and time
- Performed on a single meter or on a group of meters

8.2.1 Scheduled Demand Reset

It is possible to schedule eMCM to execute a demand reset at a future time and date. Scheduled demand reset command can be issued either from back office that is integrated with HES or from OTV. Typically, demand data is read by eMCM before it resets demand data on meter.

Optional parameters “start time” and “end time” can be specified in the demand reset command. Demand reset is executed by eMCM at the start time but no later than the end time. If end time is not included, then demand reset never expires. Start time allows users to schedule a demand reset in advance. End time allows the time out of demand reset in cases where OTA delays past start time or eMCM is not active at the time of reset.

- eMCM stores the demand reset command for future execution if the start time of the command is in future
- In the event on an eMCM reboot, after eMCM is reauthorized and reacquires time, eMCM checks for any pending demand resets and executes them if current time is in between start and end time. eMCM discards expired reset commands
- eMCM can store only one demand reset command. Thus, new reset command received prior to the execution of an old reset command, overwrites the old command
- By default, demand data is read before execution of scheduled demand reset. This can be configured in hes_config.properties file at HES. Same applies for coincident data. This provides flexibility to turn off reporting of large data that is not required

8.2.1.1 Back Office Scheduled

A back office system like CIS or MDMS that is integrated with HES via IEC-CIM can perform remote demand reset. The process for executing the reset is described above.

To execute demand reset over a group of meters, the back office has to issue individual reset commands for each meter. The back office could create a meter group and run a script issuing demand resets to each meter in the group. These resets are transmitted as CIM messages to HES, which unicasts the demand reset command to each meter.

Only one demand reset can be scheduled at eMCM in advance. New demand reset commands overwrite any unexecuted resets. Therefore, it is the responsibility of the back office system to manage issuance of demand resets appropriately.

NOTE: Back office systems integrated with HES via MultiSpeak cannot perform remote demand reset in AMI1.2 system.

8.2.1.2 OTV Scheduled

Demand reset can be scheduled from OTV for a meter or group of meters. The following has to be done to perform demand reset for group of meters:

- Create a meter group in OTV for meters of interest (if it already does not exist). This meter group would most likely contain all meters aligned on a billing cycle
- Create a managed “Demand Reset” task specifying the start time and the reset calendar schedule. Demand resets are executed at schedule time and date

HES unicasts the demand reset command to each meter of the meter group when the OTV scheduled demand reset command is executed.

8.2.2 On-Demand Demand Reset

On-demand or instantaneous demand reset is execution of demand reset by eMCM as soon as it receives the command. Instantaneous demand reset command can be issued either from back office or from OTV. The procedure to do so from

- Back office system is similar to that described for back office scheduled demand reset. Start time should not be included. If start time is not included, then eMCM executes demand reset at the time of request
- OTV is to send a “Request Meter Demand Reset” command to the meter or meter group of interest

An on-demand or instantaneous demand reset request performs only demand reset. It does not fetch the demand value. It is up to the user to explicitly fetch the demand value, if required, prior to reset via an on-demand billing read request.

NOTE: Only back office systems integrated with HES via IEC-CIM can perform on-demand demand reset in AMI1.2 system.

8.2.3 Confirmations

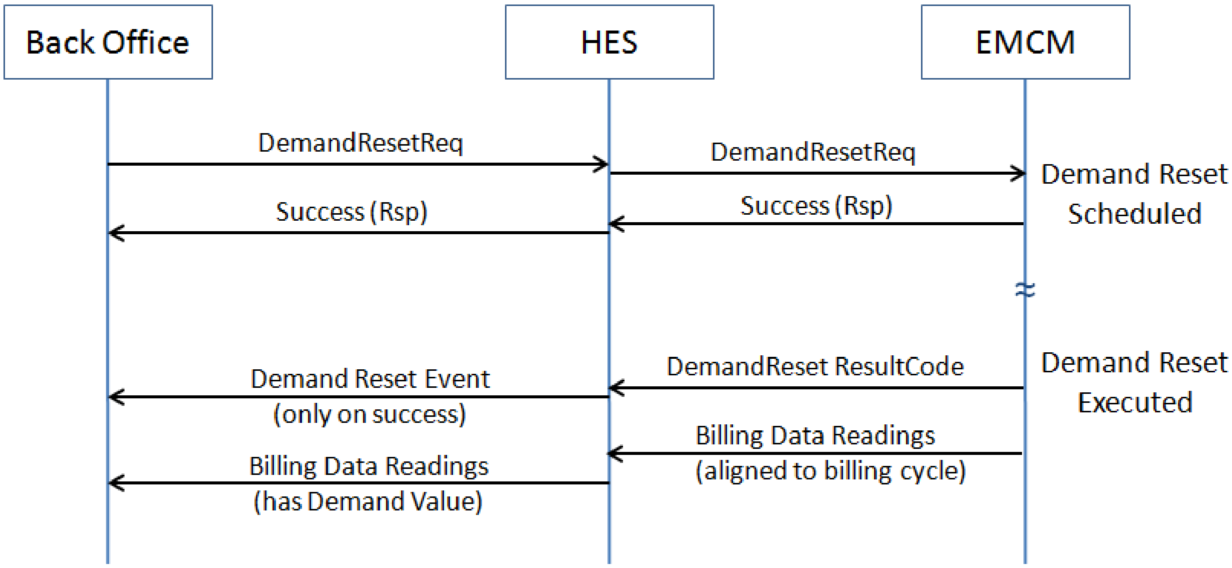


Figure 23. Demand Reset Request-Responses

Two messages are sent from the eMCM in response to a demand reset command issued from back office or OTV.

- The first message is an acknowledgement message that confirms the success/failure in scheduling of demand reset command at eMCM. This message originates from the eMCM. The latency associated with this message is in the order of 40 - 50 seconds.
- The second message is sent when the demand reset is actually executed by eMCM. This message originates at eMCM and and it contains the following information:
  - Event type = Demand Reset
  - Time stamp
  - Number of demand resets executed prior to current demand reset execution
- Demand value before reset is sent in the billing cycle aligned register/billing data read message. The latency of receiving this message is up to 5 hours.
- All the above messages are forwarded by HES to its destination, either back office systems or OTV, as CIM messages

Demand reset event is sent to HES or back office only if the eMCM successfully executes the reset command. The number of demand resets executed, including the most recent reset, is contained in the register/billing data reading message, which is configured to be sent either daily and/or aligned with billing cycle.

8.2.4 Daily Demand Reset

Demand reset can be performed every day at a time aligned with daily register/billing data reading. It is executed after the daily billing data read, typically at midnight local time. A utility company could perform daily demand readings and resets, and identify the peak demand value over a billing cycle at the back office.

Thus, a utility company could protect itself from missing demand reset execution at the end of a billing cycle. For example, if a demand reset is not executed due to power outage at scheduled time and date, it will only happen at the end of next billing cycle. The utility company might be unable to bill its customers for demand data.

Daily demand reset has to be scheduled at HES in data_orders.properties file. It gets installed at eMCM during boot time.

8.2.5 Outage Scenarios

Power Outage

A power outage could occur at the time of a scheduled demand reset. When power is restored, the eMCM reauthorizes itself and reacquires network time. After that eMCM checks for any pending demand resets and their validity, i.e., if the current time is in between start and end time. The eMCM executes all valid pending demand resets and it discards expired reset commands.

No notifications are sent to HES if eMCM discards expired reset commands. Therefore, the back office has to re-issue demand reset command, if required, in power outage scenarios.

Network Outage

If a meter happens to have network connectivity issues, then a demand reset execution event might not be transmitted to back office in time. In such scenarios, the user might execute on-demand demand reset, which could result in two executions of demand reset command. To avoid such scenarios, the user could use the “number of demand resets executed” count to identify if a demand reset needs to be executed again. This counter gets incremented after each reset execution. This counter can be obtained via on-demand billing data reads or scheduled billing data reads.

It is highly advisable to not execute on-demand demand reset function until there is surety that scheduled demand reset did not execute.

8.3 Relays

Relays and load control points in smart meters enable connection and disconnection of loads and consumers. Their primary application is for demand side management. This includes reduction of peak demand, energy saving through individual load switching, accurate billing of consumers and disconnection of consumers who have defaulted on their electric bills. No soft switches are required for relay functionality in GE meters. The meters either come installed with relays or don’t.

Table 21. Relays and Load Control Points in GE meters

	I-210+	I-210+c	SGM3000
Physical Relays			
Main relay	1	1	1
Auxiliary relay	0	0	2
Load Control Points[1]			
ECP, DLP, PPM, Lockout	NA	✓	NA
PPM, ESC, UFLS, SC, PU, SA, Top cover removal, Terminal cover removal, Excessive current, Disable override	NA	NA	✓
Configuration & Management			
Connect/disconnect relays	From back office systems & OTV IEC-CIM control commands, MultiSpeak		
Enable/disable load control points	NA	From back office systems & OTV IEC-CIM control commands	Meter program update[2]
Configuration of load control (for event triggered connect/disconnect)	NA	Meter program update	
Event Reporting			
Connect/disconnect of relays[3]	IEC-CIM events, MultiSpeak		
Load control points enabled/disabled	NA	IEC-CIM events	

Note: kV2c meters do not have any relays

[1] Refer meter specific documentation for description of load control points

[2] SGM meters do not allow OTA enable/disable of load control points

[3] Two events returned:

(1) success/failure in executing command
(2) success/failure in change of relay or load control point state

I-210+c Meters

NBR_OF_CONTROL_POINTS in ST111 table of ANSI C12.19 compliant meters denotes number of supported relays. I-210+c meters have maximum of one main relay and five (5) NBR_OF_CONTROL_POINTS. eMCM logically maps these load control points in I-210+c meters as follows: Main (0), ECP (1), DLP (2), PPM (3), and LOCKOUT (4). eMCM periodically monitors only the main relay for state changes.

SGM3000 Meters

SGM3000 meters can have a maximum of three relays, which corresponds to NBR_OF_CONTROL_POINTS. First one corresponds to main relay and the other two corresponds to auxiliary relays. AMI system polls for state changes to all these relays and reports the changes.

8.3.1 Remote Connect & Disconnect

Over-the-air relay connect and disconnect (RC-DC) of relays, main and auxiliary, is possible from a back office system that is integrated with AMI system as well as from OTV.

- eMCM receives the RC-DC commands from back office and OTV
- eMCM executes RC-DC command immediately after receiving it
- RC-DC command specify the relay number (0=main, 1=auxiliary-1, 2= auxiliary-2)
- RC-DC commands have a default "time-to-live" setting of 1 hour (explained below)
- RC-DC does not apply to kV2c meters as they do not contain relays
- Two part event responses for RC-DC commands (explained below)
- IEC-CIM (control) and MultiSpeak interfaces are supported by the AMI system for RC-DC

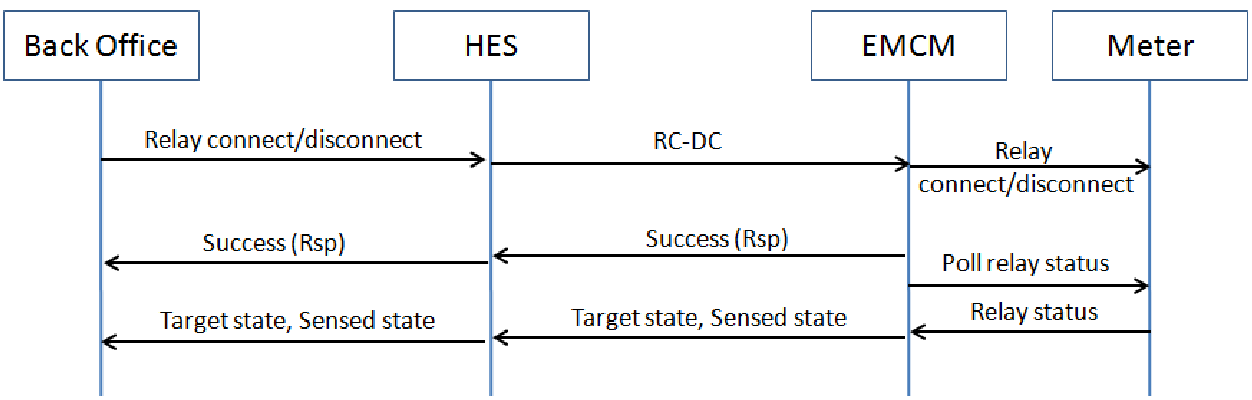


Figure 24. Remote connect/disconnect of relays

Time-to-live: RC-DC commands have a default setting of one hour for "time-to-live." That is, eMCM discards the command if it does not execute the command within one hour since HES received the command from back office system or OTV. eMCM might not be able to execute RC-DC command within an hour of issue for reasons such as delays in reception due to network connectivity, power outage, etc. Time-to-live setting is configurable in "hes_config.properties" file.

