PANHAA SYSTEMIC DESIGN OF REGULATION ENABLING ONTOLOGY

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Abstract: The deregulation of economies has re-created the need for regulation. From a Systems perspective, the unbundling of large monolithic industrial setups into smaller independent companies results in the dissolution of high level management structures which, in the pre-deregulated era, had the overall control of the end-to-end delivery process. In the absence of such holistic oversight mechanisms, deregulated industries remain vulnerable to systemic failure. Industry regulators need to go beyond the usual concerns of price, quality, and access, and invest in methods that capture the interactions between the different stakeholders in an industry. It is the understanding of the individual interactions that can help piece together a holistic view of the industry; thereby allowing the regulator to devise well informed interventions. In this paper we model industry interactions as a multi-party value realization process and take a Systems approach in analyzing them. Every value realization is analyzed both at the industry level and at the level of stakeholders within the industry. The design patterns that emerge from this whole/composite view of value realization form the basis for formalizing the concepts required to analyze the working of an industry. An explicit specification of these concepts is presented as Regulation Enabling Ontology, REGENT.

1 INTRODUCTION

The deregulation of economies has led to the unbundling of large, vertically integrated, monolithic, industrial monopolies into lean, efficient and more focused entities with the freedom to develop upstream and downstream interconnections (Baldwin & Cave, 1999). Network Industries (Shy, 2004), such as electricity, telecommunication, transportation, posts, gas and water supply, are most representative of such restructuring. From a management perspective, such unbundling results in the dissolution of the high level management structures which, in the pre-deregulated era, were responsible for the complete end-to-end delivery process. A deregulated industry is, instead, composed of multiple smaller management structures, each restricted in scope to some specific aspect of the overall industry. For instance, the deregulation of Electricity Supply Industry (Zaccour, 1998) led to its restructuring along functional lines. Separate companies emerged for generation, transmission and distribution of electricity. These companies have independent management structures, each responsible for their part of the industry and interacting purely on an economic basis. The absence of a holistic industry wide management structure makes deregulated industries vulnerable to systemic failure. Modern regulatory systems need to go beyond the usual concerns of price, quality, output and access, and invest in schemes that capture the interactions among the stakeholders of the industry. Understanding these individual interactions help piece together a holistic view of the industry, thereby allowing the regulator to devise well informed interventions that can ensure the sustainable development of the overall industry.

Industries are composed of multiple stakeholder groups: the companies that supply certain goods or services, the individuals that consume them, the government that facilitates these transactions and the environment that provides the necessary backdrop for these interactions. Any interaction within an

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industry can be reduced to an instance of the multi-party relation that exists between these four stakeholder groups. The plurality in relationship and the diversity in stakeholder beliefs that underlie these relationships make the effort of developing a holistic understanding of an industry even more challenging.

To address these challenges, we invoke the notion of value and model every relationship in an industry as a set of value realization processes. Value is a qualitative concept and, thus, well suited for an interdisciplinary discourse. Taking a Systems perspective, we analyze the value realization process both at the industry level and at the level of individual stakeholders within the industry. Two important design patterns emerge from this whole/composite view of value exchange: any value created in an industry has an associated supplier and adopter, a supplier of one set of value is an adopter of some other set of value. These design patterns form the basis for formalizing the concepts required to explain multi-party relationships in an industry.

This paper is an attempt to provide an explicit specification of these concepts as ontology. The ontology will provide regulators with a standard representational vocabulary with which they can document the material and information interplay between the different stakeholders of an industry. It is the abstraction of industry specific configuration details as shared pan-industry concepts that will facilitate the knowledge-level communication among the community of regulators, thereby enabling more effective and speedy sharing of regulatory best practices. Section 2 provides a brief overview of Systems thinking approach and presents a Systems perspective of the de-regulated electricity supply industry. Section 3 explores the notion of value in greater detail and introduces the concepts of resource and feature as building blocks of the value realization process. Section 4 describes the Regulation Enabling Ontology, REGENT, in detail, highlighting the different design choices that were made during the development of REGENT. Section 5 instantiates REGENT for the Urban Household Electricity Industry and, as an example, demonstrates its effectiveness in establishing regulatory oversight. Section 6 presents some related work in this field. The paper concludes with future work directions in Section 7.

2 A SYSTEMS PERSPECTIVE OF INDUSTRY

A Systems approach to understanding the relationship between the stakeholders of an industry allows taking a holistic view of the industry and analyzing how these relationships influence one another in the context of the overall well being of the industry. This is particularly useful for deregulated industries where management structures only exhibit knowledge about local relationships and the relevance of these relationships to the entire system remains largely unexplored. For a regulator to act as a true custodian of the industry, it is important that it has the complete knowledge about the different interactions that occur in an industry and the bearing these relationships may have on the overall working of the industry. To further illustrate the affect of deregulation on the overall management of the industry, we use the visual semantics of SEAM to analyze the evolution of Electricity Supply Industry.

SEAM is a set of Systemic Enterprise Architecture Methods (Wegmann, Julia, Regev, & Rychkova, 2007) that exploit the principles of General Systems Thinking (GST) (Weinberg, 1975). GST advocates that the component parts of a system can be best understood in the context of relationships with each other and with other systems, rather than in isolation. An important way to fully analyze a system is to understand the part in relation to the whole. SEAM represents any perceived reality as a hierarchy of systems. Each system can be analyzed as a whole [W] - showing its externally visible characteristics or as a composite [C] – showing its' constituents as a set of interrelated parts. When applying SEAM to an industry, two main aspects are analyzed: (1) How different stakeholders cooperate together to achieve some common objective; these groups of stakeholders are referred to as value network, VN. (2) How these value networks interact within an industry; these interactions are referred to as Multi-Party Relationship, MPR. The visual syntax of SEAM includes block arrows for systems, annotated ovals for externally visible properties, diamonds for relations, simple lines for active participation to a relation, dashed lines for pseudo participation to a relation and rounded end-point lines for emphasizing the identical nature of modelling elements.

Figure 1 presents a SEAM depiction of a pre-deregulated Electricity Supply industry. The four prominent entities that engage in the activities of this industry are the Electricity Supply Company (ESC), Electricity Consumer VN, Government VN and the Environment VN. When viewed as a whole, the ESC [W] exhibits the overall responsibility of maintaining an end-to-end supply of electricity –

from generation to distribution. When viewed as a composite, the ESC [C] reveals its' constituent subsystems. ESCs can have different architectures. Nevertheless, for these subsystems to work as a viable whole, each ESC has some form of management subsystem (Beer, 1985) that oversees the end-to-end delivery process.

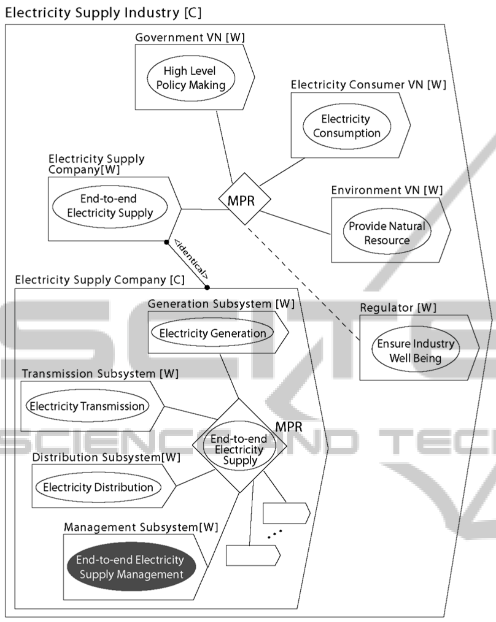

Figure 1: Pre-deregulated Electricity Supply Industry.

