Monitoring and Control MIB for Power and Energy

Abstract

This document defines a subset of the Management Information Base (MIB) for power and energy monitoring of devices.

Status of This Memo

This is an Internet Standards Track document.

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1. Introduction

This document defines a subset of the Management Information Base (MIB) for use in energy management of devices within or connected to communication networks. The MIB modules in this document are designed to provide a model for energy management, which includes monitoring for Power State and energy consumption of networked elements. This MIB takes into account the "Energy Management Framework" [RFC7326], which, in turn, is based on the "Requirements for Energy Management" [RFC6988].

Energy management can be applied to devices in communication networks. Target devices for this specification include (but are not limited to) routers, switches, Power over Ethernet (PoE) endpoints, protocol gateways for building management systems, intelligent meters, home energy gateways, hosts and servers, sensor proxies, etc. Target devices and the use cases for Energy Management are discussed in Energy Management Applicability Statement [EMAN-AS].

Where applicable, device monitoring extends to the individual components of the device and to any attached dependent devices. For example, a device can contain components that are independent from a Power State point of view, such as line cards, processor cards, hard drives. A device can also have dependent attached devices, such as a switch with PoE endpoints or a power distribution unit with attached endpoints.

1.1. Conventions Used in This Document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2. The Internet-Standard Management Framework

For a detailed overview of the documents that describe the current Internet-Standard Management Framework, please refer to section 7 of RFC 3410 [RFC3410].

Managed objects are accessed via a virtual information store, termed the Management Information Base or MIB. MIB objects are generally accessed through the Simple Network Management Protocol (SNMP). Objects in the MIB are defined using the mechanisms defined in the Structure of Management Information (SMI). This memo specifies MIB modules that are compliant to SMIv2, which is described in STD 58, RFC 2578 [RFC2578], STD 58, RFC 2579 [RFC2579] and STD 58, RFC 2580 [RFC2580].
3. Use Cases

Requirements for power and energy monitoring for networking devices are specified in [RFC6988]. The requirements in [RFC6988] cover devices typically found in communications networks, such as switches, routers, and various connected endpoints. For a power monitoring architecture to be useful, it should also apply to facility meters, power distribution units, gateway proxies for commercial building control, home automation devices, and devices that interface with the utility and/or smart grid. Accordingly, the scope of the MIB modules in this document are broader than that specified in [RFC6988]. Several use cases for Energy Management have been identified in the "Energy Management (EMAN) Applicability Statement" [EMAN-AS].

4. Terminology

Please refer to [RFC7326] for the definitions of the following terminology used in this document.

- Energy Management
- Energy Management System (EnMS)
- Energy Monitoring
- Energy Control
- electrical equipment
- non-electrical equipment (mechanical equipment)
- device
- component
- power inlet
- power outlet
- energy
- power
- demand
- provide energy
- receive energy
- meter (energy meter)
- battery
- Power Interface
- Nameplate Power
- Power Attributes
- Power Quality
- Power State
- Power State Set
5. Architecture Concepts Applied to the MIB Modules

This section describes the concepts specified in the Energy Management Framework [RFC7326] that pertain to power usage, with specific information related to the MIB module specified in this document. This subsection maps concepts developed in the Energy Management Framework [RFC7326].

The Energy Monitoring MIB has two independent MIB modules: ENERGY-OBJECT-MIB and POWER-ATTRIBUTES-MIB. The first, ENERGY-OBJECT-MIB, is focused on measurement of power and energy. The second, POWER-ATTRIBUTES-MIB, is focused on power quality measurements for Energy Objects.

Devices and their sub-components can be modeled using the containment tree of the ENTITY-MIB [RFC6933].

5.1. Energy Object Tables

5.1.1. ENERGY-OBJECT-MIB

The ENERGY-OBJECT-MIB module consists of five tables.

The first table is the eoMeterCapabilitiesTable. It indicates the instrumentation available for each Energy Object. Entries in this table indicate which other tables from the ENERGY-OBJECT-MIB and POWER-ATTRIBUTES-MIB are available for each Energy Object. The eoMeterCapabilitiesTable is indexed by entPhysicalIndex [RFC6933].

The second table is the eoPowerTable. It reports the power consumption of each Energy Object as well as the units, sign, measurement accuracy, and related objects. The eoPowerTable is indexed by entPhysicalIndex.

The third table is the eoPowerStateTable. For each Energy Object, it reports information and statistics about the supported Power States. The eoPowerStateTable is indexed by entPhysicalIndex and eoPowerStateIndex.

The fourth table is the eoEnergyParametersTable. The entries in this table configure the parameters of energy and demand measurement collection. This table is indexed by eoEnergyParametersIndex.

The fifth table is the eoEnergyTable. The entries in this table provide a log of the energy and demand information. This table is indexed by eoEnergyParametersIndex.
A "smidump-style" tree presentation of the MIB modules contained in the document is presented. The meaning of the three symbols is a compressed representation of the object’s MAX-ACCESS clause, which may have the following values:

- "not-accessible" -> "---"
- "accessible-for-notify" -> "--n"
- "read-only" -> "r-n"
- "read-write" -> "rwn"

```
eoMeterCapabilitiesTable(1)
  |---eoMeterCapabilitiesEntry(1)[entPhysicalIndex]
  |     |---r-n BITS eoMeterCapability

eoPowerTable(2)
  |---eoPowerEntry(1) [entPhysicalIndex]
  |    |---r-n Integer32 eoPower(1)
  |    |---r-n Unsigned32 eoPowerNamePlate(2)
  |    |---r-n UnitMultiplier eoPowerUnitMultiplier(3)
  |    |---r-n Integer32 eoPowerAccuracy(4)
  |    |---r-n INTEGER eoPowerMeasurementCaliber(5)
  |    |---r-n INTEGER eoPowerCurrentType(6)
  |    |---r-wn PowerStateSet eoPowerAdminState(8)
  |    |---r-n PowerStateSet eoPowerOperState(9)
  |    |---r-n OwnerString eoPowerStateEnterReason(10)

eoPowerStateTable(3)
  |---eoPowerStateEntry(1)
  |    [entPhysicalIndex, eoPowerStateIndex]
  |    |-----n PowerStateSet eoPowerStateIndex(1)
  |    |---r-n Integer32 eoPowerStateMaxPower(2)
  |    |---r-n UnitMultiplier eoPowerStatePowerUnitMultiplier(3)
  |    |---r-n TimeTicks eoPowerStateTotalTime(4)
  |    |---r-n Counter32 eoPowerStateEnterCount(5)
```

+eoEnergyParametersTable(4)
5.1.2.  POWER-ATTRIBUTES-MIB

The POWER-ATTRIBUTES-MIB module consists of three tables.

The first table is the eoACPwrAttributesTable. It indicates the power quality available for each Energy Object. The eoACPwrAttributesTable is indexed by entPhysicalIndex [RFC6933].

The second table is the eoACPwrAttributesDelPhaseTable. The entries in this table configure the parameters of energy and demand measurement collection. This table is indexed by eoEnergyParametersIndex.

The third table is the eoACPwrAttributesWyePhaseTable. For each Energy Object, it reports information and statistics about the supported Power States. The eoPowerStateTable is indexed by entPhysicalIndex and eoPowerStateIndex.
eoACPwrAttributesTable(1)
  +-- eoACPwrAttributesEntry(1) [ entPhysicalIndex]
      |   +-- eoACPwrAttributesConfiguration(1)
      |   +-- eoACPwrAttributesAvgVoltage(2)
      |   +-- eoACPwrAttributesAvgCurrent(3)
      |   +-- eoACPwrAttributesFrequency(4)
      |      +-- UnitMultiplier
      |      |    eoACPwrAttributesPowerUnitMultiplier(5)
      |   +-- eoACPwrAttributesPowerAccuracy(6)
      |   +-- eoACPwrAttributesTotalActivePower(7)
      |   +-- eoACPwrAttributesTotalReactivePower(8)
      |   +-- eoACPwrAttributesTotalApparentPower(9)
      |   +-- eoACPwrAttributesTotalPowerFactor(10)
      |   +-- eoACPwrAttributesThdCurrent(11)
      |   +-- eoACPwrAttributesThdVoltage(12)
  +-- eoACPwrAttributesDelPhaseTable(2)
  +-- eoACPwrAttributesDelPhaseEntry(1)
      |   |   +-- eoACPwrAttributesDelPhaseIndex(1)
      |   +-- eoACPwrAttributesDelPhaseToNextPhaseVoltage(2)
      |   +-- eoACPwrAttributesDelThdPhaseToNextPhaseVoltage(3)
  +-- eoACPwrAttributesWyePhaseTable(3)
  +-- eoACPwrAttributesWyePhaseEntry(1)
      |   |   +-- eoACPwrAttributesWyePhaseIndex(1)
      |   +-- eoACPwrAttributesWyePhaseToNeutralVoltage(2)
      |   +-- eoACPwrAttributesWyeCurrent(3)
      |   +-- eoACPwrAttributesWyeActivePower(4)
5.1.3.  UML Diagram

A Unified Modeling Language (UML) diagram representation of the MIB objects in the two MIB modules, ENERGY-OBJECT-MIB and POWER-ATTRIBUTES-MIB, is presented.
Figure 1: UML Diagram for energyObjectMib

(*) Compliance with the ENERGY-OBJECT-CONTEXT-MIB
Figure 2: UML Diagram for the POWER-ATTRIBUTES-MIB

(*) Compliance with the ENERGY-OBJECT-CONTEXT-MIB
5.2. Energy Object Identity

The Energy Object identity information is specified in the ENERGY-OBJECT-CONTEXT-MIB module [RFC7461] primary table, i.e., the eoTable. In this table, Energy Object context such as domain, role description, and importance are specified. In addition, the ENERGY-OBJECT-CONTEXT-MIB module specifies the relationship between Energy Objects. There are several possible relationships between Energy Objects, such as meteredBy, metering, poweredBy, powering, aggregatedBy, and aggregating as defined in the IANA-ENERGY-RELATION-MIB module [RFC7461].

5.3. Power State

An Energy Object may have energy-conservation modes called "Power States". There may be several intermediate energy-saving modes between the ON and OFF states of a device.

Power States, which represent universal states of power management of an Energy Object, are specified by the eoPowerState MIB object. The actual Power State is specified by the eoPowerOperState MIB object, while the eoPowerAdminState MIB object specifies the Power State requested for the Energy Object. The difference between the values of eoPowerOperState and eoPowerAdminState indicates that the Energy Object is busy transitioning from eoPowerAdminState into the eoPowerOperState, at which point it will update the content of eoPowerOperState. In addition, the possible reason for a change in Power State is reported in eoPowerStateEnterReason. Regarding eoPowerStateEnterReason, management stations and Energy Objects should support any format of the owner string dictated by the local policy of the organization. It is suggested that this name contain at least the reason for the transition change, and one or more of the following: IP address, management station name, network manager’s name, location, or phone number.

The MIB objects eoPowerOperState, eoPowerAdminState, and eoPowerStateEnterReason are contained in the eoPowerTable.

eoPowerStateTable enumerates the maximum power usage in watts for every single supported Power State of each Power State Set supported by the Energy Object. In addition, eoPowerStateTable provides additional statistics such as eoPowerStateEnterCount, i.e., the number of times an entity has visited a particular Power State, and eoPowerStateTotalTime, i.e., the total time spent in a particular Power State of an Energy Object.
5.3.1. Power State Set

There are several standards and implementations of Power State Sets. An Energy Object can support one or multiple Power State Set implementations concurrently.

There are currently three Power State Sets defined:

- IEEE1621(256) - [IEEE1621]
- DMTF(512) - [DMTF]
- EMAN(768) - [RFC7326]

The Power State Sets are listed in [RFC7326] along with each Power State within the Power Set. The Power State Sets are specified by the PowerStateSet Textual Convention (TC) as an IANA-maintained MIB module. The initial version of this MIB module is specified in this document.