Responses: eMCM executes a RC-DC command immediately upon its receipt. The eMCM then sends a response back to back office system/OTV to indicate if it was successful or not in executing the command. Success response from eMCM only means that eMCM was able to send the command to the meter. A RC-DC command execution could still fail at meter. The latency of this eMCM response, from the time the RC-DC command was issued, is in the order of forty (40) seconds.

A second event response is sent approximately twenty (20) seconds later. This event carries two state fields – “target state” of the relay and “sensed state” of the relay. Target state is the same as the RC-DC command. Sensed state is the state of the relay after the execution of RC-DC command. A meter has failed to execute RC-DC command if the target state does not match the sensed state.

Responses to RC-DC commands can be sent as IEC-CIM or MultiSpeak messages. The response with actual relay states can be sent in current AMI system as only IEC-CIM messages.

8.3.2 Activation of Load Control Points

Among GE smart meters, I-210+c and SGM3000 meters have load control points. OTA enabling and disabling of load control points from back office system can be accomplished using IEC-CIM interface only.

Table 22. Enabling & disabling of control points

Control Point		Meter	Auxiliary Relay	Control Command (CIM code)	
Abbrev.	Name			Enable	Disable
ECP	Emergency conservation period	I-210+c	1	3.31.6.42.1	3.31.6.68.1
DLP	Demand limiting period	I-210+c	2	3.31.6.42.2	3.31.6.68.2
PPM	Prepayment mode	I-210+c	3	3.31.6.42.3	3.31.6.68.3
--	Lockout	I-210+c	4	3.31.6.42.4	3.31.6.68.4
--	Disable override	SGM3k	--	Automatic (manual connect / disconnect driven)	3.31.6.237.0

I-210+c meters: The AMI system maps load control points of I-210+c meters to “auxiliary relays” – ECP (1), DLP (2), PPM (3), and LOCKOUT (4). Enabling and disabling from back office systems integrated with the AMI system is similar to issuing a RC-DC command. The difference is that the “relay number” in the command would be a value 1-4 instead of 0, which is for the main relay. Only IEC-CIM control command interfaces are supported for enabling and disabling of load control points.

SGM3000 meters: While load control points can be enabled and disabled remotely for I-210+c meters, it is not possible to do the same for SGM meters. Meter program update has to be performed for enabling or disabling of load control points in SGM meters. It is however, possible to remotely disable “override” in SGM meters. Please refer section 8.3.2.2 for details on this. SGM3000 meters have load control points such as PPM, ESC, UFLS, SC, PU, etc. (please refer GE meter documentation for description of these load control points).

8.3.2.1 Relay connect/disconnect and Load Control in I-210+c

Manual or OTA connect/disconnect of relays causes disabling of load control points in I-210+c meters. An event is generated to back office and this event lists the control point(s) disabled. The control points have to be explicitly re-enabled after a remote connect/disconnect of relay operation to restore the previous state of the control point(s). Back office can remotely restore the control points using a CIM command. It is also possible to do the same operation from OTV.

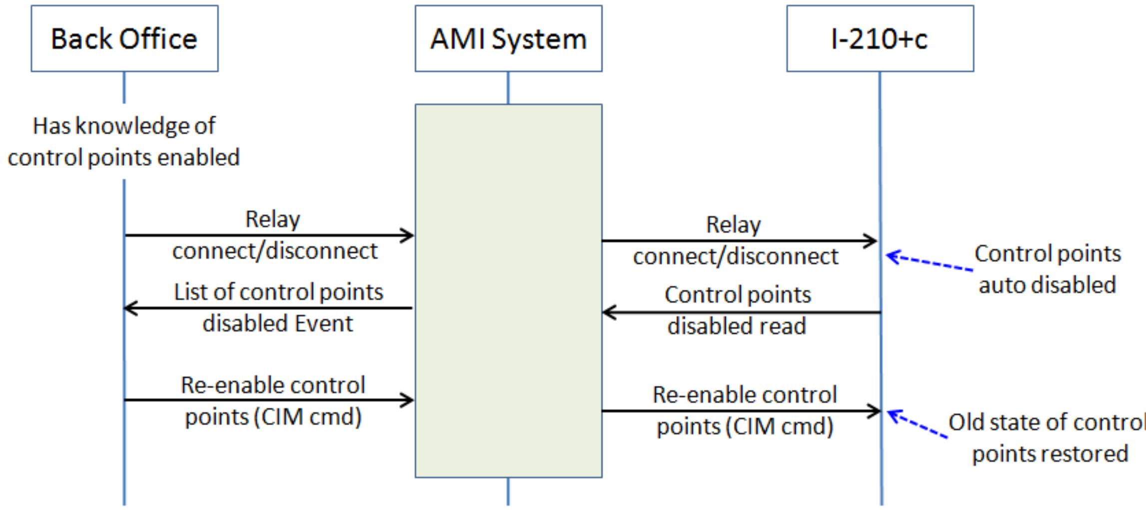


Figure 25. Control points auto disabled in I-210+c when manual RC-DC performed

ECP, DLP and LOCKOUT are mutually exclusive load control points. Only one of them can be enabled along with PPM.

If LOCKOUT is enabled, OTA or via meter program, then OTA relay disconnect does not work. The only way for relay disconnect to work is to first disable LOCKOUT. A use case for this application is "patients on life support equipment." Once LOCKOUT is enabled in smart meters of homes of life support patients, then service disconnect cannot be performed. Thus, the patients are protected under all circumstances.

8.3.2.2 Relay connect/disconnect and Load Control in SGM3000 meters

Manual or OTA connect/disconnect of relays in SGM3000 family of meters results in load control points "override enabled" and associated event notification. Prior state of load control points can easily be restored by issuing an "override disable" command from either the back office systems or the OTV. Unlike I-210+c meters, there is no need to have knowledge of specific control points and their explicit re-enablement in SGM meters.

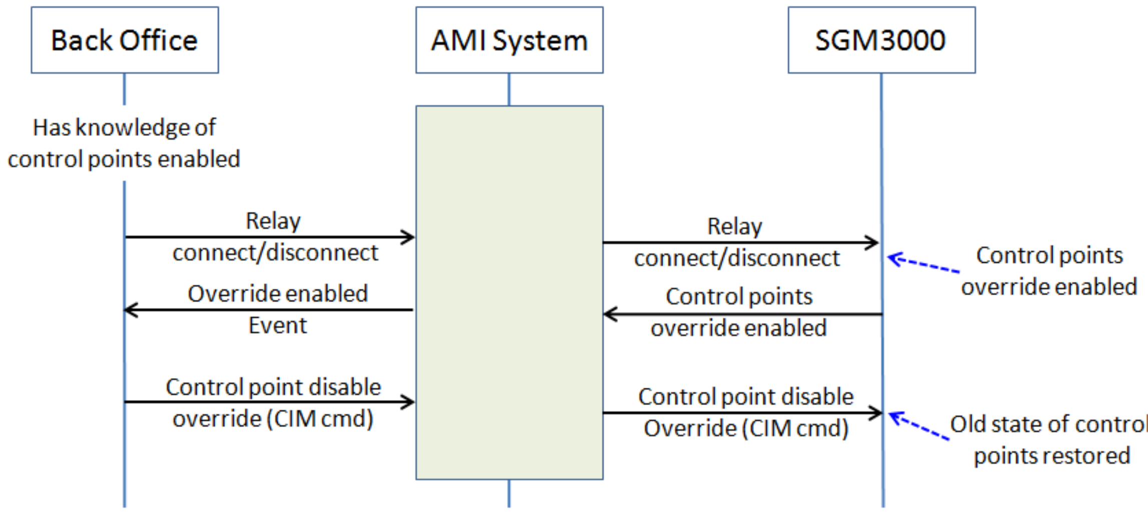


Figure 26. Disable override for control points in SGM3000 meters

8.3.3 Event Driven Connect & Disconnect

When certain thresholds are crossed, the relays in GE's smart meters automatically connect or disconnect. For example, the relay could get disconnected due to ECP (Emergency Conservation Period) being effective. These thresholds that determine the behavior of relays and load control points are configurable in the meter program via GE's MeterMate™ tool.

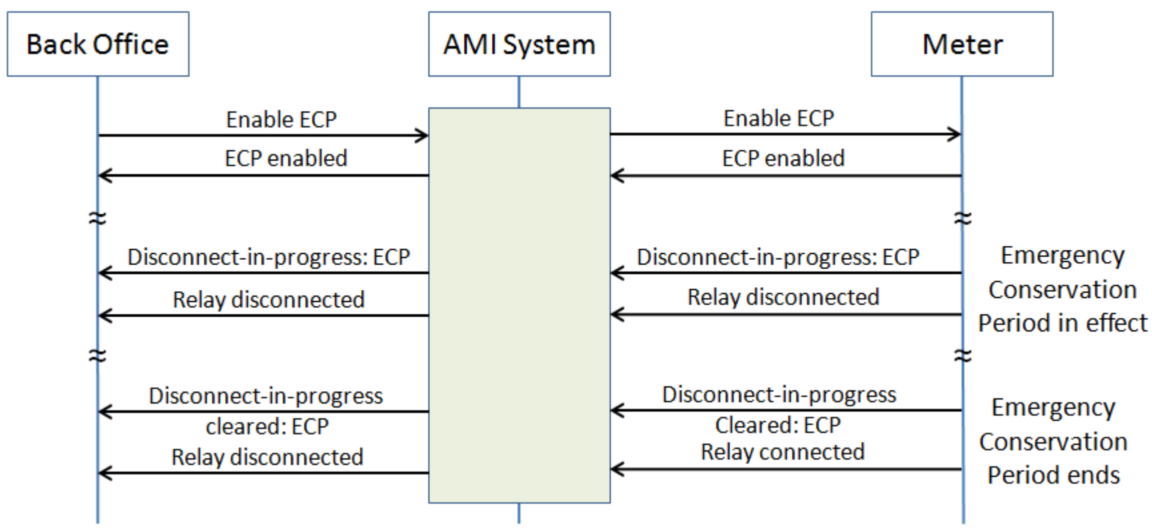


Figure 27. Illustration of event driven connect/disconnect

Event triggered connects and disconnects are accompanied by two event notifications.

- First event notifies the state change of the relay
- Second event provides the cause or reason behind the relay state change

For example, in the figure shown above, emergency conservation period (ECP) is enabled in the smart meter. When ECP goes into effect, the relay is automatically disconnected. Two events are generated. The first one informs that a load disconnect is in progress and the reason for it is ECP. The second event informs of the relay disconnect. When the ECP ends, the relay reconnects. Again, two events are generated to back office systems – first one informs the load disconnect is cleared (ECP) and the second one informs the relay was reconnected. Event notifications for all meter relay state changes are sent by eMCM to the back office system.

Interface for connect/disconnect event notifications, and reason for relay state notifications, is via IEC-CIM interface. AMI system's MultiSpeak interface supports only connect/disconnect event notifications.

Monitoring of State Changes

eMCM monitors every five minutes for relays state changes in the smart meter. Basic state of a relay in ANSI C12.19 compliant meters is recorded in Standard Table ST112 – "Load Control Status Table." Basic state of relay may be further qualified by manufacturer-defined status indicators.

Similarly, eMCM also monitors every five minutes for state changes of load control points. State changes of load control manifest as status indicators in meter flags. These are reported in meter status table ST3.

8.3.4 Events Associated with Control Points

When control points in smart meters are enabled/disabled from back office or their "disconnect" is activated or deactivated, events are reported AMI system to back office. Details about these events are listed below.