Figure 2 presents a SEAM depiction of a deregulated Electricity Supply Industry. The vertically integrated ESC of the pre-deregulated era stands unbundled into independent Generation, Transmission and Distribution Companies. The presence of multiple such companies constitutes competition, and provides the Electricity Consumer VN the choice to buy electricity from one Generation Company, get it transmitted through some other Transmission Company and receive the end supply service from yet another Distribution Company. These three companies when put together represent the Electricity Supplier VN. From a management perspective, each of these companies is controlled by an independent management sub-system which is strictly limited to its' part of industry operations, e.g. generation, transmission or distribution. Unlike the pre-deregulated era, there exists no end-to-end electricity supply management system that can be held responsible for the overall delivery of the supply.

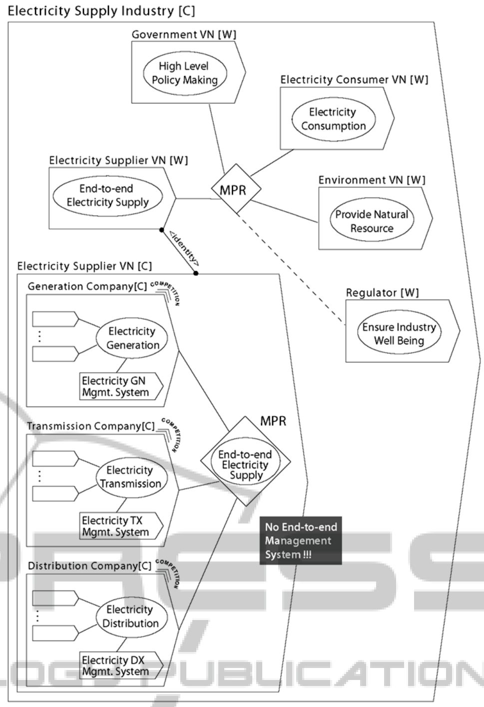

Figure 2: Deregulated Electricity Supply Industry.

3 THE RESOURCE-FEATURE-VALUE TRIUNE

An industry is a complex composition of diverse stakeholder groups. Suppliers are primarily concerned about issues related to market share, profit and return-on-investment; consumers are concerned about cost, availability, reliability and ease-of-use; governments are concerned about collective welfare, institutional relevance and political indispensability; and the issues of interest from an environment point of view include habitat and climate related ecological concerns. To realize the benefits of Systems approach in analyzing the different facets of an industry, it is important to first identify a unifying concept that can act as a generic platform for the interdisciplinary discourse required in an industry. In this paper we exploit the notion of *value* as the unifying concept and treat the above mentioned stakeholder concerns as context specific manifestations of the value concept.

Based on the analysis presented in (Ramsay, 2005), we define value as the tangible or intangible effect accrued by a stakeholder through the consumption or trade of a service or good. The notion of value is at the heart of MPR modeling.

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Stakeholders aspiring for a common set of value are grouped together as a VN. MPR models industry interactions as a value realization process between VNs. VNs exchange resources, material and information. Any resource addition to the VN affects the stakeholders of the VN either in a favorable way, realizing positive value, or in an unfavorable way, realizing negative value. Figure 3 depicts MPR as a bi-directional value realization process between the different VNs in an Electricity Supply Industry.

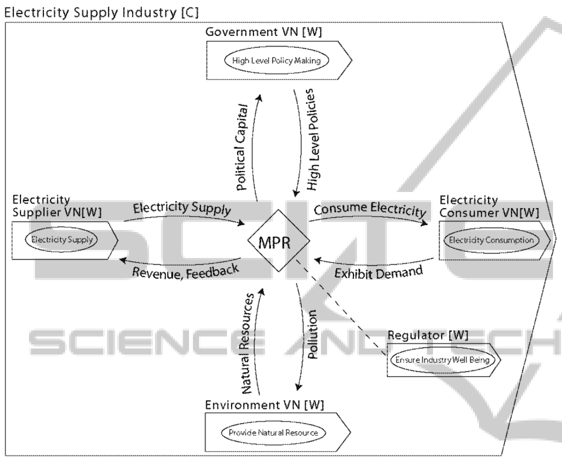

Figure 3: Bi-directional value realization in MPR.

Value is a subjective notion, dependent exclusively on stakeholder perceptions. An effect welcome by some stakeholders may be completely rejected by others. For example, time based electricity pricing schemes where a consumer can pay less for off peak electricity usage is perceived by many as a positive value as it provides an opportunity to reduce electricity bills by shifting workloads to low cost off peak durations. For others this may not be a welcome change as it results in increased night time activity in the neighbourhood. As a result it is desirable to explicitly specify the context in which a value is created, delivered or consumed. We accomplish this by introducing the concepts of resource and feature.

We follow the definition given in (Barney, 1991), where *resources* are defined as "... assets, capabilities, processes, and information" in control of the stakeholder. Thus resource can be considered as the contribution an individual stakeholder can bring to a VN. *Feature* on the other hand is a composite attribute which exists only at the VN level. Based on the resources available with the different stakeholders of a VN, the VN may exhibit different properties. These properties emerge from the different combinations between these resources, and are known as the features of the VN. For a given industry, an MPR identifies the different resources available with each VN, the set of possible features that may emerge from them and the value these features may bring to the other VNs. The same is presented in Figure 4. The use of the term enterprise in the figure is a more formal way of referring to stakeholders constituting a VN. The resource, feature and value concepts coupled with the GST inspired whole-composite view of value exchange guides our ontology design activity. Two important design patters emerge from this combination.

D1. *For every value created in an industry there exists a supplier VN and an adopter VN*

D2. *Each VN in an industry acts as a supplier of one set of value and an adopter of another set of value*

Supplier and adopter are roles assigned to VNs while analyzing MPRs. The supplier role signifies ownership of resources required to create/produce and deliver the services or goods. The adopter role signifies ownership of resources required to consume the service or good thereby realizing the value advertised through the features of the service or good.

Design Patterns have their genesis in the field of architecture where they were first proposed as an architectural concept by Christopher Alexander (Alexander, 1979). These were later adopted in software engineering, and are defined as an artifact in the form of a construct, a model, a method or an instantiation, which is general enough to be reusable in solving commonly occurring problems (Gamma, Helm, Johnson, Vlissides, & John, 1995). In this paper we use these two design patterns as the basic constructs for formally specifying the knowledge required to formulate an overall understanding of any industry.

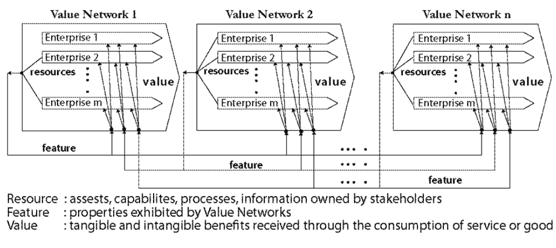

Figure 4: The Resource-Feature-Value triune in MPR.

