PETRI NET MODEL FOR SMART GRID SYSTEM

A Paper
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Anand Swaroop Pandey

In Partial Fulfillment
for the Degree of
MASTER OF SCIENCE

Major Department:
Computer Science

March 2014

Fargo, North Dakota

North Dakota State University

Graduate School

Title

Petri Net Model For Smart Grid System

By

Anand Swaroop Pandey

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

SUPERVISORY COMMITTEE:

Dr. Kendall Nygard
Chair

Dr. Juan (Jen) Li

Dr. Saeed Salem

Dr. Sanjay Karmakar

Approved:

04-14-2014	Dr. Brian M. Slator
Date	Department Chair

ABSTRACT

The concept of a smart grid is to provide self-healing, reliable, economic, and environment friendly energy-saving, sustainable electricity services to the users including the freedom to choose and set priorities according to the requirement and budget. This paper proposes a Petri Net model which can be used for such smart-grid systems. It provides the concept of an alternate power supply in the situation of a blackout due to any possible reasons, maintaining the reliability and healing nature of the smart grid. The model is developed with the help of the Renew 2.4 tool. Java functions are used to control the power supply's in the smart grid system.

Further experiments are done on the dynamic power supply to the consumers per their requirement with different time range which provides the consumer need versus power supply analysis to maintain the balance of power generation and transmission in the system.

ACKNOWLEDGEMENTS

Foremost, I would like to express my sincere gratitude to my adviser, Dr. Kendall E. Nygard, for the continuous support of my study and research as well as for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me with the research and writing of this paper. I could not have imagined having a better adviser and mentor for my study.

I would also like to thank the rest of my committee, Dr. Juan (Jen) Li, Dr. Saeed Salem, and Dr. Sanjay Karmakar, for their encouragement and insightful comments. My sincere thanks go to Dr. Kenneth Magel, Dr. Dean Knudson, Dr. Gursimran Walia, and Dr. Hyunsook Do for encouraging me on exciting projects.

I thank my fellow members of Smart Grid Research Group: Steve Boughosn, Ryan McCulloch, Davin Loegering, Prakash Ranganathan, Md. Chowdhury, Satheesh Chakravarthi, and MD Khan. I am grateful to Dr. Nygard for enlightening me with the world of research. I would like to thank my parents and my wife for their unending love and support throughout this endeavor. Without it, completing the degree would not have been possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. INTRODUCTION

1.1. Smart Grid

"A smart grid is a modernized electrical grid that uses information and communication technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity."

Link: http://en.wikipedia.org/wiki/Smart_grid (U.S. Department of Energy. "Smart Grid / Department of Energy" Retrieved 2012-06-18).

The concept of a smart grid is to provide an intelligent system that can support self-healing, reliable, economic, environment friendly, and sustainable electricity services for users. At the present time, mathematical models of the smart grid are inadequate for comparing and analyzing smart topologies and setting parameters.

In 1882, Thomas Edison introduced the first commercial generator in New York City. Initially, the electric grid was a one-way path from power generation to consumers. The concept of a smart grid allows a two-way flow by adding computer intelligence and communication to the electricity distribution network, ranging from solar panels and wind mills to smart appliances in order to connect electric vehicles. It gives majestic assurance for a controlled power supply, green environment, and future possibilities of making the power supply safer and more reliable.

The term "smart grid" was introduced in the late 1990s, and the first practical, large-scale example was introduced in the early 2000s. Boulder, Colorado, is the first fully well-designed smart-grid city.

The objective of this research is to provide a Petri Net model for the smart-grid system and to introduce a Java function using the Renew 2.4 tool to control the model's flow. This model helps to analyze the performance and constraints, to identify and prioritize the appropriate smart-grid system parameters, and to help compare with alternate models for a smart-grid simulator in order to get a better picture for future implementations of the system.

Some common formalisms are as follows:

- Process Algebras
- Modal Logic
- Petri Net (See Section 2.1 of Chapter 2.)

1.2. Process Algebras

Process algebra is based on modeling processes and events [Paananen 95]. The algebra provides operations for combining events and processes. A process is specified by defining its behavior as a sequence of possible events. The names of the events in the process algebra are known as actions. Examples of process algebraic formalisms are Language Of Temporal Ordering Specification (LOTOS), Calculus of Communicating Systems (CCS), and Communicating Sequential Processes (CSP).

1.3. Modal Logic

Modal logics are the outcome of adding one or more modal operators to a particular logic. Modal logic is the propositional logic. A propositional formula consists of primitive propositions (represented by propositional letters) and propositional connectives (or, and, not,

implication). A propositional modal is a propositional formula with modal operator(s). Attempts have been made to merge the object-oriented paradigm and nearly all potential forms of modal logic [Uustalu 91]. For example, in temporal logic, an object-oriented temporal logic language is TEMPO++ [Ramirez 95]. With TEMPO++, the concurrency issues are separated from the code. Each instance of a class is active and is treated as a concurrent (temporal logic) process. Labeling allows the class instances to be synchronized.

CHAPTER 2. BACKGROUND AND LITERATURE REVIEW

2.1. Petri Net

The object-orientation structuring in a language provides a number of advantages, and there are several ways to introduce object-oriented structuring to a concurrent language. The concurrent formalism is exceptionally advantageous for the development of a concurrent system. There are different types of formalisms, such as process algebras, modal logics, and Petri Net.

Petri Net were first developed by Carl Adam Petri in 1962 [1] as a mathematical tool for modeling systems. Under the MAC project at the Massachusetts Institute of Technology (MIT), research on Petri Net observed that this can be used in a wide range of applications for modeling finite state machines, communication protocols, synchronization control, parallel activities, discrete event systems, dataflow computations, and asynchronous circuits [2]. Petri Net model the notions of concurrency, non-determinism, communication, and synchronization [Khodabandeh 96]. The basic idea is to illustrate the state changes in a system with transitions.

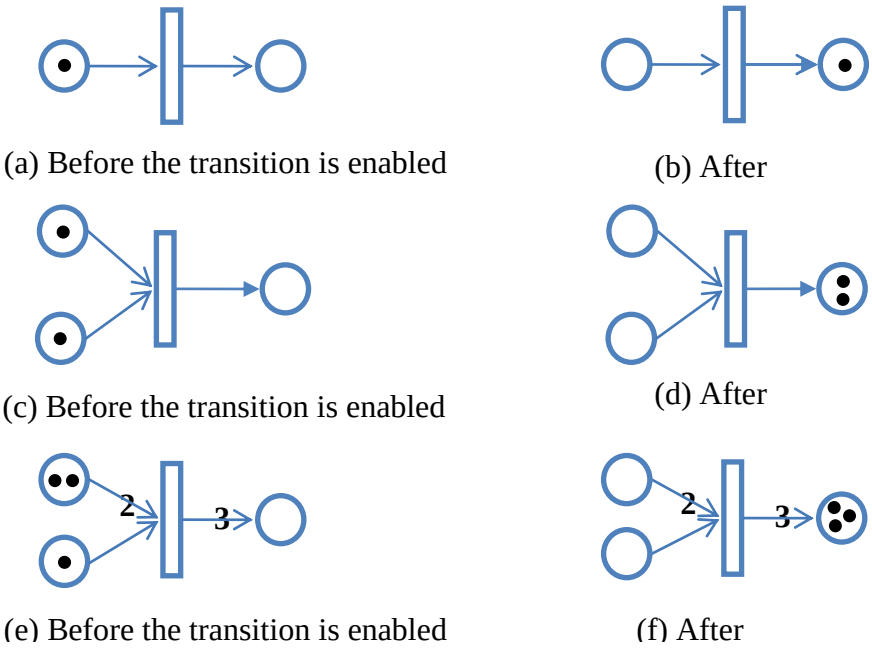
A place-transition net may be defined as a triple: N = (P, T, F), where P is a finite set of places represented by the symbols drawn as circles. T is a finite set of transitions represented by the symbols drawn as rectangles or lines. F is a flow relation such that $F \subseteq (P \times T) \cup (T \times P)$ with the conditions $P \cap T = \varnothing$ and $P \cup T \neq \varnothing$ as represented by the symbol arrow.

Table 1. Common Petri Net Symbols

Place		Flow	
Transition		Token	

The Petri-net formalism can be used for the design, specification, verification, validation, simulation, and implementation of synchronized systems. A combination of Petri Net and object-orientated concepts, which ultimately contribute countless benefits of object-orientation to the Petri Net formalism, is represented in Object Petri Net (OPNs) [Lakos 94].

A black and white Petri Net is a digraph. The nodes of the graph are places or transitions. Tokens are represented as dots and are used for marking the Petri Net because each place can contain zero or more tokens at any particular time. Input arcs are represented as direct edges that connect places to transitions, and the corresponding places are represented as input places. Also, output arcs are represented as transitions to places, and the corresponding places are represented as output places.



(a) Before the transition is enabled (b) After

(c) Before the transition is enabled (d) After

(e) Before the transition is enabled (f) After

Figure 1. Simple Black and White Petri Net

A transition is said to be enabled if the input places of a transition contain at least one token (Figure 1a). A transition may fire if it is enabled. Once a transition fires, one token is taken

from each input place, and one token is added to each output place (Figure 1c). If two transitions are simultaneously enabled, the one which fires first is not defined. A similar concept is shown in Figure 1e.

2.2. Coloured Petri Net (CPN)

The group at Aarhus University originally invented Coloured Petri Net which can be found at Kurt Jensen and his group "K. Jensen, Coloured Petri Net: A high-level Language for System Design and Analysis, LNCS vol. 483, Springer Verlag 1990". The main architects behind the tool are Kurt Jensen, Søren Christensen, Lars M. Kristensen, and Michael Westergaard. CPN tools were transferred to the AIS group in 2010, Eindhoven University of Technology, Netherlands.

In Dahl and Wolthusen [3], the CPN is defined a 5-tuple (Σ, P, T, C, F) as a timed interval, where P is a finite set of places, T is a finite set of transitions such that $P \cap T = \varnothing$, C is a color function, F is the transition function, and Σ is a finite set of types that is also referred to as colors. "A continuing problem with Jensen's hierarchy concept is the lack of an obvious design methodology. We suggest to transfer object-oriented concepts to Petri Net design*."* [Becker 93 p1]

To improve the command of Petri Net and to obtain the benefits of object-oriented modeling, many attempts have been made to combine Petri Net and the object-oriented approach. A Petri Net is often referred to as high-level nets used to model and analyze applications. The work in [4] explains the significance of the smart grid to the present generation and to talk about an approach for describing the objective, its idea, and related scenarios to fulfill the customers' requirements. In [5], advanced meters for electricity are focused for providing

two-way communication to upload commands and to download measuring data from the meters. In [6], several standardized wired and wireless communication technologies are available for various smart-grid applications. In [7], Jiang identifies several specific areas to apply computational intelligence in a smart electric grid. In [8], a logical model using a Petri Net has been proposed for distributed data management in a data warehouse to ease the Online Analytical Processing (OLAP) operations. In [9], a model based on access graphs for evaluating the security exposure of a large-scale smart grid has been introduced. In [10], the importance of Advanced Metering Infrastructure (AMI) towards a smart grid is discussed.

In [11], unmanned aerial vehicle simulation as Petri Net (PN) based software architecture has been proposed via visual modeling and analysis. In [12], a PN-based pilot behavior model is proposed as part of the knowledge-based cockpit assistant system. In [13], Stochastic Petri Net has been used to analyze signal transduction pathways for angiogenesis processes. In [14], a weighted fuzzy Petri Net has been used for fault analysis of a flight control system. In [15], the time Petri Net has been used to analyze the performance of the flexible production system. In [16], system performance is compared for PN models by analyzing attack trees. In [17], an e-commerce workflow access control model shows Petri-net based analysis, and in [18], Busi and Pinna explain the process discovery to reproduce the logs under consideration for process mining. In [19], the CPN model of an urban traffic network for performance evaluation is discussed. In [20], a Multistage Interconnection Network is modeled via another alternative for the high-level S-net.