Table 23. CIM codes of events reported by state changes of control points

Control Point		Meter Support	Control Point		Control Point Disconnect	
Abbrev	Name		Enabled	Disabled	Activated	Deactivated
PPM	Prepayment mode	I-210+c, SGM3k	3.15.16.238.0	3.15.16.237.0	3.15.17.68.0	3.15.17.42.0
ECP	Emergency conservation period	I-210+c	3.15.16.238.1	3.15.16.237.1	3.15.17.68.1	3.15.17.42.1
DLP	Demand limiting period	I-210+c	3.15.16.60	3.15.16.59	3.15.17.68.2	3.15.17.42.2
ESC	Energy supply capacity	SGM3k	3.15.16.238.3	3.15.16.237.3	3.15.17.68.3	3.15.17.42.3
UFLS	Under frequency load shedding	SGM3k	Not reported	Not reported	3.15.17.68.4	3.15.17.42.4
SC	Supply capacity	SGM3k	3.15.16.238.5	3.15.16.237.5	3.15.17.68.5	3.15.17.42.5
PU	Power usage	SGM3k	3.15.16.238.6	3.15.16.237.6	3.15.17.68.6	3.15.17.42.6
	Excessive current	SGM3k	Not reported	Not reported	3.15.17.68.7	3.15.17.42.7
SA	Safety alert	SGM3k	NA		3.15.17.68.10	3.15.17.42.10
	Top cover removal	SGM3k	NA		3.15.17.68.20	3.15.17.42.20

Control Point		Meter Support	Control Point		Control Point Disconnect	
Abbrev	**Name**		**Enabled**	**Disabled**	**Activated**	**Deactivated**
	Terminal cover removal	SGM3k	NA		3.15.17.68.21	3.15.17.42.21
	Lockout	I-210+c	3.31.16.66	3.31.16.76	NA	NA
	Override	SGM3k	3.15.17.66	3.15.17.76	NA	NA

8.3.5 Outage Scenarios

Relay connect/disconnect commands sent from HES that do not arrive at the meter within one hour (default time-to-live value) of dispatch from HES due to network outage or connectivity issues will be discarded by the meter. If a RC-DC command is received but not executed before a power outage at the meter, the meter would check the command's time stamp and time-to-live to determine if the command has to be executed when power to the meter is restored.

When a relay connect/disconnect command is not executed by eMCM because the time-to-live has expired, eMCM sends a response indicating that the RC-DC request timed out. If HES is unable to send within an hour a RC-DC command to the meter due to network connectivity issues at the meter, then HES would send an IEC-CIM response to the back office indicating command failure.

In the event of network connectivity issues, relay state change event notifications from the meter that have already been scheduled for transmission will be transmitted to the back office systems when the network is available. However, not all relay state changes during a network outage may be notified to back office system. This depends on the number of messages already queued for transmission.

8.4 Back Office Triggered Pricing Changes

There are two ways for a utility company to collect customer's electricity usage for billing. Both approaches require a smart meter to collect customer's electricity usage data, albeit in different ways.

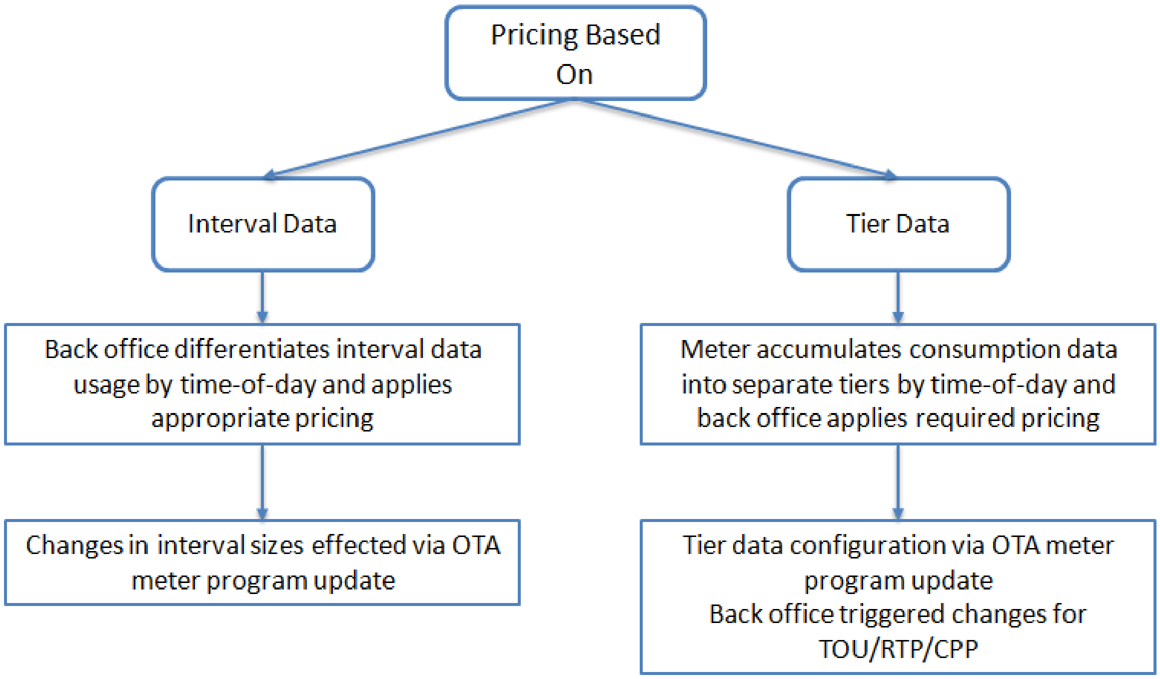


Figure 28. Meter data accumulation for pricing

- **Interval Data:** In the first approach, the utility company relies on interval data collected and reported by a smart meter for billing. The AMI system does not have to do anything additional if the utility is billing on interval data usage
  - Changes to interval sizes have to be via meter program update
  - Changes to reporting frequency have to be made in data_orders.properties
- **Tier Data:** In the second approach, the utility relies on smart meter's capability to collect electricity usage data in different tiers, as per conditions specified by the utility. The AMI system facilitates the configuration of the meter to collect electricity consumption into different tiers

PS: Utility companies could also implement billing scheme that employs some combination of the above two methods.

A utility company has to inform its customers of the pricing scheme in place before the utility can bill them in either of the two above mentioned ways. E.g., electric customers have to be notified in advance of real-time pricing being in effect for next day between 12pm and 5pm. Back office manages all signaling and communication regarding pricing to its electricity users in both the scenarios.

8.4.1 Tiers in GE Smart Meter

GE smart meters can operate in different modes – demand mode, demand/LP mode, TOU mode, etc. Meters operating in TOU (Time-of-Use) mode have the ability to record electricity usage in multiple tiers based on tier switches programmed in the meter.

GE smart meters in demand or demand/LP mode do not have tier switches. They however have the ability to record data in a separate tier based on an explicit command. This separate tier is called “Tier A” (also known as “RTP tier”).

The Utility can define in meter program the tier switches into which electricity usage has to be accumulated.

Table 24. Number of tiers by meter type and meter mode

Meter Type	Meter Mode	Number of Tiers
I-210+	Energy only	None
I-210+c	Demand, Demand/LP	1 (Tier A or RTP tier)
I-210+c	TOU	4
kV2c	Demand, Demand/LP	1 (Tier A or RTP tier)
kV2c	TOU	4
SGM3000	TOU	10

8.4.2 Time of Use (TOU) Pricing

In TOU pricing, electricity prices are set for broad blocks of hours on in advance or forward basis, typically not changing more often than twice a year. Prices paid for energy consumed during these periods are pre-established and known to consumers in advance.

Season	Day Type	TOU Period	Start Time	End Time	Segment Hours
Winter	Weekday	On Peak	07:00	11:00	4
			17:00	19:00	2
		Mid Peak	11:00	17:00	6
		Off Peak	00:00	07:00	7
			19:00	24:00	5
	Weekend and Holidays	Off Peak	00:00	24:00	24
Summer	Weekday	On Peak	11:00	17:00	6
		Mid Peak	07:00	11:00	4
			17:00	19:00	2
		Off Peak	00:00	07:00	7
			19:00	24:00	5
	Weekend and Holidays	Off Peak	00:00	24:00	24

Figure 29. Sample season change/TOU map

A season change/TOU map, such as the one shown above, is configured in a meter program, which is programmed into the meter. The TOU map can be updated via over-the-air partial meter program update. TOU periods like on-peak, mid-peak, and off-peak are mapped to different tiers of the meter. This is specified in calendar table ST54 of the meter. Electricity consumption is then accumulated in the different tiers as specified in the TOU map.

8.4.2.1 Season Change

A season change affects the timing of accumulation of data into different tiers. It also affects price change. E.g., when season changes from winter to summer, electricity usage accumulation for 7:00 to 11:00 hours switches from on-peak tier to mid peak tier (in the above example).

Begin and end dates of each season is specified in meter program. This schedule of seasons can be updated via meter program update. Seasons are not known in advance in some countries as the government decides the dates on a yearly basis. In such situations, changing seasons requires yearly OTA meter program updates.

NOTE: Season change is applicable only when the meter is in TOU mode.

8.4.2.2 Back Office Triggered Season Change

Performing season change function from back office or OTV is an alternative to meter program update. This approach provides tremendous flexibility as the season change can be performed pretty much when required. It is also simple, for it involves simply sending a downlink "Season Change" request instead of performing a partial or full meter program update.

The Downlink "SeasonChangeReq" message is sent down to the meter from either back office (IEC-CIM interface) or OTV. The request takes the following:

- Parameter (values can be 0 to 3) indicating up to four different seasons
- Start time (optional) – Time when season change command is to be effective
- End time (optional) – Time when season change command ceases to be effective

Start time allows user to schedule the command in advance. End time allows the user to time out the command in cases where OTA delivery delays are past start time or eMCM is not yet active (booted or unauthorized). In addition, end time facilitates an additional purpose: it allows the user to bring the season state to same state as before the start time.

If start time is not included, then eMCM executes the command at the time of the request. If end time is not included, then request never expires and meter season state is altered until an explicit command is received to change it back. If end time is included, then eMCM stores the current season state in its persistent memory and reverts back to the stored season state after expiry of end time.

NOTE: If a new season change request is received prior to the execution of old request, then previous request is overwritten. The eMCM stores only a single season change request.

8.4.3 Real Time Pricing (RTP)

When utility company employs RTP, electricity prices may change as often as hourly. Price signal is provided to the user on an advanced or forward basis, reflecting the utility's cost of generating and/or purchasing electricity at the wholesale level.

Table 25. RTP and CPP in GE Meters

Meter Type	Meter Mode	RTP	CPP
I-210+c, kV2c	Demand, Demand/LP	Tier A (RTP tier)	-
I-210+c, kV2c	TOU	Configured tier1	-
SGM3000	None	-	Configured tier1

[1]Configured in meter program via MeterMate™

RTP applies to GE's I-210+c and kV2c meters. A meter starts accumulating electricity consumption in specific tiers for the duration of RTP. The utility company can apply the real-time pricing to the meter data accumulated in the specific tiers.

- If RTP is activated when the meter is in Demand or Demand/LP mode, the meter starts accumulating electricity consumption in Tier A (also known as RTP tier)
- If RTP is activated when the meter is in TOU mode, then meter accumulates consumption in the specific tier that is configured in the meter program
- When RTP is deactivated, the meter stops accumulating consumption in the special tiers

Similar to season change, performing RTP function from back office or OTV is simple and it adds tremendous flexibility. A downlink "RTP Change" request is sent down to the meter from either back office (IEC-CIM interface) or OTV. The request takes the following:

- Parameter indicating if RTP is in effect or not (enable/disable)
- Start time (optional) – Time when RTP is to be effective
- End time (optional) – Time when RTP ceases to be effective

Start time allows user to schedule the command in advance. End time allows the user to time out the command in cases where OTA delivery delays are past start time or eMCM is not yet active (booted or unauthorized). In addition, end time facilitates an additional purpose: it allows the user to bring the RTP state to same state as before the start time.

If start time is not included, then eMCM executes the command at the time of the request. If end time is not included, then request never expires and meter RTP state is altered until an explicit command is received to change it back. If end time is included, then eMCM stores the current RTP state in its persistent memory and reverts back to the stored RTP state after expiry of end time.

NOTE: If a new RTP request is received prior to the execution of old request, then previous request is overwritten. eMCM stores only a single RTP request.

8.4.4 Critical Peak Pricing (CPP)

CPP is similar to RTP from an AMI perspective. CPP applies to GE SGM3000 meters. When CPP is activated, meter starts accumulating consumption in a pre-configured tier. When CPP is deactivated, the meter goes back to normal mode of operation where accumulation is governed by tier switches programmed in Calendar Table. The utility company can apply the critical peak pricing to the meter data accumulated in the pre-configured tier.

The same downlink "RTP Change" request message from back office or OTV is used by the AMI system for CPP as well. The behavior and handling of this message in CPP is same as for RTP, which is described in section 8.4.3 Real Time Pricing (RTP).

8.5 Time and Calendar

Not all GE meters have notion of time. Also, notion of time depends on their mode of operation. Table below categories meters that have a notion of time, based on mode of operation.

NOTE 1: I-210+c, kV2c, and SGM3k meters can be configured to report energy only

NOTE 2: SGM3000 meters do not have any modes

Table 26. Meters with notion of time based on their mode of operation

Meter Type	Energy Only	Demand Only	Demand/Load Profile	TOU
I-210+	X	n/a	n/a	n/a
I-210+c	n/a	X	✓	✓
kV2c	n/a	X	✓	✓
SGM3000	✓			

8.5.1 Time Zone Offset and Daylight Savings

For meters that have a notion of time, based on mode of operation, time zone offsets and daylight savings time switches are programmed into meter as part of meter program update. Changes to time zone offset and DST switches is possible via partial meter program update.