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4 REGENT: A REGULATION ENABLING ONTOLOGY

As defined in (Gruber, 1993), ontology is an explicit specification of a shared conceptualization. It is aimed at formalizing a specific view point that enables/enriches the discourse on some aspect of interest in the real world. The purpose of REGENT is to enable the discourse on industry regulation. Formalization of the concepts that constitute an industry and the relationships that hold among these concepts provides a common vocabulary with which regulators can represent their understanding of the industry. Such a standardized way of documenting information is particularly useful in promoting knowledge-level communication between the different industry regulators.

Various ontology languages exist to represent these concepts and relationships. The most prominent of these is OWL (W3C, 2004). It is developed by the World Wide Web Consortium and consists of individuals, properties, and classes. Individuals represent the objects in the domain of interest, properties are binary relations on these individuals, and classes are interpreted as sets that contain these individuals. Our reference to concept and relationship maps to the notion of class and property in OWL. Individuals are instantiation of concept. OWL has three sub-languages: OWL-Lite, OWL-DL and OWL-Full. The expressiveness of OWL-DL falls between that of OWL-Lite and OWL-Full. It is based on Description Logics (Baader, Calvanese, McGuinness, Nardi, & Patel-Schneider, 2003) which are a decidable fragment of First Order Logic and are thus conducive for automated reasoning. For this purpose we use OWL-DL as the language for specifying REGENT. The development of REGENT was done using the ontology development tool, Protégé (Stanford Center for Biomedical Informatics Research, 2010). The visualizations presented in this paper have been created using the OntoViz graphical plug-in in Protégé. In the following, we present our design choices for REGENT.

REGENT has two top level classes: `IndustryConcept` class and `ConceptSpacePartition` class. `IndustryConcept` is the foundational class for all the concepts in an industry. It is based on the Resource-Feature-Value triune detailed in sub-section 2.3. `ConceptSpacePartition` is the class which subsumes the different viewpoints that can be useful in analyzing the set of concepts detailed in the `IndustryConcept` class.

4.1 The IndustryConcept Class

The `IndustryConcept` class formalizes the concepts of resource, feature and value. Figure 5 presents the taxonomy of the `Resource` class. The `Resource` class has two subclasses: `Commercial` and `Operational`. This refinement of the `Resource` class is a manifestation of the design pattern D2. As depicted in Figure 3, every value realization is a bi-directional process. We exploit the dual nature of VN, i.e. the simultaneous role of a supplier of one value and an adopter of some other value, to classify the resources available with a VN. From an industry perspective, a product or service creation process has two parts – the operational process of bringing the service or good into existence and the commercial process of making it tradable (Smith, 1904). The operational process is related to the supplier role of VN; the supplier has complete control over this process. On the other hand, the commercial process is related to the adopter role of VN. It is aimed at making the service or good conducive for consumption and, thus, requires taking an adopter perspective. Accordingly, the set of resources in an industry can be divided into two – the ones required to realize the operational process, the `RS_Operational` class, and the others required to realize the commercial process, defined as the `RS_Commercial` class.

We can further refine this classification by exploiting the insights of the supplier and adopter process. At the supplier end, bringing a service or good into existence entails two aspects – production and delivery. For instance, in the Electricity Supply Industry it is not sufficient for the electricity to be generated at the generation units, it is equally important that it is available at the prospective location of consumption. Operational resources that contribute towards the production of the industry offering are categorized as the `RS_OP_Production` class while the ones that contribute towards the delivery of the industry offering are categorized as the `RS_OP_Delivery` class. At the adopter end, realizing the benefits of the offering entails two aspects – reception and consumption. For instance, the complementary nature of electricity requires the availability of electrical appliances to consume electricity. Commercial resources that contribute towards the consumption of the industry offering are categorized as the `RS_CM_Consumption` class while the ones that contribute towards the reception of the

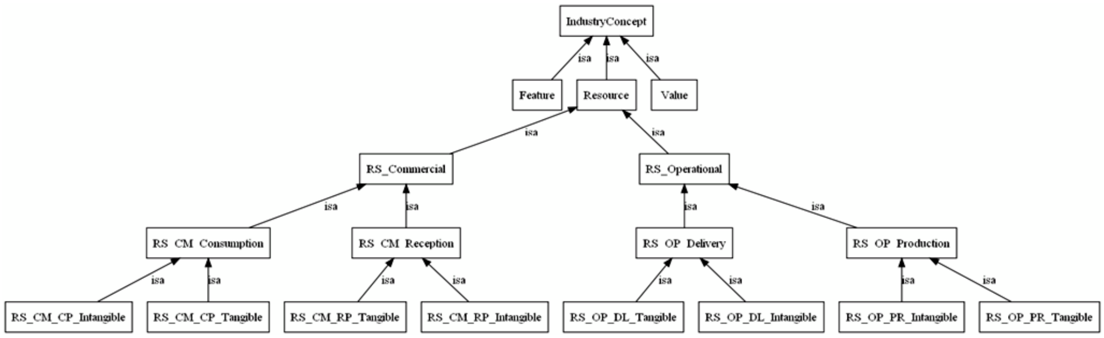

Figure 5: Taxonomy of the Resource class.

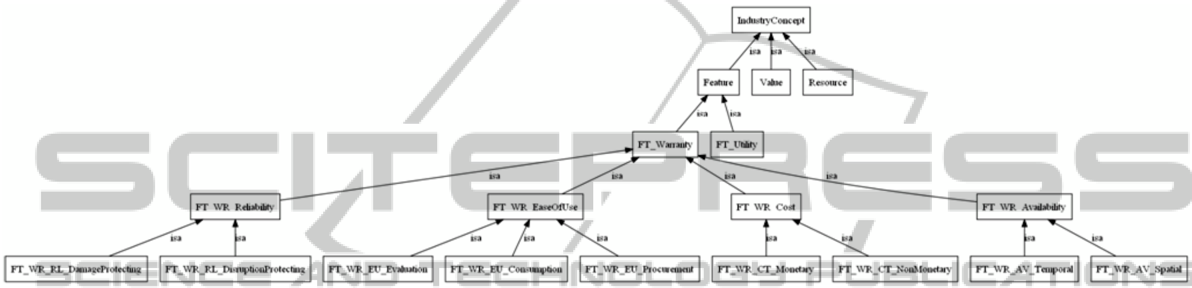

Figure 6: Taxonomy of the Feature class.

industry offering are categorized as the `RS_CM_Reception` class. Finally, based on their cognitive orientation a resource can be further classified as tangible and intangible. The leaf nodes of the taxonomy presented in Figure 6 refine the higher level `RS_CM_*` and `RS_OP_*` classes as `RS_*_*_Tangible` and `RS_*_*_Intangible` subclasses.

