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Power and Energy Monitoring MIB
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Status of this Memo

Abstract

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

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].

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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 [EMAN-FMWK], which in turn, is based on the Requirements for Energy Management [EMAN-REQ].

Energy management is applicable 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.

Devices and their sub-components may be characterized by the power-related attributes of a physical entity present in the ENTITY-MIB, even though the ENTITY-MIB compliance is not a requirement due to the variety and broad base of devices concerned with energy management.

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 [EMAN-REQ]. The requirements in [EMAN-REQ] 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 is broader than that specified in [EMAN-REQ]. Several use cases for Energy Management have been identified in the

"Energy Management (EMAN) Applicability Statement" [EMAN-AS]. An illustrative example scenario is presented in Section 8.

4. Terminology

Please refer to [EMAN-FMWK] for the definitions of the following terminology used in this draft.

Device

Component

Energy Management

Energy Management System (EnMS)

ISO Energy Management System

Energy

Power

Demand

Power Characteristics

Electrical Equipment

Non-Electrical Equipment (Mechanical Equipment)

Energy Object

Electrical Energy Object

Non-Electrical Energy Object

Energy Monitoring

Energy Control

Provide Energy:

Receive Energy:

Power Interface

Power Inlet

Power Outlet

Energy Management Domain

Energy Object Identification

Energy Object Context

Energy Object Relationship

Aggregation Relationship

Metering Relationship

Power Source Relationship

Proxy Relationship

Energy Object Parent

Energy Object Child

Power State

Power State Set

Nameplate Power

5. Architecture Concepts Applied to the MIB Module

This section describes the concepts specified in the Energy Management Framework [EMAN-FMWK] that pertain to power usage, with specific information related to the MIB module specified in this document. This subsection maps to the section "Architecture High Level Concepts" in the Power Monitoring Architecture [EMAN-FMWK].

The Energy Monitoring MIB has 2 independent MIB modules. The first MIB module energyObjectMib is focused on measurement of power and energy. The second MIB module powerCharMIB is focused on Power Characteristics measurements.

The energyObjectMib MIB module consists of four tables. The first table eoPowerTable is indexed by entPhysicalIndex. The second table eoPowerStateTable indexed by entPhysicalIndex, and eoPowerStateIndex. The eoEnergyParametersTable is indexed by eoEnergyParametersIndex. The eoEnergyTable is indexed by eoEnergyParametersIndex and eoEnergyCollectionStartTime.

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

    eoPowerTable(1)
     |
     +---eoPowerEntry(1) [entPhysicalIndex]
     |   |
     |   +---r-n Integer32         eoPower(1)
     |   +-- r-n Integer32         eoPowerNamePlate(2)
     |   +-- r-n UnitMultiplier    eoPowerUnitMultiplier(3)
     |   +-- r-n Integer32         eoPowerAccuracy(4)
     |   +-- r-n INTEGER           eoMeasurementCaliber(5)
     |   +-- r-n INTEGER           eoPowerCurrentType(6)
     |   +-- r-n INTEGER           eoPowerOrigin(7)
     |   +-- rwn Integer32         eoPowerAdminState(8)
     |   +-- r-n Integer32         eoPowerOperState(9)
     |   +-- r-n OwnerString       eoPowerStateEnterReason(10)
     |   |
     |   |
     +---eoPowerStateTable(2)
     |      +--eoPowerStateEntry(1)
     |      |     [entPhysicalIndex,
     |      |      eoPowerStateIndex]
     |      |
     |      +-- --n IANAPowerStateSet  eoPowerStateIndex(1)
     |      +-- r-n Interger32         eoPowerStateMaxPower (2)
     |      +-- r-n UnitMultiplier
     |                      eoPowerStatePowerUnitMultiplier (3)
     |      +-- r-n TimeTicks          eoPowerStateTotalTime(4)
     |      +-- r-n Counter32         eoPowerStateEnterCount(5)
     |

     +eoEnergyParametersTable(1)
     +---eoEnergyParametersEntry(1) [eoEnergyParametersIndex]
     |

     |   +-- --n PhysicalIndex        eoEnergyObjectIndex (1)
     |   +   r-n Integer32            eoEnergyParametersIndex (2)
     |   +-- r-n TimeInterval
```

```
     |               eoEnergyParametersIntervalLength (3)
     |   +-- r-n Integer32
     |               eoEnergyParametersIntervalNumber (4)
     |   +-- r-n Integer32
     |               eoEnergyParametersIntervalMode (5)
     |   +-- r-n TimeInterval
     |               eoEnergyParametersIntervalWindow (6)
     |   +-- r-n Integer32
     |               eoEnergyParametersSampleRate (7)
     |   +-- r-n RowStatus  eoEnergyParametersStatus (8)
     |
     +eoEnergyTable (1)
     +---eoEnergyEntry(1) [ eoEnergyParametersIndex,
   eoEnergyCollectionStartTime]
     |
     |   +-- r-n TimeTicks     eoEnergyCollectionStartTime (1)
     |   +-- r-n Integer32     eoEnergyConsumed (2)
     |   +-- r-n Integer32     eoEnergyyProduced (3)
     |   +-- r-n Integer32     eoEnergyNet (4)
     |   +-- r-n UnitMultiplier
     |                eoEnergyUnitMultiplier (5)
     |   +-- r-n Integer32     eoEnergyAccuracy(6)
     |   +-- r-n Integer32     eoEnergyMaxConsumed (7)
     |   +-- r-n Integer32     eoEnergyMaxProduced (8)
     |   +-- r-n TimeTicks
     |                   eoEnergyDiscontinuityTime(9)
     |   +-- r-n RowStatus     eoEnergyParametersStatus (10)
```

The powerCharacteristicsMIB consists of four tables. eoACPwrCharacteristicsTable is indexed by entPhysicalIndex. eoACPwrCharacteristicsPhaseTable is indexed by entPhysicalIndex and eoPhaseIndex. eoACPwrCharacteristicsWyePhaseTable and eoACPwrCharacteristicsDelPhaseTable are indexed by entPhysicalIndex and eoPhaseIndex.

```
   eoACPwrCharacteristicsTable (1)
     |
     +---eoACPwrCharacteristicsEntry (1) [ entPhysicalIndex]
     |   |
     |   |
     |   +---r-n INTEGER      eoACPwrCharacteristicsConfiguration
   (1)
     |   +-- r-n Interger32   eoACPwrCharacteristicsAvgVoltage (2)
     |   +-- r-n Integer32    eoACPwrCharacteristicsAvgCurrent (3)
     |   +-- r-n Integer32    eoACPwrCharacteristicsFrequency  (4)
     |   +-- r-n UnitMultiplier
     |             eoACPwrCharacteristicsPowerUnitMultiplier (5)
```

```
     |   +-- r-n Integer32    eoACPwrCharacteristicsPowerAccuracy
   (6)
     |   +-- r-n Interger32
   eoACPwrCharacteristicsTotalActivePower (7)
     |   +-- r-n Integer32
     |            eoACPwrCharacteristicsTotalReactivePower (8)
     |   +-- r-n Integer32
   eoACPwrCharacteristicsTotalApparentPower (9)
     |   +-- r-n Integer32
   eoACPwrCharacteristicsTotalPowerFactor(10)
     |   +-- r-n Integer32    eoACPwrCharacteristicsThdAmpheres
   (11)
     |
     +eoACPwrCharacteristicsPhaseTable (1)
     +---EoACPwrCharacteristicsPhaseEntry(1)[ entPhysicalIndex,
     |     |                          eoPhaseIndex]
     |     |
     |     +-- r-n Integer32  eoPhaseIndex  (1)
     |     +-- r-n Integer32
     |     |          eoACPwrCharacteristicsPhaseAvgCurrent     (2)
     |     +-- r-n Integer32
     |     |          eoACPwrCharacteristicsPhaseActivePower    (3)
     |     +-- r-n Integer32
     |     |          eoACPwrCharacteristicsPhaseReactivePower  (4)
     |     +-- r-n Integer32
     |     |          eoACPwrCharacteristicsPhaseApparentPower  (5)
     |     +-- r-n Integer32
     |     |          eoACPwrCharacteristicsPhasePowerFactor    (6)
     |     +-- r-n Integer32
     |     |          eoACPwrCharacteristicsPhaseImpedance      (7)
     |     |
     +eoACPwrCharacteristicsDelPhaseTable (1)
     +-- eoACPwrCharacteristicsDelPhaseEntry(1)
     |     |                          [entPhysicalIndex,
     |     |                           eoPhaseIndex]
     |     +-- r-n Integer32
     |     |    eoACPwrCharacteristicsDelPhaseToNextPhaseVoltage
   (1)
     |     +-- r-n Integer32
     |     |   eoACPwrCharacteristicsDelThdPhaseToNextPhaseVoltage
   (2)
     |     +-- r-n Integer32  eoACPwrCharacteristicsDelThdCurrent
   (3)
     |     |
     +eoACPwrCharacteristicsWyePhaseTable (1)
     +-- eoACPwrCharacteristicsWyePhaseEntry (1)
     |     |                           [entPhysicalIndex,
     |     |                            eoPhaseIndex]
```

```
     |     +-- r-n Integer32
     |     |      eoACPwrCharacteristicsWyePhaseToNeutralVoltage
   (1)
     |     +-- r-n Integer32
     |     |     eoACPwrCharacteristicsWyePhaseCurrent (2)
     |     +-- r-n Integer32
     |     |     eoACPwrCharacteristicsWyeThdPhaseToNeutralVoltage
   (3)
     |     .
```

A UML representation of the MIB objects in the two MIB modules are energyObjectMib and powerCharacteristicsMIB are presented.