NOTE: DST switches are stored in the meter's calendar table.

eMCM maintains time and performs time-based actions for meters that do not have a notion of time. The eMCM is programmed with time zone offset and DST switches via data_orders.properties file. Changes to data_orders.properties file can be performed by AMI administrator at HES.

8.5.2 Local Time Synchronization

The meters work off of local time, which can be deducted from UTC time, time zone offsets and daylight savings time switches calendar schedule. The eMCM is the source of UTC time for the meter.

Every fifteen minutes (configurable parameter in AMI system), the eMCM obtains UTC time from the RPMA network, which uses GPS. At the same time, the eMCM fetches the local time and the DST information of the meter. The eMCM corrects meter's time if any of the following conditions hold true:

1. If (computed current local time – meter's current local time) > 15 seconds

   Computed local time is a function of:

   - UTC time (from network)

- DST (from meter)
- Time zone offsets (from meter)

2. If DST state of the meter (i.e., DST in effect or not) does not match DST setting in meter's calendar tables or data_orders.properties
3. If day-of-the-week computed from UTC time, DST and time zone offsets does not match the day-of-the-week in the meter

8.6 Over-The-Air Updates

8.6.1 Meter Program Update

Smart meter's "meter program" specifies how the meter is supposed to function –data it is supposed to record, interval lengths over which it is to record, time-of-use calendar and schedule, alerts that need to be reported, meter diagnostics, etc.

The task of generating a program for smart meters can be a complicated one. GE's MeterMate™ program creation software simplifies the process of creation and maintenance of meter programs. Once a meter program is created, the OTV is used to perform over-the-air update of the meter program to group of meters of interest. The entire process of program creation and OTA update requires manual intervention.

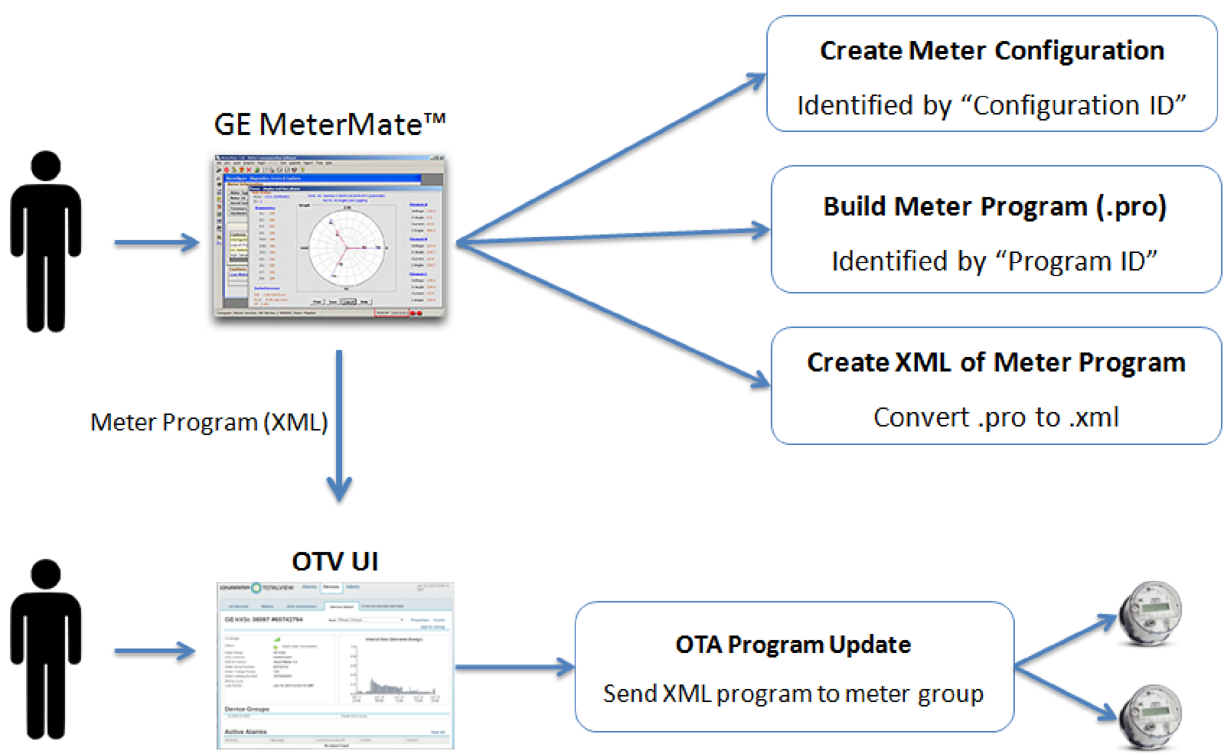


Figure 30. Meter program update process

GE's MeterMate™ tool is used for creation of meter program. The following steps have to be executed in MeterMate™ by the meter technician to create a meter program:

- Create a meter configuration ("Configuration ID")
  meter configuration identifies the measurement profiles to be used, the interval channels to record, the calendar configuration, etc
- "Build" a meter program ("Program ID")
  required inputs are meter configuration, meter model number, meter's firmware version, element volts, current class, etc.
- Convert to XML file
  convert the .pro meter program file to .xml file, which would be loaded into the meter

Once the meter program is created, the following steps have to be executed in OTV by meter technician:

- Create a multicast (MUD) meter group consisting of meters for OTA program update
- Select the XML meter program file to be sent to the meters
- Select the start and end time; and send the program file

NOTE 1: GE meters do not have a provision to enable the OTV/AMI system to read the current version of meter program deployed on the meter.

NOTE 2: OTV does not maintain track of meter programs installed on the different meters. OTV does not have a meter program "versioning system" either. It is the responsibility of utility company to track and maintain meter program versions and the meters in which they are deployed.

The AMI system will multicast the meter program over the RPMA network and the meters specified in the MUD group will download the meter program. eMCM in the meter performs the download and it will program the meter. Meter program update is achieved via a meter-specific sequence of writes and procedure executes. In addition, meter-specific constraints may require delay between operations, provisions for setting up time, and validation based on some meter data. Note that meter program is not just a set of configuration parameters to be updated but also has a complex set of dependencies whose consistency is important for proper functioning of the meter.

It takes about 15 to 20 minutes to perform OTA meter program update for a 3 to 5kB meter program.

NOTE: OTA meter program fails if there is a mismatch between the existing measurement profiles in the meter and the measurement profiles specified in the MeterMate™ tool.

8.6.2 Meter Firmware Update

AMI 1.2 does not support OTA update of Meter firmware.

8.6.3 eMCM Firmware Update

eMCM firmware upgrade is performed by EMS in the core communication system. The current firmware image is in the order of 50kB and it can take between 3.5 days to 2 weeks to update meters on the field with the firmware image. The firmware image is broadcast to all meters on the Broadcast Channel (BCH) of the RPMA network. It takes longer to update the meters on the edge of the network and might require more than one broadcast attempt.

- Once the meter receives the eMCM firmware image, the node requests permission from Gateway to switch over to the new network
- Once-a-day the node requests Gateway permission to switch over to new eMCM firmware image. The request is sent out in the first 36 minutes from UTC midnight time
- Gateway manages permissions for switch over based on a list that lists nodes/meters permitted to switch over

When a node receives the permission from Gateway, the eMCM auto reboots after firmware update. When the reboot happens, all information sitting in dynamic memory and flash memory is wiped out. Hence, there is potential for loss of meter data to occur:

- Messages sitting in uStream buffer awaiting transmission
- Register or billing data sitting in the eMCM flash memory

8.7 Device Reset

Device reset involves a reboot of the eMCM. There are two kinds of device reset – hard device reset and soft device reset.

8.7.1 Hard Reset

Reboot of the eMCM along with complete erasure of flash memory. Contents of RAM are erased. All data in flash memory is also erased, including register/billing data, data_orders.properties, meter program downloaded, eMCM firmware image downloaded, etc. Thus, there is a risk of loss of meter data with a hard reset.

The eMCM performs a self-check of RAM during the reboot process. As all flash memory contents are erased, the eMCM is de-authorized and it has to perform a re-authorization. It needs to re-fetch data_orders.properties file. Thus, the boot process post a hard reset is similar to a new meter joining the network.

Remote hard device reset can be performed from OTV only.

8.7.2 Soft Reset

In a soft reset, only the eMCM is rebooted. The contents of flash memory are not erased. The potential for loss of meter data is minimized to only contents of the uStream buffer in RAM, which could be easily retransmitted.

Remote soft device reset can be performed from OTV only.

8.8 Setting "data_orders.properties"

eMCM's reading and reporting of meter data – register/billing data, interval data, power quality data, general and power quality events, etc. – and meter time synchronization setting is configured in data_orders.properties file. This file resides at HES. Reading and reporting configurations for all types of meters installed in the AMI network is listed in this file. When a meter joins the AMI network after authentication, HES sends the relevant reporting configuration of data_orders.properties file, based on meter type, to eMCM. In the absence of reporting configuration for a meter type, the "default" setting in the file is used. A sample of data_orders.properties file is listed in Appendix section A.8.

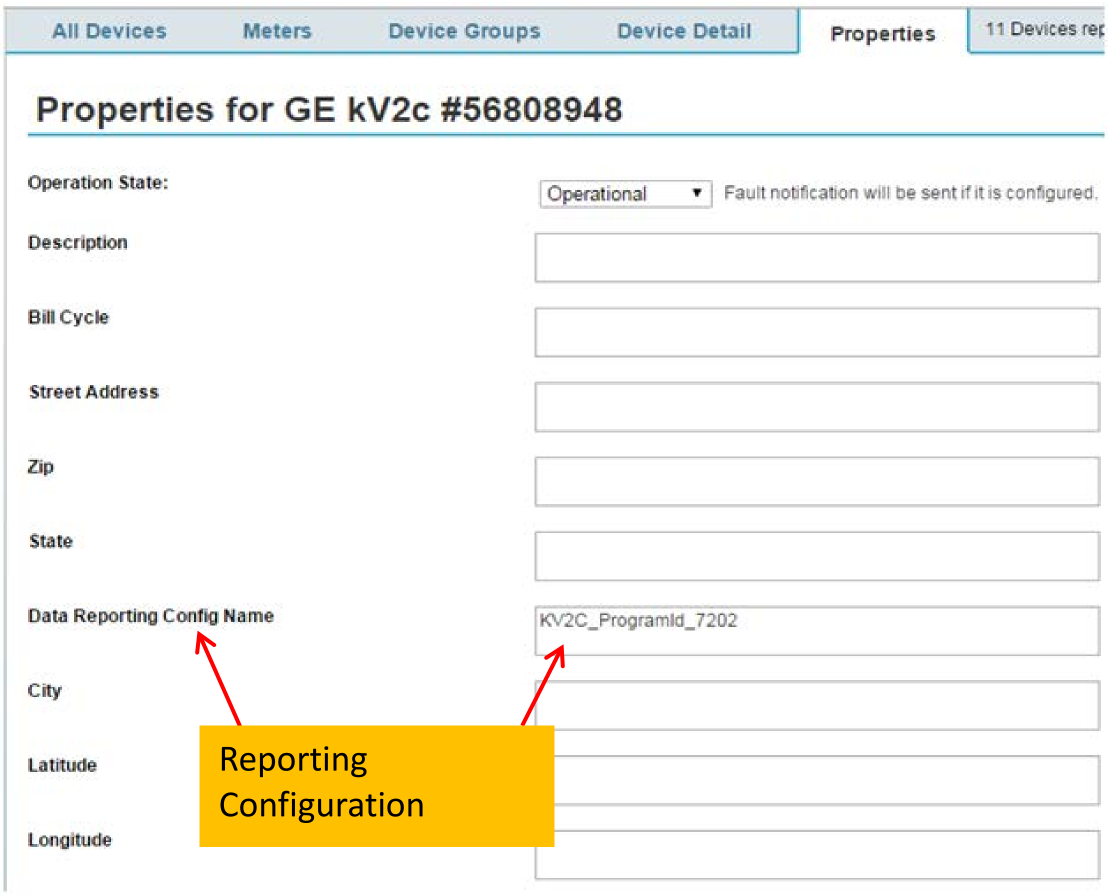


Figure 31. Meter's reporting configuration depicted in OTV

A meter's reporting configuration name can be viewed in OTV. Figure depicts the same. If the meter does not have a custom reporting configuration and is using the default configuration, then the "Data Reporting Config Name" field in OTV display will be blank and not populated.