Figure 6 presents the taxonomy of the `Feature` class. The `Feature` class is a manifestation of the design pattern D1. As argued in (Ramsay, 2005), we do not treat value as an intrinsic characteristic of a product or service, and hence do not subscribe to the value chain metaphor (Porter, 1985) which is often interpreted to suggest that a value can be moved from the supplier to the adopter. The notion of supplier and adopter in D1 is to highlight the role of VNs in supplying resources that lead to the realization of some value at the adopter VN. Nevertheless, connecting resources directly to value will bypass an intermediate composition level where resources from different enterprises within a VN come together to define artifacts with some potential value content. This concept of composition is concretized in the `Feature` class. Features can, thus, be viewed as the potential value of a combination of one or more resources of a supplier VN. This potential value gets transformed into realized value when the adopter VN consumes the underlying artifact i.e. the industry offering. Thus feature and value differ only in the context of the observer. Feature expresses the view of the supplier of his product or service and value is the view of the adopter of the consumed product or service. This difference is captured as property constraints and is further detailed in Section 4.3.

From a taxonomy point of view, interpretation of features as potential value results in similar refinements of the `Feature` and `Value` classes. The taxonomy of the `Feature` class is presented in Figure 6. We posit that the `Value` class has a similar taxonomy tree hence do not present it separately. The following discussion on the specificities of feature refinement applies equally to the value concept.

The `Feature` class has two subclasses: `FT_Utility` and `FT_Warranty`. Utility and warranty are two concepts publicized as part of the Information Technology Infrastructure Library (ITIL) (OGC, 2007), developed by the UK's Office of Government Commerce (OGC) for Information Technology Services Management. Utility captures the functionality offered by a product or service and is informally interpreted as ‘what the industry offering does’. On the other hand, warranty is the promise that a product or service will meet its’ agreed requirements, informally interpreted as ‘how the industry offering is done’. In the

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Requirements Engineering field, these are often termed as the function and non-functional requirements (Gause & Weinberg, 1989).

The utility of a service or good is usually well understood. It is the warranty aspect that is open to interpretation and is hence further refined. A warranty can be related to the availability, reliability, ease of use and cost of the service or good. The `FT_WR_Availability` class represents the attributes that capture the readiness of the service or good to be consumed by the adopter. The readiness can be both temporal, `FT_WR_AV_Temporal` class, and spatial, `FT_WR_AV_Spatial` class. The presence of electricity supply at the time and place of consumption will constitute the temporal and spatial availability of the service provided by the ECN. The objects of the `FT_WR_Reliability` class represent the appropriateness of the service or good for consumption. Appropriateness can be achieved by ensuring safeguards against disruptive failures, the `FT_WR_RL_DisruptionProtecting` class, and damaging failures, the `FT_WR_RL_DamageProtecting` class. For instance, the use of surge protector equipment can protect against slight variations in electricity supply but a line breaker would be required to stop the supply in the event of very high variations in supply. The `FT_WR_EaseOfUse` class represents the (in) convenience of evaluating – `FT_WR_EU_Evaluation`, procuring - `FT_WR_EU_Procurement`, and consuming - `FT_WR_EU_Consumption`, a product or service. The `FT_WR_Cost` class captures the attributes that define the cost of the service or good. The cost can be interpreted both in monetary, `FT_WR_CT_Monetary`, and in non-monetary terms, `FT_WR_CT_NonMonetary`.

4.2 The ConceptSpacePartition Class

The taxonomy of the `ConceptSpacePartition` class is presented in Figure 7. As the name suggests, this class creates a partition on the set of concepts represented in the `IndustryConcept` Class. A partition imposes a certain view of the industry. The `Enterprise` subclass partitions the various concepts in an Industry along the well established boundaries of legal ownership and undertaking. For instance every resource in an industry is owned by some enterprise. `Enterprise` subclass is the default partition of the objects represented by `IndustryConcept` class.

The `ValueNetworkPartition` subclass is a manifestation of the Value Network concept in SEAM. It relies on the default `Enterprise` class imposed partition on industry concepts. More specifically, the `ValueNetworkPartition` subclass partitions the various concepts in an industry along the common intent of the enterprises where these concepts originate. It is important to note that the absence of an explicit intent is also a commonality and, hence, can form a valid partition of the Industry concepts. As a result, the `ValueNetworkPartition` class is further sub-divided into `VNP_Strategic` and `VNP_NonStrategic`. The strategic subclass refers to a partition that is based on some maximizing something – profit, welfare, power, etc. By contrast, the non-strategic subclass is blind and has no objective, no preferences, and no foresight, for instance the Environment (Birchler & Bütler, 2007).

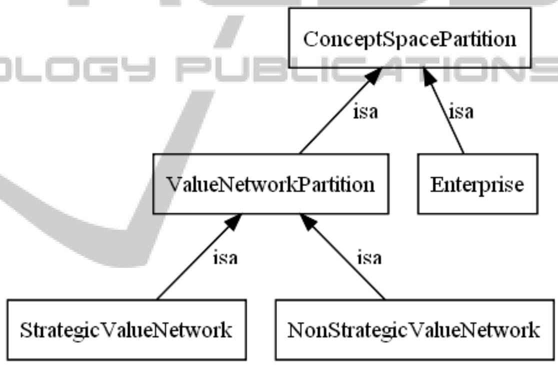

Figure 7: The Taxonomy for ConceptSpacePartition Class.

4.3 Property Constraints

The properties that bind the different concepts in REGENT are depicted in Figure 8. Properties in OWL are binary relations constraining the interaction between any two classes. For any property connecting an object o1 to object o2 an inverse property can also be specified which connects object o2 with o1. In the following, we discuss these properties on a class by class basis. For the sake of clarity, words starting with upper case alphabet are class names and the same when written in lowercase represent objects of that class.

The objects in the Resource class are constrained through two properties. 1) The *hasOwner* property mandates that each resource is connected to some enterprise. To ensure the uniqueness of this relation we limit the property to have a single value i.e. each resource has only one owner. In OWL this is accomplished by setting the property characteristics

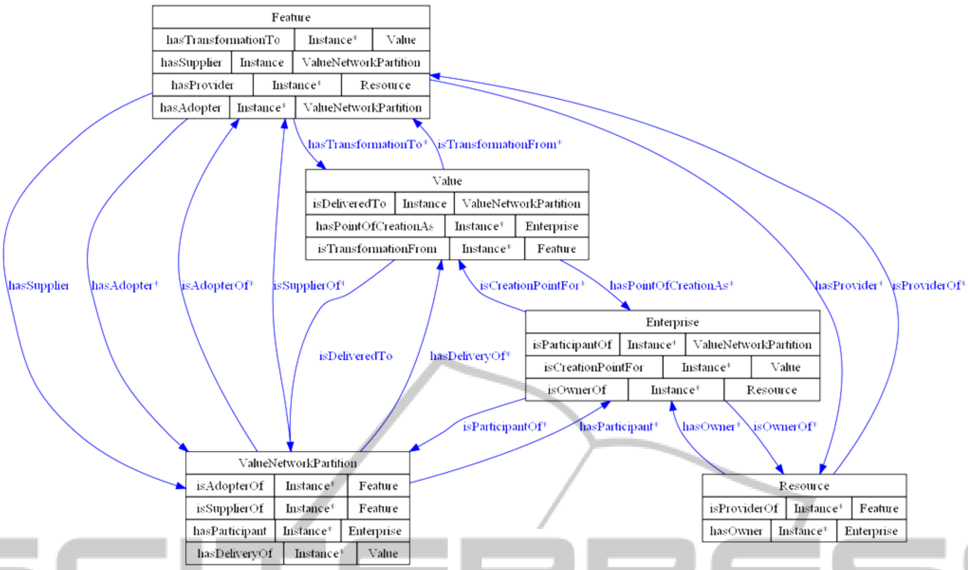

Figure 8: A visual representation of properties constraining REGENT concepts.