```
   +--------------------------+
   |    Energy Object ID      |
   | -----------------------  |
   |                          |
   | entPhysIndex (*)         |
   | entPhysicalName (*)      |
   | entPhysicalUUID (*)      | +---------------------------+
   |                          | |                           |
   |                          | |  Energy Object Attributes |
   |                          | | ------------------------- |
   |                          | |                           |
   +--------------------------+ | eoPowerNamePlate          |
             |                | | eoPowerMeasurementCaliber |
             |                | | eoPowerOrigin             |
             |                | | eoPowerCurrentType        |
             |                | +---------------------------+
             |                |       |
             |                |       |
             v                |       v
   +-----------------------------------------+
   |  Energy Object Measurement              |
   | --------------------------------------- |
   | eoPower                                 |
   | eoPowerUnitMultiplier                   |
   | eoPowerAccuracy                         |
   +-----------------------------------------+
             ^                 |       ^
             |                 |       |
   +-------------------------+ |       |
   |    Energy Object State  | |  +------------------------+
   | ----------------------- | |  | Energy Object State    |
```

```
   | eoPowerAdminState       | |  |    Statistics          |
   | eoPowerOperState        | |  |----------------------- |
   | eoPowerStateEnterReason | |  | eoPowerStateMaxPower   |
   +-------------------------+ |  | eoPowerStateTotalTime  |
                               |  | eoPowerStateEnterCount |
                               |  +------------------------+
                               |
                               |
                               |
                               |
```

Figure 1:UML diagram for energyObjectMib

(*)   Link with the ENTITY-MIB

```
                              |
                              |
                              V

          +---------------------------------------+
          |    Energy ParametersTable             |
          | ------------------------------------- |
          |                                       |
          |  eoEnergyObjectIndex                  |
          |  eoEnergyParametersIndex              |
          |  eoEnergyParametersIntervalLength     |
          |  eoEnergyParametersIntervalNumber     |
          |  eoEnergyParametersIntervalMode       |
          |  eoEnergyParametersIntervalWindow     |
          |  eoEnergyParametersSampleRate         |
          |  eoEnergyParametersStatus             |
          +---------------------------------------+

                              |
                              |
                              |
                              V
          +---------------------------------------+
          |    Energy Table                       |
          | ------------------------------------- |
          |  eoEnergyCollectionStartTime          |
          |  eoEnergyConsumed                     |
          |  eoEnergyProduced                     |
          |  eoEnergyNet                          |
```

```
          |  eoEnergyUnitMultiplier                 |
          |  eoEnergyAccuracy                       |
          |  eoMaxConsumed                          |
          |  eoMaxProduced                          |
          |  eoDiscontinuityTime                    |
          +-----------------------------------------+



           +---------------------------+
           |    EnergyObject ID        |
           | ----------------------    |
           |                           |
           | entPhysicalIndex   (*)    |
           |                           |
           +---------------------------+
                          |
                          v
              +---------------------------------------------+
              |  Power Characteristics                      |
              | -----------------------------------         |
              | eoACPwrCharacteristicsConfiguration         |
              | eoACPwrCharacteristicsAvgVoltage            |
              | eoACPwrCharacteristicsAvgCurrent            |
              | eoACPwrCharacteristicsFrequency             |
              | eoACPwrCharacteristicsPowerUnitMultiplier   |
              | eoACPwrCharacteristicsPowerAccuracy         |
              | eoACPwrCharacteristicsTotalActivePower      |
              | eoACPwrCharacteristicsTotalReactivePower    |
              | eoACPwrCharacteristicsTotalApparentPower    |
              | eoACPwrCharacteristicsTotalPowerFactor      |
              | eoACPwrCharacteristicsThdAmpheres           |
              +---------------------------------------------+
                               ^                   ^
                               |                   |
                               |                   -----------
                               |                             |
                               |                             |
             +---------------------------------------------+ |
             |  Power Phase Characteristics                | |
             |  ---------------------------------          | |
             | eoPhaseIndex                                | |
             | eoACPwrCharacteristicsPhaseAvgCurrent       | |
             | eoACPwrCharacteristicsAvgCurrent            | |
             | eoACPwrCharacteristicsFrequency             | |
             | eoACPwrCharacteristicsPowerUnitMultiplier   | |
```

```
             | eoACPwrCharacteristicsPowerAccuracy        |  |
             | eoACPwrCharacteristicsPhaseActivePower     |  |
             | eoACPwrCharacteristicsPhaseReactivePower   |  |
             | eoACPwrCharacteristicsPhaselApparentPower  |  |
             | eoACPwrCharacteristicsPhaseImpedance       |  |
             +--------------------------------------------+  |
                                                             |
                                                             |
                                                             |
                                                             |
                                                             |
                                                             |
           +------------------------------------------------------+
           |  AC Input DEL Configuration                          |
           |                                                      |
           | eoACPwrCharacteristicsDelPhaseToNextPhaseVoltage     |
           | eoACPwrCharacteristicsDelThdPhaseToNextPhaseVoltage  |
           | eoACPwrCharacteristicsDelThdCurrent                  |
           +------------------------------------------------------+
                                                            |
                                                            |
             +----------------------------------------------------+
             |  AC Input WYE Configuration                        |
             |                                                    |
             | eoACPwrCharacteristicsWyePhaseToNeutralVoltage     |
             | eoACPwrCharacteristicsWyePhaseCurrent              |
             | eoACPwrCharacteristicsWyeThdPhaseToNeutralVoltage  |
             +----------------------------------------------------+
```

Figure 2: UML diagram for the powerCharacteristicsMIB

(*)   Link with the ENTITY-MIB

5.1. Energy Object Information

Refer to the "Energy Object Information" section in [EMAN-FMWK] for background information. An energy aware device is considered as an instance of a Energy Object as defined in the [EMAN-FMWK].

The Energy Object identity information is specified in the MIB ENERGY-AWARE-MIB module [EMAN-AWARE-MIB] primary table, i.e. the eoTable. In this table, every Energy Object SHOULD have a printable name eoName, and MUST HAVE a unique Energy Object index entPhysicalUUID and entPhysicalIndex. The ENERGY-AWARE-MIB module returns the relationship (parent/child) between Energy Objects. There are several possible relationships between Parent and Child as defined in [EMAN-AWARE-MIB] such as MeteredBy, PoweredBy, AggregatedBy and ProxyedBy.

5.2. Power State

Refer to the "Power States" section in [EMAN-FMWK] for background information.

An Energy Object may have energy conservation modes called Power States. Between the ON and OFF states of a device, there can be several intermediate energy saving modes. Those energy saving modes are called as Power States.

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 can be attributed 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 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 MIB table.

The eoPowerStateTable table 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, PowerStateTable provides additional statistics: eoPowerStateEnterCount, the number of times an entity has visited a particular Power State, and eoPowerStateTotalTime, the total time spent in a particular Power State of an Energy Object.

5.2.1. Power State Set

There are several standards and implementations of Power State Sets. A Energy Object can support one or multiple Power State Set implementation(s) concurrently.

There are currently three Power State Sets advocated:

```
unknown(0)
IEEE1621(256) - [IEEE1621]
DMTF(512)     - [DMTF]
EMAN(1024)    - [EMAN-MONITORING-MIB]
```

The respective specific states related to each Power State Set are specified in the following sections. The guidelines for addition of new Power State Sets have been specified in the IANA Considerations Section.

5.2.2. IEEE1621 Power State Set

The IEEE1621 Power State Set [IEEE1621] consists of 3 rudimentary states : on, off or sleep.

on(0)   - The device is fully On and all features of the device are in working mode.
off(1)   - The device is mechanically switched off and does not consume energy.
sleep(2) - The device is in a power saving mode, and some features may not be available immediately.

The Textual Convention IANAPowerStateSet provides the proposed numbering of the Power States within the IEEE1621 Power State Set.

5.2.3. DMTF Power State Set

DMTF [DMTF] standards organization has defined a power profile standard based on the CIM (Common Information Model) model that consists of 15 power states ON (2), SleepLight (3), SleepDeep

(4), Off-Hard (5), Off-Soft (6), Hibernate(7), PowerCycle Off-Soft (8), PowerCycle Off-Hard (9), MasterBus reset (10), Diagnostic Interrupt (11), Off-Soft-Graceful (12), Off-Hard Graceful (13), MasterBus reset Graceful (14), Power-Cycle Off-Soft Graceful (15), PowerCycle-Hard Graceful (16). DMTF standard is targeted for hosts and computers. Details of the semantics of each Power State within the DMTF Power State Set can be obtained from the DMTF Power State Management Profile specification [DMTF].

DMTF power profile extends ACPI power states. The following table provides a mapping between DMTF and ACPI Power State Set:

DMTF Power State	ACPI Power State
Reserved(0)	
Reserved(1)	
ON (2)	G0-S0
Sleep-Light (3)	G1-S1 G1-S2
Sleep-Deep (4)	G1-S3
Power Cycle (Off-Soft) (5)	G2-S5
Off-hard (6)	G3
Hibernate (Off-Soft) (7)	G1-S4
Off-Soft (8)	G2-S5
Power Cycle (Off-Hard) (9)	G3
Master Bus Reset (10)	G2-S5
Diagnostic Interrupt (11)	G2-S5
Off-Soft Graceful (12)	G2-S5
Off-Hard Graceful (13)	G3
MasterBus Reset Graceful (14)	G2-S5
Power Cycle off-soft Graceful (15)	G2-S5