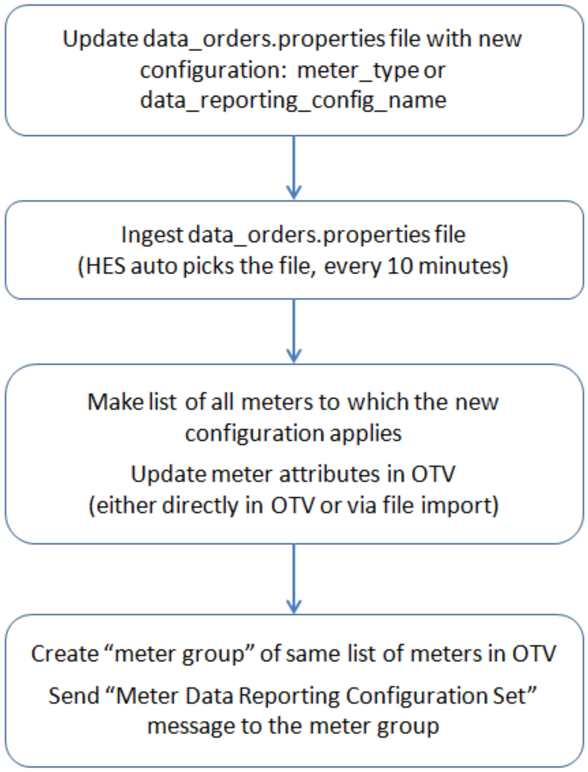


Figure 32. Procedure to add new configuration attribute in data_order.properties

Figure about lists the process to add a new configuration attribute to data_orders.properties, either for new meter type and/or for a new data reporting configuration. This is best illustrated with the help of an example. Suppose, the data_orders.properties contains a configuration attribute for kV2c meters operating in 60-min reading and reporting of interval data. If a set of kV2c meters are added to the AMI network to function as bellwether meters, i.e. 5-min reading and reporting of interval data, a new configuration attribute has to be added in data_orders.properties for these meters.

- The first step is to edit the existing data_orders.properties file and add a new configuration attribute, say “kV2c_bellwether”, and populate it appropriately. When the file is saved and closed, HES would ingest it.
- The next step is to identify the kV2c meters (bellwether) with the new configuration attribute. For this, a file has to be created listing the meters and their configuration attribute, which in this case is “kV2c_bellwether.” This file is imported into OTV.
- The final step is to push the configuration settings to kV2c bellwether meters. This involves creating a meter group in OTV for the same kV2c meters (bellwether) and sending the “Meter Data Reporting Configuration Set” message from OTV. HES sends the relevant configuration (5-min reading & reporting) to kV2c bellwether meters while preserving the old configuration (60-min reading & reporting) for other kV2c meters.

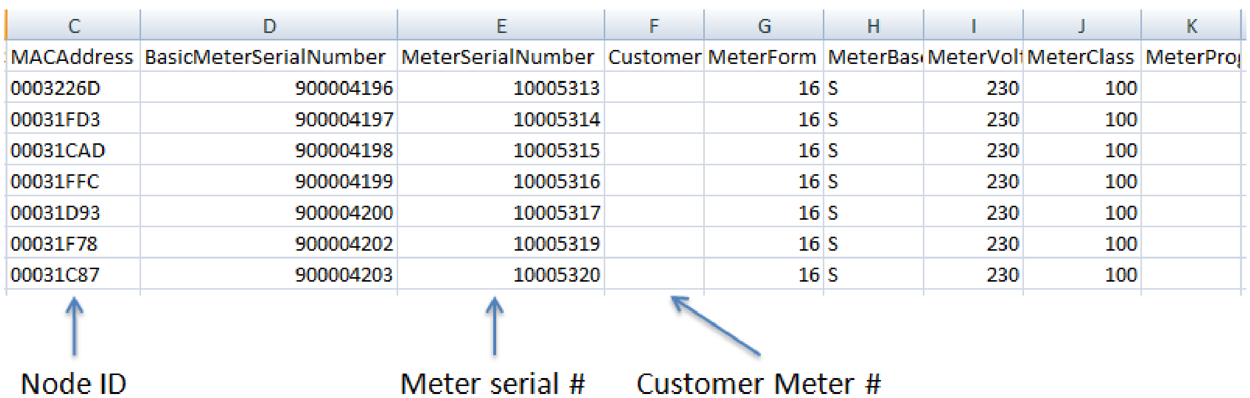
Please refer “OTV Supplement: Electric AMI” document for further details on data_orders.properties file.

9 Synchronization with Back Office

9.1 Marriage between Meter and eMCM

When smart meters are manufactured in the factory, they are identified by a unique meter serial number. GE's ANSI meters – I-210+/+n/+c and kV2c – are typically manufactured with AMI communication modules. GE's IEC meters – SGM3000 family – have an option to install the AMI communication modules at a later time, for example on the field. AMI communication modules (eMCM) are identified by "MACAddress", also known as "NodeID." The "marriage" or association between the MeterSerialNumber and MACAddress is made in a "Marriage File", which is either a CSV file or an XML file.

Marriage file is generated at GE's factory when meters are manufactured. This file can be edited at any point of time. The marriage file has to be imported in OTV's GUI. Some of the key fields in the marriage file are MeterSerialNumber, MACAddress, OldMeterSerialNumber, Old_MACAddress, and CustomerMeterNumber. The Marriage Import function ingests either a CSV file or an XML file. The GE factory header file is the only format supported when importing a CSV file.



C	D	E	F	G	H	I	J	K
MACAddress	BasicMeterSerialNumber	MeterSerialNumber	Customer	MeterForm	MeterBas	MeterVol	MeterClass	MeterPro
0003226D	900004196	10005313		16	S	230	100	
00031FD3	900004197	10005314		16	S	230	100	
00031CAD	900004198	10005315		16	S	230	100	
00031FFC	900004199	10005316		16	S	230	100	
00031D93	900004200	10005317		16	S	230	100	
00031F78	900004202	10005319		16	S	230	100	
00031C87	900004203	10005320		16	S	230	100	

Figure 33. Sample of a marriage file

The marriage file has to be imported in OTV before the meters are installed on the field. When the meters are installed, they would try to join the AMI network. HES/OTV depends on the marriage file for authentication of the meters before they can join the AMI network.

eMCM tags all meter data and events with MACAddress and reports it to HES/OTV. HES/OTV then re-stamps the data with either the CustomerMeterNumber or the MeterSerialNumber before sending or exporting meter data and events to back office systems. The CustomerMeterNumber can be populated with Utility Company's unique identifier for the meter or customer.

Refer "HES/OTV AMI Interface Guide" for more details on marriage file.

9.2 Divorce of Meter and eMCM

It might be required to break the association between meter and eMCM and replace the eMCM in the meter. This could be, for example, due to a defective eMCM. This effectively calls for divorce of meter and eMCM.

An extension of this scenario could involve the eMCM from one meter replaced with an eMCM from another meter. This involves divorce of eMCM from the meter, followed by marriage with a different meter.

Populating the Old_MACAddress and the OldMeterSerialNumber fields in the CSV marriage file breaks the existing linkage between the eMCM and the meter and reassigns it using the specified new MACAddress and MeterSerialNumber. This process severs access to the history of the divorced eMCM and meter in the OTV database, and it creates a new history in OTV database for the newly married eMCM and meter. The history of the divorced eMCM and meter remains in the OTV database but it is not accessible through the operator UI.

Refer “HES/OTV AMI Interface Guide” for more details on marriage file.

9.3 Customer Info Synchronization

OTV imports the device information properties listed in the table below. These properties can be imported any time after the marriage process. The properties can be imported from an XML file only. Refer “HES/OTV AMI Interface Guide” for details on device info import process.

It is also possible to update device info properties via REST interface. Refer “OTV REST API Guide” for details on how to update device information (metadata).

Table 27. Device info import properties

Property	Function
Bill Cycle	TWACS billing cycle identifier.
Description	Searchable description field.
Street Address	Display only.
City	Display only.
State	Display only.
Latitude	Map view latitude in decimal degrees.
Longitude	Map view longitude in decimal degrees.
Zip	Display only.

9.4 Meter Groups Synchronization

Meter groups for the AMI 1.2 system can be created in OTV UI only. Meter groups that exist in back office system cannot be synchronized in OTV.

Appendix A AMI 1.2

A.1 AMI 1.2 Feature Matrix

Table 28. Summary of AMI 1.2 Features

	Features	AMI1.2			
		I-210+	I-210+C	kV2c	SGM
Register & Interval Data Reads	Billing data read				
	Scheduled read of all data from all tiers (bulk, demand and coincident)	✓*	✓	✓	✓
	Scheduled read of summations from total tier (enables frequent read schedule)	✓	✓	✓	✓
	On demand read of all data	✓	✓	✓	✓
	On demand read of limited set of UOMs (reduces latency)	✓	✓	✓	✓
	Back filling of persistently stored data	✓[1]	✓[2]	✓[2]	✓[2]
	Interval data read				
	Scheduled reads of all load profile sets in the meter		✓	✓	✓
	Scheduled read of all load profile channels		✓	✓	✓
	On demand read of load profile data		✓	✓	✓
End Device Controls	Demand reset (eMCM): daily reset & calendar scheduled	✓	✓	✓	✓
	OTA remote connect/disconnect of relays				
	Main relay	✓	✓		✓
	Auxiliary relay				✓
	Arm-to-Connect				✓
	OTA enabling/disabling of load control points		✓		✓
	TOU and season change triggered by enterprise SW		✓	✓	✓
	Daylight savings time support: LP & TOU modes		✓	✓	✓
	Daylight savings time support: Demand only mode		✓	✓	✓
	Daylight savings time support: Energy Only Meter	✓			
	OTA meter program (configuration) update		✓	✓	✓

* Energy Only

[1]96 Reads

[2]Two most recent scheduled (not on-demand) billing reads – All tiers

	Features	AMI1.2			
		I-210+	**I-210+C**	**kV2c**	**SGM**
Notifications & Reporting	Momentary outage detection and reporting	✓	✓	✓	✓
	LastGasp: outage reporting	✓	✓	✓	✓
	Power quality events				
	Sag/swell log reporting	✓	✓	✓	✓
	Voltage imbalance, over/under frequency reporting				✓
	Under and over-voltage alerts at poll time		✓	✓	
	Voltage imbalance and distortion alerts at poll time			✓	
	Relay state changes notification – main & auxiliary	✓	✓		✓
	Load control event notification – Prepayment (paid at meter), load shedding etc.		✓[3]		✓[3]
	Configurable monitoring periods for event notifications	✓	✓	✓	✓
Instantaneous Power Quality Reads	Power quality metrics read: scheduled & on demand				
	Line-to-line Voltage			✓	
	Line-to-neutral Voltage	✓	✓	✓	✓
	RMS current			✓	✓
	Momentary Power Factor		✓	✓	✓
	Running Avg Power Factor, Voltage Angle, Current Angle			✓	
	ITHD.VTHD,TDD, Distortion Volt-Amp, Distortion Power Factor			✓	
	Temperature	✓	✓	✓	
	Frequency			✓	
	Active Power	✓		✓	✓
	Reactive Power			✓	✓
	Apparent Power			✓	✓
Quality over Intervals	Quality over intervals				
	Power: Active (KW), Reactive (kVAr),Phasor Apparent (kVA)		✓	✓	✓
	Power: Apparent			✓	
	RMS Voltage, Average Voltage		✓	✓	✓
	RMS Current, Power Factor (concident only)			✓	✓
	Voltage Squared, Current Squared			✓	
	VTHD,ITHD, TDD			✓	✓
	Distortion (kVA) , distortion Power Factor			✓	
	Vx - Vy (V)				✓
	Quality			✓	
	Frequency			✓	✓
	Pulses		X	X	X

[3]Credits not directly supported over IEC-CIM

NOTES:

- Reported quantities may have per phase values (if meter is 3 phase), F or F+H
- I210+ reporting is not affected by filtering
- I210+c new FW release 5.x is expected to contain Instantaneous Active Power (not supported)

A.2 Supported Meter Platforms

GE MeterMate™ 6.4 version is officially supported by AMI 1.2 release.

