

Internet Engineering Task Force (IETF)
Request for Comments: 7460
Category: Standards Track
ISSN: 2070-1721

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March 2015

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.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in [Section 2 of RFC 5741](#).

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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-n TruthValue     eoPowerMeasurementLocal(7)
|   +---rwn 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)
|

```

```

+---eoEnergyParametersEntry(1) [eoEnergyParametersIndex]
|
|   +--- --n PhysicalIndex   eoEnergyObjectIndex(1)
|   +   r-n Integer32       eoEnergyParametersIndex(2)
|   +--- rwn TimeInterval    eoEnergyParametersIntervalLength(3)
|   +--- rwn Unsigned32      eoEnergyParametersIntervalNumber(4)
|   +--- rwn INTEGER         eoEnergyParametersIntervalMode(5)
|   +--- rwn TimeInterval    eoEnergyParametersIntervalWindow(6)
|   +--- rwn Unsigned32      eoEnergyParametersSampleRate(7)
|   +--- rwn StorageType     eoEnergyParametersStorageType(8)
|   +--- rwn RowStatus       eoEnergyParametersStatus(9)
|
+eoEnergyTable(5)
|
+---eoEnergyEntry(1)
|   [eoEnergyParametersIndex,eoEnergyCollectionStartTime]
|
|   +--- r-n TimeTicks       eoEnergyCollectionStartTime(1)
|   +--- r-n Unsigned32     eoEnergyConsumed(2)
|   +--- r-n Unsigned32     eoEnergyProvided(3)
|   +--- r-n Unsigned32     eoEnergyStored(4)
|   +--- r-n UnitMultiplier eoEnergyUnitMultiplier(5)
|   +--- r-n Integer32      eoEnergyAccuracy(6)
|   +--- r-n Unsigned32     eoEnergyMaxConsumed(7)
|   +--- r-n Unsigned32     eoEnergyMaxProduced(8)
|   +--- r-n TimeTicks      eoEnergyDiscontinuityTime(9)

```

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]
|
|   +---r-n INTEGER      eoACPwrAttributesConfiguration(1)
|   +--- r-n Integer32   eoACPwrAttributesAvgVoltage(2)
|   +--- r-n Unsigned32  eoACPwrAttributesAvgCurrent(3)
|   +--- r-n Integer32   eoACPwrAttributesFrequency(4)
|   +--- r-n UnitMultiplier
|                       eoACPwrAttributesPowerUnitMultiplier(5)
|   +--- r-n Integer32   eoACPwrAttributesPowerAccuracy(6)
|   +--- r-n Integer32
|                       eoACPwrAttributesTotalActivePower(7)
|   +--- r-n Integer32
|                       eoACPwrAttributesTotalReactivePower(8)
|   +--- r-n Integer32
|                       eoACPwrAttributesTotalApparentPower(9)
|   +--- r-n Integer32
|                       eoACPwrAttributesTotalPowerFactor(10)
|   +--- r-n Integer32   eoACPwrAttributesThdCurrent(11)
|   +--- r-n Integer32   eoACPwrAttributesThdVoltage(12)
|
+eoACPwrAttributesDelPhaseTable(2)
|
+-- eoACPwrAttributesDelPhaseEntry(1)
|   |   [entPhysicalIndex, eoACPwrAttributesDelPhaseIndex]
|   |
|   +-- r-n Integer32
|   |   eoACPwrAttributesDelPhaseIndex(1)
|   +-- r-n Integer32
|   |   eoACPwrAttributesDelPhaseToNextPhaseVoltage(2)
|   +-- r-n Integer32
|   |   eoACPwrAttributesDelThdPhaseToNextPhaseVoltage(3)
|
+eoACPwrAttributesWyePhaseTable(3)
|
+-- eoACPwrAttributesWyePhaseEntry(1)
|   |   [entPhysicalIndex, eoACPwrAttributesWyePhaseIndex]
|   |
|   +-- r-n Integer32
|   |   eoACPwrAttributesWyePhaseIndex(1)
|   +-- r-n Integer32
|   |   eoACPwrAttributesWyePhaseToNeutralVoltage(2)
|   +-- r-n Integer32
|   |   eoACPwrAttributesWyeCurrent(3)
|   +-- r-n Integer32
|   |   eoACPwrAttributesWyeActivePower(4)