```
        ---------------------------------------------------
        | Power Cycle off-hard Graceful (16)| G3          |
        ---------------------------------------------------
```

Figure 3: DMTF and ACPI Powe State Set Mapping

The Textual Convention IANAPowerStateSet contains the proposed numbering of the Power States within the DMTF Power State Set.

5.2.4. EMAN Power State Set

The EMAN Power State Set represents an attempt for a uniform standard approach to model the different levels of power consumption of a device. The EMAN Power States are an expansion of the basic Power States as defined in IEEE1621 that also incorporate the Power States defined in ACPI and DMTF. Therefore, in addition to the non-operational states as defined in ACPI and DMTF standards, several intermediate operational states have been defined.

There are twelve Power States, that expand on IEEE1621 on, sleep and off. The expanded list of Power States are divided into six operational states, and six non-operational states. The lowest non-operational state is 1 and the highest is 6. Each non-operational state corresponds to an ACPI state [ACPI] corresponding to Global and System states between G3 (hard-off) and G1 (sleeping). For Each operational state represent a performance state, and may be mapped to ACPI states P0 (maximum performance power) through P5 (minimum performance and minimum power).

An Energy Object may have fewer Power States than twelve and would then map several policy states to the same power state. Energy Object with more than twelve states, would choose which twelve to represent as power policy states.

In each of the non-operational states (from mechoff(1) to ready(6)), the Power State preceding it is expected to have a lower power consumption and a longer delay in returning to an operational state:

IEEE1621 Power(off):

mechoff(1) : An off state where no entity features are available. The entity is unavailable. No energy is being consumed and the power

```
                           connector can be removed.  This
                           corresponds to ACPI state G3.

            softoff(2)  : Similar to mechoff(1), but some
                           components remain powered or receive
                           trace power so that the entity
                           can be awakened from its off state.  In
                           softoff(2), no context is saved and the
                           device typically requires a complete boot
                           when awakened.  This corresponds to ACPI
                           state G2.

   IEEE1621 Power(sleep)

            hibernate(3): No entity features are available.  The
                           entity may be awakened without requiring
                           a complete boot, but the time for
                           availability is longer than sleep(4). An
                           example for state hibernate(3) is a save
                           to-disk state where DRAM context is not
                           maintained. Typically, energy consumption
                           is zero or close to zero.  This
                           corresponds to state G1, S4 in ACPI.

            sleep(4)    : No entity features are available, except
                           for out-of-band management, for example
                           wake-up mechanisms. The time for
                           availability is longer than standby(5).
                           An example for state sleep(4) is a save-
                           to-RAM state, where DRAM context is
                           maintained.  Typically, energy
                           consumption is close to zero. This
                           corresponds to state G1, S3 in ACPI.

            standby(5) : No entity features are available, except
                          for out-of-band management, for example
                          wake-up mechanisms. This mode is analogous
                          to cold-standy.  The time for availability
                          is longer than ready(6).  For example, the
                          processor context is not maintained.
                          Typically, energy consumption is close to
                          zero. This corresponds to state G1, S2 in
                          ACPI.

            ready(6)    : No entity features are available, except
                           for out-of-band management, for example
                           wake-up mechanisms. This mode is
                           analogous to hot-standby.  The entity can
```

be quickly transitioned into an operational state. For example, processors are not executing, but processor context is maintained. This corresponds to state G1, S1 in ACPI.

IEEE1621 Power(on):

lowMinus(7) : Indicates some entity features may not be available and the entity has selected measures/options to provide less than low(8) usage. This corresponds to ACPI State G0. This includes operational states lowMinus(7) to full(12).

low(8) : Indicates some features may not be available and the entity has taken measures or selected options to provide less than mediumMinus(9) usage.

mediumMinus(9): Indicates all entity features are available but the entity has taken measures or selected options to provide less than medium(10) usage.

medium(10) : Indicates all entity features are available but the entity has taken measures or selected options to provide less than highMinus(11) usage.

highMinus(11): Indicates all entity features are available and power usage is less than high(12).

high(12) : Indicates all entity features are available and the entity is consuming the highest power.

The Textual Convention IANAPowerStateSet contains the proposed numbering of the Power States within the EMAN Power State Set.

5.3. Energy Object Usage Information

Refer to the "Energy Object Usage Measurement" section in [EMAN-FMWK] for background 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 Textual Convention (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 (System International) units of measure. Measured values are represented in SI units obtained by BaseValue * 10 raised to the power of the scale.

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 eoACPwrCharacteristicsPowerUnitMultiplier.

In addition to knowing the usage and magnitude, it is useful to know how a eoPower measurement was obtained. An NMS can use this to account for the accuracy and nature of the reading between different implementations. For this eoPowerOrigin 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, which may not be able to measure or report power consumption. For those devices, the object eoPowerMeasurementCaliber shall report that 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.

5.4. Optional Power Usage Characteristics

Refer to the "Optional Power Usage Characteristics" section in [EMAN-FMWK] for background information.

The optional powerCharacteristicsMIB MIB module can be implemented to further describe power usage characteristics measurement. The powerCharacteristicsMIB MIB module adheres closely to the IEC 61850 7-2 standard to describe AC measurements.

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

In case of 3-phase power, the eoACPwrCharacteristicsPhaseTable additional table is populated with Power Characteristics measurements per phase (so double indexed by the entPhysicalIndex and eoPhaseIndex). This table, which describes attributes common to both WYE and DEL configurations, contains the average current, active/reactive/apparent power, power factor, and impedance.

In case of 3-phase power with a DEL configuration, the eoACPwrCharacteristicsDelPhaseTable table describes the phase-to-phase power characteristics measurements, i.e., voltage and current.

In case of 3-phase power with a Wye configuration, the eoACPwrCharacteristicsWyePhaseTable table describes the phase-to-neutral power characteristics measurements, i.e., voltage and current.

5.5. Optional Energy Measurement

Refer to the "Optional Energy and demand Measurement" section in [EMAN-FMWK] for the definition and terminology information.

It is relevant to measure energy when there are actual power measurements from an Energy Object, and not when the power measurement is assumed or predicted as specified in the description clause of the object eoPowerMeasurementCaliber.

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. Energy information will be an accumulation with no interval. Demand information can be represented.
The eoEnergyParametersTable consists of the parameters defining eoEnergyParametersIndex, an index of that specifies the setting for collection of energy measurements for an 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 the three different modes of collection are based on IEC standard 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, ..., Sx where x is the value of eoEnergyParametersIntervalNumber.

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

```
         |             |             | =========== |
         |============ |             |             |
         |             |             |             |
         |             |============ |             |
         |             |             |             |
         | <--- L ---> | <--- L ---> | <--- L ---> |
         |             |             |             |
        S1            S2            S3             S4
```

Figure 4 : 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, ...

```
                  |============ |
                  |             |
                  | <--- L ---> |
                  |             |
                  |   |============ |
                  |   |             |
                  |   | <--- L ---> |
                  |   |             |
                  |   |   |============ |
                  |   |   |             |
                  |   |   | <--- L ---> |
                  |   |   |             |
                  |   |   |   |============ |
                  |   |   |   |             |
                  |   |   |   | <--- L ---> |
                 S1   |   |   |             |
                      |   |   |             |
                      |   |   |             |
                     S2   |   |             |
                          |   |             |
                          |   |             |
                         S3   |             |
                              |             |
                              |             |
                             S4
```

Figure 5 : Sliding eoEnergyParametersIntervalMode

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

```
   |                          |
   |========================= |
   |                          |
   |                          |
   |                          |
   |  <--- Total length --->  |
```