5.4. Energy Object Usage Information

For an Energy Object, power usage is reported using eoPower. The magnitude of measurement is based on the eoPowerUnitMultiplier MIB variable, based on the UnitMultiplier TC. Power measurement magnitude should conform to the IEC 62053-21 [IEC.62053-21] and IEC 62053-22 [IEC.62053-22] definition of unit multiplier for the SI units of measure (where SI is the International System of Units). Measured values are represented in SI units obtained by BaseValue * 10 raised to the power of the unit multiplier.

For example, if current power usage of an Energy Object is 3, it could be 3 W, 3 mW, 3 kW, or 3 MW, depending on the value of eoPowerUnitMultiplier. Note that other measurements throughout the two MIB modules in this document use the same mechanism, including eoPowerStatePowerUnitMultiplier, eoEnergyUnitMultiplier, and oACPwrAttributesPowerUnitMultiplier.

In addition to knowing the usage and magnitude, it is useful to know how an eoPower measurement was obtained. A Network Management System (NMS) can use this to account for the accuracy and nature of the reading between different implementations. eoPowerMeasurementLocal describes whether the measurements were made at the device itself or from a remote source. The eoPowerMeasurementCaliber describes the method that was used to measure the power and can distinguish actual or estimated values. There may be devices in the network that may not be able to measure or report power consumption. For those devices, the object eoPowerMeasurementCaliber shall report that the measurement mechanism is "unavailable" and the eoPower measurement shall be "0".
The nameplate power rating of an Energy Object is specified in eoPowerNameplate MIB object.

5.5. Optional Power Usage Attributes

The optional POWER-ATTRIBUTES-MIB module can be implemented to further describe power attributes usage measurement. The POWER-ATTRIBUTES-MIB module is aligned with the IEC 61850 7-2 standard to describe alternating current (AC) measurements.

The POWER-ATTRIBUTES-MIB module contains a primary table, eoACPwrAttributesTable, that defines power attributes measurements for supported entPhysicalIndex entities, as a sparse extension of the eoPowerTable (with entPhysicalIndex as primary index). This eoACPwrAttributesTable table contains such information as the configuration (single phase, DEL 3 phases, WYE 3 phases), frequency, power accuracy, total active/reactive power/apparent power, amperage, and voltage.

In case of three-phase power, an additional table is populated with power attributes measurements per phase (hence, double indexed by the entPhysicalIndex and a phase index). This table, describes attributes specific to either WYE or DEL configurations.

In a DEL configuration, the eoACPwrAttributesDelPhaseTable describes the phase-to-phase power attributes measurements, i.e. voltage. In a DEL configuration, the current is equal in all three phases.

In a WYE configuration, the eoACPwrAttributesWyePhaseTable describes the phase-to-neutral power attributes measurements, i.e., voltage, current, active/reactive/apparent power, and power factor.

5.6. Optional Energy Measurement

It is only relevant to measure energy and demand when there are actual power measurements obtained from measurement hardware. If the eoPowerMeasurementCaliber MIB object has values of unavailable, unknown, estimated, or presumed, then the energy and demand values are not useful.

Two tables are introduced to characterize energy measurement of an Energy Object: eoEnergyTable and eoEnergyParametersTable. Both energy and demand information can be represented via the eoEnergyTable. Demand information can be represented. The eoEnergyParametersTable consists of the parameters defining eoEnergyParametersIndex -- an index for the Energy Object, eoEnergyObjectIndex -- linked to the entPhysicalIndex of the Energy Object, the duration of measurement intervals in seconds,
(eoEnergyParametersIntervalLength), the number of successive intervals to be stored in the eoEnergyTable, (eoEnergyParametersIntervalNumber), the type of measurement technique (eoEnergyParametersIntervalMode), and a sample rate used to calculate the average (eoEnergyParametersSampleRate). Judicious choice of the sampling rate will ensure accurate measurement of energy while not imposing an excessive polling burden.

There are three eoEnergyParametersIntervalMode types used for energy measurement collection: period, sliding, and total. The choices of the three different modes of collection are based on IEC standard 61850-7-4 [IEC.61850-7-4]. Note that multiple eoEnergyParametersIntervalMode types MAY be configured simultaneously. It is important to note that for a given Energy Object, multiple modes (periodic, total, sliding window) of energy measurement collection can be configured with the use of eoEnergyParametersIndex. However, simultaneous measurement in multiple modes for a given Energy Object depends on the Energy Object capability.

These three eoEnergyParametersIntervalMode types are illustrated by the following three figures, for which:

- The horizontal axis represents the current time, with the symbol <--- L ---> expressing the eoEnergyParametersIntervalLength and the eoEnergyCollectionStartTime is represented by S1, S2, S3, S4, eoEnergyParametersIntervalNumber.

- The vertical axis represents the time interval of sampling and the value of eoEnergyConsumed can be obtained at the end of the sampling period. The symbol =========== denotes the duration of the sampling period.

```
| ========= | ========= |
| <--- L ---> | <--- L ---> |
| S1          | S2          |
```

Figure 3: Period eoEnergyParametersIntervalMode
A eoEnergyParametersIntervalMode type of 'period' specifies non-overlapping periodic measurements. Therefore, the next eoEnergyCollectionStartTime is equal to the previous eoEnergyCollectionStartTime plus eoEnergyParametersIntervalLength.

\[ S2 = S1 + L; \quad S3 = S2 + L, \ldots \]

Figure 4: Sliding eoEnergyParametersIntervalMode

A eoEnergyParametersIntervalMode type of 'sliding' specifies overlapping periodic measurements.

\[ \text{Total length} \]

Figure 5: Total eoEnergyParametersIntervalMode
An eoEnergyParametersIntervalMode type of 'total' specifies a continuous measurement since the last reset. The value of eoEnergyParametersIntervalNumber should be (1) one and eoEnergyParametersIntervalLength is ignored.

The eoEnergyParametersStatus is used to start and stop energy usage logging. The status of this variable is "active" when all the objects in eoEnergyParametersTable are appropriate, which, in turn, indicates whether or not eoEnergyTable entries exist. Finally, the eoEnergyParametersStorageType variable indicates the storage type for this row, i.e., whether the persistence is maintained across a device reload.

The eoEnergyTable consists of energy measurements of eoEnergyConsumed, eoEnergyProvided and eoEnergyStored, unit scale of measured energy with eoEnergyUnitMultiplier, percentage accuracy with eoEnergyAccuracy, and the maximum observed energy within a window in eoEnergyMaxConsumed, eoEnergyMaxProduced, and eoEnergyDiscontinuityTime.

Measurements of the total energy consumed by an Energy Object may suffer from interruptions in the continuous measurement of energy consumption. In order to indicate such interruptions, the object eoEnergyDiscontinuityTime is provided for indicating the time of the last interruption of total energy measurement. eoEnergyDiscontinuityTime shall indicate the sysUpTime [RFC3418] when the device was reset.

The following example illustrates the eoEnergyTable and eoEnergyParametersTable:

First, in order to estimate energy, a time interval to sample energy should be specified, i.e., eoEnergyParametersIntervalLength can be set to "900 seconds" or 15 minutes and the number of consecutive intervals over which the maximum energy is calculated (eoEnergyParametersIntervalNumber) as "10". The sampling rate internal to the Energy Object for measurement of power usage (eoEnergyParametersSampleRate) can be "1000 milliseconds", as set by the Energy Object as a reasonable value. Then, the eoEnergyParametersStatus is set to active to indicate that the Energy Object should start monitoring the usage per the eoEnergyTable.

The indices for the eoEnergyTable are eoEnergyParametersIndex, which identifies the index for the setting of energy measurement collection Energy Object, and eoEnergyCollectionStartTime, which denotes the start time of the energy measurement interval based on sysUpTime [RFC3418]. The value of eoEnergyConsumed is the measured energy consumption over the time interval specified
(eoEnergyParametersIntervalLength) based on the Energy Object internal sampling rate (eoEnergyParametersSampleRate). While choosing the values for the eoEnergyParametersIntervalLength and eoEnergyParametersSampleRate, it is recommended to take into consideration both the network element resources adequate to process and store the sample values and the mechanism used to calculate the eoEnergyConsumed. The units are derived from eoEnergyUnitMultiplier. For example, eoEnergyConsumed can be "100" with eoEnergyUnitMultiplier equal to 0, the measured energy consumption of the Energy Object is 100 watt-hours. The eoEnergyMaxConsumed is the maximum energy observed and that can be "150 watt-hours".

The eoEnergyTable has a buffer to retain a certain number of intervals, as defined by eoEnergyParametersIntervalNumber. If the default value of "10" is kept, then the eoEnergyTable contains 10 energy measurements, including the maximum.

Here is a brief explanation of how the maximum energy can be calculated. The first observed energy measurement value is taken to be the initial maximum. With each subsequent measurement, based on numerical comparison, maximum energy may be updated. The maximum value is retained as long as the measurements are taking place. Based on periodic polling of this table, an NMS could compute the maximum over a longer period, e.g., a month, 3 months, or a year.

5.7. Fault Management

[RFC6988] specifies requirements about Power States such as "the current Power State", "the time of the last state change", "the total time spent in each state", "the number of transitions to each state", etc. Some of these requirements are fulfilled explicitly by MIB objects such as eoPowerOperState, eoPowerStateTotalTime, and eoPowerStateEnterCount. Some of the other requirements are met via the SNMP NOTIFICATION mechanism. eoPowerStateChange SNMP notification which is generated when the value of oPowerStateIndex, eoPowerOperState, or eoPowerAdminState have changed.

6. Discovery

It is probable that most Energy Objects will require the implementation of the ENERGY-OBJECT-CONTEXT-MIB [RFC7461] as a prerequisite for this MIB module. In such a case, the eoPowerTable of the EMAN-ENERGY-OBJECT-MIB is cross-referenced with the eoTable of ENERGY-OBJECT-CONTEXT-MIB via entPhysicalIndex. Every Energy Object MUST implement entPhysicalIndex, entPhysicalClass, entPhysicalName, and entPhysicalUUID from the ENTITY-MIB [RFC6933]. As the primary
index for the Energy Object, entPhysicalIndex is used: it characterizes the Energy Object in the ENERGY-OBJECT-MIB and the POWER-ATTRIBUTES-MIB MIB modules (this document).

The NMS must first poll the ENERGY-OBJECT-CONTEXT-MIB MIB module [RFC7461], if available, in order to discover all the Energy Objects and the relationships between those Energy Objects. In the ENERGY-OBJECT-CONTEXT-MIB module tables, the Energy Objects are indexed by the entPhysicalIndex.

From there, the NMS must poll the eoPowerStateTable (specified in the ENERGY-OBJECT-MIB module in this document), which enumerates, amongst other things, the maximum power usage. As the entries in eoPowerStateTable table are indexed by the Energy Object (entPhysicalIndex) and by the Power State Set (eoPowerStateIndex), the maximum power usage is discovered per Energy Object, and the power usage per Power State of the Power State Set. In other words, reading the eoPowerStateTable allows the discovery of each Power State within every Power State Set supported by the Energy Object.

The MIB module may be populated with the Energy Object relationship information, which have its own Energy Object index value (entPhysicalIndex). However, the Energy Object relationship must be discovered via the ENERGY-OBJECT-CONTEXT-MIB module.

Finally, the NMS can monitor the power attributes with the POWER-ATTRIBUTES-MIB MIB module, which reuses the entPhysicalIndex to index the Energy Object.

7. Link with the Other IETF MIBs

7.1. Link with the ENTITY-MIB and the ENTITY-SENSOR MIB

[RFC6933] defines the ENTITY-MIB module that lists the physical entities of a networking device (router, switch, etc.) and those physical entities indexed by entPhysicalIndex. From an energy-management standpoint, the physical entities that consume or produce energy are of interest.