2.3. Renew 2.4

The Renew tool for Petri-net development can be downloaded from http://www.renew.de. It supports several Petri Net dialects which include P/T, timed Petri Net, high-level, and object-oriented. The advantage includes support for modeling object-oriented concepts and synchronization channels, an advanced communication mechanism, a number of supported arc types, and a rich graphical environment (Kummer & Wienberg, 00). Renew uses XML to overcome the problem of model exchange with other Petri Net tools which is not included in DaNAMiCS. XML documents containing Petri-net models can be described using a Document Type Definition (DTD; Kummer et al., 01). Such a DTD is defined starting from the same assumptions that underlie Petri Net Markup Language (PNML), and as a consequence, those DTDs have common elements (net, place, transition, and arc). We have developed an Extensible Stylesheet Language Transformation (XSLT) that converts a PNML document to the Renew XML format. Renew is a Java-based, high-level Petri Net simulator that provides a flexible modeling approach based on reference nets.

Table 2. High-Level Petri-Net Tools

Tool Name	CoopnBuilder	AlPiNA	CPN Tools	HISIm	PIPE+	Renew 2.4
High level Net Type	CO-OPN language	Algebraic Petri Net	Colored Petri Net	Hybrid Petri Net	High-level Petri Net	Object-Oriented
Graphical Editor	✓	✓	✓	✓	✓	✓
Simulator	×	×	✓	✓	✓	✓

Renew is an integrated environment that gives the user access to all required tools, including an editor. The fundamental design principles of the editor are that it has an easy-to-use interface, a minimal input for the user, a direct relationship to the functionality, and a provision

for high-level formalism. Figure 2 shows a screen shot where the main toolbars and a net drawing are visible.

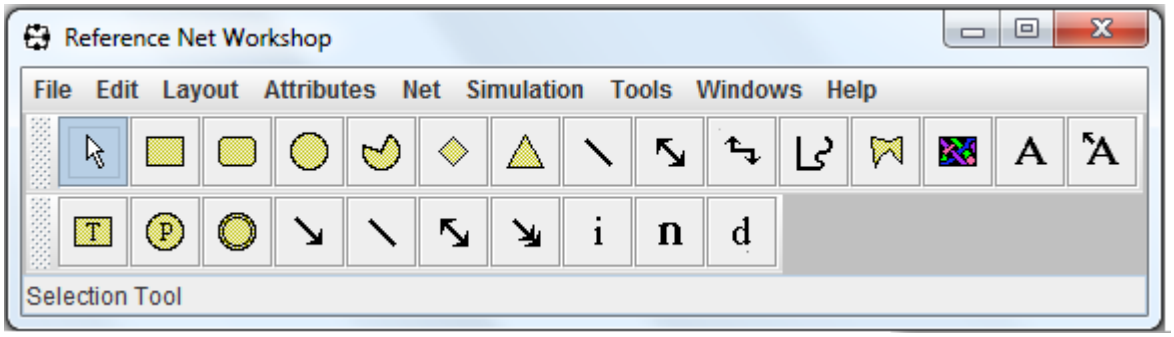


Figure 2. Renew 2.4 Tool Bar

Figure 3 shows the Renew 2.4 Petri-net design of a simple example with three places, A, B and C, with both A and B having two tokens, and the weight of flow towards transition T is one in each. Figure 4 shows the simulation of a design that has a transition of tokens and the final token being received at place C. Figure 5 shows the simulator steps performed for the entire process.

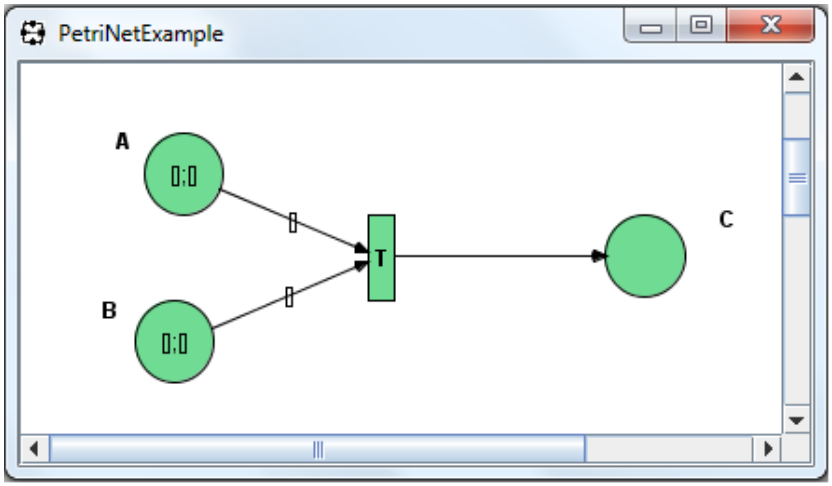


Figure 3. Petri Net Example Drawing

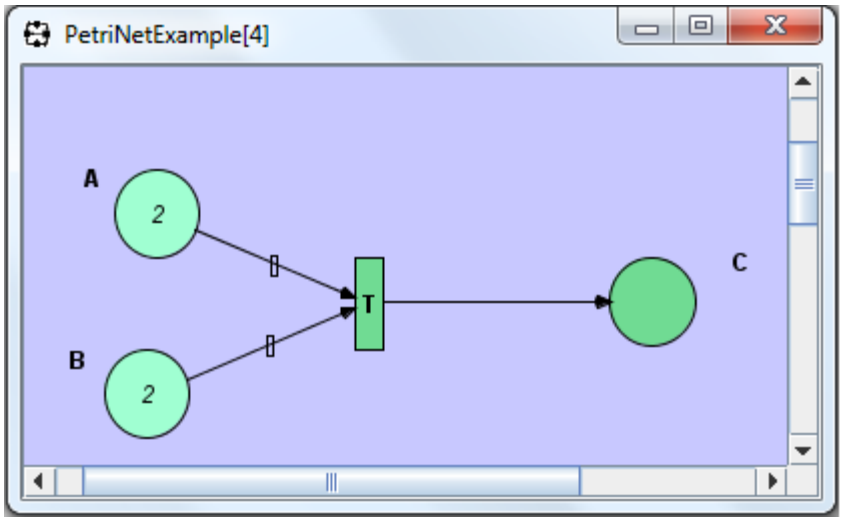


Figure 4. Petri Net Simulation Example

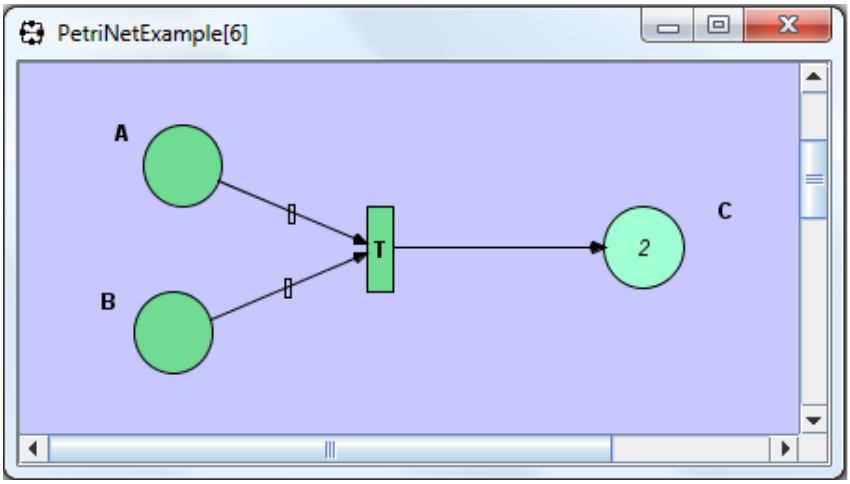


Figure 5. Petri Net Example of Final State Simulation

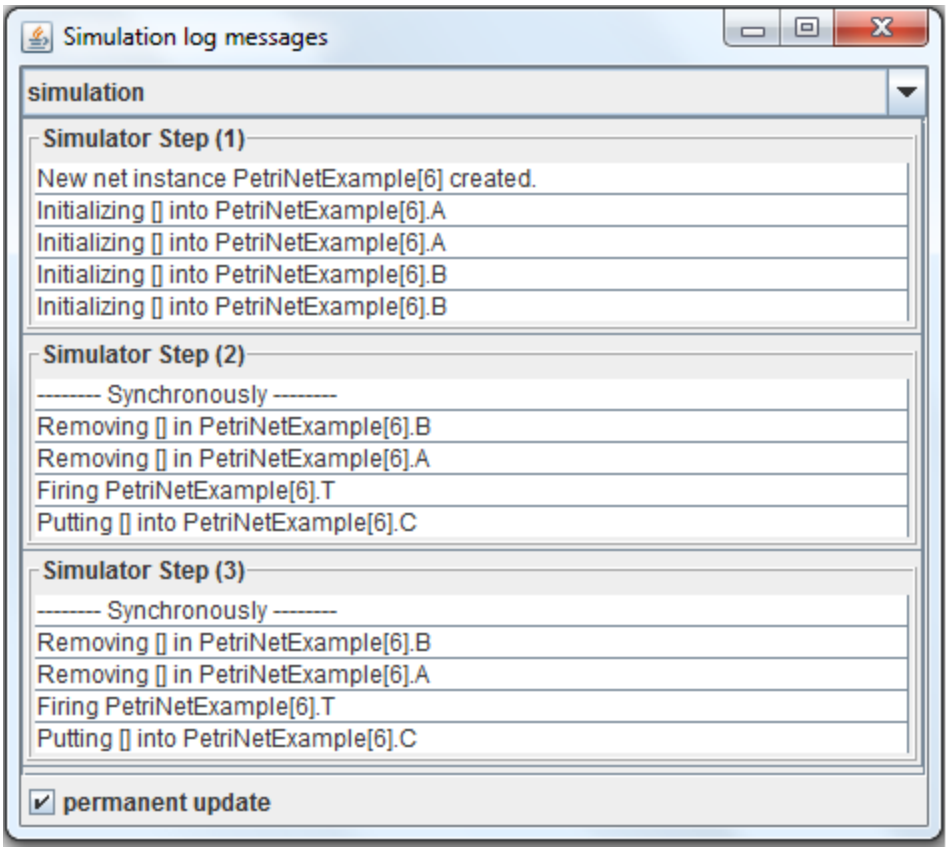


Figure 6. Petri Net Simulation Traces Example

The basic functionality of Renew is provided by the plug-ins depicted in Figure 7 (from de.renew.gui). To run a simulation for some reference nets without graphical feedback, the Util, Core, Simulator, and Formalism plug-ins are needed. The configuration of the simulation can then be done by setting several properties on the command line.

The main component is the Simulator plug-in. It is comprised of the simulation engine and some packages providing in- and output abstractions for the simulation. Nets can be fed to the simulation engine by using the so-called shadow-API which abstracts from the layout information and retains only the topological net structure. This provides a convenient way to create non-graphical nets algorithmically.