Table 29. Compatibility between GE meters and AMI software releases

Platform	Meter FW	Form Factor	eMCM	MCM Versions	Meter Modes
I-210+ I-210+n	3.6.1 4.0.8	2S/3S/12S	Raptor	eMCM 2.8.6(AMI 1.2),Node 6.4.5 eMCM 2.3.7(AMI 1.1), Node 6.4.5 eMCM 1.9.4(AMI 1.0), Node 6.3.10/6.4.5	Energy only (Default)
kV2c	4.11.9.12 4.11.7.12	2S/9S/12S/16S	Ptero	eMCM 2.8.6(AMI 1.2), Node 6.4.5 eMCM 2.3.7(AMI 1.1), Node 6.4.5 eMCM 1.10.5(AMI 1.0), Node 6.3.10/6.4.5	TOU, Demand, Demand/LP
I-210+c I-210+cn	3.3.0	2S/3S/4S/12S	Raptor	eMCM 2.8.6(AMI 1.2), Node 6.4.5 eMCM 1.10.6(AMI 1.0), Node 6.3.10/6.4.5	TOU, Demand, Demand/LP
SGM3011 SGM3031	1.4.3 1.7.4	N/A	Falcon	eMCM 2.8.6(AMI 1.2), Node 6.4.5 eMCM 1.9.4(AMI 1.0), Node 6.3.10/6.4.5	N/A
SGM30C2	1.7.4	N/A	Falcon	eMCM 2.8.6(AMI 1.2), Node 6.4.5	N/A

A.3 Key Exchange during Provisioning

The provisioning server generates symmetric keys, which are programmed into the Nodes. The Nodes are part of the eMCM. The symmetric key is a root key from which daughter keys are generated by the Node. The Node encrypts all information it transmits with daughter keys. To ensure security, the Node keeps changing the daughter keys it uses.

The KMS provides its public key to the provisioning server, which is located at the factory. The symmetric keys generated by the provisioning server are encrypted with this public key of KMS and sent to KMS. The KMS decrypts to retrieve the symmetric keys and ingests them. KMS uses these keys to authenticate all communication from Nodes.

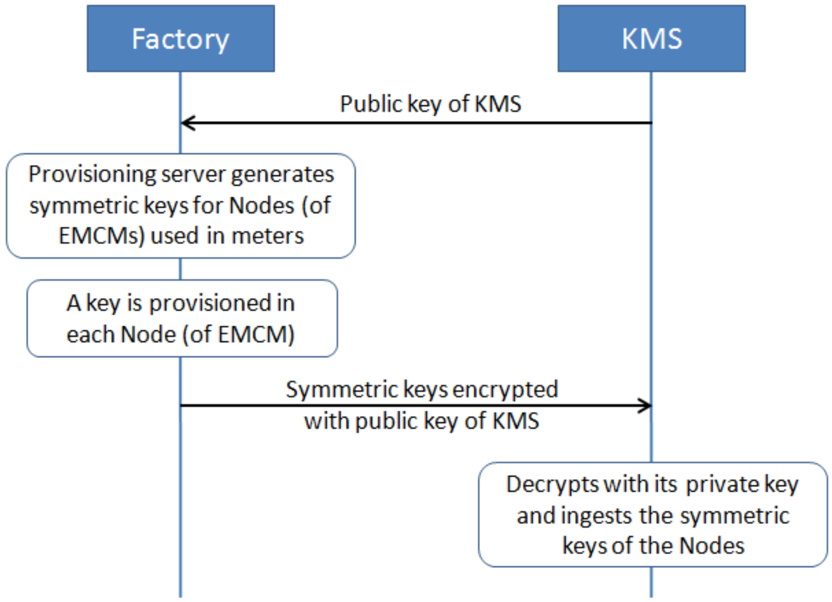


Figure 34. Generation of Node keys and their exchange

A.4 Meter Boot Process

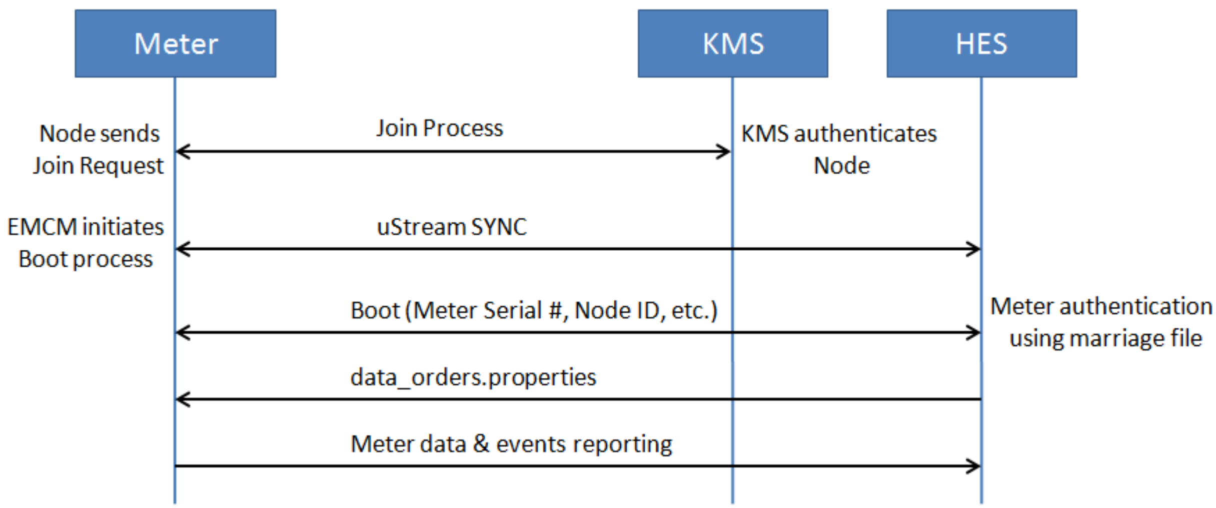


Figure 35. Meter boot process

When a meter is installed, the Node transmits a join request. This request is authenticated by the KMS, which has the symmetric keys of the Node. Thereafter, the eMCM initiates the boot process. The HES authenticates all meters based on the marriage file, which contains the meter serial number to Node ID (MACAddress) relationships. After meter is authenticated, HES sends the data reporting configuration for the meter, which overwrites the default reporting configuration. The meter then starts transmitting data according to the new received reporting configuration.

A.5 List of UOMs

Table 30. List of UOMs supported by meters for billing and interval data

Quantity	ANSI ID_CODE	I210+	I210+c	kV2C	SGM3000
Active (kW & kWh)*	0	✓	✓	✓	✓
Reactive (kVAr)*	1		✓	✓	✓
Apparent (kVA)*	2			✓	
Distortion (kVA)1	2			✓	
Phasor Apparent (kVA)*	3		✓	✓	✓
Quantity (Q)	4			✓	
Phasor Reactive (kVAr)	6				
(rms) Voltage (V)	8		✓	✓	✓
Average Voltage (V)	9		✓	✓	✓
Voltage square (V2)	10			✓	
(rms) Current (A)	12			✓	✓
Current square (A2)	14			✓	
VTHD	16			✓	✓
ITHD	17			✓	✓
TDD	17			✓	
Vx - Vy (V)	21				✓
Distortion Power Factor	24			✓	
Power Factor (concident only)	25			✓	✓
Average Power Factor	26				
Frequency	33			✓	✓
Pulses3	34		X	X	X

Shaded blank = Meter does not support
X = Meter supports but AMI 1.2 does not support
[1]Include both energy and power
[3]Pulse counting is legacy from AMR. It is not need in AMI systems
**Multi-quadrant measurements supported

Refer R&P guide for complete list.

A.6 uStream Protocol

uStream is a transport layer protocol between HES and application platforms such as eMCM. It provides end-to-end message reliability, flow control, quality of service (QoS), and large file transfer capability over the On-Ramp Wireless Total Network.

A.6.1 Prioritization of Uplink Transmissions

Table below shows priority, in decreasing order, of uplink transmission messages from eMCM.

Table 31. Priority of uplink message transmissions from eMCM on RPMA network

Usage	Resumable	Notes
High priority responses to downlink requests	No	Responses to on-demand requests. E.g. billing data read, relay connect/disconnect, demand reset etc.
Periodic reports and autonomous reports	No	Scheduled read and poll driven event reporting. E.g., scheduled interval reports, power quality events, relay state, secondary billing read schedule, etc.
Large file transfers	Yes	E.g., large meter table reads

Besides priority of transmission, QoS is ensured also by availability of transmission buffer size for different types of meter data. Responses to on-demand requests has the largest portion of Tx buffer followed by billing data from primary schedule, which is followed by interval data and billing data from secondary schedule, and finally the power quality events.

A.6.2 Prioritization of Downlink Transmissions

Table below shows priority, in decreasing order, of downlink transmission messages to eMCM.

Table 32. Priority of downlink message transmissions to eMCM on RPMA network

Usage	Resumable	Notes
Meter configuration control	No	Control and management of AMI meters. For example, meter configuration, setting billing read schedule, etc.
Meter data & control	No	Back office triggered requests. For example, demand reset, billing data read, relay connect/disconnect, interval data read, etc.
Generic requests and image transfers	Yes	For example, meter program update

A.7 Additional Relay and Control Points Information

Table 33. List of relay and load control events in I-210+c meters

Meter event	Description
Communication error with switch control board	Indicates a communication error or no response has occurred during recent communication with switch control board
Switch state inconsistent	Indicates that current switch state, switch controller status, and current reading in meter are not a valid combination.
Switch failed to close	The switch controller detected no load side voltage and the meter detected no current was running through meter while the switch control board reported the switch to be closed.
Alternate source present	Indicates that the switch controller detected a load side voltage that is out of phase with line side voltage, while the switch is open with no current running through the meter.
Switch Bypassed	Indicates that the meter has detected a load side voltage that is in phase with line side voltage while the switch was open, and no current is running through the meter.
Switch failed to open	Indicates that the meter has detected a load side voltage that is in phase with line side voltage and current was running through the meter, while the switch was reported to be open.
Negative prepayment credit	Indicates PPM remaining credit is negative. 0 = PPM Remaining Credit > 0, 1 = PPM Remaining Credit <= 0

Table 34. List of relay and load control events in SGM3000 meters

METER EVENT	DESCRIPTION
SWITCH_FAILED_TO_CLOSE_FLAG	Indicates that the meter detected no load-side voltage and no current after attempting to close the switch. 0 = False, 1 = True
SWITCH_FAILED_TO_OPEN_FLAG	Indicates that the switch should be open but the meter is recording watt-hour accumulation above the creep threshold. 0 = False, 1 = True
UNEXPECTED_LOAD_SIDE_VOLT_FLAG	Indicates that the meter detected load-side voltage after attempting to open the switch. 0 = False, 1 = True.
LOAD_SIDE_VOLT_INFO_ERR_FLAG	Indicates problem with LSV info from metering chip. Either meter is not able to get load side voltage info from teridian or LSV info provided by metering chip is not correct. 0=False, 1- True
EXTERNAL_SOURCE_WARNING_FLAG	This is a warning flag indicates there is a possibility of external source while closing relay and so relay can't be closed
PHASE_ERR_FLAG	Indicates problem with one or more phases or phase configuration in MT71 and so relay can't close
FAIL_TO_REC_LSV_INFO_FLAG	When set, indicates that meter is failed to get LSV info

METER EVENT	DESCRIPTION
FAIL_TO_REC_MI_EVENT_FLAG	When set, indicates that meter is failed to get MI event
CMD_REJECTED_FLAG	When set, indicates relay driver rejected command
ARMED_FOR_CLOSURE_FLAG	Indicates that the switch has been armed and is waiting for manual intervention to close the switch. 0 = False, 1 = True.
ARMING_ENDED_WO_CLOSURE	Relay was previously armed, but the armed state was ended without the relay’s closure.
RTC_ERR_FLAG	When set, this bit indicates that there is an issue with RTC
PPM_ALERT_FLAG	When set, this bit indicates that the REMAINING_CREDIT value has fallen below zero.
PPM_OVERDRAFT_FLAG	When set, this bit indicates that REMAINING_CREDIT has fallen below the overdraft limit.
PPM_SHORT_TERM_RC_FLAG	Set when service is reconnect for configured short term reconnection duration during PPM mode
INVALID_SCH_ENTRIES_FLAG	When set, Indicates invalid schedule entries are configured in meter