[RFC3433] defines the ENTITY-SENSOR MIB module that provides a standardized way of obtaining information (current value of the sensor, operational status of the sensor, and the data-unit precision) from sensors embedded in networking devices. Sensors are associated with each index of the entPhysicalIndex of the ENTITY-MIB [RFC6933]. While the focus of the Monitoring and Control MIB for Power and Energy is on measurement of power usage of networking equipment indexed by the ENTITY-MIB, this MIB supports a customized
power scale for power measurement and different Power States of networking equipment and the functionality to configure the Power States.

The Energy Objects are modeled by the entPhysicalIndex through the entPhysicalEntity MIB object specified in the eoTable in the ENERGY-OBJECT-CONTEXT-MIB MIB module [RFC7461].

The ENTITY-SENSOR MIB [RFC3433] does not have the ANSI C12.x accuracy classes required for electricity (e.g., 1%, 2%, and 0.5% accuracy classes). Indeed, entPhysSensorPrecision [RFC3433] represents "The number of decimal places of precision in fixed-point sensor values returned by the associated entPhysSensorValue object". The ANSI and IEC standards are used for power measurement and these standards require that we use an accuracy class, not the scientific-number precision model specified in RFC3433. The eoPowerAccuracy MIB object models this accuracy. Note that eoPowerUnitMultipler represents the scale factor per IEC 62053-21 [IEC.62053-21] and IEC 62053-22 [IEC.62053-22], which is a more logical representation for power measurements (compared to entPhysSensorScale), with the mantissa and the exponent values X * 10 ^ Y.

Power measurements specifying the qualifier 'UNITS' for each measured value in watts are used in the LLDP-EXT-MED-MIB, Power Ethernet [RFC3621], and UPS [RFC1628] MIBs. The same 'UNITS' qualifier is used for the power measurement values.

One cannot assume that the ENTITY-MIB and ENTITY-SENSOR MIBs are implemented for all Energy Objects that need to be monitored. A typical example is a converged building gateway, which can monitor other devices in a building and provides a proxy between SNMP and a protocol like BACnet. Another example is the home energy controller. In such cases, the eoPhysicalEntity value contains the zero value, using the PhysicalIndexOrZero Textual Convention.

The eoPower is similar to entPhysSensorValue [RFC3433] and the eoPowerUnitMultipler is similar to entPhysSensorScale.

7.2. Link with the ENTITY-STATE MIB

For each entity in the ENTITY-MIB [RFC6933], the ENTITY-STATE MIB [RFC4268] specifies the operational states (entStateOper: unknown, enabled, disabled, testing), the alarm (entStateAlarm: unknown, underRepair, critical, major, minor, warning, indeterminate), and the possible values of standby states (entStateStandby: unknown, hotStandby, coldStandby, providingService).
From a power-monitoring point of view, in contrast to the entity operational states of entities, Power States are required, as proposed in the Monitoring and Control MIB for Power and Energy. Those Power States can be mapped to the different operational states in the ENTITY-STATE MIB, if a formal mapping is required. For example, the entStateStandby "unknown", "hotStandby", and "coldStandby" states could map to the Power State "unknown", "ready", "standby", respectively, while the entStateStandby "providingService" could map to any "low" to "high" Power State.

7.3. Link with the POWER-OVER-ETHERNET MIB

The Power-over-Ethernet MIB [RFC3621] provides an energy monitoring and configuration framework for power over Ethernet devices. RFC 3621 defines a port group entity on a switch for power monitoring and management policy and does not use the entPhysicalIndex index. Indeed, pethMainPseConsumptionPower is indexed by the pethMainPseGroupIndex, which has no mapping with the entPhysicalIndex.

If the Power-over-Ethernet MIB [RFC3621] is supported, the Energy Object eoethPortIndex and eoethPortGrpIndex contain the pethPsePortIndex and pethPsePortGroupIndex, respectively. However, one cannot assume that the Power-over-Ethernet MIB is implemented for most or all Energy Objects. In such cases, the eoethPortIndex and eoethPortGrpIndex values contain the zero value, via the new PethPsePortIndexOrZero and PethPsePortGroupIndexOrZero TCs.

In either case, the entPhysicalIndex MIB object is used as the unique Energy Object index.

Note that, even though the Power-over-Ethernet MIB [RFC3621] was created after the ENTITY-SENSOR MIB [RFC3433], it does not reuse the precision notion from the ENTITY-SENSOR MIB, i.e., the entPhySensorPrecision MIB object.

7.4. Link with the UPS MIB

To protect against unexpected power disruption, data centers and buildings make use of Uninterruptible Power Supplies (UPS). To protect critical assets, a UPS can be restricted to a particular subset or domain of the network. UPS usage typically lasts only for a finite period of time, until normal power supply is restored. Planning is required to decide on the capacity of the UPS based on output power and duration of probable power outage. To properly provision UPS power in a data center or building, it is important to
first understand the total demand required to support all the entities in the site. This demand can be assessed and monitored via the Monitoring and Control MIB for Power and Energy.

The UPS MIB [RFC1628] provides information on the state of the UPS network. Implementation of the UPS MIB is useful at the aggregate level of a data center or a building. The MIB module contains several groups of variables:

- upsIdent: Identifies the UPS entity (name, model, etc.).
- upsBattery group: Indicates the battery state (upsbatteryStatus, upsEstimatedMinutesRemaining, etc.)
- upsInput group: Characterizes the input load to the UPS (number of input lines, voltage, current, etc.).
- upsOutput: Characterizes the output from the UPS (number of output lines, voltage, current, etc.).
- upsAlarms: Indicates the various alarm events.

The measurement of power in the UPS MIB is in volts, amperes, and watts. The units of power measurement are root mean square (RMS) volts and RMS amperes. They are not based on the EntitySensorDataScale and EntitySensorDataPrecision of ENTITY-SENSOR-MIB.

Both the Monitoring and Control MIB for Power and Energy and the UPS MIB may be implemented on the same UPS SNMP agent, without conflict. In this case, the UPS device itself is the Energy Object and any of the UPS meters or submeters are the Energy Objects with a possible relationship as defined in [RFC7326].

7.5. Link with the LLDP and LLDP-MED MIBs

The Link Layer Discovery Protocol (LLDP) is a Data Link Layer protocol used by network devices to advertise their identities, capabilities, and interconnections on a LAN network.

The Media Endpoint Discovery is an enhancement of LLDP, known as LLDP-MED. The LLDP-MED enhancements specifically address voice applications. LLDP-MED covers six basic areas: capability discovery, LAN speed and duplex discovery, network policy discovery, location identification discovery, inventory discovery, and power discovery.
Of particular interest to the current MIB module is the power
discovery, which allows the endpoint device (such as a PoE phone) to
convey power requirements to the switch. In power discovery,
LLDP-MED has four Type-Length-Values (TLVs): power
type, power
source, power priority, and power value. Respectively, those TLVs
provide information related to the type of power (power sourcing
entity versus powered device), how the device is powered (from the
line, from a backup source, from external power source, etc.), the
power priority (how important is it that this device has power?), and
how much power the device needs.

The power priority specified in the LLDP-MED MIB [LLDP-MED-MIB]
actually comes from the Power-over-Ethernet MIB [RFC3621]. If the
Power-over-Ethernet MIB [RFC3621] is supported, the exact value from
the pethPsePortPowerPriority [RFC3621] is copied over into the
lldpXMedRemXPoEPDPowerPriority [LLDP-MED-MIB]; otherwise, the value
in lldpXMedRemXPoEPDPowerPriority is "unknown". From the Monitoring
and Control MIB for Power and Energy, it is possible to identify the
pethPsePortPowerPriority [RFC3621], via the eoethPortIndex and
eoethPortGrpIndex.

The lldpXMedLocXPoEPDPowerSource [LLDP-MED-MIB] is similar to
eoPowerMeasurementLocal in indicating if the power for an attached
device is local or from a remote device. If the LLDP-MED MIB is
supported, the following mapping can be applied to the
eoPowerMeasurementLocal: lldpXMedLocXPoEPDPowerSource fromPSE(2) and
local(3) can be mapped to false and true, respectively.

8. Structure of the MIB

The primary MIB object in the energyObjectMib MIB module is the
energyObjectMibObjects root. The eoPowerTable table of
energyObjectMibObjects describes the power measurement attributes of
an Energy Object entity. The identity of a device in terms of
uniquely identification of the Energy Object and its relationship to
other entities in the network are addressed in [RFC7461].

Logically, this MIB module is a sparse extension of the ENERGY-
OBJECT-CONTEXT-MIB module [RFC7461]. Thus, the following
requirements that are applied to [RFC7461] are also applicable. As a
requirement for this MIB module, [RFC7461] SHOULD be implemented and
as Module Compliance of ENTITY-MIB V4 [RFC6933] with respect to
entity4CRCCompliance MUST be supported, which requires four MIB
objects: entPhysicalIndex, entPhysicalClass, entPhysicalName, and
entPhysicalUUID MUST be implemented.
The eoMeterCapabilitiesTable is useful to enable applications to determine the capabilities supported by the local management agent. This table indicates the energy-monitoring MIB groups that are supported by the local management system. By reading the value of this object, it is possible for applications to know which tables contain the information and are usable without walking through the table and querying every element that involves a trial-and-error process.

The power measurement of an Energy Object contains information describing its power usage (eoPower) and its current Power State (eoPowerOperState). In addition to power usage, additional information describing the units of measurement (eoPowerAccuracy, eoPowerUnitMultiplier), how power usage measurement was obtained (eoPowerMeasurementCaliber), the source of power measurement (eoPowerMeasurementLocal), and the type of power (eoPowerCurrentType) are described.

An Energy Object may contain an optional eoEnergyTable to describe energy measurement information over time.

An Energy Object may contain an optional eoACPwrAttributesTable table (specified in the POWER-ATTRIBUTES-MIB module) that describes the electrical characteristics associated with the current Power State and usage.

An Energy Object may also contain optional battery information associated with this entity.

9. MIB Definitions

9.1. The IANAPowerStateSet-MIB Module

-- *****************************************************
--
-- This MIB, maintained by IANA, contains a single Textual
-- Convention: PowerStateSet
--
-- *****************************************************

IANAPowerStateSet-MIB DEFINITIONS ::= BEGIN

IMPORTS
    MODULE-IDENTITY, mib-2 FROM SNMPv2-SMI
    TEXTUAL-CONVENTION FROM SNMPv2-TC;

ianaPowerStateSet MODULE-IDENTITY
PowerStateSet ::= TEXTUAL-CONVENTION

STATUS current
DESCRIPTION
"IANAPowerState is a textual convention that describes Power State Sets and Power State Set Values an Energy Object supports. IANA has created a registry of Power State supported by an Energy Object and IANA shall administer the list of Power State Sets and Power States."
The Textual Convention assumes that Power States in a Power State Set are limited to 255 distinct values. For a Power State Set S, the named number with the value S * 256 is allocated to indicate the Power State Set. For a Power State X in the Power State Set S, the named number with the value S * 256 + X + 1 is allocated to represent the Power State.

Requests for new values should be made to IANA via email (iana@iana.org).