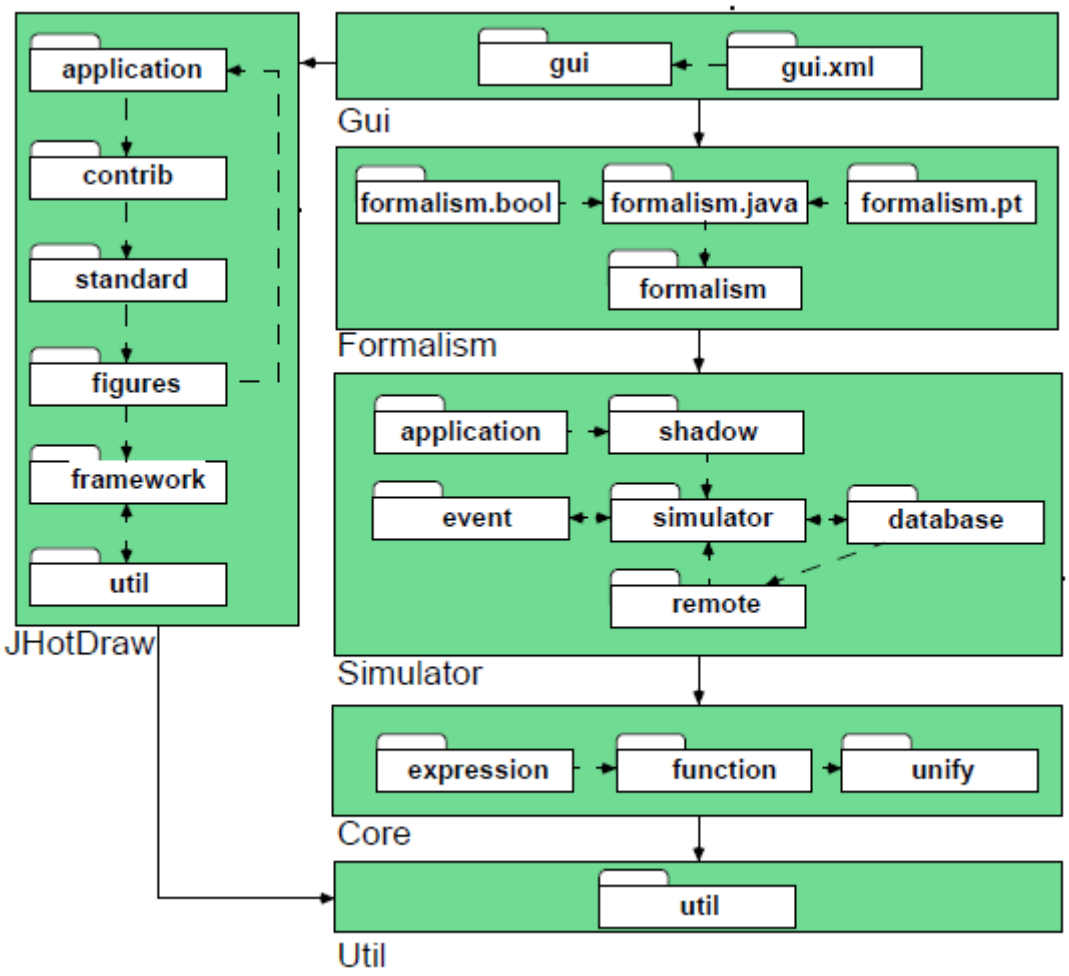


Figure 7. Basic Plug-ins of Renew 2.4

Renew is used in our group to develop and run medium-sized applications that are implemented in a mixture of reference nets and Java code (e.g., about 100 nets and the same number of Java classes). The mix of reference nets and Java is well supported because any Java object can be used as a token in nets and because any net can be wrapped by a so-called “stub” to make it appear as a Java class. When mixing nets and classic code, the developer can benefit from both sides: he has the clarity of nets at his hand when it comes to concurrency and synchronization, and he has access to the rich functionality of the Java-class libraries.

Figure 8 shows the compiler menu selection of Renew 2.4 tool. With the help of this menu the user can select the required formalism to run the simulator like shown in figure 8. In this research paper I have also used the timed java compiler to simulate the Petri Net model.

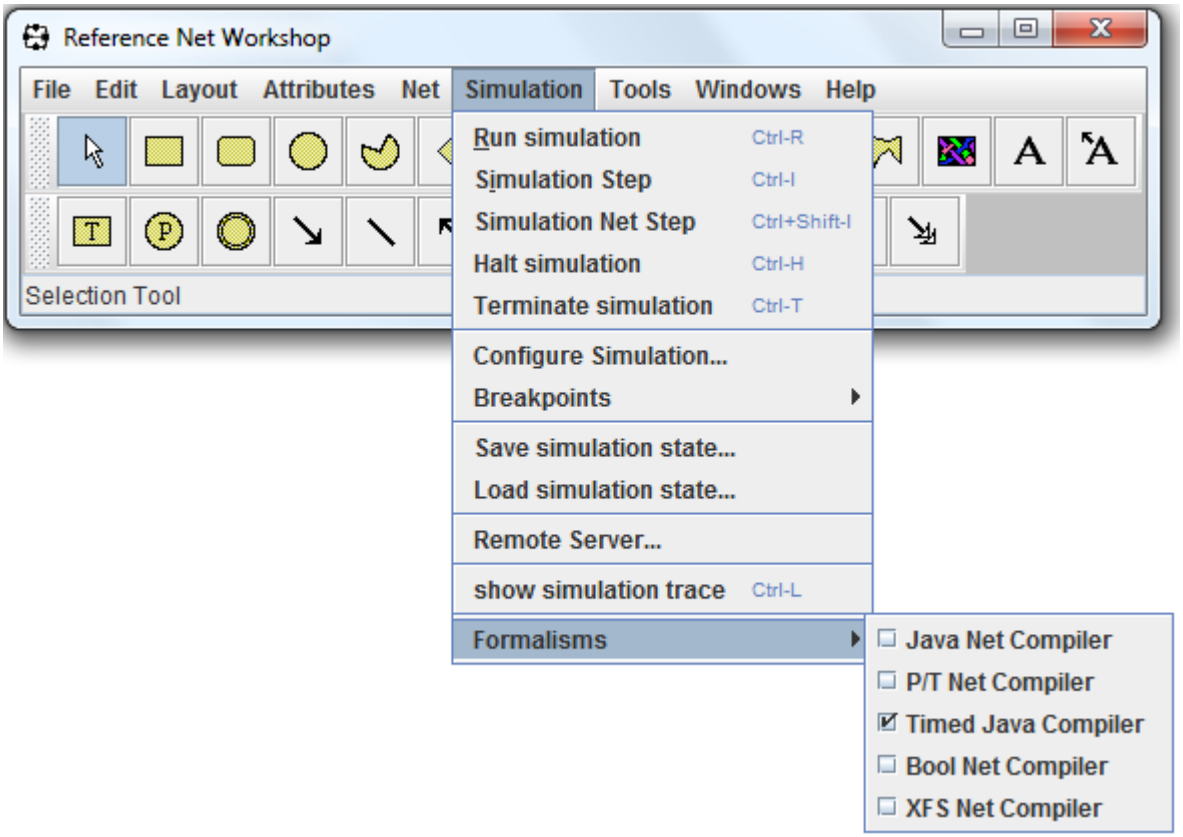


Figure 8. Renew 2.4 Compiler Selection Menu

In Figure 9 and figure 10, the dependencies among the various packages are shown. Two sub-hierarchies can be found here, de.renew.formalism and de.renew.gui, which are responsible for implementing specific net formalisms and for implementing a GUI, respectively.

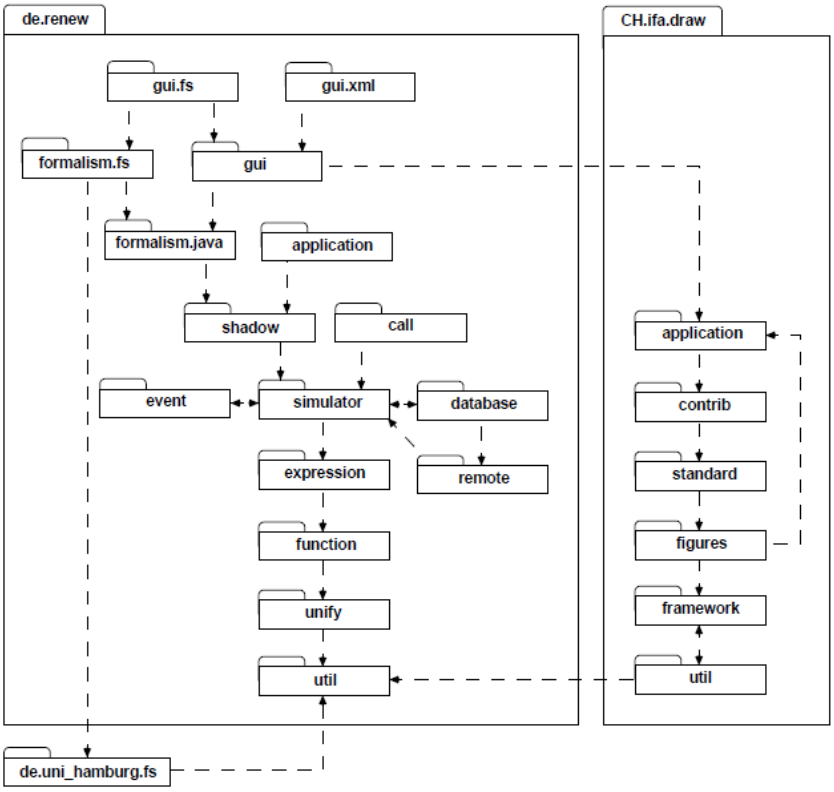


Figure 9. Renew 2.4 Overview of Packages

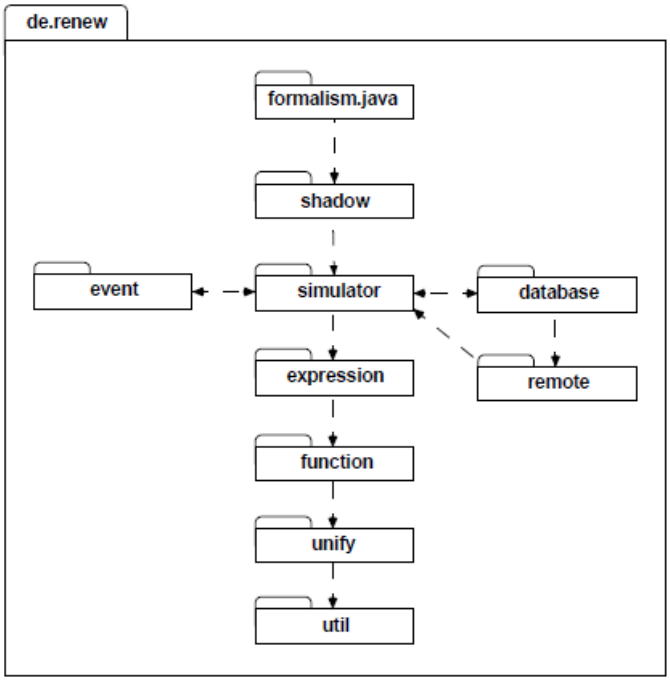


Figure 10. Renew 2.4 Overview of Simulation Core Packages

CHAPTER 3. PETRI NET MODEL FOR SMART-GRID SYSTEM

3.1. Modules for the Petri Net model

The proposed Petri Net model for the smart grid includes the characteristics of a smart grid to provide self-healing, reliable, economic, and sustainable electricity services to the users, giving them the freedom to choose and set their priorities according to their requirements and budgets in the grid. The Petri-net model for a smart grid is safe and deadlock free for analysis of the system.

The smart grid has four major modules which are initiated with smart power generation; smart power transmission; smart power distribution; and, finally, smart power consumption as shown in Figure 11. The designed smart-grid model for a Petri Net covers all these modules which have both timed and immediate transitions.