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as functional. The corresponding inverse property that connects an enterprise to its resources is the *isOwnerOf* property. The one-to-many nature of this relation is visually represented with an asterisk (*). An enterprise can own more than one resource. 2) The *isProviderOf* property links a resource to the feature it contributes. The corresponding inverse property that connects a feature to its constituent resources is the *hasProvider* property. Both of these properties represent a one-to-many relation – a resource can enable more than one feature and a feature can be enabled by more than one resource.

The objects in the Feature class are constrained through four properties. 1) The *hasTransformationTo* relation specifies the values that are realization of the features. The corresponding inverse property *isTransformationFrom* specifies the features that constitute the value. Both of these relations exhibit multiplicity – multiple features can aid a value creation and multiple values can be enabled by a feature. 2) The *hasSupplier* relation specifies the supplier value network for a feature. This is a single value relation which restricts each feature to have a unique supplier. The same is imposed by setting the functional characteristic of this property. The corresponding inverse property, *isSupplierOf*, is a multi-valued relation. A value network can be a supplier of more than one feature. 3) The *hasProvider* relation is already discussed above. 4) The *hasAdopter* relation specifies the adopter value network for a feature. The corresponding inverse property, *isAdopterOf*, specifies the set of features that a value network adopts. Both of these are multi-valued properties – a value network can adopt multiple features and a feature can be adopted by multiple VNs.

The objects in the `Value` class are constrained through three properties. 1) The *isDeliveredTo* property specifies the value network where a value is realized. This is a single value property; a value is closely associated to the perception of the consumer and, is hence, unique to the value network. We do this by setting the functional characteristic of the property. The corresponding inverse property, *hasDeliveryO,* specifies the value that a value network consumes. 2) The *hasPointOfCreationAs* property specifies the precise enterprise which consumes this value. Again, consumption is unique to an enterprise; hence, this property is a single-valued function. The corresponding inverse property, *isCreationPointFor*, identifies all the values that are consumed by an enterprise. This is a multi-valued property. 3) The *isTransformationFrom* property has been detailed earlier.

In addition to the properties exhibited by the Feature, Resource and Value class. There exists an additional relation between the objects of the Enterprise class and the objects of the ValueNetworkPartition class. The property *isParticipantOf* identifies the value network to which the enterprise participates. To highlight the fact that an enterprise when part of two value networks does so in different roles, we model this relation as a single-value property – setting its functional characteristic. The corresponding inverse property, *hasParticipant*, is a multi-valued property and identifies all the enterprises that are members of a VN.

5 THE CASE OF URBAN RESIDENTIAL ELECTRICITY SUPPLY

In this section, we use REGENT to provide a systematic view of the Urban Residential Electricity Supply Industry (URESI). Details about the URESI were gathered from various reports (US Aid, 2007) (Malaman, April, 2001), best practices (OECD, 1997), guidelines (Queensland Competition Authority, 2001), national regulations (GOI, 2002) and personal communication with Industry representatives. The later was done through a consultation meeting, 'The Role of IT in Regulatory Governance', held on December 05, 2009 at TATA Consultancy Services Ltd., Lucknow India.

We begin by identifying the different stakeholders in a URESI. Stakeholders with common objectives, or lack of objective, are grouped into same Value Network. Four VNs emerge from this exercise: The Economic Value Network (ECN) that represents enterprises with primarily economic motivation, Social Value Network (SCN) that represents enterprises with primarily social motivation, Environmental Value Network (EVN) that represents non strategic enterprises and Government Value Network (GVN) that represents the collective welfare as the overriding motivation. The enterprises constituting the ECN are Generation Company, Transmission Company and the Distribution Company. The enterprise constituting the SCN is the Urban Household. The enterprises constituting the ENV are Climate and Habitat. Climate represents the macro level aspects of the environment while habitat represents the micro level aspects of our immediate surroundings. ECN and SCN are generalizations of the Electricity Supplier Value Network and the Electricity Consumer Value Network mentioned in the Sections 2 and 4.

5.1 Resource Identification

For each of these VN, we take a commercial and operational view of the value exchange and identify the tangible/intangible resources that aid the production/delivery of the VN offering and the reception/consumption of the counter offering from other VNs. These resources along with the related Enterprise and Value Network are listed in Table 1.

In the case of ECN, the Generation Company provides fuel specific generation plants (r73-83) as tangible resources for the production process. The Distribution and Transmission Companies provide the necessary network, both large area and local area, to transport the generated electricity to the prospective place of consumption. The elements of these networks (r51-63) represent the tangible, delivery related operational resources in ECN. To enable the return path, the Distribution Company makes available different Billing plans (r27-31), Collection modes (r32-35), Communication channels (r38-40) and Maintenance Equipments (r36, 37) as tangible resources for receiving the revenue and information (feedback) flow. The accompanying intangible resources for this purpose include billing, repair and support related capabilities (r21-25). The information resulting from this feedback is consumed by Generation Companies in fine tuning their generation strategies, for instance operate the generation units in the increasing order of marginal production cost or in the increasing order of marginal emission (r1, 2).

In the case of EVN, the Habitat provides the different kind of fuels such as Gas, Coal, Nuclear, etc. (r88-96), as tangible resources for the production process. On the delivery front, EVN provides an intangible resource in the form of ease of procurement of natural resources. It is the procurement feasibility (r47) that allows a natural resource to be available as a fuel in the electricity production process. To enable the return path, the Climate makes available air, land and water (r41-43) as tangible resources for receiving the pollution that results from the electricity production process. The pollution is finally consumed as a displeasing benefit through the five human senses (r3-7), which act as the intangible consumption resource.

In the case of GVN, policy making exploits the following four resources available with any government institution: information (Nodal), power (Authority), money (Treasure) and management (Organization). The NATO concept was introduced by (Hood & Margetts, 2007) and has since been widely used to study the working of governments. The information, power and management (r68-70) represent intangible and money (r97) represents tangible, operational resources for producing high level policies.

Table 1: List of Resource identified in URESI.