```



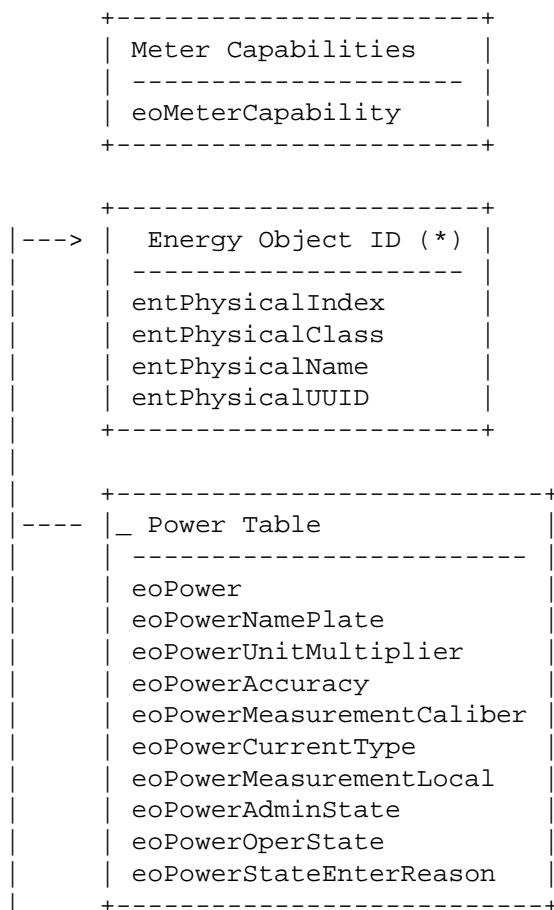
```

|      +-- r-n Integer32
|      |      eoACPwrAttributesWyeReactivePower(5)
|      +-- r-n Integer32
|      |      eoACPwrAttributesWyeApparentPower(6)
|      +-- r-n Integer32
|      |      eoACPwrAttributesWyePowerFactor(7)
|      +-- r-n Integer32
|      |      eoACPwrAttributesWyeThdCurrent(9)
|      +-- r-n Integer32
|      |      eoACPwrAttributesWyeThdPhaseToNeutralVoltage(10)

```

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.