A.8 Sample of data_orders.properties File

```
# DATA ORDER CONFIGURATIONS - START
# ====================================================================================================
# Set Data Orders Req is constructed based on
# the following optional parameters. A meter specific setting will take priority over a
# generic setting. To make a value meter specific, include one of the following meter names
# between 'emcm-transformer.' and '.billing_data_order_req':
#   GE_I210_PLUS
#   GE_I210_PLUS_C
#   GE_SGM3000
#   VISION_V2S
#   GE_KV2C
#   LG_FOCUS_AX
#   LG_FOCUS_S4X
# (default value used when not specified here is in parens)

# Data Orders can also be grouped by other unique strings besides meter names. Simply replace the
# METER_NAME with another unique string. The above meter names are reserved.

# ====================================================================================================
# BILLING ORDER 1 CONFIGURATIONS
#  - Billing Order 1 is always required. If there is nothing configured, default values will be sent
#  - monthlyDemandOffset: day of month from 0-28
# ====================================================================================================
# emcm-transformer.[METER_NAME.]billing_data_order_req.billing.0.filter.summations=<all | comma separated list of UOMs,
prefixed with 0x, full uom hex> (all)
# emcm-transformer.[METER_NAME.]billing_data_order_req.billing.0.filter.demands=<all | comma separated list of UOMs,
prefixed with 0x, full uom hex> (all)
# emcm-transformer.[METER_NAME.]billing_data_order_req.billing.0.filter.coincidents=<all | comma separated list of UOMs,
prefixed with 0x, full uom hex> (all)
```

```
# emcm-transformer.[METER_NAME.]billing_data_order_req.billing.0.filter.tiers=<all | comma separated list of tier numbers> (all)
# emcm-transformer.[METER_NAME.]billing_data_order_req.billing.0.schedule.offsetSeconds=<int> (0)
# emcm-transformer.[METER_NAME.]billing_data_order_req.billing.0.schedule.offsetRelativeToLocalTime=<true | false> (true)
# emcm-transformer.[METER_NAME.]billing_data_order_req.billing.0.schedule.readPeriodSeconds=<int> (86400)
# emcm-transformer.[METER_NAME.]billing_data_order_req.billing.0.schedule.reportingPeriodSeconds=<int> (14400)
# emcm-transformer.[METER_NAME.]billing_data_order_req.billing.0.demandResetType=<none | daily | monthly> (none)
# emcm-transformer.[METER_NAME.]billing_data_order_req.billing.0.monthlyDemandOffset=<int> (no default value set)

# ====================================================================================================
# BILLING ORDER 2 CONFIGURATIONS - for energy only metering
#  - If no Billing Order 2 is configured, none should be sent down to emcm and emcm should not report any
# ====================================================================================================
# emcm-transformer.[METER_NAME.]billing_data_order_req.billing.1.filter.summations=<all | comma separated list of UOMs, prefixed with 0x, full uom hex> (no default value set)
# emcm-transformer.[METER_NAME.]billing_data_order_req.billing.1.schedule.readPeriodSeconds=<int> (no default value set)
# emcm-transformer.[METER_NAME.]billing_data_order_req.billing.1.schedule.reportingPeriodSeconds=<int> (no default value set)

# ====================================================================================================
# LOAD PROFILE CONFIGURATIONS
#  - By default, no load profile sets will be sent if there are no data order configurations specified
#  - A maximum of 4 load profile sets may be configured
#  - HES will not send more load profile set configurations than are reported in the MeterConfigReportRsp
#  - If a load profile filter is empty, the reportingPeriodSeconds will be set to 0 to disable reporting of that LP set
# ====================================================================================================
# emcm-transformer.[METER_NAME.]billing_data_order_req.load_profile.0.filter=<all | comma separated list of UOMs> (no default value set)
# emcm-transformer.[METER_NAME.]billing_data_order_req.load_profile.0.schedule.reportingPeriodSeconds=<int> (900)
# emcm-transformer.[METER_NAME.]billing_data_order_req.load_profile.0.maxIntervalsPerReport=<int> (no default value set)
# emcm-transformer.[METER_NAME.]billing_data_order_req.load_profile.0.maxLpBacklogSec=<int> (no default value set)

# ====================================================================================================
# POWER QUALITY EVENT CONFIGURATIONS
#  - maxNumEvents should be within 0-5 range
#  - reportingPeriodSeconds cannot be 0
#  - both maxNumEvents and reportingPeriodSeconds need to be specified to be included
# ====================================================================================================
# emcm-transformer.[METER_NAME.]billing_data_order_req.power_quality_event.maxNumEvents=<int> (no default value set)
# emcm-transformer.[METER_NAME.]billing_data_order_req.power_quality_event.schedule.reportingPeriodSeconds=<int> (no default value set)

# ====================================================================================================
# POWER QUALITY REPORT CONFIGURATIONS
#  - both filter and reportingPeriodSeconds need to be specified to be included
#  - reportingPeriodSeconds cannot be 0
# ====================================================================================================
# emcm-transformer.[METER_NAME.]billing_data_order_req.power_quality_report.schedule.reportingPeriodSeconds=<int> (no default value set)
# emcm-transformer.[METER_NAME.]billing_data_order_req.power_quality_report.filter=<all | comma separated list of named filters > (no default value set)

#   Power Quality Report Filter values:
#     L_TO_L_VOLTAGE_MAGNITUDE
#     L_TO_N_VOLTAGE_MAGNITUDE
#     CURRENT_MAGNITUDE
#     MOMENTARY_PF
#     AVERAGE_PF
```

```
#    ITHD
#    VTHD
#    TDD
#    DISTORTION_PF
#    TEMPERATURE
#    FREQUENCY
#    ACTIVE_POWER
#    REACTIVE_POWER
#    DISTORTION
#    APPARENT_POWER

# emcm-transformer.[METER_NAME.]billing_data_order_req.power_quality_report.filter2=<all | comma separated list of
named filters > (no default value set)

#   Power Quality Report Filter 2 values:
#    VOLTAGE_ANGLES
#    CURRENT_ANGLES

# ====================================================================================================
# METER EVENT IND CONFIGURATIONS
#  - should be no smaller than 60 seconds
# ====================================================================================================
# emcm-transformer.[METER_NAME.]billing_data_order_req.meter_event_ind_polling_period=<int> (no default value set)

# ====================================================================================================
# TIME CONFIGURATIONS
#  - all time_config properties need to be included, if this is to be used
#
# Rdate format: Month-Qualifier-Weekday-Day format (16 bits)
#   Setting DST on and off times shall follow the following rules for correct effect: Please check ANSI C12.19 for more details
#   Rdate = DDDD DWWW QQQQ MMMM (16 bits), where "DDDDD" is 5-bit day number in binary, "WWW" is a 3-bit
representation for weekday, "QQQQ" is a 4-bit qualifier and "MMMM" is a 4-bit month in binary"
#
#   US defaults should be (crossing fingers hoping we are not wrong again:
#    emcm-transformer.billing_data_order_req.time_config.dst_on_event=0x0833
#    emcm-transformer.billing_data_order_req.time_config.dst_off_event=0x082b
#
# ====================================================================================================
# emcm-transformer.[METER_NAME.]billing_data_order_req.time_config.timezone_offset=<int> (no default value set)
# emcm-transformer.[METER_NAME.]billing_data_order_req.time_config.dst_time_amt=<int> (no default value set)
# emcm-transformer.[METER_NAME.]billing_data_order_req.time_config.dst_on_event=<hex rdate, prefixed with 0x> (no
default value set)
# emcm-transformer.[METER_NAME.]billing_data_order_req.time_config.dst_off_event=<hex rdate, prefixed with 0x> (no
default value set)
# emcm-transformer.[METER_NAME.]billing_data_order_req.time_config.dst_time_eff=<int> (no default value set)

# ====================================================================================================
# METER FLAGS IGNORE MASK CONFIGURATIONS
#  - if the values are 0 or the config line is ommitted, reporting is enabled for all those flags
# ====================================================================================================
# emcm-transformer.[METER_NAME.]billing_data_order_req.meter_flags_ignore_mask.edModeBfld=<int> (no default value
set)
# emcm-transformer.[METER_NAME.]billing_data_order_req.meter_flags_ignore_mask.edStdStatus1Bfld=<int> (no default
value set)
# emcm-transformer.[METER_NAME.]billing_data_order_req.meter_flags_ignore_mask.edStdStatus2Bfld=<int> (no default
value set)
# emcm-transformer.[METER_NAME.]billing_data_order_req.meter_flags_ignore_mask.edMfgStatusBfld=<hex, prefixed with
0x> (no default value set)
```

```
# emcm-transformer.[METER_NAME.]billing_data_order_req.meter_flags_ignore_mask.extraMfgFlags=<hex, prefixed with 0x>
(no default value set)

# ==========================================================================================
# DATA ORDER CONFIGURATIONS - END
# ==========================================================================================

# ==========================================================================================
# SAMPLE DATA ORDER CONFIGURATION - DEFAULT
# ==========================================================================================
# emcm-transformer.billing_data_order_req.billing.0.filter.summations=all
# emcm-transformer.billing_data_order_req.billing.0.filter.demands=all
# emcm-transformer.billing_data_order_req.billing.0.filter.coincidents=all
# emcm-transformer.billing_data_order_req.billing.0.filter.tiers=all
# emcm-transformer.billing_data_order_req.billing.0.schedule.offsetSeconds=0
# emcm-transformer.billing_data_order_req.billing.0.schedule.offsetRelativeToLocalTime=true
# emcm-transformer.billing_data_order_req.billing.0.schedule.readPeriodSeconds=86400
# emcm-transformer.billing_data_order_req.billing.0.schedule.reportingPeriodSeconds=18000
# emcm-transformer.billing_data_order_req.billing.0.demandResetType=daily
# emcm-transformer.billing_data_order_req.load_profile.0.filter=all
# emcm-transformer.billing_data_order_req.load_profile.0.schedule.reportingPeriodSeconds=900
# emcm-transformer.billing_data_order_req.load_profile.1.filter=all
# emcm-transformer.billing_data_order_req.load_profile.1.schedule.reportingPeriodSeconds=1800
# emcm-transformer.billing_data_order_req.load_profile.2.filter=all
# emcm-transformer.billing_data_order_req.load_profile.2.schedule.reportingPeriodSeconds=3600
# emcm-transformer.billing_data_order_req.load_profile.3.filter=all
# emcm-transformer.billing_data_order_req.load_profile.3.schedule.reportingPeriodSeconds=3600
# emcm-transformer.billing_data_order_req.power_quality_report.schedule.reportingPeriodSeconds=86400
# emcm-transformer.billing_data_order_req.power_quality_report.filter=all
# emcm-transformer.billing_data_order_req.power_quality_report.filter2=all
# emcm-transformer.billing_data_order_req.power_quality_event.maxNumEvents=5
# emcm-transformer.billing_data_order_req.power_quality_event.schedule.reportingPeriodSeconds=900
# emcm-transformer.billing_data_order_req.meter_event_ind_polling_period=300

# ==========================================================================================
# SAMPLE DATA ORDER CONFIGURATION - ADDITIONS FOR DEMAND ONLY
#  - Sample time config uses Pacific Time
# ==========================================================================================
# emcm-transformer.billing_data_order_req.billing.1.filter.summations=all
# emcm-transformer.billing_data_order_req.billing.1.schedule.readPeriodSeconds=3600
# emcm-transformer.billing_data_order_req.billing.1.schedule.reportingPeriodSeconds=0
# emcm-transformer.billing_data_order_req.time_config.timezone_offset=-480
# emcm-transformer.billing_data_order_req.time_config.dst_time_amt=60
# emcm-transformer.billing_data_order_req.time_config.dst_on_event=0x0833
# emcm-transformer.billing_data_order_req.time_config.dst_off_event=0x082b
# emcm-transformer.billing_data_order_req.time_config.dst_time_eff=7200

# ==========================================================================================
# SAMPLE DATA ORDER CONFIGURATION - ADDITIONS FOR GE I210+ METERS
# ==========================================================================================
# emcm-transformer.GE_I210_PLUS.billing_data_order_req.billing.0.schedule.readPeriodSeconds=900
# emcm-transformer.GE_I210_PLUS.billing_data_order_req.billing.0.schedule.reportingPeriodSeconds=900
```