TAXONOMY			ID	VN	ENTERPRISE	RESOURCE LIST
Commercial	Consumption	Intangible	r1	ECN	Generation Co	MarginalCostBasedGenerationStrategy
			r2	ECN	Generation Co	MarginalEmissionBasedGenerationStrategy
			r3	EVN	Habitat	AuditoryHumanSense
			r4	EVN	Habitat	OlfactoryHumanSense
			r5	EVN	Habitat	TactileHumanSense
			r6	EVN	Habitat	VisualHumanSense
			r7	EVN	Habitat	GustatoryHumanSense
			r8	GVN	Ministry of Power	AuthorityReinforcement
			r9	GVN	Ministry of Power	InformationReinforcement
			r10	GVN	Ministry of Power	OrganizationReinforcement
			r11	SCN	Household	UsageBehavior
		Tangible	r12	GVN	Ministry of Power	TreasureReinforcement
			r13	SCN	Household	AssistedLivingElectricalAppliance
			r14	SCN	Household	BulkChargingElectricalAppliance
			r15	SCN	Household	ClimateControlElectricalAppliance
			r16	SCN	Household	HeatingCoolingElectricalAppliance
			r17	SCN	Household	HomeOfficeElectricalAppliance
			r18	SCN	Household	LightingElectricalAppliance
			r19	SCN	Household	MotorDrivenMiscElectricalAppliance
			r20	SCN	Household	PersonalUseElectricalAppliance
	Reception	Intangible	r21	ECN	Distribution Co	BillCollectionCapability
			r22	ECN	Distribution Co	BillGenerationCapability
			r23	ECN	Distribution Co	BillTransmissionCapability
			r24	ECN	Distribution Co	SupplyRepairCapability
			r25	ECN	Distribution Co	SupplySupportCapability
			r26	GVN	Ministry of Power	PublicOpinion
		Tangible	r27	ECN	Distribution Co	Cash
			r28	ECN	Distribution Co	Credit
			r29	ECN	Distribution Co	ExternalCounter
			r30	ECN	Distribution Co	InternalCounter
			r31	ECN	Distribution Co	LightMaintainenceEquipment
			r32	ECN	Distribution Co	HeavyMaintainenceEquipment
			r33	ECN	Distribution Co	InternetAsCommChannel
			r34	ECN	Distribution Co	Phone
			r35	ECN	Distribution Co	SnailMail
			r36	EVN	Climate	Air
			r37	EVN	Climate	Land
			r38	EVN	Climate	Water
			r39	GVN	Ministry of Power	Election
			r40	GVN	Ministry of Power	Nomination
			r41	SCN	Household	Identity
Operational	Delivery	Intangible	r42	EVN	Climate	ProcurementFeasability
			r43	GVN	Ministry of Power	Campaign
			r44	GVN	Ministry of Power	MoralSuasion
			r45	GVN	Ministry of Power	Propaganda
		Tangible	r46	ECN	Distribution Co	AutomaticSwitch
			r47	ECN	Distribution Co	MannualSwitch
			r48	ECN	Distribution Co	ConventionalMeter
			r49	ECN	Distribution Co	SmartMeter
			r50	ECN	Distribution Co	SinglePhaseLoad
			r51	ECN	Distribution Co	ThreePhaseLoad
			r52	ECN	Distribution Co	UndergroundCable
			r53	ECN	Distribution Co	OverheadCable
			r54	ECN	Distribution Co	OilTransformer
			r55	ECN	Distribution Co	FerroTransformer
			r56	ECN	Transmission Co	HighVoltagePowerLine
			r57	ECN	Transmission Co	LowVoltagePowerLine
			r58	ECN	Transmission Co	VeryHighVoltagePowerLine
			r59	GVN	Ministry of Power	Grant
			r60	GVN	Ministry of Power	Loan
			r61	GVN	Ministry of Power	Tax
			r62	GVN	Ministry of Power	Rebate
	Production	Intangible	r63	GVN	Ministry of Power	Authority
			r64	GVN	Ministry of Power	Information
			r65	GVN	Ministry of Power	Organisation
			r66	SCN	Household	SpendingStrategy
			r67	SCN	Household	WorkloadCharacteristics (Batch/Interactive)
		Tangible	r68	ECN	Generation Co	BioWastePlant
			r69	ECN	Generation Co	CentralisedPlant
			r70	ECN	Generation Co	CoalPlant
			r71	ECN	Generation Co	DistributedGenerationPlant
			r72	ECN	Generation Co	GasPlant
			r73	ECN	Generation Co	HydroPlant
			r74	ECN	Generation Co	NuclearPlant
			r75	ECN	Generation Co	PetroleumPlant
			r76	ECN	Generation Co	SolarFarm
			r77	ECN	Generation Co	TidalUnit
			r78	ECN	Generation Co	WindFarm
			r79	ECN	Generation Co	VariableOutputPlant
			r80	ECN	Generation Co	FixedOutputPlant
			r81	ECN	Generation Co	LargeCapacityPlant
			r82	ECN	Generation Co	SmallCapacityPlant
			r83	EVN	Habitat	BioWaste
			r84	EVN	Habitat	Coal
			r85	EVN	Habitat	Gas
			r86	EVN	Habitat	Hydro
			r87	EVN	Habitat	Nuclear
			r88	EVN	Habitat	Petroleum
			r89	EVN	Habitat	Solar
			r90	EVN	Habitat	Tidal
			r91	EVN	Habitat	Wind
			r92	GVN	Ministry of Power	Treasure
			r93	SCN	Household	MonthlyLoad
			r94	SCN	Household	MonthlyBudget

To deliver its policies the government uses various social and economic instruments (r48-50, 64-67). It receives the benefits of policy making through election, nominations and public opinion formation (r26, 44, 45). Any political capital thus accrued is encashed by reinforcing (r8-10, 12) it resources for further policy making.

In the case of SCN, the demand for electricity at an Urban Household is a combination of its load requirements and the willingness/capability to pay. The tangible resources that produce this demand include the household monthly budget and monthly load (r98, 99). The corresponding intangible resources include the spending strategy and the consumption characteristic (r71, 72). In an urban setting, there are no extra resources required to make this demand visible to the ECN, as a result there are no delivery related resources listed for SCN. Nevertheless, this is not always the case. In a rural setting, the economic prospects of serving an isolated demand may not be too attractive. Very often, in these situations, the GVN lends its resources to deliver such demands, aka Universal Service Obligation. On the commercial front, the SCN obtains a connection using its identity as the resource to guarantee the intent of upholding the terms and conditions. The household identity (r46) is thus the tangible, reception oriented commercial resource of SCN. Finally, the different kind of electrical appliances (r13-20) in the household and the usage behaviour (r11) of household members act as the tangible and the intangible resources required to consume electricity.

Table 2: List of Feature identified in URESI.