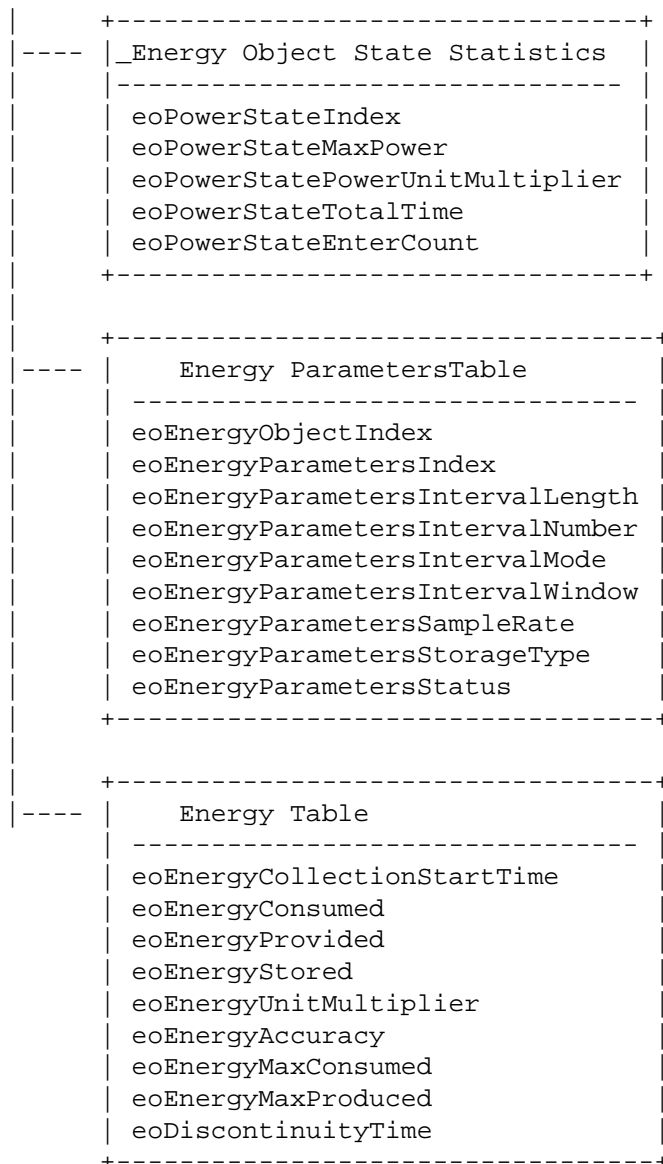


Figure 1: UML Diagram for energyObjectMib

(*) Compliance with the ENERGY-OBJECT-CONTEXT-MIB

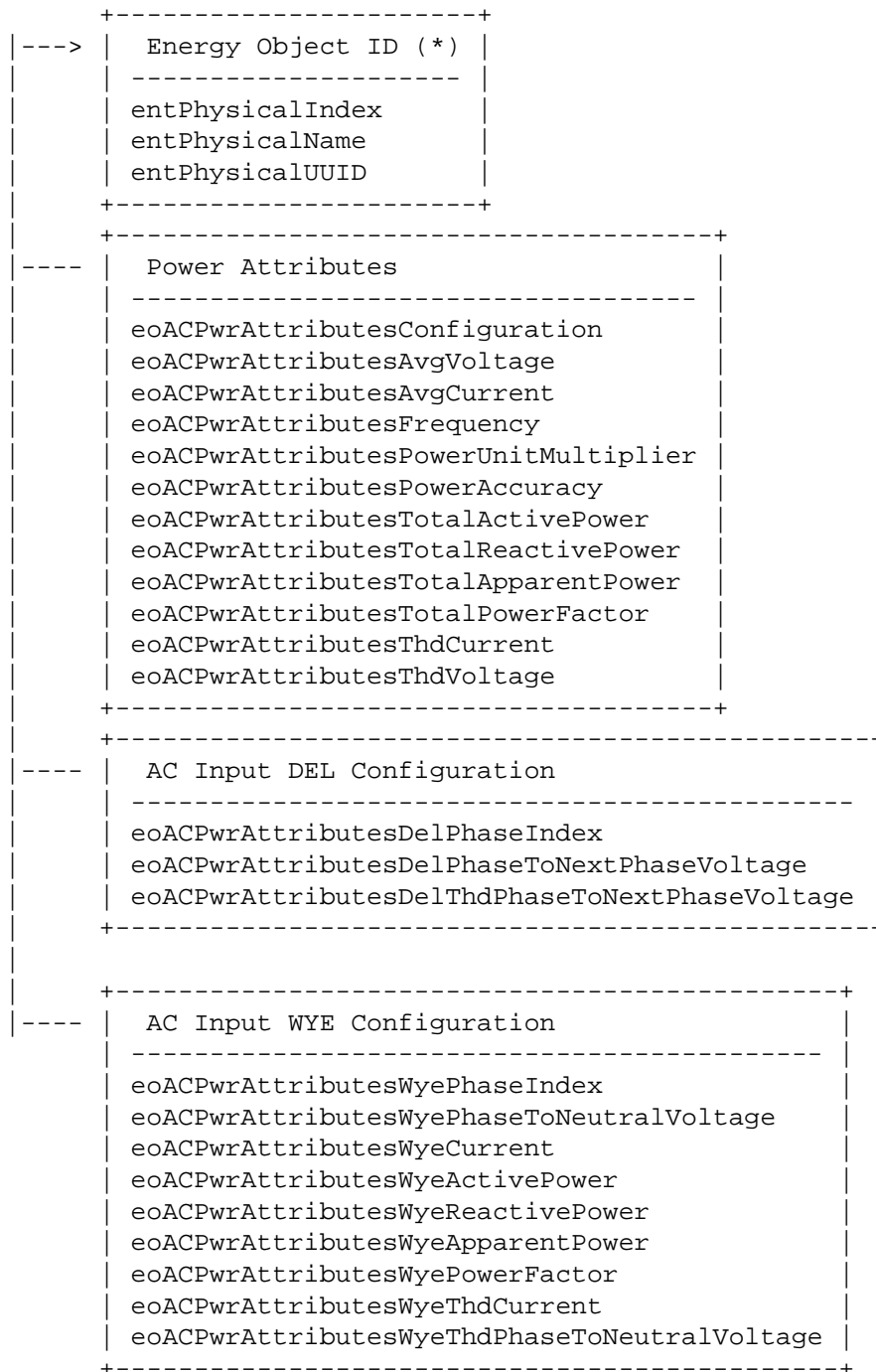


Figure 2: UML Diagram for the POWER-ATTRIBUTES-MIB

(*) 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.

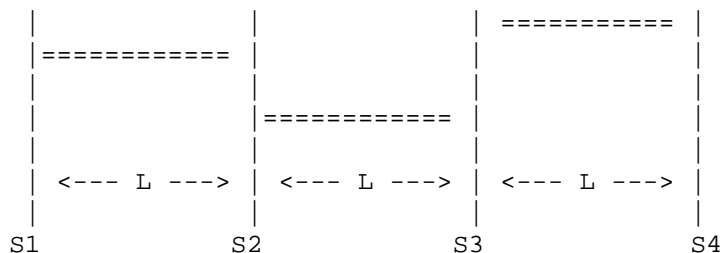


Figure 3: Period eoEnergyParametersIntervalMode

A `eoEnergyParametersIntervalMode` type of 'period' specifies non-overlapping periodic measurements. Therefore, the next `eoEnergyCollectionStartTime` is equal to the previous `eoEnergyCollectionStartTime` plus `eoEnergyParametersIntervalLength`.
 $S2 = S1 + L$; $S3 = S2 + L$, ...

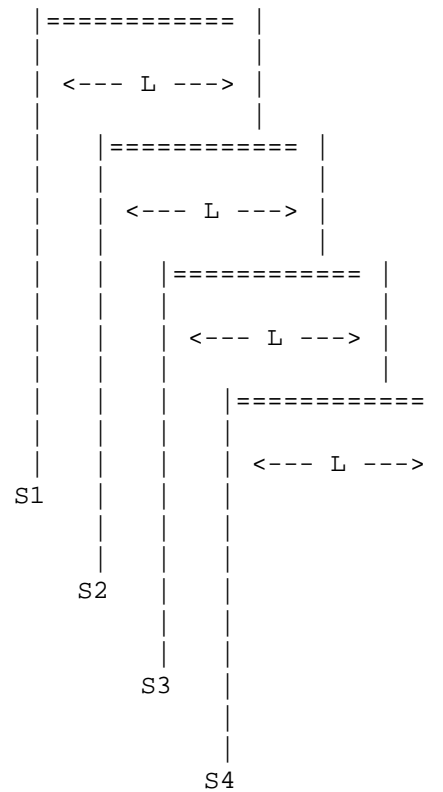


Figure 4: Sliding `eoEnergyParametersIntervalMode`

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

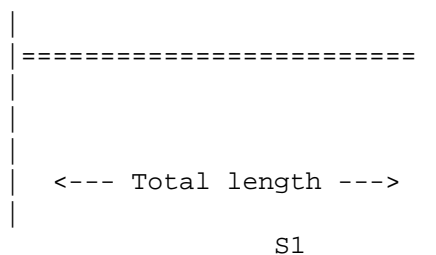


Figure 5: Total `eoEnergyParametersIntervalMode`

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, `entPhySensorPrecision` [RFC3433] represents "The number of decimal places of precision in fixed-point sensor values returned by the associated `entPhySensorValue` 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 `eoPowerUnitMultiplier` 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 `entPhySensorScale`), 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 `entPhySensorValue` [RFC3433] and the `eoPowerUnitMultiplier` is similar to `entPhySensorScale`.