REFERENCE
"http://www.iana.org/assignments/power-state-sets"

SYNTAX INTEGER {
  other(0),             -- indicates other set
  unknown(255),        -- unknown
  ieee1621(256),       -- indicates IEEE1621 set
  ieee1621Off(257),
  ieee1621Sleep(258),
  ieee1621On(259),
  dmtf(512),           -- indicates DMTF set
  dmtfOn(513),
  dmtfSleepLight(514),
  dmtfSleepDeep(515),
  dmtfOffHard(516),
  dmtfOffSoft(517),
  dmtfHibernate(518),
  dmtfPowerOffSoft(519),
  dmtfPowerOffHard(520),
  dmtfMasterBusReset(521),
  dmtfDiagnosticInterrupt(522),
  dmtfOffSoftGraceful(523),
  dmtfOffHardGraceful(524),
  dmtfMasterBusResetGraceful(525),
  dmtfPowerCycleOffSoftGraceful(526),
  dmtfPowerCycleHardGraceful(527),
  eman(1024),          -- indicates EMAN set
  emanMechOff(1025),
  emanSoftOff(1026),
  emanHibernate(1027),
  emanSleep(1028),
  emanStandby(1029),
  emanReady(1030),
  emanLowMinus(1031),
  emanLow(1032),
}
9.2. The ENERGY-OBJECT-MIB MIB Module

--  ************************************************************
--  "This MIB is used to monitor power usage of network devices"
--  ************************************************************

ENERGY-OBJECT-MIB DEFINITIONS ::= BEGIN

IMPORTS
  MODULE-IDENTITY,
  OBJECT-TYPE,
  NOTIFICATION-TYPE,
  mib-2,
  Integer32, Counter32, Unsigned32, TimeTicks
  FROM SNMPv2-SMI
  TEXTUAL-CONVENTION, RowStatus, TimeInterval,
  TimeStamp, TruthValue, StorageType
  FROM SNMPv2-TC
  MODULE-COMPLIANCE, NOTIFICATION-GROUP, OBJECT-GROUP
  FROM SNMPv2-CONF
  OwnerString
  FROM RMON-MIB
  entPhysicalIndex
  FROM ENTITY-MIB
  PowerStateSet
  FROM IANAPowerStateSet-MIB;

energyObjectMib MODULE-IDENTITY
LAST-UPDATED  "201502090000Z"  -- 9 February 2015
ORGANIZATION  "IETF EMAN Working Group"
CONTACT-INFO
  "WG charter:
  http://datatracker.ietf.org/wg/eman/charter/"
  Mailing Lists:
  General Discussion: eman@ietf.org
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https://www.ietf.org/mailman/listinfo/eman

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DESCRIPTION
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This MIB is used to monitor power and energy in devices.

The tables eoMeterCapabilitiesTable and eoPowerTable are a sparse extension of the eoTable from the ENERGY-OBJECT-CONTEXT-MIB. As a requirement, [RFC7461] SHOULD be implemented.

Module Compliance of ENTITY-MIB v4 with respect to entity4CRCCompliance MUST be supported which requires implementation of 4 MIB objects: entPhysicalIndex, entPhysicalClass, entPhysicalName and entPhysicalUUID."

REVISION "201502090000Z" -- 9 February 2015
DESCRIPTION
"Initial version, published as RFC 7460."

::= { mib-2 229 }

energyObjectMibNotifs OBJECT IDENTIFIER
 ::= { energyObjectMib 0 }

energyObjectMibObjects OBJECT IDENTIFIER
 ::= { energyObjectMib 1 }

energyObjectMibConform OBJECT IDENTIFIER
 ::= { energyObjectMib 2 }

-- Textual Conventions

UnitMultiplier ::= TEXTUAL-CONVENTION
STATUS current
DESCRIPTION "The Unit Multiplier is an integer value that represents the IEEE 61850 Annex A units multiplier associated with the integer units used to measure the power or energy."

Chandramouli, et al. Standards Track [Page 29]
For example, when used with eoPowerUnitMultiplier, -3 represents $10^{-3}$ or milliwatts.

REFERENCE


SYNTAX INTEGER {
yocto(-24), -- $10^{-24}$
zepto(-21), -- $10^{-21}$
atto(-18), -- $10^{-18}$
femto(-15), -- $10^{-15}$
pico(-12), -- $10^{-12}$
nano(-9), -- $10^{-9}$
micro(-6), -- $10^{-6}$
milli(-3), -- $10^{-3}$
units(0), -- $10^0$
kilo(3), -- $10^3$
mega(6), -- $10^6$
giga(9), -- $10^9$
tera(12), -- $10^{12}$
peta(15), -- $10^{15}$
exa(18), -- $10^{18}$
zetta(21), -- $10^{21}$
yotta(24) -- $10^{24}$
}

-- Objects

eoMeterCapabilitiesTable OBJECT-TYPE
SYNTAX SEQUENCE OF EoMeterCapabilitiesEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION "This table is useful for helping applications determine the monitoring capabilities supported by the local management agents. It is possible for applications to know which tables are usable without going through a trial-and-error process."
::= { energyObjectMibObjects 1 }

eoMeterCapabilitiesEntry OBJECT-TYPE
SYNTAX EoMeterCapabilitiesEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION "An entry describes the metering capability of an Energy Object."
INDEX { entPhysicalIndex }
::= { eoMeterCapabilitiesTable 1 }

EoMeterCapabilitiesEntry ::= SEQUENCE {
    eoMeterCapability            BITS
}

eoMeterCapability OBJECT-TYPE
SYNTAX   BITS {
    none(0),
    powermetering(1), -- power measurement
    energymetering(2), -- energy measurement
    powerattributes(3)   -- power attributes
}
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
"An indication of the energy-monitoring capabilities supported by this agent. This object use a BITS syntax and indicates the MIB groups supported by the probe. By reading the value of this object, it is possible to determine the MIB tables supported."
::= { eoMeterCapabilitiesEntry 1 }

eoPowerTable OBJECT-TYPE
SYNTAX          SEQUENCE OF EoPowerEntry
MAX-ACCESS      not-accessible
STATUS          current
DESCRIPTION
"This table lists Energy Objects."
::= { energyObjectMibObjects 2 }

eoPowerEntry OBJECT-TYPE
SYNTAX          EoPowerEntry
MAX-ACCESS      not-accessible
STATUS          current
DESCRIPTION
"An entry describes the power usage of an Energy Object."
INDEX { entPhysicalIndex }
::= { eoPowerTable 1 }

EoPowerEntry ::= SEQUENCE {
    eoPower                         Integer32,
    eoPowerNameplate                Unsigned32,
    eoPowerUnitMultiplier           UnitMultiplier,
    eoPowerAccuracy                 Integer32,
    eoPowerMeasurementCaliber       INTEGER,
    eoPowerCurrentType              INTEGER,
    eoPowerMeasurementLocal         TruthValue,
}
eoPower OBJECT-TYPE
SYNTAX          Integer32
UNITS          "watts"
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
"This object indicates the power measured for the Energy Object. For alternating current, this value is obtained as an average over fixed number of AC cycles. This value is specified in SI units of watts with the magnitude of watts (milliwatts, kilowatts, etc.) indicated separately in eoPowerUnitMultiplier. The accuracy of the measurement is specified in eoPowerAccuracy. The direction of power flow is indicated by the sign on eoPower. If the Energy Object is consuming power, the eoPower value will be positive. If the Energy Object is producing power, the eoPower value will be negative.

The eoPower MUST be less than or equal to the maximum power that can be consumed at the Power State specified by eoPowerState.

The eoPowerMeasurementCaliber object specifies how the usage value reported by eoPower was obtained. The eoPower value must report 0 if the eoPowerMeasurementCaliber is 'unavailable'. For devices that cannot measure or report power, this option can be used."
::= { eoPowerEntry 1 }

eoPowerNameplate OBJECT-TYPE
SYNTAX          Unsigned32
UNITS          "watts"
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
"This object indicates the rated maximum consumption for the fully populated Energy Object. The nameplate power requirements are the maximum power numbers given in SI watts and, in almost all cases, are well above the expected operational consumption. Nameplate power is widely used for power provisioning. This value is specified in either units of watts or voltage and current. The units are therefore SI watts or equivalent
Volt-Amperes with the magnitude (milliwatts, kilowatts, etc.) indicated separately in eoPowerUnitMultiplier.

::= { eoPowerEntry 2 }

eoPowerUnitMultiplier OBJECT-TYPE
SYNTAX          UnitMultiplier
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
"The magnitude of watts for the usage value in eoPower and eoPowerNameplate."

::= { eoPowerEntry 3 }

eoPowerAccuracy OBJECT-TYPE
SYNTAX          Integer32 (0..10000)
UNITS           "hundredths of percent"
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
"This object indicates a percentage value, in hundredths of a percent, representing the assumed accuracy of the usage reported by eoPower. For example, the value 1010 means the reported usage is accurate to +/- 10.1 percent. This value is zero if the accuracy is unknown or not applicable based upon the measurement method.

ANSI and IEC define the following accuracy classes for power measurement:
IEC 62053-22 60044-1 class 0.1, 0.2, 0.5, 1 3.
ANSI C12.20 class 0.2, 0.5"

::= { eoPowerEntry 4 }

eoPowerMeasurementCaliber OBJECT-TYPE
SYNTAX          INTEGER  {
    unavailable(1),
    unknown(2),
    actual(3),
    estimated(4),
    static(5)
}
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
"This object specifies how the usage value reported by eoPower was obtained:

- unavailable(1): Indicates that the usage is not available. In such a case, the eoPower value must be 0 for devices that cannot measure or report power this
option can be used.

- unknown(2): Indicates that the way the usage was determined is unknown. In some cases, entities report aggregate power on behalf of another device. In such cases it is not known whether the usage reported is actual, estimated, or static.

- actual(3): Indicates that the reported usage was measured by the entity through some hardware or direct physical means. The usage data reported is not estimated or static but is the measured consumption rate.

- estimated(4): Indicates that the usage was not determined by physical measurement. The value is a derivation based upon the device type, state, and/or current utilization using some algorithm or heuristic. It is presumed that the entity’s state and current configuration were used to compute the value.

- static(5): Indicates that the usage was not determined by physical measurement, algorithm, or derivation. The usage was reported based upon external tables, specifications, and/or model information. For example, a PC Model X draws 200W, while a PC Model Y draws 210W.

::: ( eoPowerEntry 5 )

eoPowerCurrentType OBJECT-TYPE
SYNTAX INTEGER { ac(1), dc(2), unknown(3) }
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"This object indicates whether the eoPower for the Energy Object reports alternating current 'ac', direct current 'dc', or that the current type is unknown."
::: ( eoPowerEntry 6 )

eoPowerMeasurementLocal OBJECT-TYPE
SYNTAX TruthValue
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"This object indicates the source of power measurement and can be useful when modeling the power usage of
attached devices. The power measurement can be performed by the entity itself or the power measurement of the entity can be reported by another trusted entity using a protocol extension. A value of true indicates the measurement is performed by the entity, whereas false indicates that the measurement was performed by another entity.

::= { eoPowerEntry 7 }

**eoPowerAdminState** OBJECT-TYPE
SYNTAX PowerStateSet
MAX-ACCESS read-write
STATUS current
DESCRIPTION
"This object specifies the desired Power State and the Power State Set for the Energy Object. Note that other(0) is not a Power State Set and unknown(255) is not a Power State as such, but simply an indication that the Power State of the Energy Object is unknown.
Possible values of eoPowerAdminState within the Power State Set are registered at IANA. A current list of assignments can be found at <http://www.iana.org/assignments/power-state-sets>"

::= { eoPowerEntry 8 }

**eoPowerOperState** OBJECT-TYPE
SYNTAX PowerStateSet
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"This object specifies the current operational Power State and the Power State Set for the Energy Object. other(0) is not a Power State Set and unknown(255) is not a Power State as such, but simply an indication that the Power State of the Energy Object is unknown.
Possible values of eoPowerOperState within the Power State Set are registered at IANA. A current list of assignments can be found at <http://www.iana.org/assignments/power-state-sets>"

::= { eoPowerEntry 9 }

**eoPowerStateEnterReason** OBJECT-TYPE
SYNTAX OwnerString
MAX-ACCESS read-write
STATUS current
DESCRIPTION
"This string object describes the reason for the
eoPowerAdminState transition. Alternatively, this string may contain with the entity that configured this Energy Object to this Power State.

DEFVAL { "" } ::= { eoPowerEntry 10 }

eoPowerStateTable OBJECT-TYPE
SYNTAX SEQUENCE OF EoPowerStateEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
"This table enumerates the maximum power usage, in watts, for every single supported Power State of each Energy Object.