TAXONOMY			ID	VN	FEATURE LIST
Utility			f1	ECN	ElectricitySupply
			f2	EVN	ElectricityFuel
			f3	GVN	HighLevelPolicy
			f4	SCN	ElectricityDemand
Warranty	Reliability	Disruption	f5	ECN	TimeToRepair
			f6	ECN	GenerationFromRenewable
			f7	GVN	NoticePeriodForNewPolicyAdoption
			f8	SCN	BackupSupport
			f9	SCN	IncomeStability
		Dmg	f10	ECN	ApplianceProtectionInsurance
			f11	GVN	PolicyReviewOption
	Availability	Spatial	f12	ECN	ConnectionTransfer
			f13	SCN	ResidentialStability
			f14	GVN	UniformityInPolicyAcrossSupplyRegion
		Temporal	f15	ECN	FrequencyOfInterruption
			f16	ECN	DurationOfInterruption
			f17	EVN	RenewableFuelSource
			f18	EVN	NonRenewableFuelSource
			f19	GVN	FrequencyOfPolicyChange
			f20	SCN	PaymentTimeliness
	EaseOfUse	Evaluation	f21	GVN	Command&Control
			f22	GVN	Reward&Penality
			f23	SCN	LoadVerifiability
			f24	SCN	IncomeVerifiability
		Procurement	f25	ECN	DistanceFromGrid
			f26	ECN	DistanceFromSource
			f27	ECN	InitialCostOfConnection
			f28	ECN	InitialTimeToConnection
			f29	ECN	IndividualContract
			f30	ECN	CommunityContract
		Consumption	f31	ECN	EaseOfBillPayment
			f32	ECN	EaseOfServiceSupport
			f33	ECN	VariableLoadSupport
			f34	GVN	UniquenessOfInterpretation
			f35	SCN	TimeOfDayInSensitiveConsumption
			f36	SCN	TimeOfDaySensitiveConsumption
			f37	SCN	TimeOfWeekInSensitiveConsumption
			f38	SCN	TimeOfWeekSensitiveConsumption
			f39	SCN	TimeOfYearInSensitiveConsumption
			f40	SCN	TimeOfYearSensitiveConsumption
			f41	SCN	LoadVariance
	Cost	Monetory	f42	ECN	FixedSupplyTariff
			f43	ECN	QuantityBasedSupplyTariff
			f44	ECN	TimeofUseSupplyTariff
			f45	ECN	FrequentTarrifVariationUnknownApriori
			f46	ECN	OccassionalTarrifVariationKnownApriori
			f47	GVN	ComplianceCost
			f48	SCN	CostSenstivityOfWorkload
		NonMonetory	f49	ECN	ToxicWasteOutput(emission)
			f50	ECN	WasteDisposal
			f51	EVN	CarbonIntenseNaturalResource
			f52	EVN	CarbonNeutralNaturalResource
			f53	GVN	ComplainceOutcomeOnTrade
			f54	SCN	QualitySensitivityOfWorkload

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5.2 Feature Identification

Every VN in an industry contributes some service or good to other VNs in the industry. As described in Section 2.4.1, a VN offering can be detailed along the utility and warranty dimensions. Table 2 lists the utility and warranty details of the VN offerings in the Urban Residential Electricity Industry.

The utility of ECN is to provide electricity (f1) for residential purposes. For the electricity supply to be useful, it provides a set of warranties related to temporal (f15, 16) and spatial availability (f12), dollar (f42-46) and non-dollar cost (f49, 50), ease of use (f25-33) and reliability (f5, 6, 10).

The utility of ENV offering is to provide natural-resources (f2) required for electricity generation. These natural-resources can either be provided in perpetuity (f17) or only for a limited period of time (f18), with little (f52) or significant (f51) ecological impact, thereby constituting the warranty of the ENV offering.

The utility of SCN is to exhibit demand (f4) for electricity. Demand includes both the expected load and the willingness/ability to pay. The temporal sensitivity of consumption (f35-40, 48), the specificities of the expected electrical load (f23, 41), tolerance to qualitative variance (f54) and the payment guarantees (f9, 13, 20, 24) are the warranties that detail the utility offered by the SCN to other VNs in the industry.

The utility of GVN is to provide the high level policy (f3) framework that guides the industry in the desired direction. These policies can be evaluated for their suitability of implementation - command & control (f21) or reward & penalty (f22). A simplified (f34), sensitive (f7, 11), stable (f19) and uniform policy regime (f14) limits the industries' cost of compliance (f47) and results in the industry growth (f53).

5.3 Value Identification

Every VN in an industry receives some value in return to his contribution to the Industry. Value can either be positive or negative, solicited in the case of strategic VNs or unsolicited in the case of non-strategic players. Table 3 lists the utility and warranty of the different value created in the Urban Residential Electricity Supply Industry, the VNs that adopt these value and the enterprises in the adopter VN where these value are realized.

The utility of the positive value realized at the ECN is profit (v1-3). To accomplish this, the Distribution Company tries to forecast demand (v8), inform policy makers about its requirements (v12), exploit the need of consumers for electricity (v18) and ensure continued flow of revenue (v19). On the transmission front, the spatial diversity of demand (v14) creates more business opportunities for the Transmission Company. Continued availability of fuel (v17) for electricity generation is the primary warranty for a Generation Company. All the ECN enterprises bear the transaction cost (v29-31) of doing business under some policy regime.

The utility of the negative value realized at the EVN is pollution (v4, 5). At the micro level the pollution can lead to a variety of displeasures (v34-38) to the inhabitants of a certain geographical area. At the macro level pollution can manifest itself as undesired alterations to climate (v39-41).

The utility of the positive value realized at the SCN is the comfortable living (v7) of household members. The household convenience is maximised by ensuring safe & continued operation of electrical appliances (v13, 21) and giving the household complete freedom of the financial (v33) and social aspect (v16, 23) of electricity supply. Simplifying the interactions between the household and the service provider (v28) also brings added comfort to the household. In certain situations, specificities of the supply network may impose restrictions on the use of some types of appliances (v10), for instance heavy load motors on single phase connections.

The utility of the positive value realized at the GVN is to ensure collective welfare of the society by accumulating political capital (v6). Achieving independence in electricity supply (v9) through increased investments (v15, 20, 26), making electricity available for every one (v24), ensuring minimum quality standard of supply (v27) at a fair price (v32) are important warranties of electricity supply that affect the consumers at large.

Table 3: List of Value identified in URESI.

TAXONOMY			ID	VN	ENTERPRISE	VALUE LIST
Utility			v1	ECN	DistributionCo.	Profit
			v2	ECN	TransmissionCo.	Profit
			v3	ECN	GenerationCo.	Profit
			v4	EVN	Habitat	HabitatPollution
			v5	EVN	Climate	ClimatePollution
			v6	GVN	MinistryOfPower	PoliticalCapital
			v7	SCN	Household	Comfortable Living
Warranty	Reliability	Disruptio	v8	ECN	DistributionCo.	Demand Foresight
			v9	GVN	MinistryOfPower	ElectricitySupplyIndependence
			v10	SCN	Household	RestrictionOnTypeOfAppliance
		Damage	v11	ECN	DistributionCo.	PlanningOpportunity
			v12	ECN	DistributionCo.	OpinionSharing
			v13	SCN	Household	SafeOperationOfElectricalAppliance
	Availability	Spatial	v14	ECN	TransmissionCo.	SpatialDiversityOfDemand
			v15	GVN	MinistryOfPower	CapitalInvestmentInTransmission
			v16	SCN	Household	EaseOfResidenceChange
		Temporal	v17	ECN	GenerationCo.	ContinuedAccessToFuel
			v18	ECN	DistributionCo.	ContinuedDemandForElectricity
			v19	ECN	DistributionCo.	ContinuedRevenueInflow
			v20	GVN	MinistryOfPower	CapitalInvestmentInGeneration
			v21	SCN	Household	ContinuedOperationOfElectricalAppliance
	EaseOfUse	Evalu	v22	SCN	Household	RestrictedChoice
			v23	SCN	Household	ChoiceOfElectricitySource
		Procu	v24	GVN	MinistryOfPower	UniversalAvailabilityOfSupply
			v25	SCN	Household	InitialPayment
		Consum	v26	GVN	MinistryOfPower	CapitalInvestmentInDistribution
			v27	GVN	MinistryOfPower	MinimumQualityofSupply
			v28	SCN	Household	CommercialConvenience
Cost	Monetory		v29	ECN	GenerationCo.	TransactionCost - emission, distributed generation
			v30	ECN	TransmissionCo.	TransactionCost - infrastructure expansion
			v31	ECN	DistributionCo.	TransactionCost - service delivery
			v32	GVN	MinistryOfPower	FairPrice
			v33	SCN	Household	OpportunityToReduceMonthlyBill
	NonMonetory		v34	EVN	Habitat	AuditoryDispleasure
			v35	EVN	Habitat	GustatoryDispleasure
			v36	EVN	Habitat	OlfactoryDispleasure
			v37	EVN	Habitat	TactitoryDispleasure
			v38	EVN	Habitat	VisibleDispleasure
			v39	EVN	Climate	AirPollution
			v40	EVN	Climate	LandPollution
			v41	EVN	Climate	WaterPollution
			v42	GVN	MinistryOfPower	EnvironmentalStandardComplaince
			v43	SCN	Household	InconvenienceOfReschedulingHouseholdWork