```
   |                          |
                 S1
```

Figure 6 : Total eoEnergyParametersIntervalMode

A 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 if eoEnergyTable entries exist or not.

The eoEnergyTable consists of energy measurements in eoEnergyConsumed, eoEnergyProduced and eoEnergyNet, the units of the measured energy eoEnergyUnitMultiplier, and the maximum observed energy within a window, eoEnergyMaxConsumed, eoEnergyMaxProduced.

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 (value 1) 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 eoEnergyComsumed 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 either 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, i.e. a month, 3 months, or a year.

5.6. Fault Management

[EMAN-REQ] 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(s) of ,eoPowerStateIndex, eoPowerOperState, eoPowerAdminState have changed.

6. Discovery

It is foreseen that most Energy Objects will require the implementation of the ENERGY-AWARE MIB [EMAN-AWARE-MIB] as a prerequisite for this MIB module. In such a case, eoPowerTable of the EMAN-MON-MIB is a sparse extension of the eoTable of ENERGY-AWARE-MIB. Every Energy Object MUST implement entPhysicalIndex, entPhysicalUUID and entPhysicalName from the ENTITY-MIB [EMAN-ENTITY]. As the primary index for the Energy Object, entPhysicalIndex is used.

The NMS must first poll the ENERGY-AWARE-MIB module [EMAN-AWARE-MIB], if available, in order to discover all the Energy Objects and the relationships between those (notion of Parent/Child). In the ENERGY-AWARE-MIB module tables, the Energy Objects are indexed by the entPhysicalIndex.

If an implementation of the ENERGY-AWARE-MIB module is available in the local SNMP context, for the same Energy Object, the entPhysicalIndex value (EMAN-AWARE-MIB) shall be used. The entPhysicalIndex characterizes the Energy Object in the energyObjectMib and the powerCharacteristicsMIB MIB modules (this document).

From there, the NMS must poll the eoPowerStateTable (specified in the energyObjectMib 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), 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, polling the eoPowerStateTable allows the discovery of each Power State within every Power State Set supported by the Energy Object.

If the Energy Object is an Aggregator or a Proxy, the MIB module would be populated with the Energy Object Parent and Children information, which have their own Energy Object index value (entPhysicalIndex). However, the parent/child relationship must be discovered thanks to the ENERGY-AWARE-MIB module.

Finally, the NMS can monitor the power characteristics thanks to the powerCharacteristicsMIB 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

RFC 4133 [RFC4133] 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.

RFC 3433 [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 units precision) from sensors embedded in networking devices. Sensors are associated with each index of entPhysicalIndex of the ENTITY-MIB [RFC4133]. While the focus of the Power and Energy Monitoring MIB is on measurement of power usage of networking equipment indexed by the ENTITY-MIB, this MIB proposes a customized power scale for power measurement and different power state states of networking equipment, and functionality to configure the power state states.

When this MIB module is used to monitor the power usage of devices like routers and switches, the ENTITY-MIB and ENTITY-SENSOR MIB SHOULD be implemented. In such cases, the Energy Objects are modeled by the entPhysicalIndex through the entPhysicalEntity MIB object specified in the eoTable in the ENERGY-AWARE-MIB MIB module [EMAN-AWARE-MIB].

However, the ENTITY-SENSOR MIB [RFC3433] does not have the ANSI C12.x accuracy classes required for electricity (i.e., 1%, 2%, 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 eoPowerUnitMultipler represents the scale factor per IEC 62053-21 [IEC.62053-21] and IEC 62053-22 [IEC.62053-22], which is a more logical representation for power measurements (compared to 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, POE

[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 MIB are implemented for all Energy Objects that need to be monitored. A typical example is a converged building gateway, monitoring several other devices in the building, doing the 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, thanks to PhysicalIndexOrZero textual convention.

The eoPower is similar to entPhySensorValue [RFC3433] and the eoPowerUnitMultipler is similar to entPhySensorScale.

7.2. Link with the ENTITY-STATE MIB

For each entity in the ENTITY-MIB [RFC4133], 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 Power and Energy Monitoring MIB module. 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", "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

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

One cannot assume that the Power-over-Ethernet MIB is implemented for all Energy Objects that need to be monitored. A typical example is a converged building gateway, monitoring several other devices in the building, doing the proxy between SNMP and a protocol like BACNET. Another example is the home energy controller. In such cases, the eoethPortIndex and eoethPortGrpIndex values contain the zero value, thanks to new PethPsePortIndexOrZero and textual PethPsePortGroupIndexOrZero conventions.

However, if the Power-over-Ethernet MIB [RFC3621] is supported, the Energy Object eoethPortIndex and eoethPortGrpIndex contain the pethPsePortIndex and pethPsePortGroupIndex, respectively.

As a consequence, the entPhysicalIndex MIB object has been kept 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 Power and Energy Monitoring MIB.

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 RMS volts and RMS Amperes. They are not based on the EntitySensorDataScale and EntitySensorDataPrecision of ENTITY-SENSOR-MIB.

Both the Power and Energy Monitoring MIB 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 Parent and any of the UPS meters or submeters are the Energy Object Children.

7.5. Link with the LLDP and LLDP-MED MIBs

The LLDP Protocol 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 6 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 in the lldpXMedRemXPoEPDPowerPriority [LLDP-MED-MIB]; otherwise the value in lldpXMedRemXPoEPDPowerPriority is "unknown". From the Power and Energy Monitoring MIB, it is possible to identify the pethPsePortPowerPriority [RFC3621], thanks to the eoethPortIndex and eoethPortGrpIndex.

The lldpXMedLocXPoEPDPowerSource [LLDP-MED-MIB] is similar to eoPowerOrigin 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 eoPowerOrigin: lldpXMedLocXPoEPDPowerSource fromPSE(2) and local(3) can be mapped to remote(2) and self(1), respectively.

8. Implementation Scenario

This section provides an illustrative example scenario for the implementation of the Energy Object, including Energy Object Parent and Energy Object Child relationships.

Example Scenario of a campus network: Switch with PoE Endpoints with further connected devices.

The campus network consists of switches that provide LAN connectivity. The switch with PoE ports is located in wiring closet. PoE IP phones are connected to the switch. The IP phones draw power from the PoE ports of the switch. In addition, a PC is daisy-chained from the IP phone for LAN connectivity.

The IP phone consumes power from the PoE switch, while the PC consumes power from the wall outlet.

The switch has implementations of ENTITY-MIB [EMAN-ENTITY] and ENERGY-AWARE MIB [EMAN-AWARE-MIB] while the PC does not have implementation of the ENTITY-MIB, but has an implementation of ENERGY-AWARE MIB [EMAN-AWARE-MIB]. The switch has the following attributes, entPhysicalIndex "1", and entPhysicalUUID "UUID 1000". The power usage of the switch is "440 Watts". The switch does not have an Energy Object Parent.

The PoE switch port has the following attributes: The switch port has entPhysicalIndex "3", and entPhysicalUUID is "UUID 1000:3". The power metered at the POE switch port is "12 watts". In this example, the POE switch port has the switch as the Energy Object Parent, with its eoParentID of "1000".

The attributes of the PC are given below. The PC does not have an entPhysicalIndex, and the entPhysicalUUID is "UUID 1000:57 ". The PC has an Energy Object Parent, i.e. the switch port whose entPhysicalUUID is "UUID 1000:3". The power usage of the PC is "120 Watts" and is communicated to the switch port.

This example illustrates the important distinction between the Energy Object Children: The IP phone draws power from the switch, while the PC has LAN connectivity from the phone, but is powered from the wall outlet. However, the Energy Object Parent sends power control messages to both the Energy Object Children (IP phone and PC) and the Children react to those messages.

```
|--------------------------------------------------------|
|                             Switch                     |
|========================================================|
|  Switch          |  Switch      | Switch      | Switch |
| entPhyIndx       |  UUID        |eoParentId   | eoPower|
| ====================================================== |
|     1            |  UUID 1000  |    null     |   440   |
| ====================================================== |
|                                                        |
|                            SWITCH PORT                 |
| ====================================================== |
| | Switch       |   Switch      | Switch      | Switch  |
| | Port         |    Port       | Port        | Port    |
| | entPhyIndx   |    UUID       | eoParentId  | eoPower |
| ====================================================== |
| |    3         | UUID 1000:3   | 1000        |  12     |
| =======================================================|
|                                   ^
|                                   |
|-----------------------------------|-------------------
                                    |
                                    |
                  POE IP PHONE      |
                                    |
                                    |
======================================================
| IP phone     | IP phone     | IP phone     |  IP phone |
| entPhyIndx   | UUID         | eoParentID   |  eoPower  |
======================================================
|  Null        | UUID 1000:31| UUID 1000:3 |  12        |
=======================================================
```

```
                                             |
                                             |
   PC connected to switch via IP phone       |
                                             |
   =====================================================
   | PC          | PC           | PC           | PC        |
   |entPhyIndx   | UUID         | eoParentID   | eoPower   |
   =====================================================
   |  7          | UUID 1000:57| UUID 1000:3 | 120        |
   =====================================================
```

Figure 1: Example scenario

9. Structure of the MIB

The primary MIB object in this MIB module is the energyObjectMibObject. The eoPowerTable table of energyObjectMibObject describes the power measurement attributes of an Energy Object entity. The notion of identity of the device in terms of uniquely identification of the Energy Object and its relationship to other entities in the network are addressed in [EMAN-AWARE-MIB].

Logically, this MIB module is a sparse extension of the [EMAN-AWARE-MIB] module. Thus the following requirements which are applied to [EMAN-AWARE-MIB] are also applicable. As a requirement for this MIB module, [EMAN-AWARE-MIB] should be implemented and as Module Compliance of ENTITY-MIB V4 [EMAN-ENTITY] with respect to entity4CRCompliance should be supported which requires 3 MIB objects (entPhysicalIndex, entPhysicalName and entPhysicalUUID) MUST be implemented.

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 which 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 (eoPowerOrigin) and the type of power (eoPowerCurrentTtype) are described.

An Energy Object may contain an optional eoPowerCharacteristics table that describes the electrical characteristics associated with the current power state and usage.

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

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

10. MIB Definitions

```
-- ************************************************************
--
--
-- 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, TimeTicks
        FROM SNMPv2-SMI
    TEXTUAL-CONVENTION, DisplayString, RowStatus, TimeInterval,
    TimeStamp
        FROM SNMPv2-TC
    MODULE-COMPLIANCE, NOTIFICATION-GROUP, OBJECT-GROUP
        FROM SNMPv2-CONF
    OwnerString
        FROM RMON-MIB
    entPhysicalIndex, PhysicalIndex
       FROM ENTITY-MIB;
```

```
   energyObjectMib MODULE-IDENTITY
        LAST-UPDATED    "201210220000Z"     -- 22 October   2012

        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

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                69115 Heidelberg
                DE
                Phone: +49 6221 4342-128
                Email: Thomas.Dietz@nw.neclab.eu

                Benoit Claise
                Cisco Systems, Inc.
                De Kleetlaan 6a b1
                Degem 1831
                Belgium
                Phone:  +32 2 704 5622
                Email: bclaise@cisco.com"

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

           This table sparse extension of the eoTable
           from the ENERGY-AWARE-MIB. As a requirement
           [EMAN-AWARE-MIB] should be implemented.