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 entity4CRCompliance 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

LAST-UPDATED "201502090000Z" -- 9 February 2015
ORGANIZATION "IANA"
CONTACT-INFO "
 Internet Assigned Numbers Authority
 Postal: ICANN
 12025 Waterfront Drive, Suite 300
 Los Angeles, CA 90094
 United States
 Tel: +1-310-301 5800
 EMail: iana@iana.org"

DESCRIPTION

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This MIB module defines the PowerStateSet Textual Convention, which specifies the Power State Sets and Power State Set Values an Energy Object supports.

The initial version of this MIB module was published in [RFC 7460](#); for full legal notices see the RFC itself."

-- revision history

REVISION "201502090000Z" -- 9 February 2015

DESCRIPTION

"Initial version of this MIB module, as published as [RFC 7460](#)."

::= { mib-2 228 }

PowerStateSet ::= TEXTUAL-CONVENTION

STATUS current

DESCRIPTION

"IANA PowerState 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),
```

```
        emanMediumMinus(1033),
        emanMedium(1034),
        emanHighMinus(1035),
        emanHigh(1036)
    }
END
```

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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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 entity4CRCompliance 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.

For example, when used with eoPowerUnitMultiplier, -3 represents 10^{-3} or milliwatts."

REFERENCE

"The International System of Units (SI), National Institute of Standards and Technology, Spec. Publ. 330, August 1991."

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,

```

```

    eoPowerAdminState      PowerStateSet,
    eoPowerOperState       PowerStateSet,
    eoPowerStateEnterReason OwnerString
}

```

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:

State	MaxUsage	Units
emanmechoff	0	W
emansoftoff	0	W
emanhibernate	0	W
emansleep	0	W
emanstandby	0	W
emanready	8	W
emanlowMinus	8	W
emanlow	11	W
emanmediumMinus	11	W
emanmedium	11	W
emanhighMinus	11	W

emnanhigh 11 W

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 }

`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 with the magnitude 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
    entity4CRCCompliance 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

```



```
        eoEnergyConsumed,
        eoEnergyProvided,
        eoEnergyStored,
        eoEnergyUnitMultiplier,
        eoEnergyAccuracy,
        eoEnergyMaxConsumed,
        eoEnergyMaxProduced,
        eoEnergyDiscontinuityTime
    }
STATUS          current
DESCRIPTION
    "This group contains the collection of all the objects
    related to the Energy Table."
 ::= { energyObjectMibGroups 4 }

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

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

energyObjectMibNotifGroup NOTIFICATION-GROUP
NOTIFICATIONS    {
                    eoPowerStateChange
                }
STATUS          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
    UnitMultiplier
        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
    UNITS        "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
    UNITS        "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
    UNITS        "watts"
    MAX-ACCESS   read-only
    STATUS       current
    DESCRIPTION

```

"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 }

powerAttributesMIBGroups 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
    entity4CRCCompliance 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 {
    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

```

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 energy 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:

Descriptor -----	OBJECT IDENTIFIER value -----
IANAPowerStateSet-MIB	{ mib-2 228 }
energyObjectMIB	{ mib-2 229 }
powerAttributesMIB	{ mib-2 230 }

11.1. IANAPowerStateSet-MIB Module

The initial set of Power State Sets are specified in [RFC7326]. IANA maintains a Textual Convention PowerStateSet in the IANAPowerStateSet-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.

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Acknowledgments

The authors would like to thank Shamita Pisal for her prototype of this MIB module and her valuable feedback. The authors would like to Michael Brown for improving the text dramatically.

The authors would like to thank Juergen Schoenwalder for proposing the design of the Textual Convention for PowerStateSet and Ira McDonald for his feedback. Special appreciation to Laurent Guise for his review and input on power quality measurements. Thanks for the many comments on the design of the EnergyTable from Minoru Teraoka and Hiroto Ogaki.

Many thanks to Alan Luchuk for the detailed review of the MIB and his comments.

And finally, thanks to the EMAN chairs: Nevil Brownlee and Tom Nadeau.

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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