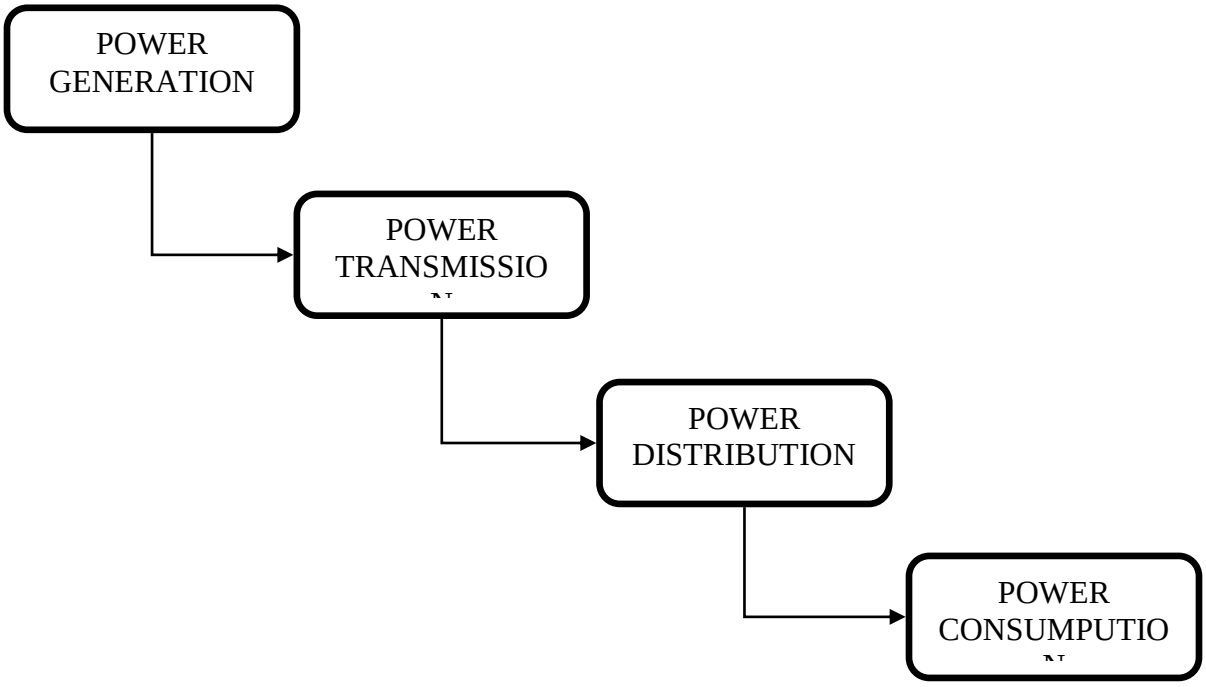


Figure 11. Basic Concept of End-to-End Power Flow

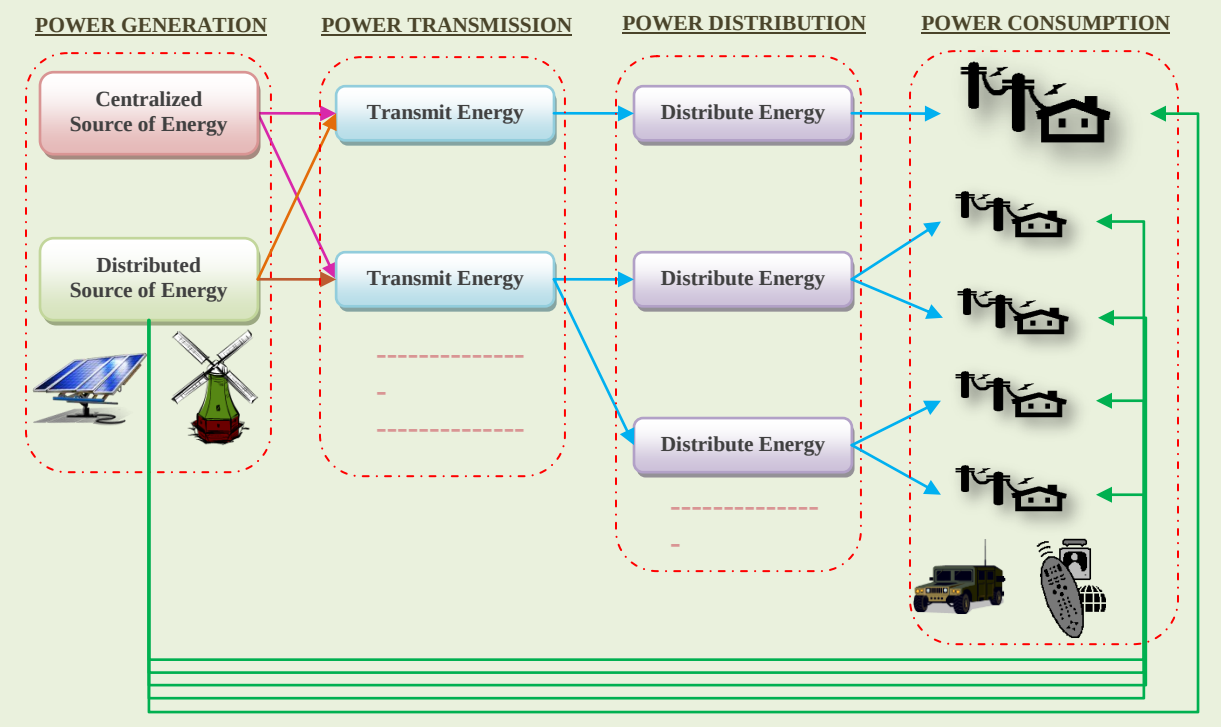


Figure 12. The Module's Design Concept

Figure 12 gives the high level design and flow of the model. The proposed petri new model of the smart grid has been simulated using a tool called Renew 2.4 (a platform-independent Petri Net). As the number of timed transitions increases, the number of tangible states also increases. The model makes sure that only a finite number of tangible states are formed for Petri Net analysis. Because the smart grid is an exceptionally big electric power infrastructure, it is normal that the model representing the smart grid is complex. Thus, each module of the smart grid will be taken separately. The first module in a smart-grid system is power generation. Figure 13 explain the same structure in a process flow format and the interaction between four modules which make the smart grid successful.

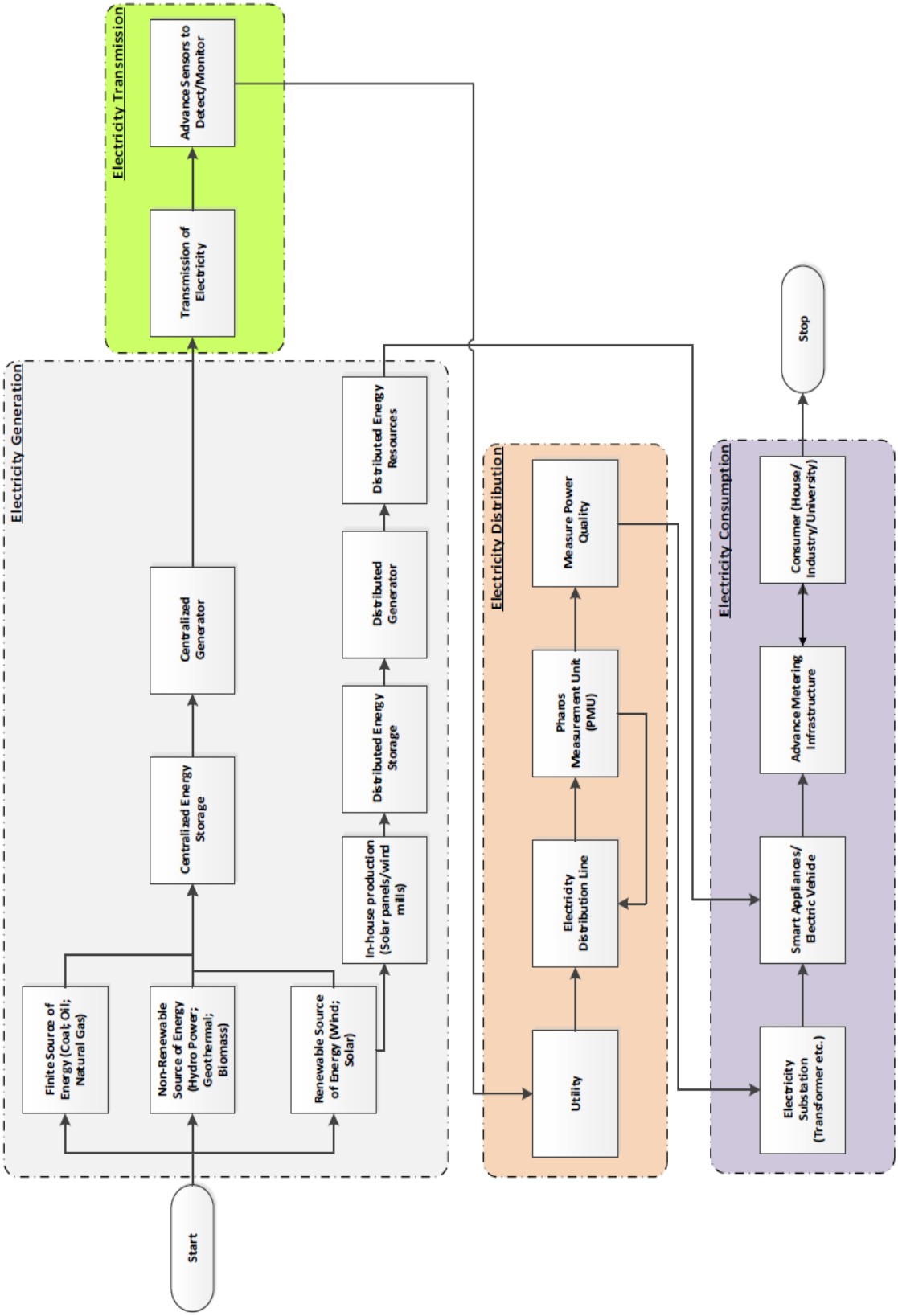


Figure 13. Design Workflow

3.1.1. Module 1: Power Generation

In Figure 14, Tz represents the harnessing of renewable energy from various sources which are infinite. This transition is represented as hanging transitions without any preset. When the energy sources are very intense and more electricity than usual is required, net will be activated because these are timed transitions to harness the energy and fulfill the electricity requirement. The availability of these finite energy sources is dependent on load and how much extra usage is required to balance the smart-grid system.

In any power grid, electricity is generated from finite and non-renewable energy sources, Tx and Ty transition, such as coal, oil, and natural gas. This is represented by the "finite source of energy" and "non-renewable source of energy" elements as shown in figure 13. Processing these energy sources, represented by transitions T1 and T2, are timed transitions. The token is fired only when the amount of energy is above a certain minimum level and is enabled with the availability of coal, oil, and natural gas.

Generating a renewable source of energy, i.e., solar and wind, which includes roof-top and in-house wind mills also has been shown by T5, T6, T7, and T8 in Figure 14. The place will be enabled with the availability of energy but is only fired when the amount of energy in the centralized energy storage falls below a certain minimum. In the centralized power storage, all the generated electricity is stored. The energy is generated per the requirements because storing energy can be expensive.

The centralized electricity generator converts this energy into electricity. The generation of electricity is shown by T9 in Figure 14. T9 is enabled whenever energy is present in the

storage, but the generation of electricity is based on the demand in the grid. This permits the demand-response management as expected from a smart grid.