            Module Compliance of ENTITY-MIB v4
            with respect to entity4CRCompliance should
            be supported which requires implementation
            of 3 MIB objects (entPhysicalIndex,
            entPhysicalName and entPhysicalUUID)."

       REVISION
             "201210220000Z"     -- 22 October  2012

       DESCRIPTION
          "Initial version, published as RFC XXXX."

      ::= { mib-2 xxx }


   energyObjectMibNotifs OBJECT IDENTIFIER
       ::= { energyObjectMib 0 }

   energyObjectMibObjects OBJECT IDENTIFIER
       ::= { energyObjectMib 1 }

   energyObjectMibConform  OBJECT IDENTIFIER
       ::= { energyObjectMib 2 }
```

```
   -- Textual Conventions



   IANAPowerStateSet ::= TEXTUAL-CONVENTION
       STATUS  current
       DESCRIPTION

          "IANAPowerState is a textual convention that describes
   Power State Sets and Power State Set Values an Energy Object
   supports. IANA has created a registry of Power State supported
   by an Energy Object and IANA shall administer the list of Power
   State Sets and Power States.

     The textual convention assumes that power states in a power
     state set are limited to 255 distinct values. For a Power
     State Set S, the named number with the value S * 256 is
     allocated to indicate the power state set. For a Power State X
     in the Power State S, the named number with the value S * 256
     + X + 1 is allocated to represent the power state."

       REFERENCE
          "http://www.iana.org/assignments/eman
     RFC EDITOR NOTE: please change the previous URL if this is
     not the correct one after IANA assigned it."

       SYNTAX      INTEGER {
                      other(0),        -- indicates other set
                      unknown(255),    -- unknown power state

                      ieee1621(256), -- indicates IEEE1621 set
                      ieee1621On(257),
                      ieee1621Off(258),
                      ieee1621Sleep(259),

                      dmtf(512),   -- indicates DMTF set
                      dmtfOn(513),
                      dmtfSleepLight(514),
                      dmtfSleepDeep(515),
                      dmtfOffHard(516),
                      dmtfOffSoft(517),
                      dmtfHibernate(518),
                      dmtfPowerOffSoft(519),
                      dmtfPowerOffHard(520),
                      dmtfMasterBusReset(521),
                      dmtfDiagnosticInterrapt(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)
                  }

   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
               powercharacteristics(3)  -- power characteristics
                     }
            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 indicate 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                 Integer32,
           eoPowerUnitMultiplier            UnitMultiplier,
           eoPowerAccuracy                  Integer32,
           eoPowerMeasurementCaliber        INTEGER,
           eoPowerCurrentType               INTEGER,
           eoPowerOrigin                    INTEGER,
           eoPowerAdminState                IANAPowerStateSet,
           eoPowerOperState                 IANAPowerStateSet,
           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 specfied 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 can not measure or
          report power, this option can be used."
       ::= { eoPowerEntry 1  }


   eoPowerNameplate OBJECT-TYPE
       SYNTAX          Integer32
       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 and, in almost
          all cases, are well above the expected operational
          consumption.  The eoPowerNameplate 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 100ths 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),
                           presumed(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 can not 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(2), estimated(3) or presumed (4).
```

```
          - 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 presumed
          (4) or estimated (3) but the real apparent current energy
          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.

         - presumed(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 eoUsage for the
          Energy Object reports alternative current AC(1), direct
          current DC(2), or that the current type is unknown(3)."
     ::= { eoPowerEntry 6  }

   eoPowerOrigin  OBJECT-TYPE
       SYNTAX          INTEGER  {
                           self (1),
                           remote (2)
                       }
       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 self(1) indicates the
          measurement is performed by the entity, whereas remote(2)
          indicates that the measurement was performed by another
          entity."
       ::= { eoPowerEntry 7  }

   eoPowerAdminState OBJECT-TYPE
       SYNTAX          IANAPowerStateSet
       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/eman>
           RFC-EDITOR: please check the location after IANA"
       ::= { eoPowerEntry 8  }

   eoPowerOperState OBJECT-TYPE
       SYNTAX          IANAPowerStateSet
       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 eoPowerAdminState within the Power
           State Set are registered at IANA.
           A current list of assignments can be found at
           <http://www.iana.org/assignments/eman>
           RFC-EDITOR: please check the location after IANA"

       ::= { eoPowerEntry 9    }

   eoPowerStateEnterReason OBJECT-TYPE
        SYNTAX     OwnerString
        MAX-ACCESS read-create
```

```
        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 an expansion-dependent relationship on 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 11W at the
          state 1 (mechoff), 6 (ready), 8 (mediumMinus), 12 (High):

               State         MaxUsage Units
                1 (mechoff       0       W
                2 (softoff)      0       W
                3 (hibernate)    0       W
                4 (sleep)        0       W
                5 (standby)      0       W
                6 (ready)        8       W
                7 (lowMinus)     8       W
                8 (low)         11       W
```

```
               9 (medimMinus)  11       W
              10 (medium)      11       W
              11 (highMinus)   11       W
              12 (high)        11       W

          Furthermore, this table extends to return 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                IANAPowerStateSet,
           eoPowerStateMaxPower             Integer32,
           eoPowerStatePowerUnitMultiplier  UnitMultiplier,
           eoPowerStateTotalTime            TimeTicks,
           eoPowerStateEnterCount           Counter32
   }

   eoPowerStateIndex OBJECT-TYPE
       SYNTAX          IANAPowerStateSet
       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 0xFFFF.
```

```
          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 hundreds
         of seconds 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."
          ::= { energyObjectMibObjects 4   }

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

   EoEnergyParametersEntry ::= SEQUENCE {
           eoEnergyObjectIndex                PhysicalIndex,
           eoEnergyParametersIndex            Integer32,
           eoEnergyParametersIntervalLength   TimeInterval,
           eoEnergyParametersIntervalNumber   Integer32,
           eoEnergyParametersIntervalMode     Integer32,
           eoEnergyParametersIntervalWindow   TimeInterval,
           eoEnergyParametersSampleRate       Integer32,
           eoEnergyParametersStatus           RowStatus
   }

   eoEnergyObjectIndex OBJECT-TYPE
       SYNTAX          PhysicalIndex
       MAX-ACCESS      read-create
       STATUS          current
       DESCRIPTION
         "The unique value, to identify the specific Energy Object
         on which the measurement is applied, the same index used
         in the eoPowerTable to identify the Energy Object."
       ::= { eoEnergyParametersEntry 1 }

   eoEnergyParametersIndex OBJECT-TYPE
       SYNTAX           Integer32 (0..2147483647)
       MAX-ACCESS       read-create
       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 capability 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 hundredth of
          seconds 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."
       DEFVAL { 90000 }
       ::= { eoEnergyParametersEntry 3 }

   eoEnergyParametersIntervalNumber OBJECT-TYPE
       SYNTAX          Integer32
       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
          replacesthe 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
       eoEnergyProduced  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
        hundredth of seconds, in order to compute the average of
        eoEnergyConsumed, eoEnergyProduced 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          Integer32
       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, eoEnergyProduced  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."
```

```
        DEFVAL { 1000 }
       ::= { eoEnergyParametersEntry 7 }

   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(1), all associated usage-data logged into
         the eoEnergyTable will be deleted. The data can be
         destroyed by setting up the eoEnergyParametersStatus to
         destroy(2)."
       ::= {eoEnergyParametersEntry 8 }

   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(2), 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                  Integer32,
        eoEnergyProduced                  Integer32,
        eoEnergyNet                       Integer32,
        eoEnergyUnitMultiplier            UnitMultiplier,
        eoEnergyAccuracy                  Integer32,
```

```
        eoEnergyMaxConsumed               Integer32,
        eoEnergyMaxProduced               Integer32,
        eoEnergyDiscontinuityTime         TimeStamp
   }

   eoEnergyCollectionStartTime OBJECT-TYPE
       SYNTAX          TimeTicks
       UNITS           "hundredths of seconds"
       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 [RFC3418].
          This object is useful for reference of interval periods
          for which the energy is measured."
       ::= { eoEnergyEntry 1 }

   eoEnergyConsumed OBJECT-TYPE
       SYNTAX          Integer32
       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 (kW-Hr, MW-Hr, etc.)
   indicated separately in eoEnergyUnitMultiplier."
       ::= { eoEnergyEntry 2 }


   eoEnergyProduced OBJECT-TYPE
       SYNTAX          Integer32
       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 (kW-Hr, MW-Hr, etc.)
   indicated separately in eoEnergyUnitMultiplier."
       ::= { eoEnergyEntry 3 }

   eoEnergyNet OBJECT-TYPE
       SYNTAX          Integer32
       UNITS           "Watt-hours"
```

```
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
   "This object indicates the resultant 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 (kW-Hr, MW-Hr, 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, eoEnergyProduced,
           eoEnergyNet, 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 value, in 100ths of a
   percent, representing the presumed accuracy 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          Integer32
        UNITS           "Watt-hours"
        MAX-ACCESS      read-only
        STATUS          current
        DESCRIPTION
```