This table has cross-reference with the eoPowerTable, containing rows describing each Power State for the corresponding Energy Object. For every Energy Object in the eoPowerTable, there is a corresponding entry in this table."

 ::= { energyObjectMibObjects 3 }

eoPowerStateEntry OBJECT-TYPE
SYNTAX EoPowerStateEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
"A eoPowerStateEntry extends a corresponding eoPowerEntry. This entry displays max usage values at every single possible Power State supported by the Energy Object.

For example, given the values of a Energy Object corresponding to a maximum usage of 0 W at the state emanmechoff, 8 W at state 6 (ready), 11 W at state emanmediumMinus, and 11 W at state emanhigh:

<table>
<thead>
<tr>
<th>State</th>
<th>MaxUsage</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>emanmechoff</td>
<td>0</td>
<td>W</td>
</tr>
<tr>
<td>emansoftoff</td>
<td>0</td>
<td>W</td>
</tr>
<tr>
<td>emanhibernate</td>
<td>0</td>
<td>W</td>
</tr>
<tr>
<td>emansleep</td>
<td>0</td>
<td>W</td>
</tr>
<tr>
<td>emanstandby</td>
<td>0</td>
<td>W</td>
</tr>
<tr>
<td>emanready</td>
<td>8</td>
<td>W</td>
</tr>
<tr>
<td>emanlowMinus</td>
<td>8</td>
<td>W</td>
</tr>
<tr>
<td>emanlow</td>
<td>11</td>
<td>W</td>
</tr>
<tr>
<td>emanmediumMinus</td>
<td>11</td>
<td>W</td>
</tr>
<tr>
<td>emanmedium</td>
<td>11</td>
<td>W</td>
</tr>
<tr>
<td>emanhighMinus</td>
<td>11</td>
<td>W</td>
</tr>
</tbody>
</table>
Furthermore, this table also includes the total time in each Power State, along with the number of times a particular Power State was entered.

INDEX { entPhysicalIndex, eoPowerStateIndex }
::= { eoPowerStateTable 1 }

EoPowerStateEntry ::= SEQUENCE {
  eoPowerStateIndex              PowerStateSet,
  eoPowerStateMaxPower           Integer32,
  eoPowerStatePowerUnitMultiplier  UnitMultiplier,
  eoPowerStateTotalTime            TimeTicks,
  eoPowerStateEnterCount            Counter32
}

eoPowerStateIndex OBJECT-TYPE
SYNTAX          PowerStateSet
MAX-ACCESS      not-accessible
STATUS          current
DESCRIPTION
 "This object specifies the index of the Power State of
the Energy Object within a Power State Set. The semantics
of the specific Power State can be obtained from the
Power State Set definition."
::= { eoPowerStateEntry 1 }

eoPowerStateMaxPower OBJECT-TYPE
SYNTAX          Integer32
UNITS          "watts"
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
 "This object indicates the maximum power for the Energy
Object at the particular Power State. This value is
specified in SI units of watts with the magnitude of the
units (milliwatts, kilowatts, etc.) indicated separately
in eoPowerStatePowerUnitMultiplier. If the maximum power
is not known for a certain Power State, then the value is
encoded as 0xFFFFFFFF.

For Power States not enumerated, the value of
eoPowerStateMaxPower might be interpolated by using the
next highest supported Power State."
::= { eoPowerStateEntry 2 }
eoPowerStatePowerUnitMultiplier OBJECT-TYPE
SYNTAX          UnitMultiplier
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
"The magnitude of watts for the usage value in
eoPowerStateMaxPower."
::= { eoPowerStateEntry 3 }

eoPowerStateTotalTime OBJECT-TYPE
SYNTAX      TimeTicks
MAX-ACCESS  read-only
STATUS      current
DESCRIPTION
"This object indicates the total time in hundredths
of a second that the Energy Object has been in this power
state since the last reset, as specified in the
sysUpTime."
::= { eoPowerStateEntry 4 }

eoPowerStateEnterCount OBJECT-TYPE
SYNTAX       Counter32
MAX-ACCESS   read-only
STATUS       current
DESCRIPTION
"This object indicates how often the Energy Object has
entered this power state, since the last reset of the
device as specified in the sysUpTime."
::= { eoPowerStateEntry 5 }

eoEnergyParametersTable OBJECT-TYPE
SYNTAX          SEQUENCE OF EoEnergyParametersEntry
MAX-ACCESS      not-accessible
STATUS          current
DESCRIPTION
"This table is used to configure the parameters for
energy measurement collection in the table eoEnergyTable.
This table allows the configuration of different
measurement settings on the same Energy Object.
Implementation of this table only makes sense for Energy
Objects that an eoPowerMeasurementCaliber of actual."
::= { energyObjectMibObjects 4 }

eoEnergyParametersEntry OBJECT-TYPE
SYNTAX       EoEnergyParametersEntry
MAX-ACCESS   not-accessible
STATUS       current
DESCRIPTION
"An entry controls an energy measurement in
eoEnergyTable."
INDEX { entPhysicalIndex, eoEnergyParametersIndex }
::= { eoEnergyParametersTable 1 }

EoEnergyParametersEntry ::= SEQUENCE {
  eoEnergyParametersIndex            Integer32,
  eoEnergyParametersIntervalLength   TimeInterval,
  eoEnergyParametersIntervalNumber   Unsigned32,
  eoEnergyParametersIntervalMode     INTEGER,
  eoEnergyParametersIntervalWindow   TimeInterval,
  eoEnergyParametersSampleRate       Unsigned32,
  eoEnergyParametersStorageType      StorageType,
  eoEnergyParametersStatus           RowStatus
}

eoEnergyParametersIndex OBJECT-TYPE
SYNTAX           Integer32 (1..2147483647)
MAX-ACCESS       not-accessible
STATUS           current
DESCRIPTION
"This object specifies the index of the Energy Parameters
setting for collection of energy measurements for an
Energy Object.  An Energy Object can have multiple
eoEnergyParametersIndex, depending on the capabilities of
the Energy Object"
::= { eoEnergyParametersEntry 2 }

eoEnergyParametersIntervalLength OBJECT-TYPE
SYNTAX          TimeInterval
MAX-ACCESS      read-create
STATUS          current
DESCRIPTION
"This object indicates the length of time in hundredths
of a second over which to compute the average
eoEnergyConsumed measurement in the eoEnergyTable table.
The computation is based on the Energy Object’s internal
sampling rate of power consumed or produced by the Energy
Object.  The sampling rate is the rate at which the Energy
Object can read the power usage and may differ based on
device capabilities.  The average energy consumption is
then computed over the length of the interval.  The
default value of 15 minutes is a common interval used in
industry."
DEFVAL { 90000 }
::= { eoEnergyParametersEntry 3 }

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eoEnergyParametersIntervalNumber OBJECT-TYPE
SYNTAX          Unsigned32
MAX-ACCESS      read-create
STATUS          current
DESCRIPTION
"The number of intervals maintained in the eoEnergyTable. Each interval is characterized by a specific
eoEnergyCollectionStartTime, used as an index to the
table eoEnergyTable. Whenever the maximum number of
entries is reached, the measurement over the new interval
replaces the oldest measurement. There is one exception
to this rule: when the eoEnergyMaxConsumed and/or
eoEnergyMaxProduced are in (one of) the two oldest
measurement(s), they are left untouched and the next
oldest measurement is replaced."
DEFVAL { 10 }
 ::= { eoEnergyParametersEntry 4 }

eoEnergyParametersIntervalMode OBJECT-TYPE
SYNTAX          INTEGER  {
                   period(1),
                   sliding(2),
                   total(3)
                   }
MAX-ACCESS      read-create
STATUS          current
DESCRIPTION
"A control object to define the mode of interval
calculation for the computation of the average
eoEnergyConsumed or eoEnergyProvided measurement in the
eoEnergyTable table.

A mode of period(1) specifies non-overlapping periodic
measurements.

A mode of sliding(2) specifies overlapping sliding
windows where the interval between the start of one
interval and the next is defined in
eoEnergyParametersIntervalWindow.

A mode of total(3) specifies non-periodic measurement.
In this mode only one interval is used as this is a
continuous measurement since the last reset. The value of
eoEnergyParametersIntervalNumber should be (1) one and
eoEnergyParametersIntervalLength is ignored."
 ::= { eoEnergyParametersEntry 5 }
eoEnergyParametersIntervalWindow  OBJECT-TYPE
SYNTAX         TimeInterval
MAX-ACCESS      read-create
STATUS          current
DESCRIPTION
"The length of the duration window between the starting
time of one sliding window and the next starting time in
hundredths of seconds, used to compute the average of
eoEnergyConsumed, eoEnergyProvided measurements in the
eoEnergyTable table. This is valid only when the
eoEnergyParametersIntervalMode is sliding(2). The
eoEnergyParametersIntervalWindow value should be a
multiple of eoEnergyParametersSampleRate."
 ::= { eoEnergyParametersEntry 6 }

eoEnergyParametersSampleRate  OBJECT-TYPE
SYNTAX         Unsigned32
UNITS           "Milliseconds"
MAX-ACCESS      read-create
STATUS          current
DESCRIPTION
"The sampling rate, in milliseconds, at which the Energy
Object should poll power usage in order to compute the
average eoEnergyConsumed, eoEnergyProvided measurements
in the table eoEnergyTable. The Energy Object should
initially set this sampling rate to a reasonable value,
i.e., a compromise between intervals that will provide
good accuracy by not being too long, but not so short
that they affect the Energy Object performance by
requesting continuous polling. If the sampling rate is
unknown, the value 0 is reported. The sampling rate
should be selected so that
eoEnergyParametersIntervalWindow is a multiple of
eoEnergyParametersSampleRate. The default value is one
second."
DEFVAL { 1000 }
 ::= { eoEnergyParametersEntry 7 }

eoEnergyParametersStorageType  OBJECT-TYPE
SYNTAX         StorageType
MAX-ACCESS      read-create
STATUS          current
DESCRIPTION
"This variable indicates the storage type for this row."
DEFVAL { nonVolatile }
 ::= { eoEnergyParametersEntry 8 }
eoEnergyParametersStatus OBJECT-TYPE
SYNTAX RowStatus
MAX-ACCESS read-create
STATUS current
DESCRIPTION "The status of this row. The eoEnergyParametersStatus is used to start or stop energy usage logging. An entry status may not be active(1) unless all objects in the entry have an appropriate value. If this object is not equal to active, all associated usage-data logged into the eoEnergyTable will be deleted. The data can be destroyed by setting up the eoEnergyParametersStatus to destroy."
::= {eoEnergyParametersEntry 9 }

eoEnergyTable OBJECT-TYPE
SYNTAX SEQUENCE OF EoEnergyEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION "This table lists Energy Object energy measurements. Entries in this table are only created if the corresponding value of object eoPowerMeasurementCaliber is active(3), i.e., if the power is actually metered."
::= { energyObjectMibObjects 5 }

eoEnergyEntry OBJECT-TYPE
SYNTAX EoEnergyEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION "An entry describing energy measurements."
INDEX { eoEnergyParametersIndex,
    eoEnergyCollectionStartTime }
::= { eoEnergyTable 1 }