5.4 Establishing Regulatory Oversight

Table 4 presents the mapping between the different members of the Resource, Feature and Value set. This mapping exploits the property constraints detailed in 2.4.4. In the interest of space, here we only elaborate the realization of auditory displeasure (v34) as a negative value created at the Habitat by the introduction of time based pricing scheme in the electricity supply industry.

Balancing the supply and demand for electricity is central to the proper functioning of an electricity grid. The demand, however, tends to exhibit time sensitivities with more electricity required during specific times of the day or year, for example increased lighting requirements during the night and higher climate control needs during peak winter/summer season. In the absence of efficient large scale electricity storage techniques such variability in demand can only be met through flexible generation capabilities. Not all generation units support variable output. For example, nuclear power plants must be run at close to-full capacity at all times whereas production from other sources such as wind and solar, though inherently variable in nature, remains hard to predict.

Table 4: Resource-Feature-Value mapping in URESI.

VALUE	FEATURE
v8	f23, f24, f41
v9	f6, f17
v10	f33
v11	f7
v12	f11, f53
v13	f10, f54
v14	f25, f26
v15	f14, f19, f21, f22, f34
v16	f12
v17	f17, f18
v18	f35-40
v19	f9, f13, f20
v20	f14, f19, f21, f22, f34
v21	f5, f8, f15, f16
v22	f29
v23	f30
v24	f20, f25, f26
v25	f27
v26	f14, f19, f21, f22, f34
v27	f5, f15, f16, f28
v28	f12, f31, f32
v29	f47
v30	f47
v31	f47
v32	f42-46
v33	f44-46
v34	f35, f44, f48
v35	f49-51
v36	f49-52
v37	f49-53
v38	f25, f26
v39	f49-51
v40	f49-52
v41	f49-53
v42	f49, f50, f52
v43	f44, f48

FEATURE	RESOURCE
f5	r24, r31
f6	r68, r73, r76-78, r83, r86, r89-91
f7	r9
f8	r14
f9	r94
f10	r46, r49, r52, r55, r58
f11	r9
f12	r22
f13	r41, r43
f14	r9, r10
f15	r46, r49, r52, r55, r58
f16	r24, r31, r46, r49, r52, r55, r58
f17	r83, r86, r89, r90, r91
f18	r84, 85, 87, 88
f19	r9, r10
f20	r21-23, r94
f21	r63-65
f22	r63-65, r92
f23	r13-20, r93
f24	r41, r43
f25	r69
f26	r71
f27	r48, r51
f28	r25
f29	r21-25
f30	r21-25
f31	r21-23
f32	r25
f33	r50, r51
f34	r8
f35	r14, r19, r67
f36	r13, r18, r67
f37	r17, r20, r67
f38	r13, r67
f39	r19, r67
f40	r15, r16, r67
f41	r67
f42	r22
f43	r22
f44	r1, r22, r49
f45	r1, r22, r49
f46	r1, r22, r49
f47	r12, r59-62
f48	r66, r94
f49	r2, r68, r70, r72, r74, r75
f50	r43-45, r59-62
f51	r84, r85, r88
f52	r83, r85-87, r89-91
f53	r43-45, r59-62
f54	r13, r17, r20

Further, the cost of electricity production varies from one type of generation unit to another. Generation Company operates these units in an increasing order of marginal costs (r1). Thus increased generation required to meet higher demands (peak hours) results in a higher per-unit cost of electricity. Similarly, during periods of low demand (off-peak hours) generation units with high marginal costs are cycled down resulting in a lower per-unit cost of electricity. Installation of smart meters (r49) allows the Distribution Co. to extend its billing capability (r22) and help the ECN introduce time of use (ToU) electricity pricing tariffs (f44). ToU presents economic incentives to enterprises in ECN and SCN alike. Electricity suppliers can increase profits by charging a higher per-unit cost during peak hours and consumers can minimize their bill (f48) by moving their time insensitive workloads (f35) to off-peak hours when the per-unit cost is low. The sensitivity of households to electricity bill is a function of their monthly budget (r94) and spending strategy (r66). Any attempt by households to move electricity workloads to off-peak hours is limited to the rescheduling of time insensitive workloads (f35) which in turn depends on the availability of requisite electrical appliances (r14, 19) and batch oriented workload characteristics (r67).

The temptation to move workloads to hours of low overall activity, e.g. night time, may result in increased noise levels during odd hours leading to the realization of a negative value of auditory displeasure (v34) to surrounding neighborhoods, the habitat. Use of REGENT to formally represent the value realization process exposes the industry concepts that enable it and the relationship these concepts have with the real world. Industry regulators can use this knowledge, for instance, to clearly identify the different industry elements that need to be monitored so as to track the realization of a given value of interest. An AND/OR graph depicting the value realization process for auditory displeasure (v34) is depicted in Figure 9.

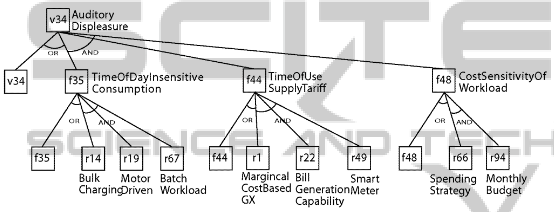

Figure 9: Monitoring auditory displeasure.

6 RELATED WORK

The role of ontology in formalizing the concepts in a knowledge system is well established. In the context of industry, ontology development has primarily focused on formalizing the domain specificities. The concepts and relationships that occur between entities from different domains have not attracted much ontological attention. E3 value (Gordijn & Akkermans, 2003) is one of the few attempts to study the value exchange between the stakeholders in an industry. It is, however, restricted to analyzing the economic exchange between companies active in an e-commerce business. Some ontology development has also been recently noticed in understanding regulation, for example IPROnto (Delgado, Gallego, Llorente, & García, 2003) which presents a formalization of the concepts in digital rights management. In the Electricity industry power quality measurement related ontology has been presented in PQONT (Küçük, Salor, Inan, Çadırcı, & Ermis, 2010).

7 CONCLUSIONS

REGENT enables an explicit specification of multi-party relationships in an industry by formalizing the concepts that influence the realization of stakeholder value. A systematic representation of industry knowledge will expose any deficiencies in regulators' understanding of the industry, thereby assisting the regulator in developing a holistic view of the industry. REGENT is an important first step in our larger effort of developing a knowledge system for the regulation of utilities.

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