```
          "This object is the maximum energy ever observed in
          eoEnergyConsumed since the monitoring started. This value
          is specified in the common billing units of watt-hours
          with the magnitude of watt-hours (kW-Hr,   MW-Hr, etc.)
          indicated separately in eoEnergyUnitMultiplier."
       ::= { eoEnergyEntry 7  }


   eoEnergyMaxProduced OBJECT-TYPE
       SYNTAX          Integer32
       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 (kW-Hr,   MW-Hr, etc.) indicated
          separately in eoEnergyEnergyUnitMultiplier."
       ::= { eoEnergyEntry 8 }


    eoEnergyDiscontinuityTime OBJECT-TYPE
       SYNTAX       TimeStamp
       MAX-ACCESS  read-only
       STATUS      current
       DESCRIPTION

         "The value of sysUpTime [RFC3418] on the most recent
         occasion at which any one or more of this entity's energy
         counters in this table suffered a discontinuity:
         eoEnergyConsumed, eoEnergyProduced or eoEnergyNet. If no
         such discontinuities have occurred since the last re-
         initialization of the local management subsystem, then
         this object contains a zero value."
       ::= { eoEnergyEntry 9 }

   -- Notifications

   eoPowerStateChange NOTIFICATION-TYPE
       OBJECTS       {eoPowerAdminState, eoPowerOperState,
   eoPowerStateEnterReason}
       STATUS        current
       DESCRIPTION
           "The SNMP entity generates the eoPowerStateChange when
           the value(s) of eoPowerAdminState or eoPowerOperState,
          in the context of the Power State Set, have changed for
          the Energy Object represented by the entPhysicalIndex."
```

```
      ::= { energyObjectMibNotifs 1 }

   -- Conformance

   energyObjectMibCompliances  OBJECT IDENTIFIER
       ::= { energyObjectMib 3 }

   energyObjectMibGroups  OBJECT IDENTIFIER
       ::= { energyObjectMib 4 }


   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 [EMAN-ENTITY]
           with respect to entity4CRCompliance should
           be supported which requires implementation
           of 3 MIB objects (entPhysicalIndex,
           entPhysicalName and entPhysicalUUID)."

       MODULE          -- this module
       MANDATORY-GROUPS {
                   energyObjectMibTableGroup,
                   energyObjectMibStateTableGroup,
                   energyObjectMibNotifGroup
                       }

         GROUP     energyObjectMibEnergyTableGroup

             DESCRIPTION "A compliant implementation does not
             have to implement.

             Module Compliance of [EMAN-ENTITY]
             with respect to entity4CRCompliance should
             be supported which requires implementation
             of 3 MIB objects (entPhysicalIndex,
             entPhysicalName and entPhysicalUUID)."


         GROUP    energyObjectMibEnergyParametersTableGroup

             DESCRIPTION "A compliant implementation does not
             have to implement.
```

```
             Module Compliance of {EMAN-ENTITY]
             with respect to entity4CRCompliance should
             be supported which requires implementation
             of 3 MIB objects (entPhysicalIndex,
             entPhysicalName and entPhysicalUUID)."


        GROUP     energyObjectMibMeterCapabilitiesTableGroup

             DESCRIPTION "A compliant implementation does not
             have to implement.

             Module Compliance of [EMAN-ENTITY]
             with respect to entity4CRCompliance should
             be supported which requires implementation
             of 3 MIB objects (entPhysicalIndex,
             entPhysicalName and entPhysicalUUID)."


       ::= { 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 [EMAN-ENTITY]
           with respect to entity4CRCompliance should
           be supported which requires implementation
           of 3 MIB objects (entPhysicalIndex,
           entPhysicalName and entPhysicalUUID)."

       MODULE          -- this module
       MANDATORY-GROUPS {
                           energyObjectMibTableGroup,
                           energyObjectMibStateTableGroup,
                           energyObjectMibNotifGroup
                       }

       OBJECT          eoPowerOperState
       MIN-ACCESS      read-only
       DESCRIPTION
           "Write access is not required."
```

```
       ::= { energyObjectMibCompliances 2 }

   -- Units of Conformance

   energyObjectMibTableGroup OBJECT-GROUP
       OBJECTS         {
                           eoPower,
                           eoPowerNameplate,
                           eoPowerUnitMultiplier,
                           eoPowerAccuracy,
                           eoPowerMeasurementCaliber,
                           eoPowerCurrentType,
                           eoPowerOrigin,
                           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         {
                           eoEnergyObjectIndex,
                           eoEnergyParametersIndex,
                           eoEnergyParametersIntervalLength,
                           eoEnergyParametersIntervalNumber,
                           eoEnergyParametersIntervalMode,
                           eoEnergyParametersIntervalWindow,
                           eoEnergyParametersSampleRate,
                           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,
                           eoEnergyProduced,
                           eoEnergyNet,
                           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 }

   energyObjectMibNotifGroup NOTIFICATION-GROUP
      NOTIFICATIONS    {
                           eoPowerStateChange
                       }
       STATUS          current
       DESCRIPTION
           "This group contains the notifications for the power and
           energy monitoring MIB Module."
```

```
       ::= { energyObjectMibGroups 6  }

   END



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

   POWER-CHARACTERISTICS-MIB DEFINITIONS ::= BEGIN

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

   powerCharacteristicsMIB MODULE-IDENTITY

       LAST-UPDATED    "201210220000Z"   -- 22 October   2012

       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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              Belgium
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              Email: bclaise@cisco.com"

       DESCRIPTION
```

```
              "This MIB is used to report AC power characteristics
              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,
              [EMAN-AWARE-MIB] should be implemented.

              Module Compliance of ENTITY-MIB v4
              with respect to entity4CRCompliance should
              be supported which requires implementation
              of 3 MIB objects (entPhysicalIndex,
              entPhysicalName and entPhysicalUUID)."

       REVISION

               "201210220000Z"     -- 22 October 2012

     DESCRIPTION
          "Initial version, published as RFC YYY."

      ::= { mib-2 yyy }



   powerCharacteristicsMIBConform  OBJECT IDENTIFIER
       ::= { powerCharacteristicsMIB 0 }


   powerCharacteristicsMIBObjects OBJECT IDENTIFIER
       ::= { powerCharacteristicsMIB 1 }

   -- Objects


   eoACPwrCharacteristicsTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF EoACPwrCharacteristicsEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This table defines power characteristics measurements
           for supported entPhysicalIndex entities. It is a sparse
           extension of the eoPowerTable."
       ::= { powerCharacteristicsMIBObjects 1 }

   eoACPwrCharacteristicsEntry OBJECT-TYPE
       SYNTAX          EoACPwrCharacteristicsEntry
```

```
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This is a sparse extension of the eoPowerTable with
           entries for power characteristics measurements or
           configuration.  Each measured value corresponds to an
           attribute in IEC 61850-7-4 for non-phase measurements
           within the object MMUX."

   INDEX {entPhysicalIndex }
       ::= { eoACPwrCharacteristicsTable 1 }

   EoACPwrCharacteristicsEntry ::= SEQUENCE {
       eoACPwrCharacteristicsConfiguration      INTEGER,
       eoACPwrCharacteristicsAvgVoltage          Integer32,
       eoACPwrCharacteristicsAvgCurrent          Integer32,
       eoACPwrCharacteristicsFrequency           Integer32,
       eoACPwrCharacteristicsPowerUnitMultiplier UnitMultiplier,
       eoACPwrCharacteristicsPowerAccuracy      Integer32,
       eoACPwrCharacteristicsTotalActivePower        Integer32,
       eoACPwrCharacteristicsTotalReactivePower  Integer32,
       eoACPwrCharacteristicsTotalApparentPower  Integer32,
       eoACPwrCharacteristicsTotalPowerFactor    Integer32,
       eoACPwrCharacteristicsThdAmpheres             Integer32,
       eoACPwrCharacteristicsThdVoltage         Integer32
   }

   eoACPwrCharacteristicsConfiguration 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."
```

```
       ::= { eoACPwrCharacteristicsEntry 1 }

   eoACPwrCharacteristicsAvgVoltage 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 3-phase
           system, this is the average voltage (V1+V2+V3)/3.  IEC
           61850-7-4 measured value attribute 'Vol'"
       ::= { eoACPwrCharacteristicsEntry 2 }

   eoACPwrCharacteristicsAvgCurrent OBJECT-TYPE
       SYNTAX          Integer32
       UNITS           "Ampheres"
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "A measured value of the current per phase. IEC 61850-
           7-4 attribute 'Amp'"
       ::= { eoACPwrCharacteristicsEntry 3 }

   eoACPwrCharacteristicsFrequency OBJECT-TYPE
       SYNTAX          Integer32 (4500..6500) -- UNITS 0.01 Hertz
       UNITS           "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'."
       ::= { eoACPwrCharacteristicsEntry 4 }

   eoACPwrCharacteristicsPowerUnitMultiplier OBJECT-TYPE
       SYNTAX          UnitMultiplier
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "The magnitude of watts for the usage value in
           eoACPwrCharacteristicsTotalActivePower,
           eoACPwrCharacteristicsTotalReactivePower
           and eoACPwrCharacteristicsTotalApparentPower
           measurements.
           For 3-phase power systems, this will also include
           eoACPwrCharacteristicsPhaseActivePower,
           eoACPwrCharacteristicsPhaseReactivePower and
           eoACPwrCharacteristicsPhaseApparentPower"
```

```
       ::= { eoACPwrCharacteristicsEntry 5 }

   eoACPwrCharacteristicsPowerAccuracy OBJECT-TYPE
       SYNTAX          Integer32 (0..10000)
       UNITS           "hundredths of percent"
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "This object indicates a percentage value, in 100ths 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"
       ::= { eoACPwrCharacteristicsEntry 6 }

   eoACPwrCharacteristicsTotalActivePower 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'."
       ::= { eoACPwrCharacteristicsEntry 7 }

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

   eoACPwrCharacteristicsTotalApparentPower OBJECT-TYPE
       SYNTAX          Integer32
       UNITS           "volt-amperes"
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
```

```
          "A measured value of the voltage and current which
          determines the apparent power.  The apparent power is
          the vector sum of real and reactive power.