EoEnergyEntry ::= SEQUENCE {
    eoEnergyCollectionStartTime       TimeTicks,
    eoEnergyConsumed                  Unsigned32,
    eoEnergyProvided                  Unsigned32,
    eoEnergyStored                    Unsigned32,
    eoEnergyUnitMultiplier            UnitMultiplier,
    eoEnergyAccuracy                  Integer32,
    eoEnergyMaxConsumed               Unsigned32,
    eoEnergyMaxProduced               Unsigned32,
    eoEnergyDiscontinuityTime         TimeStamp
}
eoEnergyCollectionStartTime OBJECT-TYPE
SYNTAX TimeTicks
UNITS "hundredths of a second"
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION "The time (in hundredths of a second) since the network management portion of the system was last re-initialized, as specified in the sysUpTime RFC 3418. This object specifies the start time of the energy measurement sample."
REFERENCE "RFC 3418: Management Information Base (MIB) for the Simple Network Management Protocol (SNMP)"
::= { eoEnergyEntry 1 }

eoEnergyConsumed OBJECT-TYPE
SYNTAX Unsigned32
UNITS "Watt-hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION "This object indicates the energy consumed in units of watt-hours for the Energy Object over the defined interval. This value is specified in the common billing units of watt-hours with the magnitude of watt-hours (kWh, MWh, etc.) indicated separately in eoEnergyUnitMultiplier."
::= { eoEnergyEntry 2 }

eoEnergyProvided OBJECT-TYPE
SYNTAX Unsigned32
UNITS "Watt-hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION "This object indicates the energy produced in units of watt-hours for the Energy Object over the defined interval. This value is specified in the common billing units of watt-hours (kWh, MWh, etc.) indicated separately in eoEnergyUnitMultiplier."
::= { eoEnergyEntry 3 }
eoEnergyStored OBJECT-TYPE
SYNTAX       Unsigned32
UNITS        "Watt-hours"
MAX-ACCESS   read-only
STATUS       current
DESCRIPTION  "This object indicates the difference of the energy consumed and energy produced for an Energy Object in units of watt-hours for the Energy Object over the defined interval. This value is specified in the common billing units of watt-hours with the magnitude of watt-hours (kWh, MWh, etc.) indicated separately in eoEnergyUnitMultiplier."
 ::= { eoEnergyEntry 4 }

eoEnergyUnitMultiplier OBJECT-TYPE
SYNTAX       UnitMultiplier
MAX-ACCESS   read-only
STATUS       current
DESCRIPTION  "This object is the magnitude of watt-hours for the energy field in eoEnergyConsumed, eoEnergyProvided, eoEnergyStored, eoEnergyMaxConsumed, and eoEnergyMaxProduced."
 ::= { eoEnergyEntry 5 }

eoEnergyAccuracy OBJECT-TYPE
SYNTAX       Integer32 (0..10000)
UNITS        "hundredths of percent"
MAX-ACCESS   read-only
STATUS       current
DESCRIPTION  "This object indicates a percentage accuracy, in hundredths of a percent, of Energy usage reporting. eoEnergyAccuracy is applicable to all Energy measurements in the eoEnergyTable.

For example, 1010 means the reported usage is accurate to +/- 10.1 percent.

This value is zero if the accuracy is unknown."
 ::= { eoEnergyEntry 6 }

eoEnergyMaxConsumed OBJECT-TYPE
SYNTAX       Unsigned32
UNITS        "Watt-hours"
MAX-ACCESS   read-only
STATUS       current
DESCRIPTION
"This object is the maximum energy observed in eoEnergyConsumed since the monitoring started or was reinitialized. This value is specified in the common billing units of watt-hours with the magnitude of watt-hours (kWh, MWh, etc.) indicated separately in eoEnergyUnitMultiplier."
 ::= { eoEnergyEntry 7 }

eoEnergyMaxProduced OBJECT-TYPE
SYNTAX Unsigned32
UNITS "Watt-hours"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"This object is the maximum energy ever observed in eoEnergyEnergyProduced since the monitoring started. This value is specified in the units of watt-hours with the magnitude of watt-hours (kWh, MWh, etc.) indicated separately in eoEnergyEnergyUnitMultiplier."
 ::= { eoEnergyEntry 8 }

eoEnergyDiscontinuityTime OBJECT-TYPE
SYNTAX TimeStamp
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"The value of sysUpTime RFC 3418 on the most recent occasion at which any one or more of this entity’s energy counters in this table suffered a discontinuity: eoEnergyConsumed, eoEnergyProvided or eoEnergyStored. If no such discontinuities have occurred since the last re-initialization of the local management subsystem, then this object contains a zero value."
REFERENCE
"RFC 3418: Management Information Base (MIB) for the Simple Network Management Protocol (SNMP)"
 ::= { eoEnergyEntry 9 }

-- Notifications

eoPowerEnableStatusNotification
OBJECT-TYPE
SYNTAX TruthValue
MAX-ACCESS read-write
STATUS current
DESCRIPTION
   "This object controls whether the system produces notifications for eoPowerStateChange. A false value will prevent these notifications from being generated."
DEFVAL { false }
 ::= { energyObjectMibNotifs 1 }

eoPowerStateChange NOTIFICATION-TYPE
   OBJECTS {eoPowerAdminState, eoPowerOperState, eoPowerStateEnterReason}
   STATUS current
   DESCRIPTION
   "The SNMP entity generates the eoPowerStateChange when the values of eoPowerAdminState or eoPowerOperState, in the context of the Power State Set, have changed for the Energy Object represented by the entPhysicalIndex."
 ::= { energyObjectMibNotifs 2 }

-- Conformance

energyObjectMibCompliances OBJECT IDENTIFIER
 ::= { energyObjectMibConform 1 }

energyObjectMibGroups OBJECT IDENTIFIER
 ::= { energyObjectMibConform 2 }

energyObjectMibFullCompliance MODULE-COMPLIANCE
   STATUS current
   DESCRIPTION
   "When this MIB is implemented with support for read-create, then such an implementation can claim full compliance. Such devices can then be both monitored and configured with this MIB.

Module Compliance of RFC 6933 with respect to entity4CRCompliance MUST be supported, which requires implementation of four MIB objects: entPhysicalIndex, entPhysicalClass, entPhysicalName and entPhysicalUUID."
REFERENCE
   "RFC 6933: Entity MIB (Version 4)"
MODULE -- this module
MANDATORY-GROUPS {
   energyObjectMibTableGroup,
   energyObjectMibStateTableGroup,
   eoPowerEnableStatusNotificationGroup,
   energyObjectMibNotifGroup
}
GROUP energyObjectMibEnergyTableGroup
DESCRIPTION
"A compliant implementation does not have to implement."

GROUP energyObjectMibEnergyParametersTableGroup
DESCRIPTION
"A compliant implementation does not have to implement."

GROUP energyObjectMibMeterCapabilitiesTableGroup
DESCRIPTION
"A compliant implementation does not have to implement."
 ::= { energyObjectMibCompliances 1 }

energyObjectMibReadOnlyCompliance MODULE-COMPLIANCE
STATUS current
DESCRIPTION
"When this MIB is implemented without support for read-create (i.e., in read-only mode), then such an implementation can claim read-only compliance. Such a device can then be monitored but cannot be configured with this MIB.

Module Compliance of [RFC6933] with respect to entity4CRCompliance MUST be supported which requires implementation of 4 MIB objects: entPhysicalIndex, entPhysicalClass, entPhysicalName and entPhysicalUUID."
REFERENCE
"RFC 6933: Entity MIB (Version 4)"
MODULE -- this module
MANDATORY-GROUPS {
  energyObjectMibTableGroup,
  energyObjectMibStateTableGroup,
  energyObjectMibNotifGroup
}
 ::= { energyObjectMibCompliances 2 }

-- Units of Conformance

energyObjectMibTableGroup OBJECT-GROUP
OBJECTS {
  eoPower,
  eoPowerNameplate,
  eoPowerUnitMultiplier,
  eoPowerAccuracy,
}
eoPowerMeasurementCaliber,
eoPowerCurrentType,
eoPowerMeasurementLocal,
eoPowerAdminState,
eoPowerOperState,
eoPowerStateEnterReason

}  
STATUS          current
DESCRIPTION      "This group contains the collection of all the objects related to the Energy Object."
::= { energyObjectMibGroups 1 }

energyObjectMibStateTableGroup OBJECT-GROUP
OBJECTS         {  
    eoPowerStateMaxPower,
eoPowerStatePowerUnitMultiplier,
eoPowerStateTotalTime,
eoPowerStateEnterCount
}
STATUS          current
DESCRIPTION      "This group contains the collection of all the objects related to the Power State."
::= { energyObjectMibGroups 2 }

energyObjectMibEnergyParametersTableGroup OBJECT-GROUP
OBJECTS         {  
    eoEnergyParametersIntervalLength,
eoEnergyParametersIntervalNumber,
eoEnergyParametersIntervalMode,
eoEnergyParametersIntervalWindow,
eoEnergyParametersSampleRate,
eoEnergyParametersStorageType,
eoEnergyParametersStatus
}
STATUS          current
DESCRIPTION      "This group contains the collection of all the objects related to the configuration of the Energy Table."
::= { energyObjectMibGroups 3 }

energyObjectMibEnergyTableGroup OBJECT-GROUP
OBJECTS         {  
    -- Note that object
    -- eoEnergyCollectionStartTime is not
    -- included since it is not-accessible

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eoEnergyConsumed,
eoEnergyProvided,
eoEnergyStored,
eoEnergyUnitMultiplier,
eoEnergyAccuracy,
eoEnergyMaxConsumed,
eoEnergyMaxProduced,
eoEnergyDiscontinuityTime

}\nSTATUS current
DESCRIPTION
"This group contains the collection of all the objects
related to the Energy Table."
 ::= { energyObjectMibGroups 4 }

energyObjectMibMeterCapabilitiesTableGroup OBJECT-GROUP
OBJECTS
 {   eoMeterCapability
 }\nSTATUS current
DESCRIPTION
"This group contains the object indicating the capability
of the Energy Object"
 ::= { energyObjectMibGroups 5 }

eoPowerEnableStatusNotificationGroup OBJECT-GROUP
OBJECTS
 {   eoPowerEnableStatusNotification
 }\nSTATUS current
DESCRIPTION
"The collection of objects that are used to enable
notification."
 ::= { energyObjectMibGroups 6 }

energyObjectMibNotifGroup NOTIFICATION-GROUP
NOTIFICATIONS
 {   eoPowerStateChange
 }\nSTATUS current
DESCRIPTION
"This group contains the notifications for
the Monitoring and Control MIB for Power and Energy."
 ::= { energyObjectMibGroups 7 }

END
9.3. The POWER-ATTRIBUTES-MIB MIB Module

-- ********************-----------------------------------------------
--
-- This MIB module is used to monitor power attributes of
-- networked devices with measurements.
--
-- This MIB module is an extension of energyObjectMib module.
--
-- ********************-----------------------------------------------

POWER-ATTRIBUTES-MIB DEFINITIONS ::= BEGIN

IMPORTS
   MODULE-IDENTITY,
   OBJECT-TYPE,
   mib-2,
   Integer32, Unsigned32
      FROM SNMPv2-SMI
   MODULE-COMPLIANCE,
   OBJECT-GROUP
      FROM SNMPv2-CONF
   UnitMultipler
      FROM ENERGY-OBJECT-MIB
   entPhysicalIndex
      FROM ENTITY-MIB;

powerAttributesMIB MODULE-IDENTITY
   LAST-UPDATED    "201502090000Z"    -- 9 February 2015
   ORGANIZATION    "IETF EMAN Working Group"
   CONTACT-INFO
      "WG charter:
       http://datatracker.ietf.org/wg/eman/charter/

      Mailing Lists:
      General Discussion: eman@ietf.org

      To Subscribe:
      https://www.ietf.org/mailman/listinfo/eman

      Archive:
      http://www.ietf.org/mail-archive/web/eman
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DESCRIPTION
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This MIB is used to report AC power attributes in devices. The table is a sparse augmentation of the eoPowerTable table from the energyObjectMib module. Both three-phase and single-phase power configurations are supported.

As a requirement for this MIB module, RFC 7461 SHOULD be implemented.

Module Compliance of ENTITY-MIB v4 with respect to entity4CRCompliance MUST be supported which requires implementation of four MIB objects: entPhysicalIndex, entPhysicalClass, entPhysicalName, and entPhysicalUUID."

