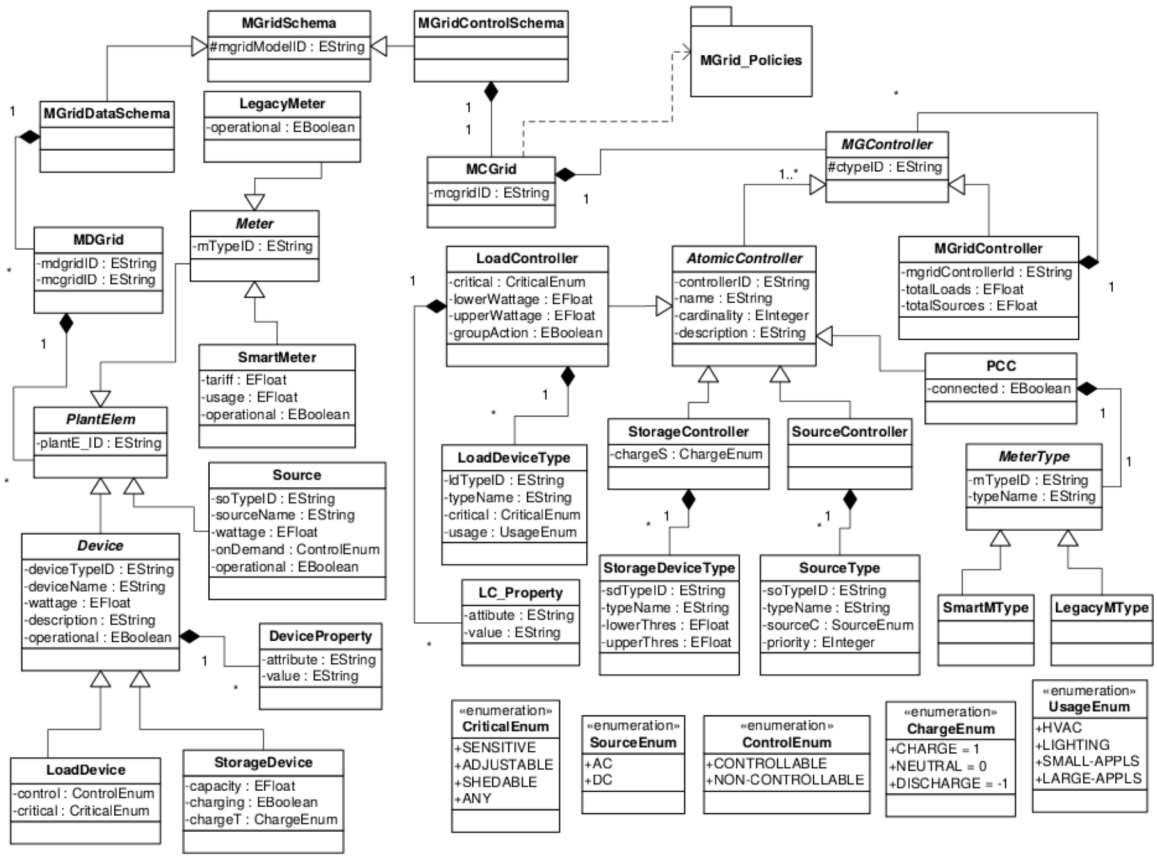

Fig. 2. MGridML Abstract Syntax.

A. Microgrid Modeling Language (MGridML)

MGridML is defined in terms of its metamodel comprising its abstract syntax and static semantics. Figure 2 shows the abstract syntax for MGridML. A MGridML model (or *schema*) may either be a *control* schema (class `MGridControlSchema`), shown at the top of the figure, or a *data* schema (`MGridDataSchema`), left side of the figure. The control schema specifies the logical configuration of the microgrid, including controllers and the existing types of plant elements. The policies, shown as a package at the top of the figure, are event-condition-action triples which allow constraints to be placed on the behavior defined by MGridML models. The data schema, in turn, specifies the instances of the plant element types defined in the control schema which actually represent the physical elements present in a given microgrid plant.

Figure 3 shows three of the models used to realize the Change Season scenario in Section III. Figure 3(a) shows the control instance for the Winter season. The rectangular shape in the middle of the model represents the microgrid controller which coordinates the activities of lower level controllers - *LoadController*, *PCC*, and *StorageController*, shown as rounded rectangles. The controllers are connected to the device types - *LoadDeviceType* with type id LDT001, *SmartMeterType* with type id SMT001, and *StorageDeviceType* with type id SDT001, shown as ovals. The oval with the dashed line shows the addition of a new device type (LDT002) to the Winter model thereby converting it to the Spring control instance, this facilitates the addition of the pool filtration system (pool).

Figure 3(b) shows the data instance for the Winter season. It contains the microgrid data entity connecting: (1) a load device (heater) with device id LD001, type id LDT001, and property *temperature* set to 75 $^{\circ}F$; (2) a smart meter with id SM001, meter type SMT001 and (3) a storage device with id SD004, type id SDT001, and not currently charging. Figure 3(c) shows the data instance for the Spring season.

B. Microgrid Virtual Machine (MGridVM)

The MGridVM is a virtual machine that takes a sequence of MGridML models that specifies the user's requirements, similar to the one shown in Figure 3, and realizes energy management in the microgrid. Figure 4(a) shows the layered architecture of MGridVM. The layers of MGridVM are described as follows:

Microgrid User Interface (MUI) - provides the user (novice or expert) with the ability to specify the requirements of their microgrid energy management application by creating a schema. The MUI validates the user's graphical model (UI-MGridML), transforms the UI-MGridML model into an