          Note: watts and volt-ampheres are equivalent units and
          may be combined.  IEC 61850-7-4 attribute 'TotVA'."
      ::= { eoACPwrCharacteristicsEntry 9 }

   eoACPwrCharacteristicsTotalPowerFactor OBJECT-TYPE
       SYNTAX          Integer32 (-10000..10000)
       UNITS           "hundredths of percent"
       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 100ths of a
           percent. A power factor of 100% indicates there is no
           inductance load and thus no reactive power. Power
           Factor can be positive or negative, where the sign
           should be in lead/lag (IEEE) form.  IEC 61850-7-4
           attribute 'TotPF'."
       ::= { eoACPwrCharacteristicsEntry 10 }

   eoACPwrCharacteristicsThdAmpheres 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'."
       ::= { eoACPwrCharacteristicsEntry 11 }

   eoACPwrCharacteristicsThdVoltage 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).  Method of calculation is not
           specified.  IEC 61850-7-4 attribute 'ThdVol'."
       ::= { eoACPwrCharacteristicsEntry 12 }

   eoACPwrCharacteristicsPhaseTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF EoACPwrCharacteristicsPhaseEntry
```

```
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "This table describes 3-phase power characteristics
           measurements.  It is a sparse extension of the
           eoACPwrCharacteristicsTable."
       ::= { powerCharacteristicsMIBObjects 2 }


   eoACPwrCharacteristicsPhaseEntry OBJECT-TYPE
       SYNTAX          EoACPwrCharacteristicsPhaseEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
           "An entry describes common 3-phase power
           characteristics measurements.

           This optional table describes 3-phase power
           characteristics measurements, with three entries for
           each supported entPhysicalIndex entity.  Entities
           having single phase power shall not have any entities.

           This table describes attributes common to both WYE and
           DEL.  Entities having single phase power shall not have
           any entries here.  It is a sparse extension of the
           eoACPwrCharacteristicsTable.

           These attributes correspond to IEC 61850-7.4 MMXU phase
           measurements."
       INDEX { entPhysicalIndex, eoPhaseIndex }
       ::= { eoACPwrCharacteristicsPhaseTable 1 }

   EoACPwrCharacteristicsPhaseEntry ::= SEQUENCE {
           eoPhaseIndex                        Integer32,
           eoACPwrCharacteristicsPhaseAvgCurrent      Integer32,
           eoACPwrCharacteristicsPhaseActivePower    Integer32,
           eoACPwrCharacteristicsPhaseReactivePower   Integer32,
           eoACPwrCharacteristicsPhaseApparentPower   Integer32,
           eoACPwrCharacteristicsPhasePowerFactor      Integer32,

           eoACPwrCharacteristicsPhaseImpedance       Integer32
   }

   eoPhaseIndex OBJECT-TYPE
       SYNTAX          Integer32 (0..359)
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
```

```
          "A phase angle typically corresponding to 0, 120, 240."
        ::= { eoACPwrCharacteristicsPhaseEntry 1 }

   eoACPwrCharacteristicsPhaseAvgCurrent OBJECT-TYPE
       SYNTAX          Integer32
       UNITS           "Ampheres"
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
           "A measured value of the current per phase. IEC 61850-
           7-4 attribute 'A'"
       ::= { eoACPwrCharacteristicsPhaseEntry 2 }

   eoACPwrCharacteristicsPhaseActivePower 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 'W'"
       ::= { eoACPwrCharacteristicsPhaseEntry 3 }

   eoACPwrCharacteristicsPhaseReactivePower 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 'VAr'"
       ::= { eoACPwrCharacteristicsPhaseEntry 4 }

   eoACPwrCharacteristicsPhaseApparentPower 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.  Active plus reactive power equals
           the total apparent power.

           Note: Watts and volt-ampheres are equivalent units and
           may be combined.  IEC 61850-7-4 attribute 'VA'."
       ::= { eoACPwrCharacteristicsPhaseEntry 5 }

   eoACPwrCharacteristicsPhasePowerFactor OBJECT-TYPE
```

```
       SYNTAX          Integer32 (-10000..10000)
       UNITS           "hundredths of percent"
       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."
       ::= { eoACPwrCharacteristicsPhaseEntry 6 }

   eoACPwrCharacteristicsPhaseImpedance OBJECT-TYPE
       SYNTAX          Integer32
       UNITS           "volt-amperes"
       MAX-ACCESS      read-only
       STATUS          current
       DESCRIPTION
   "A measured value of the impedance.  IEC 61850-7-4 attribute
   'Z'."
       ::= { eoACPwrCharacteristicsPhaseEntry 7 }

   eoACPwrCharacteristicsDelPhaseTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF
   EoACPwrCharacteristicsDelPhaseEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "This table describes DEL configuration phase-to-phase
          power characteristics measurements.  This is a sparse
          extension of the eoACPwrCharacteristicsPhaseTable."
       ::= { powerCharacteristicsMIBObjects 3 }

   eoACPwrCharacteristicsDelPhaseEntry OBJECT-TYPE
       SYNTAX          EoACPwrCharacteristicsDelPhaseEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "An entry describes  power characteristics attributes of
          a phase in a DEL 3-phase power system.  Voltage
          measurements are provided both relative to each other
          and zero.