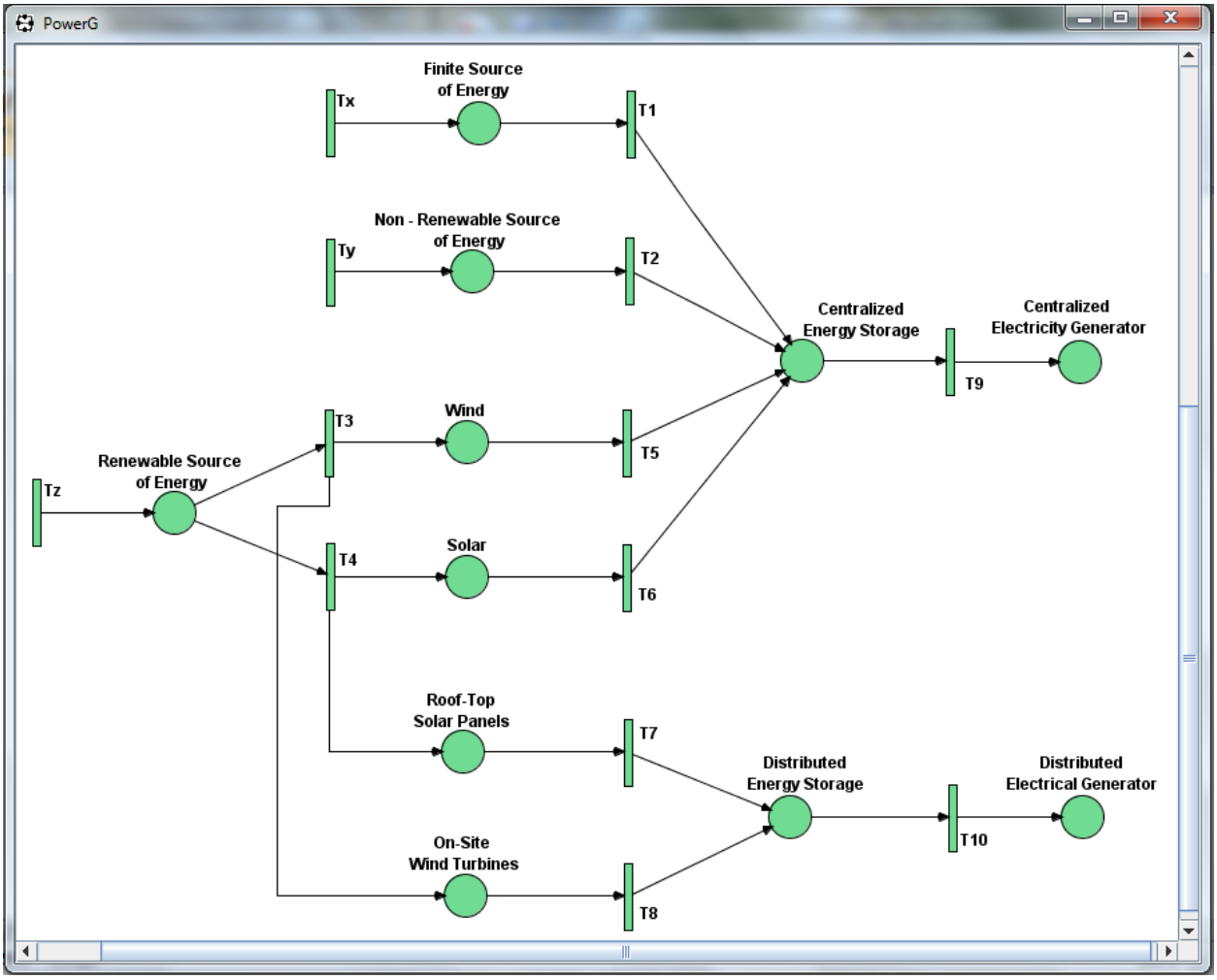


Figure 14. Renew 2.4 Power-Generation Model

Besides renewable sources of energy, a smart grid also maintains the distributed generation of energy. Roof-top solar panels and on-site wind mills harness the solar and wind energy (T7 and T8 in Figure 14) under the same criteria. To generate usable energy, T7 harnesses the energy on-site. The distributed storage energy is used to generate on-site electricity using the distributed electricity generator. The on-site produced power should be used as generated. Figure 15 shows the simulation of power generation with the Renew 2.4 tool.

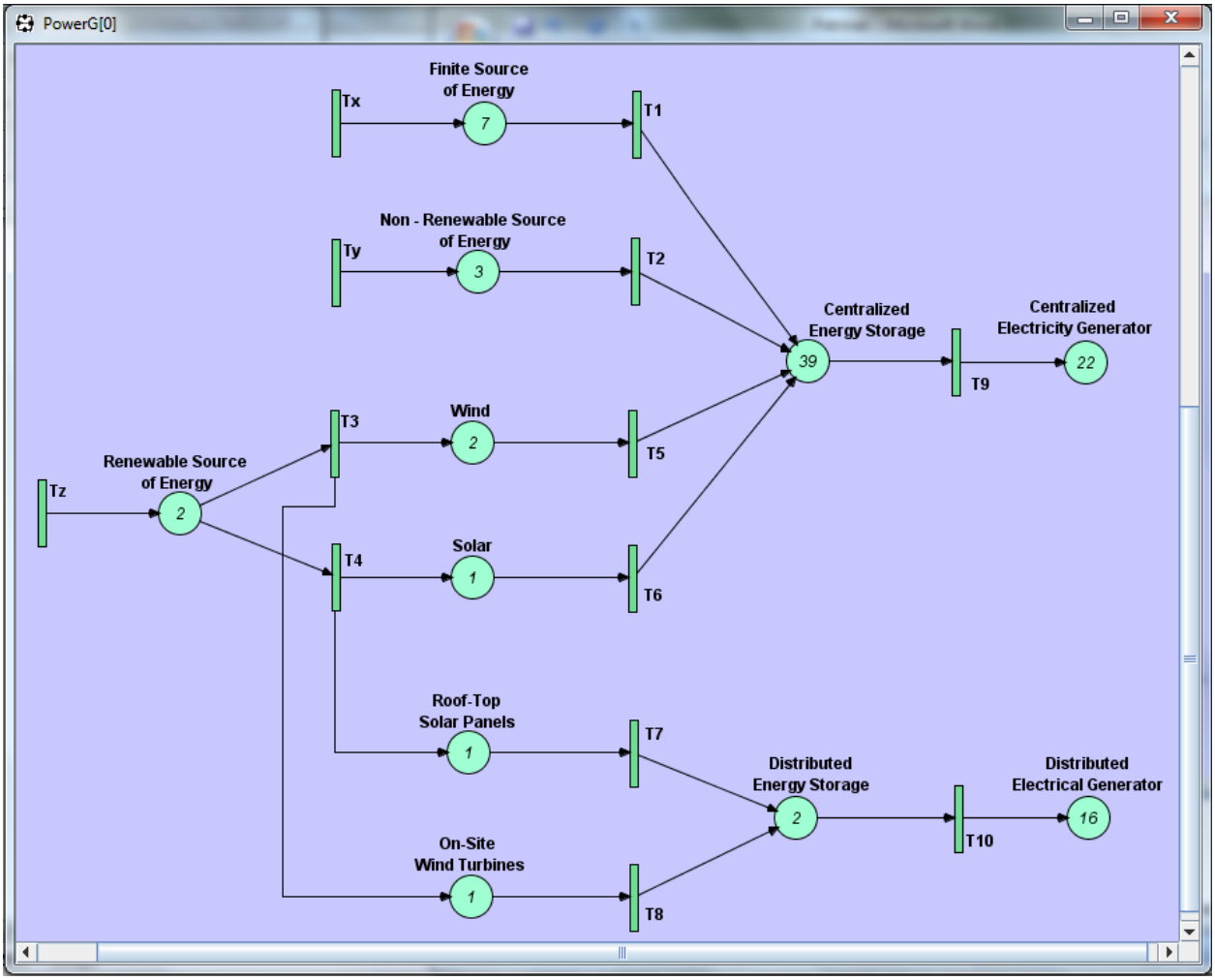


Figure 15. Renew 2.4 Simulation of Power Generation Model

3.1.2. Module 2: Power Transmission

The next module is the power transmission of the generated electricity. This property is described in Figure 16. The generated electricity at the centralized electricity generator is then moved to the transmission system. Multiple transmission lines are active in the transmission system, as shown in Figure 12, of superconducting wires to minimize the loss of electricity

during transmission and also to increase the transmission capacity. To keep the model simple, only two transmission lines are shown.

Timed transitions T1 put the generated electricity on transmission lines – 1 as shown in figure 15. The generated electricity is transmitted through the line per the requirements of the associated consumer(s). The electricity in the line is transmitted to its utility. At the utility level, advanced sensors are randomly dropped on the transmission line.

The sensors for the transmission lines - 1 and 2 are at the Advance Sensors Y and Advance Sensors X places, respectively as shown in figure 22. The real-time situation can be monitored using sensors and the visualization tools to generate the reports and to utilize the results for mapping and analysis. If the sensors detect any fault, the unit under consideration is removed from the line. This removed unit of electricity is gathered at a place, P4, to block the defective line temporarily.

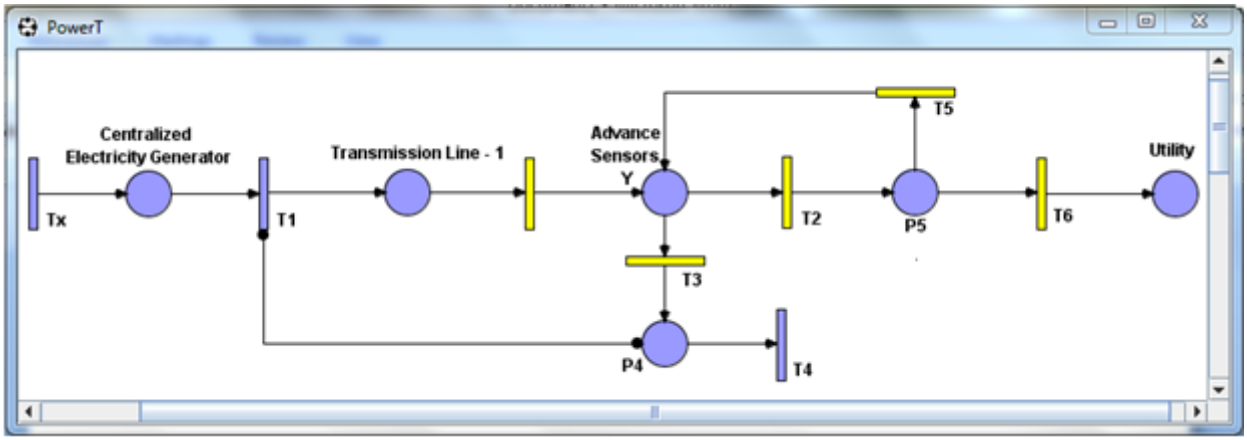


Figure 16. Renew 2.4 Power Transmission Model

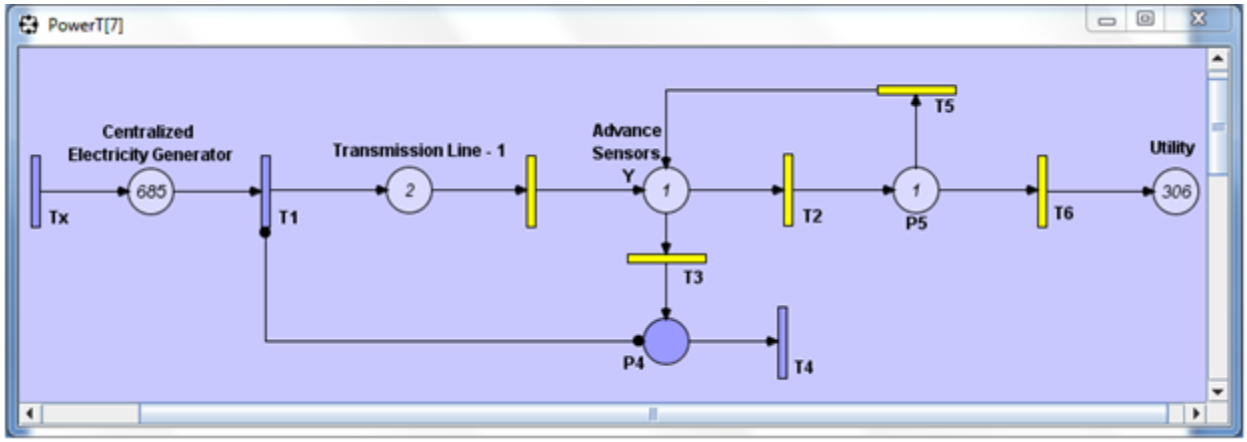


Figure 17. Renew 2.4 Simulation of Power Transmission Model

Figure 16 and 17 shows Inhibitor arcs from P4 to T1 have been used for this purpose. T1 can fire only if there is no token at Advance Sensors Y. Thus, if the sensors detect an overload or fault in the line, then that line cannot be used to transmit electricity till the fault is repaired or the load is balanced. The line is cleared by the firing of transition T3. The sensors report real-time line conditions to the advance instrument for analysis or remove the token, i.e., transmitting unit of the power supply, from the grid if any fault is identified. Sensors are always active and are represented as immediate transitions. The advance instruments and technologies supply broad-area power-system responsiveness and the fastest source of information in situations such as a black out or cascading failure to take action and to improve the electricity's supply quality for the transmission line in the smart-grid system.

3.1.3. Module 3: Power Distribution

The electricity's distribution is shown in Figure 18 and 19. Each transmission line breaks into multiple distribution lines before the electricity reaches the end users. Again, to keep the

model simple, only one of the multiple transmission lines (line 1) has been broken into two distribution lines.

From the utility, transmission line 1 is shown. The event of distributing the electricity to the distribution lines has been shown by the timed transitions, Electricity Distribution Line 1. As soon as at least one unit of electricity reaches the utility, the transition will be enabled. On the other hand, when the enabled transition would fire depends on many factors, including the customers' requirements. Before the electricity reaches the substation, the distribution line needs to be selected; this choice depends on the availability and its capacity. It will go through the Phasor Measurement Unit (PMU) for supply analysis and measurement per the consumer requirements. The PMU measures the power quality in order to control congestion. The electricity then reaches the substation.