REVISION "201502090000Z" -- 9 February 2015

DESCRIPTION
"Initial version, published as RFC 7460"

::= { mib-2 230 }

powerAttributesMIBConform OBJECT IDENTIFIER
::= { powerAttributesMIB 0 }

powerAttributesMIBObjects OBJECT IDENTIFIER
::= { powerAttributesMIB 1 }

-- Objects

eoACPwrAttributesTable OBJECT-TYPE
SYNTAX          SEQUENCE OF EoACPwrAttributesEntry
MAX-ACCESS      not-accessible
STATUS          current
DESCRIPTION
"This table contains power attributes measurements for supported entPhysicalIndex entities. It is a sparse extension of the eoPowerTable."
::= { powerAttributesMIBObjects 1 }

eoACPwrAttributesEntry OBJECT-TYPE
SYNTAX     EoACPwrAttributesEntry
MAX-ACCESS not-accessible
STATUS     current
DESCRIPTION
"This is a sparse extension of the eoPowerTable with
entries for power attributes measurements or
configuration. Each measured value corresponds to an
attribute in IEC 61850-7-4 for non-phase measurements
within the object MMXN."
INDEX { entPhysicalIndex }
::= { eoACPwrAttributesTable 1 }

EoACPwrAttributesEntry ::= SEQUENCE {
  eoACPwrAttributesConfiguration      INTEGER,
  eoACPwrAttributesAvgVoltage          Integer32,
  eoACPwrAttributesAvgCurrent          Unsigned32,
  eoACPwrAttributesFrequency           Integer32,
  eoACPwrAttributesPowerUnitMultiplier UnitMultiplier,
  eoACPwrAttributesPowerAccuracy      Integer32,
  eoACPwrAttributesTotalActivePower    Integer32,
  eoACPwrAttributesTotalReactivePower  Integer32,
  eoACPwrAttributesTotalApparentPower  Integer32,
  eoACPwrAttributesTotalPowerFactor    Integer32,
  eoACPwrAttributesThdCurrent          Integer32,
  eoACPwrAttributesThdVoltage         Integer32
}

eoACPwrAttributesConfiguration OBJECT-TYPE
SYNTAX     INTEGER {
  sngl(1),
  del(2),
  wye(3)
}
MAX-ACCESS read-only
STATUS     current
DESCRIPTION
"Configuration describes the physical configurations of
the power supply lines:

  * alternating current, single phase (SNGL)
  * alternating current, three-phase delta (DEL)
  * alternating current, three-phase Y (WYE)

Three-phase configurations can be either connected in a
triangular delta (DEL) or star Y (WYE) system. WYE
systems have a shared neutral voltage, while DEL systems
do not. Each phase is offset 120 degrees to each other."
::= { eoACPwrAttributesEntry 1 }
eoACPwrAttributesAvgVoltage OBJECT-TYPE
SYNTAX        Integer32
UNITS          "0.1 Volt AC"
MAX-ACCESS     read-only
STATUS         current
DESCRIPTION
"A measured value for average of the voltage measured
over an integral number of AC cycles. For a three-phase
system, this is the average voltage (V1+V2+V3)/3. IEC
61850-7-4 measured value attribute 'Vol'."
::= { eoACPwrAttributesEntry 2 }

eoACPwrAttributesAvgCurrent OBJECT-TYPE
SYNTAX        Unsigned32
UNITS          "amperes"
MAX-ACCESS     read-only
STATUS         current
DESCRIPTION
"A measured value for average of the current measured
over an integral number of AC cycles. For a three-phase
system, this is the average current (I1+I2+I3)/3. IEC
61850-7-4 attribute 'Amp'."
::= { eoACPwrAttributesEntry 3 }

eoACPwrAttributesFrequency OBJECT-TYPE
SYNTAX        Integer32 (4500..6500)
UNITS          "0.01 hertz"
MAX-ACCESS     read-only
STATUS         current
DESCRIPTION
"A measured value for the basic frequency of the AC
circuit. IEC 61850-7-4 attribute 'Hz'."
::= { eoACPwrAttributesEntry 4 }

eoACPwrAttributesPowerUnitMultiplier OBJECT-TYPE
SYNTAX        UnitMultiplier
MAX-ACCESS     read-only
STATUS         current
DESCRIPTION
"The magnitude of watts for the usage value in
eoACPwrAttributesTotalActivePower,
eoACPwrAttributesTotalReactivePower,
and eoACPwrAttributesTotalApparentPower measurements.
For three-phase power systems, this will also include
eoACPwrAttributesWyeActivePower,
eoACPwrAttributesWyeReactivePower, and
eoACPwrAttributesWyeApparentPower."
::= { eoACPwrAttributesEntry 5 }
eoACPwrAttributesPowerAccuracy OBJECT-TYPE
SYNTAX        Integer32 (0..10000)
UNITS         "hundredths of percent"
MAX-ACCESS    read-only
STATUS        current
DESCRIPTION   "This object indicates a percentage value, in hundredths of a
              percent, representing the presumed accuracy of active,
              reactive, and apparent power usage reporting. For
              example, 1010 means the reported usage is accurate to +/-10.1 percent. This value is zero if the accuracy is
              unknown.

              ANSI and IEC define the following accuracy classes for
              power measurement: IEC 62053-22 & 60044-1 class 0.1, 0.2,
              0.5, 1, & 3.
              ANSI C12.20 class 0.2 & 0.5"
::= { eoACPwrAttributesEntry 6 }

eoACPwrAttributesTotalActivePower OBJECT-TYPE
SYNTAX        Integer32
UNITS         "watts"
MAX-ACCESS    read-only
STATUS        current
DESCRIPTION   "A measured value of the actual power delivered to or
              consumed by the load. IEC 61850-7-4 attribute 'TotW'."
::= { eoACPwrAttributesEntry 7 }

eoACPwrAttributesTotalReactivePower OBJECT-TYPE
SYNTAX        Integer32
UNITS         "volt-amperes reactive"
MAX-ACCESS    read-only
STATUS        current
DESCRIPTION   "A measured value of the reactive portion of the apparent
              power. IEC 61850-7-4 attribute 'TotVar'."
::= { eoACPwrAttributesEntry 8 }

eoACPwrAttributesTotalApparentPower OBJECT-TYPE
SYNTAX        Integer32
UNITS         "volt-amperes"
MAX-ACCESS    read-only
STATUS        current
DESCRIPTION   "A measured value of the voltage and current that
determines the apparent power. The apparent power is the
vector sum of real and reactive power.
Note: watts and volt-amperes are equivalent units and may be combined. IEC 61850-7-4 attribute 'TotVA'.

::= { eoACPwrAttributesEntry 9 }

eoACPwrAttributesTotalPowerFactor OBJECT-TYPE
SYNTAX Integer32 (-10000..10000)
UNITS "hundredths"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"A measured value ratio of the real power flowing to the load versus the apparent power. It is dimensionless and expressed here as a percentage value in hundredths. A power factor of 100% indicates there is no inductance load and thus no reactive power. A Power Factor can be positive or negative, where the sign should be in lead/lag (IEEE) form. IEC 61850-7-4 attribute ‘TotPF’.

::= { eoACPwrAttributesEntry 10 }

eoACPwrAttributesThdCurrent OBJECT-TYPE
SYNTAX Integer32 (0..10000)
UNITS "hundredths of percent"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"A calculated value for the current total harmonic distortion (THD). Method of calculation is not specified. IEC 61850-7-4 attribute ‘ThdAmp’."

::= { eoACPwrAttributesEntry 11 }

eoACPwrAttributesThdVoltage OBJECT-TYPE
SYNTAX Integer32 (0..10000)
UNITS "hundredths of percent"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"A calculated value for the voltage total harmonic distortion (THD). The method of calculation is not specified. IEC 61850-7-4 attribute ‘ThdVol’.

::= { eoACPwrAttributesEntry 12 }

eoACPwrAttributesDelPhaseTable OBJECT-TYPE
SYNTAX SEQUENCE OF EoACPwrAttributesDelPhaseEntry
MAX-ACCESS not-accessible
STATUS current
DESCRIPTION
"This optional table describes three-phase power attributes measurements in a DEL configuration with phase-to-phase
power attributes measurements. Entities having single
phase power shall not have any entities. This is a
sparse extension of the eoACPwrAttributesTable.

These attributes correspond to measurements related to
the IEC 61850-7.4 MMXU phase and measured harmonic or
interharmonics related to the MHAI phase."
::= { powerAttributesMIBObjects 2 }

eoACPwrAttributesDelPhaseEntry OBJECT-TYPE
SYNTAX        EoACPwrAttributesDelPhaseEntry
MAX-ACCESS    not-accessible
STATUS        current
DESCRIPTION
"An entry describes power measurements of a phase in a
DEL three-phase power. Three entries are required for each
supported entPhysicalIndex entry. Voltage measurements
are provided relative to each other.

For phase-to-phase measurements, the
eoACPwrAttributesDelPhaseIndex is compared against the
following phase at +120 degrees. Thus, the possible
values are:

eoACPwrAttributesDelPhaseIndex    Next Phase Angle
       0                 120
       120                240
       240                  0
"  
INDEX { entPhysicalIndex, eoACPwrAttributesDelPhaseIndex }
::= { eoACPwrAttributesDelPhaseTable 1}

EoACPwrAttributesDelPhaseEntry ::= SEQUENCE {
  eoACPwrAttributesDelPhaseIndex                  Integer32,
  eoACPwrAttributesDelPhaseToNextPhaseVoltage    Integer32,
  eoACPwrAttributesDelThdPhaseToNextPhaseVoltage Integer32
}
eoACPwrAttributesDelPhaseIndex OBJECT-TYPE
SYNTAX        Integer32 (0..359)
MAX-ACCESS    not-accessible
STATUS        current
DESCRIPTION
"A phase angle typically corresponding to 0, 120, 240."
::= { eoACPwrAttributesDelPhaseEntry 1 }
eoACPwrAttributesDelPhaseToNextPhaseVoltage OBJECT-TYPE
SYNTAX        Integer32
UNITS           "0.1 Volt AC"
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
   "A measured value of phase to next phase voltages, where
   the next phase is IEC 61850-7-4 attribute ‘PPV’.”
::= { eoACPwrAttributesDelPhaseEntry 2 }

eoACPwrAttributesDelThdPhaseToNextPhaseVoltage OBJECT-TYPE
SYNTAX          Integer32 (0..10000)
UNITS           "hundredths of percent"
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
   "A calculated value for the voltage total harmonic
distortion for phase to next phase. Method of calculation
is not specified. IEC 61850-7-4 attribute ‘ThdPPV’.”
::= { eoACPwrAttributesDelPhaseEntry 3 }

eoACPwrAttributesWyePhaseTable OBJECT-TYPE
SYNTAX          SEQUENCE OF EoACPwrAttributesWyePhaseEntry
MAX-ACCESS      not-accessible
STATUS          current
DESCRIPTION
   "This optional table describes three-phase power attributes
measurements in a WYE configuration with phase-to-neutral
power attributes measurements. Entities having single
phase power shall not have any entities. This is a sparse
extension of the eoACPwrAttributesTable.

These attributes correspond to measurements related to
the IEC 61850-7.4 MMXU phase and measured harmonic or
interharmonics related to the MHAI phase.”
::= { powerAttributesMIBObjects 3 }

eoACPwrAttributesWyePhaseEntry OBJECT-TYPE
SYNTAX          EoACPwrAttributesWyePhaseEntry
MAX-ACCESS      not-accessible
STATUS          current
DESCRIPTION
   "This table describes measurements of a phase in a WYE
three-phase power system. Three entries are required for
each supported entPhysicalIndex entry. Voltage
measurements are relative to neutral.