          Measured values are from IEC 61850-7-2 MMUX and THD from
          MHAI objects.
```

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

                        eoPhaseIndex        Next Phase Angle
                              0                   120
                            120                   240
                            240                     0
          "
       INDEX { entPhysicalIndex, eoPhaseIndex}
       ::= { eoACPwrCharacteristicsDelPhaseTable 1}

   EoACPwrCharacteristicsDelPhaseEntry ::= SEQUENCE {
       eoACPwrCharacteristicsDelPhaseToNextPhaseVoltage
   Integer32,
       eoACPwrCharacteristicsDelThdPhaseToNextPhaseVoltage
   Integer32,
       eoACPwrCharacteristicsDelThdCurrent
   Integer32
   }

   eoACPwrCharacteristicsDelPhaseToNextPhaseVoltage 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'."
       ::= { eoACPwrCharacteristicsDelPhaseEntry 2 }

   eoACPwrCharacteristicsDelThdPhaseToNextPhaseVoltage 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
          disortion for phase to next phase. Method of calculation
          is not specified.  IEC 61850-7-4 attribute 'ThdPPV'."
       ::= { eoACPwrCharacteristicsDelPhaseEntry 3 }

   eoACPwrCharacteristicsDelThdCurrent 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
          disortion (THD) for phase to phase.  Method of
          calculation is not specified.
          IEC 61850-7-4 attribute 'ThdPPV'."
       ::= { eoACPwrCharacteristicsDelPhaseEntry 4 }

   eoACPwrCharacteristicsWyePhaseTable OBJECT-TYPE
       SYNTAX          SEQUENCE OF
   EoACPwrCharacteristicsWyePhaseEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "This table describes WYE configuration phase-to-neutral
          power characteristics measurements.  This is a sparse
          extension of the eoACPwrCharacteristicsPhaseTable."
       ::= { powerCharacteristicsMIBObjects 4 }

   eoACPwrCharacteristicsWyePhaseEntry OBJECT-TYPE
       SYNTAX          EoACPwrCharacteristicsWyePhaseEntry
       MAX-ACCESS      not-accessible
       STATUS          current
       DESCRIPTION
          "This table describes measurements of WYE configuration
          with phase to neutral power characteristics attributes.
          Three entries are required for each supported
          entPhysicalIndex entry.  Voltage measurements are
          relative to neutral.

          This is a sparse extension of the
          eoACPwrCharacteristicsPhaseTable.

          Each entry describes power characteristics attributes of
          one phase of a WYE 3-phase power system.

          Measured values are from IEC 61850-7-2 MMUX and THD from
          MHAI objects."
       INDEX {  entPhysicalIndex, eoPhaseIndex }
       ::= { eoACPwrCharacteristicsWyePhaseTable 1}

   EoACPwrCharacteristicsWyePhaseEntry ::= SEQUENCE {
           eoACPwrCharacteristicsWyePhaseToNeutralVoltage
   Integer32,
           eoACPwrCharacteristicsWyePhaseCurrent
   Integer32,
           eoACPwrCharacteristicsWyeThdPhaseToNeutralVoltage
   Integer32
   }
```

```
   eoACPwrCharacteristicsWyePhaseToNeutralVoltage 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 'PhV'."
       ::= { eoACPwrCharacteristicsWyePhaseEntry 1 }

   eoACPwrCharacteristicsWyePhaseCurrent 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'."
       ::= { eoACPwrCharacteristicsWyePhaseEntry 2 }

   eoACPwrCharacteristicsWyeThdPhaseToNeutralVoltage 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'."
       ::= { eoACPwrCharacteristicsWyePhaseEntry 3 }

   -- Conformance


   powerCharacteristicsMIBCompliances  OBJECT IDENTIFIER
       ::= { powerCharacteristicsMIB 2 }

   powerCharacteristicsMIBGroups  OBJECT IDENTIFIER
       ::= { powerCharacteristicsMIB 3 }


   powerCharacteristicsMIBFullCompliance 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 [EMAN-ENTITY] with respect to
        entity4CRCompliance should be supported which requires
        implementation of 3 MIB objects (entPhysicalIndex,
        entPhysicalName and entPhysicalUUID)."


       MODULE          -- this module
       MANDATORY-GROUPS {
                           powerACPwrCharacteristicsMIBTableGroup
                                                    }


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


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

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

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


       ::= { powerCharacteristicsMIBCompliances 1 }



   -- Units of Conformance

   powerACPwrCharacteristicsMIBTableGroup OBJECT-GROUP
       OBJECTS         {
                    -- Note that object entPhysicalIndex is NOT
                    -- included since it is not-accessible

                           eoACPwrCharacteristicsAvgVoltage,
                           eoACPwrCharacteristicsAvgCurrent,
```

```
                           eoACPwrCharacteristicsFrequency,

   eoACPwrCharacteristicsPowerUnitMultiplier,
                           eoACPwrCharacteristicsPowerAccuracy,
                           eoACPwrCharacteristicsTotalActivePower,

   eoACPwrCharacteristicsTotalReactivePower,

   eoACPwrCharacteristicsTotalApparentPower,
                           eoACPwrCharacteristicsTotalPowerFactor
                                                   }
       STATUS          current
       DESCRIPTION
          "This group contains the collection of all the power
          characteristics objects related to the Energy Object."
       ::= { powerCharacteristicsMIBGroups  1 }

    powerACPwrCharacteristicsOptionalMIBTableGroup OBJECT-GROUP
       OBJECTS         {
                           eoACPwrCharacteristicsConfiguration,
                           eoACPwrCharacteristicsThdAmpheres,
                           eoACPwrCharacteristicsThdVoltage
                       }
       STATUS          current
       DESCRIPTION
          "This group contains the collection of all the power
          characteristics objects related to the Energy Object."
       ::= { powerCharacteristicsMIBGroups  2 }


   powerACPwrCharacteristicsPhaseMIBTableGroup OBJECT-GROUP
       OBJECTS         {
                           -- Note that object entPhysicalIndex is
                           -- NOT included since it is
                           -- not-accessible
                           eoACPwrCharacteristicsPhaseAvgCurrent,
                           eoACPwrCharacteristicsPhaseActivePower,

   eoACPwrCharacteristicsPhaseReactivePower,

   eoACPwrCharacteristicsPhaseApparentPower,
                           eoACPwrCharacteristicsPhasePowerFactor,

                           eoACPwrCharacteristicsPhaseImpedance
                       }
       STATUS          current
       DESCRIPTION
```

```
          "This group contains the collection of all 3-phase power
          characteristics objects related to the Power State."
       ::= { powerCharacteristicsMIBGroups  3  }

   powerACPwrCharacteristicsDelPhaseMIBTableGroup OBJECT-GROUP
       OBJECTS         {
                       -- Note that object entPhysicalIndex and
                       -- eoPhaseIndex are NOT included
                       -- since they are not-accessible

   eoACPwrCharacteristicsDelPhaseToNextPhaseVoltage ,

   eoACPwrCharacteristicsDelThdPhaseToNextPhaseVoltage,
                       eoACPwrCharacteristicsDelThdCurrent
                       }
       STATUS          current
       DESCRIPTION
           "This group contains the collection of all  power
           characteristic attributes of a phase in a DEL 3-phase
           power system."
       ::= { powerCharacteristicsMIBGroups  4  }

   powerACPwrCharacteristicsWyePhaseMIBTableGroup OBJECT-GROUP
       OBJECTS         {
                          -- Note that object entPhysicalIndex and
                          -- eoPhaseIndex are NOT included
                          -- since they are not-accessible

   eoACPwrCharacteristicsWyePhaseToNeutralVoltage,
                          eoACPwrCharacteristicsWyePhaseCurrent,

   eoACPwrCharacteristicsWyeThdPhaseToNeutralVoltage
                       }
       STATUS          current
       DESCRIPTION
           "This group contains the collection of all WYE
           configuration phase-to-neutral power characteristics
           measurements."
       ::= { powerCharacteristicsMIBGroups  5  }


   END
```

11. Security Considerations

Some of the readable objects in these MIB modules (i.e., objects with a MAX-ACCESS other than not-accessible) may be considered sensitive or vulnerable in some network environments. It is thus important to control even GET and/or NOTIFY access to these objects and possibly to even encrypt the values of these objects when sending them over the network via SNMP.

There are a number of management objects defined in these MIB modules 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 can have a negative effect on network operations. The following are the tables and objects and their sensitivity/vulnerability:

- Unauthorized changes to the eoPowerOperState (via theeoPowerAdminState) 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 still no secure control over who on the secure network is allowed to access and GET/SET (read/change/create/delete) the objects in these MIB modules.

It is RECOMMENDED that implementers consider the security features as provided by the SNMPv3 framework (see [RFC3410], section 8), including full support for the SNMPv3 cryptographic mechanisms (for authentication and privacy).

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 these MIB modules is properly configured to give access to the objects only to those principals (users) that have legitimate rights to GET or SET (change/create/delete) them.

12. IANA Considerations

12.1. IANA Considerations for the MIB Modules

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

Descriptor	OBJECT IDENTIFIER value
energyObjectMib	{ mib-2 xxx }
powerCharacteristicsMIB	{ mib-2 yyy }

Additions to the MIB modules are subject to Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The group of experts MUST check the requested MIB objects for completeness and accuracy of the description. Requests for MIB objects that duplicate the functionality of existing objects SHOULD be declined. The smallest available OIDs SHOULD be assigned to the new MIB objects. The specification of new MIB objects SHOULD follow the structure specified in Section 10. and MUST be published using a well-established and persistent publication medium.

12.2. IANA Registration of new Power State Set

This document specifies an initial set of Power State Sets. The list of these Power State Sets with their numeric identifiers is given in Section 5.2.1. IANA maintains a Textual Convention IANAPowerStateSet with the initial set of Power State Sets and the Power States within those Power State Sets. The current version of Textual convention can be accessed http://www.iana.org/assignments/IANAPowerStateSet

New Assignments to Power State Sets shall be administered by IANA and the guidelines and procedures are listed in this Section.

New assignments for Power State Set will be administered by IANA through Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The group of experts MUST check the requested state for completeness and accuracy of the description. A pure vendor specific implementation of Power State Set shall not be adopted; since it would lead to proliferation of Power State Sets.

12.2.1. IANA Registration of the IEEE1621 Power State Set

This document specifies a set of values for the IEEE1621 Power State Set [IEEE1621]. The list of these values with their identifiers is given in Section 5.2.1. The Internet Assigned Numbers Authority (IANA) created a new registry for IEEE1621

Power State Set identifiers and filled it with the initial listin the Textual Convention IANAPowerStateSet..

New assignments (or potentially deprecation) for IEEE1621 Power State Set will be administered by IANA through Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The group of experts MUST check the requested state for completeness and accuracy of the description.

12.2.2. IANA Registration of the DMTF Power State Set

This document specifies a set of values for the DMTF Power State Set. The list of these values with their identifiers is given in Section 5.2.1. The Internet Assigned Numbers Authority (IANA) has created a new registry for DMTF Power State Set identifiers and filled it with the initial list in the Textual Convention IANAPowerStateSet.
New assignments (or potentially deprecation) for DMTF Power State Set will be administered by IANA through Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The group of experts MUST check the conformance with the DMTF standard [DMTF], on the top of checking for completeness and accuracy of the description.

12.2.3. IANA Registration of the EMAN Power State Set

This document specifies a set of values for the EMAN Power State Set. The list of these values with their identifiers is given in Section 5.2.1. The Internet Assigned Numbers Authority (IANA) has created a new registry for EMAN Power State Set identifiers and filled it with the initial list in the Textual Convention IANAPowerStateSet.
New assignments (or potentially deprecation) for EMAN Power State Set will be administered by IANA through Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The group of experts MUST check the requested state for completeness and accuracy of the description.

12.3. Updating the Registration of Existing Power State Sets

IANA maintains a Textual Convention IANAPowerStateSet with the initial set of Power State Sets and the Power States within those Power State Sets. The current version of Textual convention can be accessed http://www.iana.org/assignments/IANAPowerStateSet

With the evolution of standards, over time, it may be important to deprecate of some of the existing the Power State Sets or some of the states within a Power State Set.

The registrant shall publish an Internet-draft or an individual submission with the clear specification on deprecation of Power State Sets or Power States registered with IANA. The deprecation shall be administered by IANA through Expert Review [RFC5226], i.e., review by one of a group of experts designated by an IETF Area Director. The process should also allow for a mechanism for cases where others have significant objections to claims on deprecation of a registration. In cases, where the registrant cannot be reached, IESG can designate an Expert to modify the IANA registry for the deprecation.

12. 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.

John Parello

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14. Open Issues

OPEN ISSUE 1 check if all the requirements from [EMAN-REQ] are covered.

OPEN ISSUE 2 IANA Registered Power State Sets deferred to [EMAN-FMWK]

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