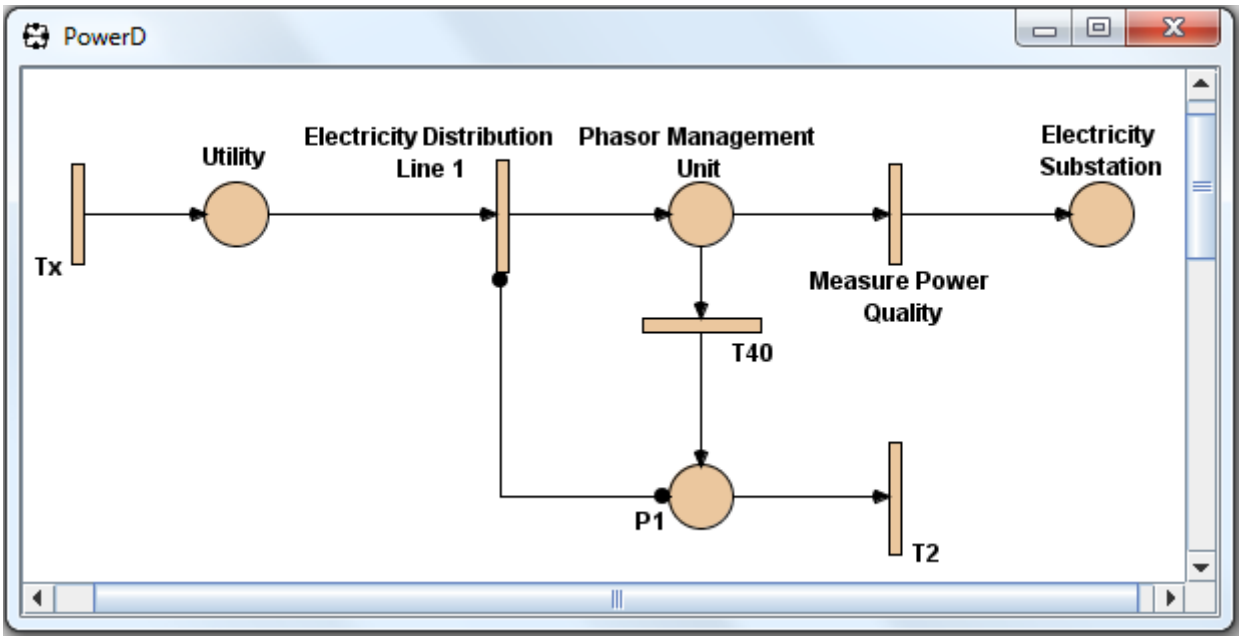


Figure 18. Renew 2.4 Power Distribution Model

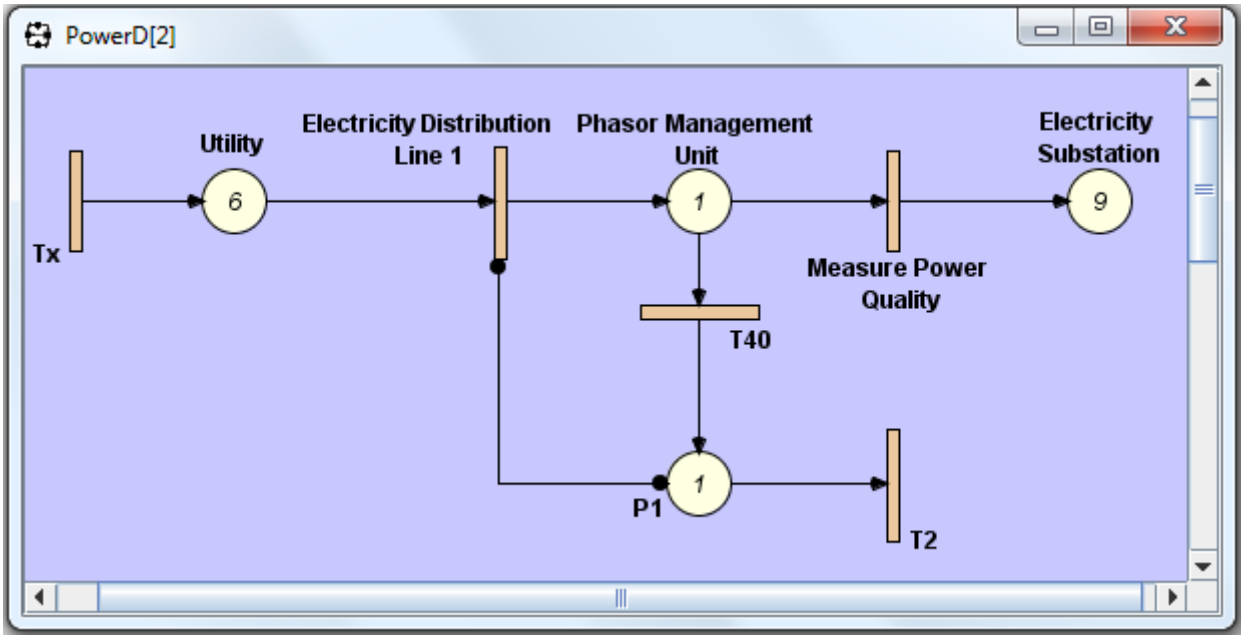


Figure 19. Renew 2.4 Simulation of Power Distribution Model

3.1.4. Module 4: Power Consumption

The next module of power consumption is shown in Figure 20 and 21. A smart-grid consumer is represented by a set of smart appliances and/or plug-in electric vehicles. The pattern of electricity usage is monitored using an Advanced Metering Infrastructure (AMI). The AMI records the amount of electricity used and the time the electricity is used so that this information can be utilized to charge a premium to those customers using electricity during peak hours. The consumer's bill is prepared using this information. The greater the number of tokens, the higher the number of chargeable units the consumer used. The electricity has been generated at the consumer's site using the distributed power generator. The electricity is then passed through the distributed energy resources (DER) based micro-grids that reduce the load before transferring it to the smart consumer appliances, etc.

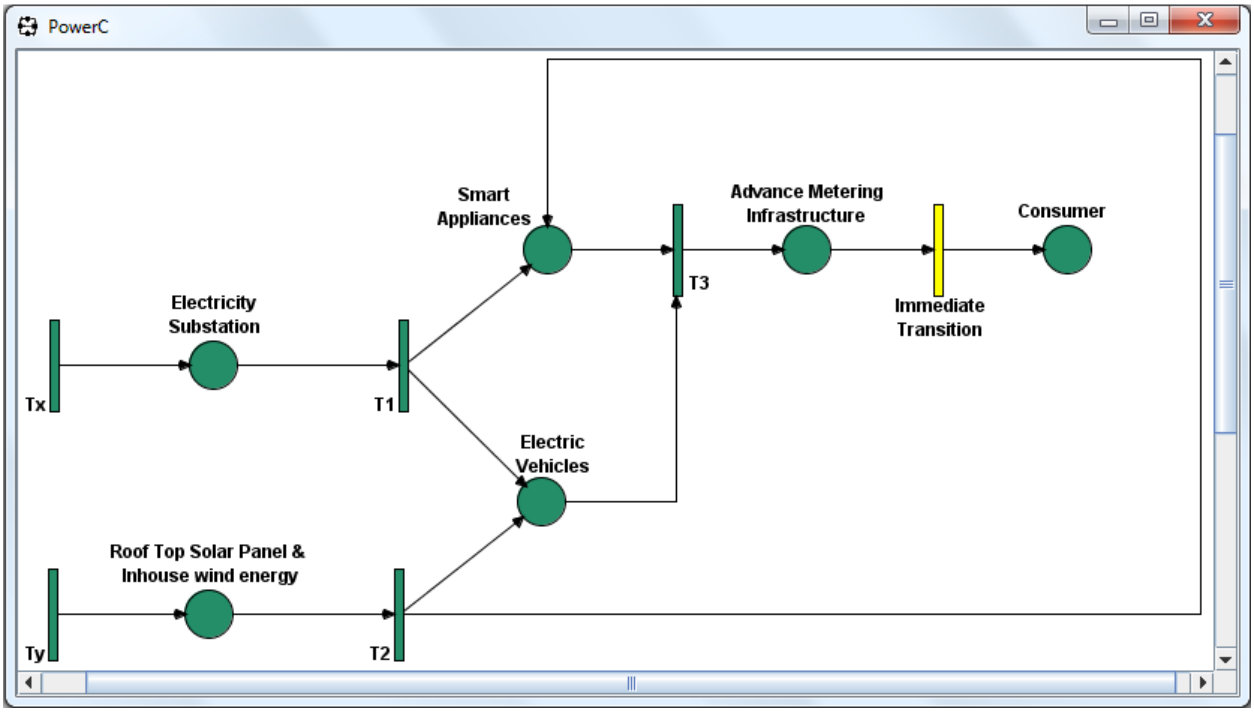


Figure 20. Renew 2.4 Power Consumption Model

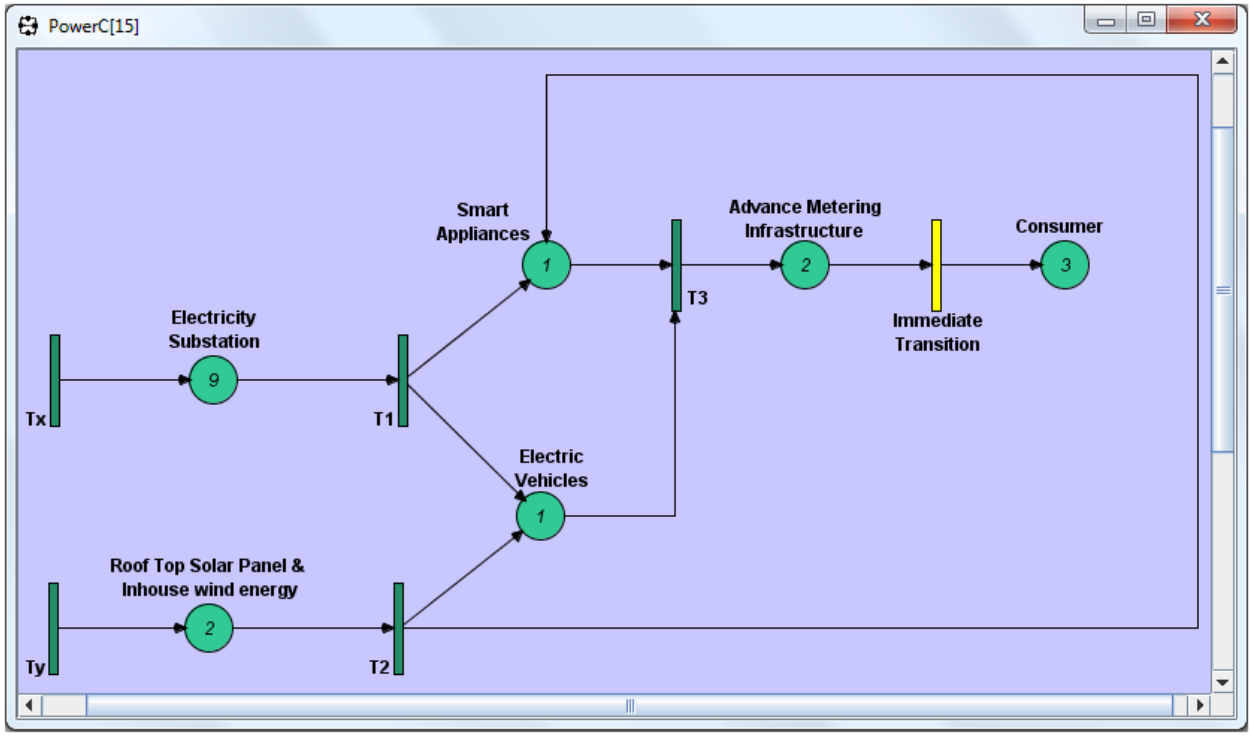


Figure 21. Renew 2.4 Simulation of Power Consumption Model

3.2. Integrated Smart Grid Petri Net Model

The screen shot of the Petri Net model for the entire smart grid simulated in Renew 2.4 is shown in Figure 22. All the features and technologies of the smart grid have been successfully incorporated into the model. The explanations provided to select a timed transition for firing from the set of multiple enabled transitions are absolutely logical. Each timed transition may be provided with a flat rate. To generate the probability for firing of each timed transition, these rates can be used.