A.9 Sample of hes_config.properties File

```
#
```

```
# HES - Configuration, properties for Gateway (AMQP), Hazelcast, Messaging Adapters and Transformers
#

### JVM Configuration###
# All options will be added as program arguments when running HES
# The -Xmx argument is the max heap size for the JVM, these may need to be increased depending on the number of adapters/transformers that are installed.
# A good rule of thumb is to run the JVM at ~60% of its max heap size
# IMPORTANT - if you are running more than 4 adapters, you may want to bump -XX:MaxPermSize in 'hes.java.opts' by 50M per each adapter over that, or stay with current default of 128m and if you see 'out of memory errros: perm gen' then you need to increase this
hes.java.opts=-Xmx1024m -XX:MaxPermSize=256M

# if connecting to AMQP broker over SSL, specify java key/trust stores
# hes.java.opts=-Xmx256m -Djavax.net.ssl.keyStore=/opt/onramp_apps/hes/instance_1/amqp-key-store.jks -Djavax.net.ssl.keyStorePassword=password -Djavax.net.ssl.trustStore=/opt/onramp_apps/hes/instance_1/amqp-trust-store.jks -Djavax.net.ssl.trustStorePassword=password
### End of JVM Configuration ###

### AMQP Configuration ###
amqp.qpid.url=amqp://${installer:amqp.user}:${installer:amqp.pwd}@/?brokerlist='tcp://${installer:amqp.host}:${installer:amqp.port}?ssl='false',maxprefetch='5',timeout='200',immediatedelivery='true',sync_ack='true',heartbeat='30''
# These will set size of thread pool for AMQP exchanges (per customer)
amqp.qpid.maxlisteners=10
amqp.qpid.minlisteners=1

# Time in milliseconds that a listener will wait for a message before rescheduling listener thread
amqp.qpid.recv_timeout=5000
# general rule of thumb, session_size should be equal to about half of 'amqp.qpid.maxlisteners' * 'number of app typeids'
# if heavy volume, and connection related exceptions in bus log, then increase up to 'amqp.qpid.maxlisteners' * 'number of app typeids'
amqp.qpid.downlink.session_size=25

# AMQP-Exchanges
amqp.customer=${installer:amqp.customer}
amqp.exchange.downlink=Southbound; {create: never, node: {type: topic}}

# AMQP-Queues
# the uplink queue is defined by Gateway provisioning script
amqp.queue.data.uplink=NorthboundQueue; {create: never,node: {type: queue}}

# AMQP Keep-Alive
# setting send_time to 0 seconds, turns off keep alive message generation
amqp.keepalive_send_time_interval_seconds=30

### End of AMQP Configuration ###

# Configuration of message request correlation queue
# The information is used to correlate gateway responses to requests
# Setting discard to true, will allow incoming requests to evict the oldest entry
# Each node will get it's own queue with the given ranges with the given size: Node 0x0001 -> [min, max]
gw.downlink.unicast.queue.size=100
gw.downlink.unicast.queue.discard=true
gw.downlink.unicast.queue.min=1
gw.downlink.unicast.queue.max=127

#Same as above except for MUD (Multicast) requests
gw.downlink.multicast.queue.size=3000
```

```
gw.downlink.multicast.queue.discard=true
gw.downlink.multicast.queue.min=1024
gw.downlink.multicast.queue.max=4095

### Hazelcast Configuration ###
# setup the communication config for distributed caches between mulitiple HES's
dht.symmetric_encrypt.enabled=false
dht.symmetric_encrypt.algorithm=PBEWithMD5AndDES
dht.symmetric_encrypt.salt=123
dht.symmetric_encrypt.passphrase=sharedsecret
dht.symmetric_encrypt.passphrase_iteration_count=4

dht.asymmetric_encrypt.enabled=false
dht.asymmetric_encrypt.algorithm=RSA/NONE/PKCS1PADDING
dht.asymmetric_encrypt.privkey_password=pass
dht.asymmetric_encrypt.privkey_alias=keystore alias name
dht.asymmetric_encrypt.keystore_password=keystorepass
dht.asymmetric_encrypt.keystore_file=/opt/apps/keystore.jks

# used for cache update task executions
dht.threadpool.coresize=5
dht.threadpool.maxsize=30
dht.threadpool.inactive_timeout_seconds=60
#only turn on jmx when debugging
dht.jmx.enabled=false
dht.management_center.enabled=false
dht.memcache.enabled=false
dht.rest.enabled=false
#level = {OFF,SILENT,NOISY}
dht.health.monitoring.level=NOISY
dht.health.monitoring.delay.seconds=30

# define what this instance should be aware of for network setup and cache peers, each hes instance should use a
coordinated/matched hes_config.properties so that members can find each other
dht.network.max_no_heartbeat_seconds=15
dht.network.listenport=5701
dht.network.tcp_interfaces.enabled=false
dht.network.interfaces.ip_addr_list=192.168.1.*, 192.168.2.34
dht.network.multicast_cluster.enabled=false
dht.network.multicast_cluster.group_ipaddr=1.2.3.4
dht.network.multicast_cluster.port=12345
# if both TCP/IP and Multicast are disabled than that means there is no cluster, it's stand-alone
# when enabling cluster, set something other than 0 for dht.sdufrag.jvm_backup_count and
dht.nodemeta.jvm_backup_count=0
dht.network.tcpip_cluster.enabled=false
dht.network.tcpip_cluster.member_ip_addrs=localhost:5702, 192.168.2.68:5701

# if more than one cluster member, then can specify a jvm_backup_count of 1,2 or 3, probably 1 is enough
dht.sdufrag.jvm_backup_count=0
# if greater than 0 then map storage is done asynchronously this many seconds after the in memory map is updated, 0=means
storage write is done synchro after in memory update
# best performance will be when greater than zero here but then the risk is if disk writes fail, then memory is out of synch with
store(hazelcast will keep retrying the disk persistence operation once very write_delay_seconds )
dht.sdufrag.write_delay_seconds=0

# node meta datda cache
dht.nodemeta.jvm_backup_count=0
dht.nodemeta.write_delay_seconds=30
```

End Hazelcast Configuration

# how often a sweep process is kicked off for removing stranded uplink frag messages
# 14400000 = 8 hours
hes.gw_uplink_frag_timeout_milliseconds=60000
# how often a sweep process is kicked off, this will search all downlink requests from adapters that are pending responses and purge those that have gone over
hes.adapter_request_timeout_sweep_interval_milliseconds=3600000

END OF HES-CORE CONFIG

A.10 Soft Switches in GE Smart Meter

Listed below are different soft switch options available by meter types. Refer GE smart meter documents for latest and most accurate information regarding soft switches.

Optional Softswitches can be loaded in the factory or by the user to activate advanced functions
O — Activates communication capability with AMR/AMI modules
S_2 — AMI/AMR calculated demand displayed on meter LCD
V_2 — Simple Voltage Event monitor in addition to a display of RMS momentary voltage on the 3 lower LCD digits

Figure 36. Soft switches for I-210+ meter

Soft-Switch Functions
A_2 Soft-switch
- The Alternate Communication Soft-switch allows a communication option board to communicate with the meter
E_2 Soft-switch
- The Event Log Soft-switch allows the meter to track the most recent 200 events. Use MeterMate™ Program Manager, Diagnostics Editor, to select the event types to be logged and how many occurrences should be tracked, up to a maximum of 200 events. Date and time stamps are included on logged events for Demand/LP or TOU meters
K_2 Soft-switch
- The kVA and kvar Soft-switch adds kVA(h) and kvar(h) measurement capability.
N_2 Soft-switch
- The Demand (N_2) Soft-switch adds billing demand calculations.
Q_2 Soft-switch
The Power Quality Measurements Soft-switch enables
- Voltage (L-N): VA (max, min, store) for summations, demand, and load profile recording
- RMS voltage measurement for reading and display
- Low potential caution
R_2 Soft-switch
- The Load Profile Soft-switch activates up to 4 channels of LP recording
T_2 Soft-switch
The Time-of-use Soft-switch enables TOU operation
- Up to four TOU periods and four Seasons
- Up to three daily rate schedule types and one holiday schedule

Figure 37. Soft switches for I-210+c meter

Softswitches Add	
B Switch	By Quadrant measurements
C Switch	Call In on Outage (Modem)
E Switch	500 Event Log
G Switch*	Revenue Guard Plus
H Switch	Expanded Flash Memory (20-channel, 384 kB)
I Switch	Instrument Transformer Correction
K Switch	kVA – Power Factor, kvar and kVA measures
L Switch	Transformer Loss Compensation
M Switch	Expanded Measures – per phase measurement
N Switch	Demand Measures
Q Switch	Power Quality Measures
R Switch	Basic Recording (4-channel, 64 KB)
T Switch	Time of Use
V Switch	Fast Voltage Event Monitor and Log (sag and swell, 1 to 65 k cycles)
W Switch	Waveform Capture (70 sample sets – 6 measures per set – V & I per phase)
X Switch	Expanded Recording (20-channel, 192 kB)
Z Switch	Totalization

Figure 38. Soft switches for kV2c meter

NOTE: There are no soft switches for SGM3000 meter family.

Appendix B Abbreviations and Terms

Abbreviation/Term	Definition
ACK	Acknowledgment
AMI	Advanced Metering Infrastructure
AP	Access Point. The On-Ramp Wireless network component geographically deployed over a territory. Product name is TRN AP-1000.
API	Application Programming Interface
BCH	Broadcast Channel
CIM	Common Information Model is a standard developed by electric power industry, and officially adopted by IEC, that aims to allow application software to exchange information about an electrical network
CIS	Customer Information System is a back office system used by Utility Companies in a smart grid to store customer and meter information
CSV	Comma Separated Values
CMEP	
CPP	Critical Peak Pricing
CRC	Cyclic Redundancy Check
Dashboard	Web page view of the aggregated end-device monitoring data
DL	Downlink
DLP	Demand Limiting Period
DST	Daylight Savings Time
ECP	Emergency Conservation Period
EEPROM	Electrically Erasable Programmable Read Only Memory
eMCM	Electronic Meter Communication Module
EMS	Element Management System
FCI	Fault Circuit Indicators
FOA	First Office Application (equivalent of a beta release)
FW	Firmware
GPS	Global Positioning System
GW	Gateway
HES	ORW’s Head End System
I-210+	GE’s basic solid state kWh ANSI meter
I-210+c	GE’s flagship residential ANSI smart meter, offering demand, load profile, TOU, service switch, and a full complement of communication options
IEC	International Electrotechnical Commission is an international standards organization that prepares and publishes International Standards for all electrical, electronic and related technologies – collectively known as "electrotechnology"
IP	Internet Protocol
IPsec	Internet Protocol Security

Abbreviation/Term	Definition
IPv6	Internet Protocol version 6. Protocol used to direct Internet traffic. This protocol provides an addressing scheme that specifies source and destination addresses for transferring data packets between hosts.
ITHD	Current Total Harmonic Distortion index
KMC	Key Management Client
KMS	Key Management System
kV2c	GE's ANSI smart meter designed for revenue class metering in commercial and industrial applications. Has real time instrumentation, power quality monitoring and cost of service measurements.
LP	Load profile
MAC	Media Access Control
MDMS	Meter Data Management System is a back office system used by Utility companies in smart grid to store and manage vast quantities of data delivered by smart metering systems
microNode	
MUD Group	Multicast User Data Group in ORW's AMI system is used for broadcasting data or commands to specific meters
MultiSpeak	MultiSpeak is a specification / standard that defines standardized interfaces among software applications commonly used by electric utilities. It defines details of data that need to be exchanged between software applications in order to support different processes commonly applied at utilities. MultiSpeak effort is funded by National Rural Electric Cooperative Association (NRECA)
Node	The wireless module developed by On-Ramp Wireless that integrates with OEM sensors and communicates sensor data to an Access Point. Also, the generic term used interchangeably with eNode or microNode.
NTP	Network Time Protocol
NVM	Non-volatile Memory
NVRAM	Non-Volatile Random Access Memory
OEM	Original Equipment Manufacturer
OMS	Outage Management System
ORW	On-Ramp Wireless
OTA	Over-the-Air
On-Ramp Total View (OTV)	The network component that passes data from the Gateway to the associated upstream databases. Formerly known as CIMA.
PPM	Prepayment
PQ	Power quality
QoS	Quality of Service is the overall performance of a network, particularly the performance seen by the users of the network
RAM	Random Access Memory
RC-DC	Relay Connect-Disconnect
REST	Representational State Transfer is a software architecture style for building scalable web services
RF	Radio Frequency
RFID	Radio Frequency Identification
ROM	Read Only Memory

Abbreviation/Term	Definition
RPMA	Random Phase Multiple Access™. A highly efficient multiple access scheme, developed by On-Ramp Wireless and deployed in its wireless communication systems.
RSSI	Receive Signal Strength Indicator
RTP	Real Time Pricing
RX	Receive / Receiver
SAIDI	System Average Interruption Duration Index SAIDI is the average outage duration for each customer served
SAIFI	System Average Interruption Frequency Index SAIFI is the average number of interruptions that a customer would experience
SGM3000	GE's series of commercial and industrial IEC smart meters designed for revenue metering, real-time instrumentation, power quality monitoring and cost of service measurements
Smart Meter	A smart meter measures electronically how much energy is used and can communicate this information to another device which, in turn, allows the customer to view how much energy they are using and how much it is costing them.
TCP	Transmission Control Protocol
TDD	Total Demand Distortion
TOU	Time of Use
TX	Transmit / Transmitter
UI	Uplink Interval Update Interval User Interface
UL	Uplink
UOM	Units of Measurement
UTC	Coordinated Universal Time is the primary time standard by which the world regulates clocks and time. It does not observe DST
VEE	Validation Estimation and Editing of metering data in order to identify and compensate for missing and inaccurate measurements. These tasks are performed by an MDMS
VTHD	Voltage Total Harmonic Distortion index
XML	Extensible Markup Language is a markup language that defines a set of rules for encoding documents in a format which is both human-readable and machine-readable

Appendix C References

https://www.smartgrid.gov/recovery_act/deployment_status/time_based_rate_programs

1. HES/OTV AMI Interface Guide (010-0120-00)
2. OTV Supplement: Electric AMI (010-0100-00)
3. On-Ramp Total View Operator Guide (010-0106-00), OTV Release 1.2