Each entry describes power attributes of one phase of a
WYE three-phase power system.”
INDEX { entPhysicalIndex, eoACPwrAttributesWyePhaseIndex }
::= { eoACPwrAttributesWyePhaseTable 1 }

EoACPwrAttributesWyePhaseEntry ::= SEQUENCE {
  eoACPwrAttributesWyePhaseIndex            Integer32,
  eoACPwrAttributesWyePhaseToNeutralVoltage  Integer32,
  eoACPwrAttributesWyeCurrent              Integer32,
  eoACPwrAttributesWyeActivePower            Integer32,
  eoACPwrAttributesWyeReactivePower          Integer32,
  eoACPwrAttributesWyeApparentPower          Integer32,
  eoACPwrAttributesWyePowerFactor            Integer32,
  eoACPwrAttributesWyeThdCurrent            Integer32,
  eoACPwrAttributesWyeThdPhaseToNeutralVoltage Integer32
}

eoACPwrAttributesWyePhaseIndex OBJECT-TYPE
SYNTAX          Integer32 (0..359)
MAX-ACCESS      not-accessible
STATUS          current
DESCRIPTION
  "A phase angle typically corresponding to 0, 120, 240."
 ::= { eoACPwrAttributesWyePhaseEntry 1 }

eoACPwrAttributesWyePhaseToNeutralVoltage OBJECT-TYPE
SYNTAX          Integer32
UNIT            "0.1 Volt AC"
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
  "A measured value of phase to neutral voltage. IEC
   61850-7-4 attribute ‘PNV’." 
 ::= { eoACPwrAttributesWyePhaseEntry 2 }

eoACPwrAttributesWyeCurrent OBJECT-TYPE
SYNTAX          Integer32
UNIT            "0.1 amperes AC"
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION
  "A measured value of phase currents. IEC 61850-7-4
   attribute ‘A’." 
 ::= { eoACPwrAttributesWyePhaseEntry 3 }

eoACPwrAttributesWyeActivePower OBJECT-TYPE
SYNTAX          Integer32
UNIT            "watts"
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION

Chandramouli, et al. Standards Track [Page 59]
"A measured value of the actual power delivered to or consumed by the load with the magnitude indicated separately in eoPowerUnitMultiplier. IEC 61850-7-4 attribute 'W'."
::= { eoACPwrAttributesWyePhaseEntry 4 }

eoACPwrAttributesWyeReactivePower OBJECT-TYPE
SYNTAX Integer32
UNITS "volt-amperes reactive"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"A measured value of the reactive portion of the apparent power with the magnitude of indicated separately in eoPowerUnitMultiplier. IEC 61850-7-4 attribute 'VAr'."
::= { eoACPwrAttributesWyePhaseEntry 5 }

eoACPwrAttributesWyeApparentPower OBJECT-TYPE
SYNTAX Integer32
UNITS "volt-amperes"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"A measured value of the voltage and current determines the apparent power with the indicated separately in eoPowerUnitMultiplier. Active plus reactive power equals the total apparent power.

Note: Watts and volt-amperes are equivalent units and may be combined. IEC 61850-7-4 attribute 'VA'."
::= { eoACPwrAttributesWyePhaseEntry 6 }

eoACPwrAttributesWyePowerFactor OBJECT-TYPE
SYNTAX Integer32 (-10000..10000)
UNITS "hundredths"
MAX-ACCESS read-only
STATUS current
DESCRIPTION
"A measured value ratio of the real power flowing to the load versus the apparent power for this phase. IEC 61850-7-4 attribute 'PF'. Power Factor can be positive or negative where the sign should be in lead/lag (IEEE) form."
::= { eoACPwrAttributesWyePhaseEntry 7 }

eoACPwrAttributesWyeThdCurrent OBJECT-TYPE
SYNTAX Integer32 (0..10000)
UNITS "hundredths of percent"
MAX-ACCESS       read-only
STATUS           current
DESCRIPTION      "A calculated value for the voltage total harmonic
distortion (THD) for phase to phase. Method of
calculation is not specified.
IEC 61850-7-4 attribute 'ThdA'."
::= { eoACPwrAttributesWyePhaseEntry 8 }

eoACPwrAttributesWyeThdPhaseToNeutralVoltage OBJECT-TYPE
SYNTAX          Integer32 (0..10000)
UNITS           "hundredths of percent"
MAX-ACCESS      read-only
STATUS          current
DESCRIPTION      "A calculated value of the voltage total harmonic
distortion (THD) for phase to neutral. IEC 61850-7-4
attribute 'ThdPhV'."
::= { eoACPwrAttributesWyePhaseEntry 9 }

-- Conformance
powerAttributesMIBCompliances OBJECT IDENTIFIER
 ::= { powerAttributesMIB 2 }

cpyowerAttributesMIBGroups OBJECT IDENTIFIER
 ::= { powerAttributesMIB 3 }

powerAttributesMIBFullCompliance MODULE-COMPLIANCE
STATUS           current
DESCRIPTION      "When this MIB is implemented with support for read-
create, then such an implementation can claim full
compliance. Such devices can then be both monitored and
configured with this MIB.

Module Compliance of RFC 6933 with respect to
entity4CRCompliance MUST be supported which requires
implementation of four MIB objects: entPhysicalIndex,
extPhysicalClass, entPhysicalName, and entPhysicalUUID."
REFERENCE
"RFC 6933: Entity MIB (Version 4)"

MODULE           -- this module
MANDATORY-GROUPS {    
    powerACPwrAttributesMIBTableGroup
  }

GROUP            powerACPwrAttributesOptionalMIBTableGroup
DESCRIPTION
"A compliant implementation does not have to implement."

GROUP       powerACPwrAttributesDelPhaseMIBTableGroup
DESCRIPTION
"A compliant implementation does not have to implement."

GROUP       powerACPwrAttributesWyePhaseMIBTableGroup
DESCRIPTION
"A compliant implementation does not have to implement."
::= { powerAttributesMIBCompliances 1 }

-- Units of Conformance

powerACPwrAttributesMIBTableGroup OBJECT-GROUP
OBJECTS
{ -- Note that object entPhysicalIndex is NOT included since it is not-accessible
  eoACPwrAttributesAvgVoltage,
  eoACPwrAttributesAvgCurrent,
  eoACPwrAttributesFrequency,
  eoACPwrAttributesPowerUnitMultiplier,
  eoACPwrAttributesPowerAccuracy,
  eoACPwrAttributesTotalActivePower,
  eoACPwrAttributesTotalReactivePower,
  eoACPwrAttributesTotalApparentPower,
  eoACPwrAttributesTotalPowerFactor
}

STATUS          current
DESCRIPTION
"This group contains the collection of all the power attributes objects related to the Energy Object."
::= { powerAttributesMIBGroups  1 }

powerACPwrAttributesOptionalMIBTableGroup OBJECT-GROUP
OBJECTS
{ eoACPwrAttributesConfiguration,
  eoACPwrAttributesThdCurrent,
  eoACPwrAttributesThdVoltage
}

STATUS          current
DESCRIPTION
"This group contains the collection of all the power attributes objects related to the Energy Object."
::= { powerAttributesMIBGroups  2 }

powerACPwrAttributesDelPhaseMIBTableGroup OBJECT-GROUP

Chandramouli, et al.         Standards Track
OBJECTS

{  
  -- Note that object entPhysicalIndex and  
  -- eoACPwrAttributesDelPhaseIndex are NOT  
  -- included since they are not-accessible  
  eoACPwrAttributesDelPhaseToNextPhaseVoltage,  
  eoACPwrAttributesDelThdPhaseToNextPhaseVoltage  
}

STATUS current

DESCRIPTION
"This group contains the collection of all power  
attributes of a phase in a DEL three-phase power system."  
::= { powerAttributesMIBGroups 3 }

powerACPwrAttributesWyePhaseMIBTableGroup OBJECT-GROUP

OBJECTS

{  
  -- Note that object entPhysicalIndex and  
  -- eoACPwrAttributesWyePhaseIndex are NOT  
  -- included since they are not-accessible  
  eoACPwrAttributesWyePhaseToNeutralVoltage,  
  eoACPwrAttributesWyeCurrent,  
  eoACPwrAttributesWyeActivePower,  
  eoACPwrAttributesWyeReactivePower,  
  eoACPwrAttributesWyeApparentPower,  
  eoACPwrAttributesWyePowerFactor,  
  eoACPwrAttributesWyeThdPhaseToNeutralVoltage,  
  eoACPwrAttributesWyeThdCurrent  
}

STATUS current

DESCRIPTION
"This group contains the collection of all power  
attributes of a phase in a WYE three-phase power system."  
::= { powerAttributesMIBGroups 4 }

END

10. Security Considerations

There are a number of management objects defined in this MIB module  
with a MAX-ACCESS clause of read-write and/or read-create. Such  
objects may be considered sensitive or vulnerable in some network  
environments. The support for SET operations in a non-secure  
environment without proper protection opens devices to attack. These  
are the tables and objects and their sensitivity/vulnerability:

- Unauthorized changes to the eoPowerOperState (via the  
eoPowerAdminState ) MAY disrupt the power settings of the  
differentEnergy Objects and, therefore, the state of  
functionality of the respective Energy Objects.
- Unauthorized changes to the eoEnergyParametersTable MAY disrupt
ergy measurement in the eoEnergyTable table.

SNMP versions prior to SNMPv3 did not include adequate security.
Even if the network itself is secure (for example by using IPsec),
there is no control as to who on the secure network is allowed to
access and GET/SET (read/change/create/delete) the objects in this
MIB module.

Implementations SHOULD provide the security features described by the
SNMPv3 framework (see [RFC3410]), and implementations claiming
compliance to the SNMPv3 standard MUST include full support for
authentication and privacy via the User-based Security Model (USM)
[RFC3414] with the AES cipher algorithm [RFC3826]. Implementations
MAY also provide support for the Transport Security Model (TSM)
[RFC5591] in combination with a secure transport such as SSH
[RFC5592] or TLS/DTLS [RFC6353].

Further, deployment of SNMP versions prior to SNMPv3 is NOT
RECOMMENDED. Instead, it is RECOMMENDED to deploy SNMPv3 and to
enable cryptographic security. It is then a customer/operator
responsibility to ensure that the SNMP entity giving access to an
instance of this MIB module is properly configured to give access to
the objects only to those principals (users) that have legitimate
rights to indeed GET or SET (change/create/delete) them.

In certain situations, energy and power monitoring can reveal
sensitive information about individuals’ activities and habits.
Implementors of this specification should use appropriate privacy
protections as discussed in Section 9 of RFC 6988 and monitoring of
individuals and homes should only occur with proper authorization.

11. IANA Considerations

The MIB modules in this document use the following IANA-assigned
OBJECT IDENTIFIER values recorded in the SMI Numbers registry:

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>OBJECT IDENTIFIER value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IANAPowerStateSet-MIB</td>
<td>{ mib-2 228 }</td>
</tr>
<tr>
<td>energyObjectMIB</td>
<td>{ mib-2 229 }</td>
</tr>
<tr>
<td>powerAttributesMIB</td>
<td>{ mib-2 230 }</td>
</tr>
</tbody>
</table>
11.1. IANA-PowerStateSet-MIB Module

The initial set of Power State Sets are specified in [RFC7326]. IANA maintains a Textual Convention PowerStateSet in the IANA-PowerStateSet-MIB module (see Section 9.1), with the initial set of Power State Sets and the Power States within those Power State Sets as proposed in the [RFC7326]. The current version of PowerStateSet Textual Convention can be accessed <http://www.iana.org/assignments/power-state-sets>.

New assignments (and potential deprecation) to Power State Sets shall be administered by IANA and the guidelines and procedures are specified in [RFC7326], and will, as a consequence, update the PowerStateSet Textual Convention.

12. References

12.1. Normative References


12.2. Informative References


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Contributors

This document results from the merger of two initial proposals. The following persons made significant contributions either in one of the initial proposals or in this document:

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