To control the flow of electricity in the Petri-net model, Java code is used. The five consumers are Consumer A, Consumer B, Consumer C, Consumer D, and Consumer E; they have different electricity requirements at different time periods. The model is designed in such a way that only the required or fixed number of tokens will be received by consumers per their requirement. This controlled system also provides the freedom for the consumers to use electricity per their requirements and gives them the ability to choose and customize their smart appliances by the electricity rates during peak and low periods. Figure 23 shows the section of the Renew 2.4 simulation for the period of 6 to 10. Consumers demand for analysis is hard coded in the java functions per time period as shown in Table 3:

Table 3. Consumer Demand Per Time Period

Token Demand Time Period	CONSUMER A	CONSUMER B	CONSUMER C	CONSUMER D	CONSUMER E
6 to 10	50	50	100	150	400
10 to 17	200	250	300	350	1000
17 to 22	100	100	200	150	300
22 to 6	50	100	200	50	350

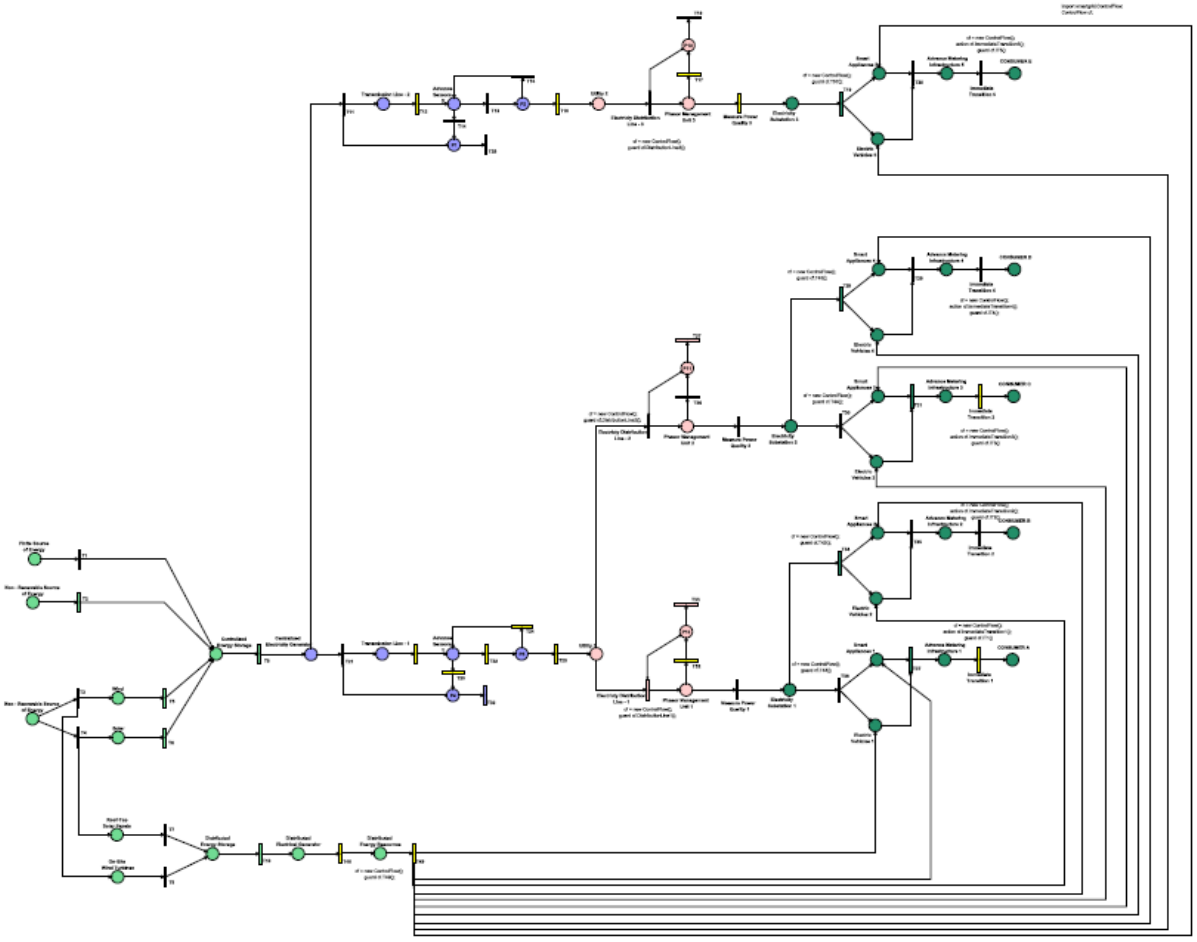


Figure 22. Renew 2.4 Petri Net Model of Smart Grid System

The model also satisfies the alternate power supply in case of any transmission line failure and provides the electricity supply from an alternate source of energy that is a renewable source of energy. Figure 22 shows the Petri Net model with the inbuilt java function to control the flow of tokens which represents a unit of power supply to the customers as final destination. Figure 23 show the section of simulation for the Petri Net model described in Figure 22 and highlighted some of the java codes places to control the tokens for a specific demand by the consumer.

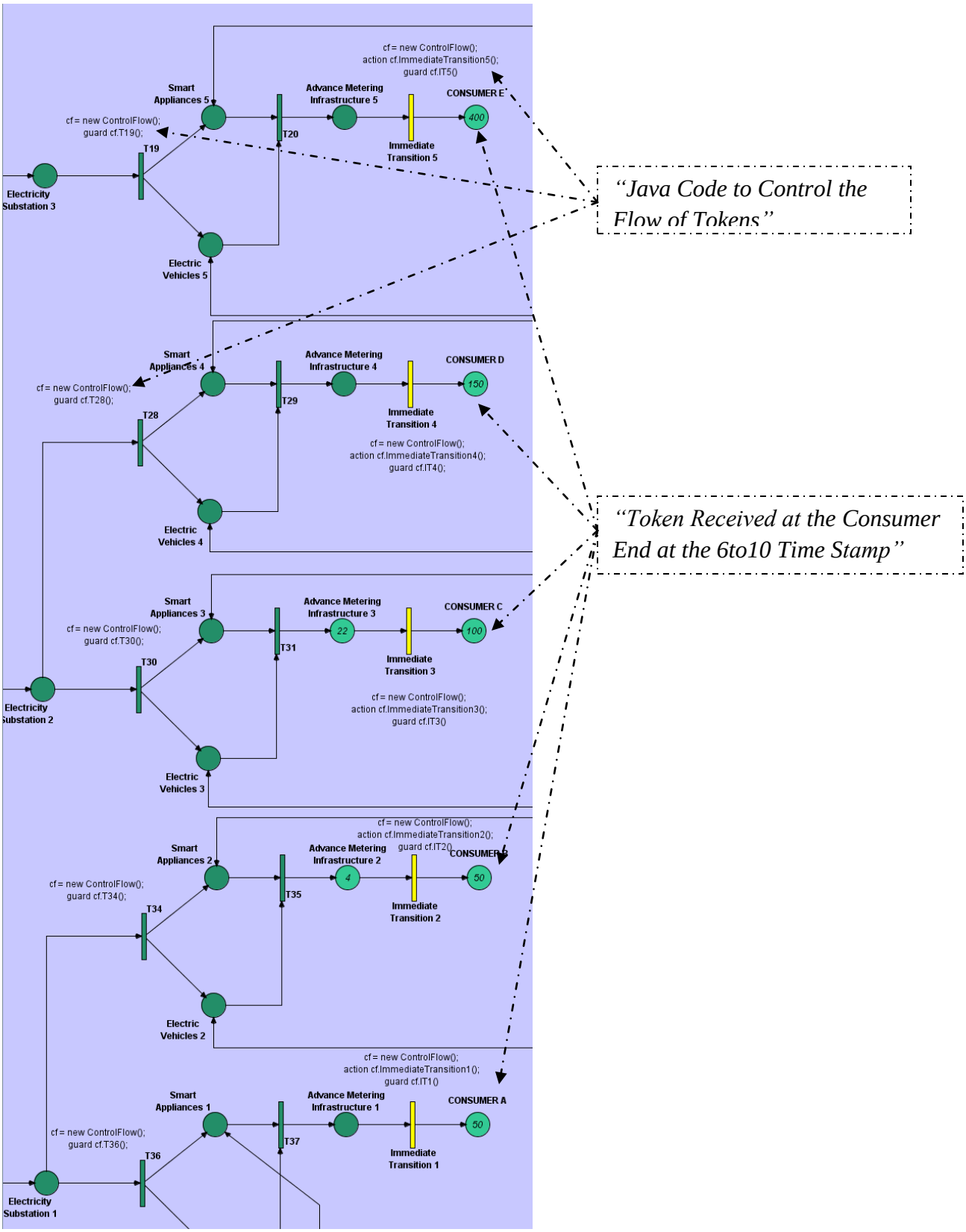


Figure 23. Renew 2.4 Petri Net Simulation of 6to10 Period

CHAPTER 4. ANALYSIS AND RESULT

4.1. Analysis

The Petri-net model of the smart grid has been simulated in Renew 2.4 using different numbers of initial random firings. The supply of tokens has been documented for 400; 600; 800; and 1,000 tokens with random firings for different time intervals: 6to10, 10to17, 17to22 and 22to6. The analysis includes five separate consumers with different electricity requirements at different time intervals. The five consumers are named as Consumer A, Consumer B, Consumer C, Consumer D, and Consumer E. Each consumer's electricity requirement, as tokens, is shown in Table 3.

The model has been simulated 20 times to note the variation of the token distribution with the same number of initial random firings for same time period. The sum of 20 sets for each of the 4 values for the initial random firings (i.e., 400; 600; 800; and 1000) have been used for the final analysis. The model clearly shows that transmission and distribution cannot begin until the electricity has been generated.

The simulation is processed for two different scenarios. The first scenario is when there is no failure in the transmission or distribution line. The second scenario is when you intentionally fail the transmission or distribution lines, and an alternate power supply is provided to fulfill the consumers' requirement for electricity at different time intervals. The simulation results have been presented graphically to aid the analysis. The token distribution has been calculated to validate the similarity of the model to the actual smart grid.

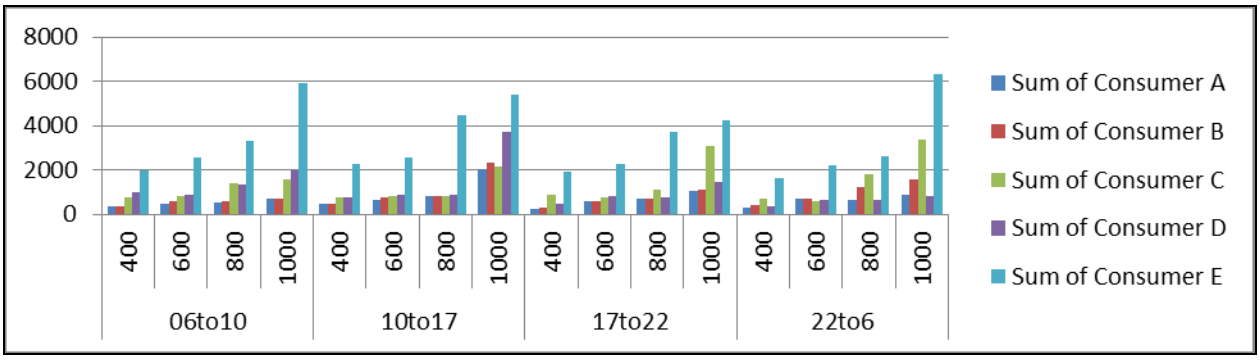


Figure 24. Analyses - 1 of Token Per Firing

Figure 24 is the first scenario where no failure of transmission or distribution happens. The figure shows the pick and lower positions at various time intervals for different numbers of tokens that have been fired. Electricity cannot be generated unless some renewable or nonrenewable source of energy is available. In the graph, we can clearly see that the number of tokens received is maximized when the consumer demand is high at a particular time period, i.e., at 10to17 with 1,000 tokens fired.

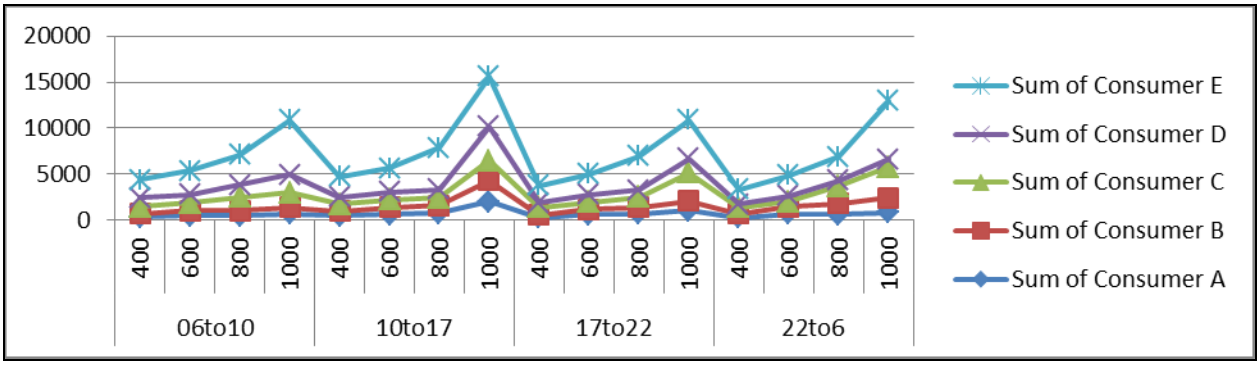


Figure 25. Analyses - 2 of Token Per Firing

For the second scenario, Figure 25 shows if the transmission or distribution network fails for some reason; then, consumers are able to generate sufficient electricity via an alternate source

of energy, such as solar panels or wind mills, or on-site resources using smart-grid technologies such as DG, DER, etc.

We can clearly see in graph that the results are quite similar because the alternate supply fulfills the consumer requirements in a similar fashion. The only difference is the supply source. Here, the number of tokens received is the largest when the consumer's demand is high at a particular time period, i.e., at 10to17 with 1,000 tokens fired.

The junctions between the various places can have more than one token at any particular instance. A small number of tokens can accumulate at these places due to the unequal rates of electricity generation, transmission, distribution, and consumption. Such a big amount of token quantity specifies entire chargeable units used by the customer throughout the available time interval.

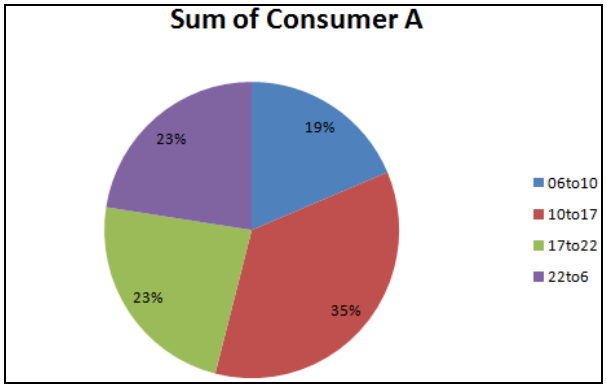


Figure 26. Consumer A Consumption

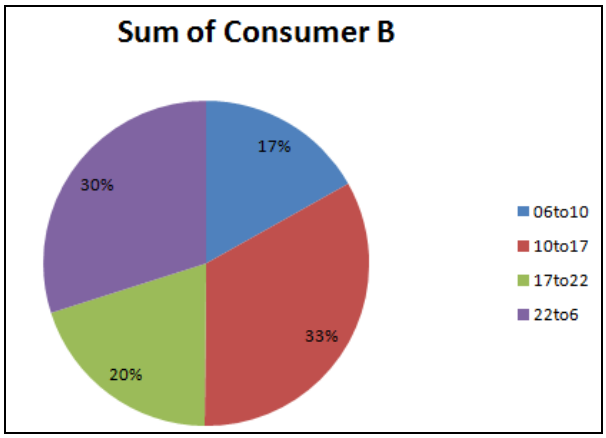


Figure 27. Consumer B Consumption

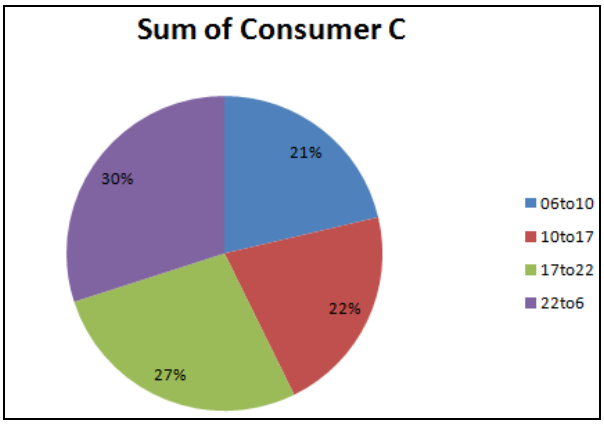


Figure 28. Consumer C Consumption

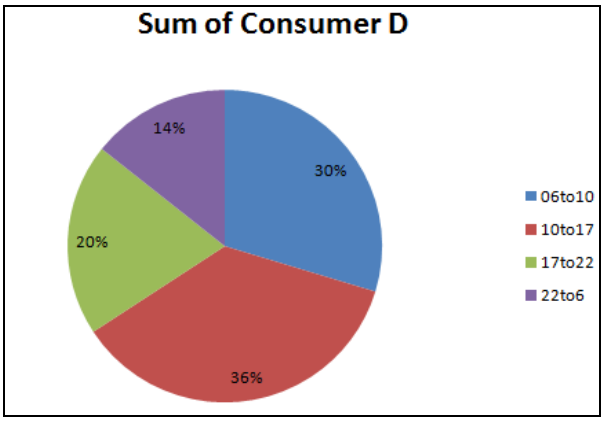


Figure 29. Consumer D Consumption

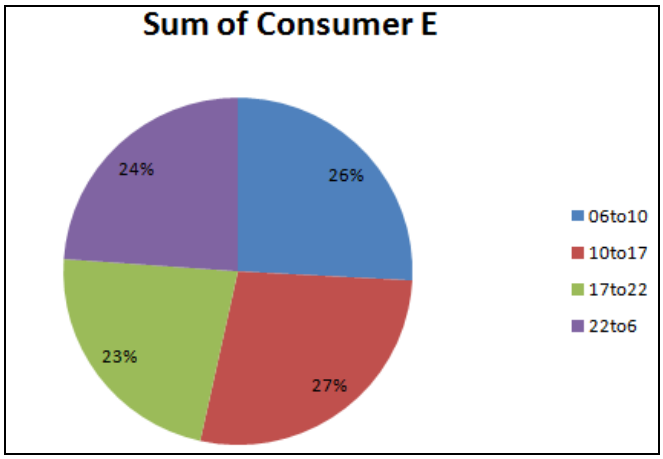


Figure 30. Consumer E Consumption

Figures 26, 27, 28, 29, and 30 show the amount of electricity consumers used at different time intervals during the analysis and shows that the consumers use maximum amount of power supply as tokens during the time period of 10to17. Other time period has lower amount of power consumption per token supplied to them.

Another point worth noting is that the AMI helps consumers to better use the received electricity to reduce their power-supply bills. Without AMI in the system, a smart grid would have successfully delivered the generated electricity to the consumers; else it would have performed similarly to this grid. Including the advanced sensors and the visualization tools at the utility level allows the smart grid to monitor the transmission to provide rapid information about power outages and electricity quality. On the other hand, the Phasor Measurement Unit provides a dynamic view of the system.

4.2. Reachability Tree

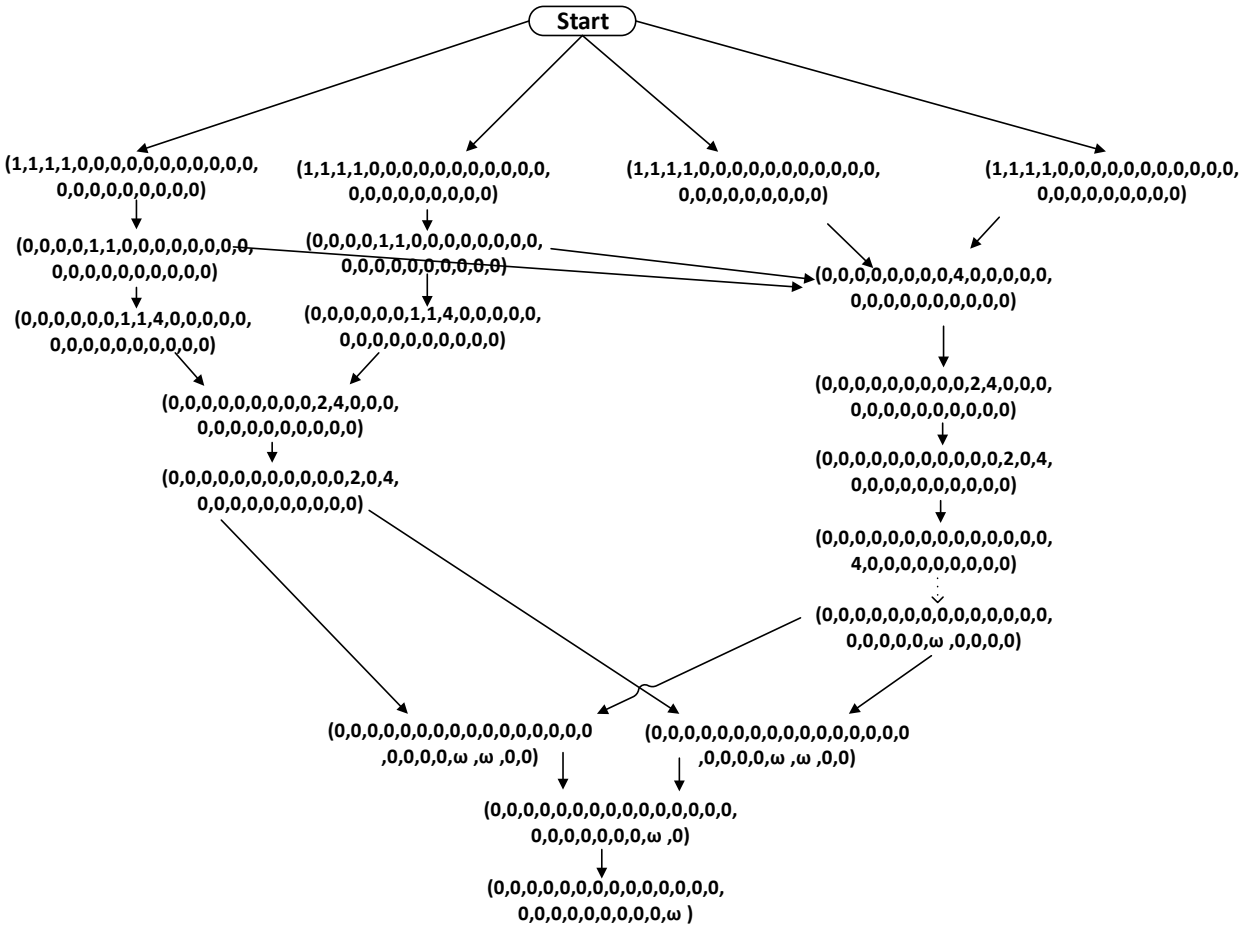


Figure 31. Reachability Tree

The reachability tree analysis is a process of finding all reachable markings. In a Petri Net model, firing one transition does not disable the firing of another transition, a parallel activity called persistent transitions. Figure 31 shows the high level reachability tree of Petri Net model for smart grid system. From this reachability tree of Petri Net model for smart grid system we can say that the model is satisfy the basic requirement of safeness and liveness.

4.2.1. Reachability Analysis

In order to study the behavior and the properties of the model, the following analyses are performed on the reachability graph presented in Figure 31. Table 4 shows the places used for a reachability tree analysis with the Petri-net model.

Table 4. Reachability Tree Analysis Places

Place	NAME	Place	NAME
P1	Finite Source of Energy	P13	Distributed Electricity Generator
P2	Non-Renewable Source of Energy	P14	Transmission Line
P3	Renewable Source of Energy - 1	P15	Advance Sensors
P4	Renewable Source of Energy - 2	P16	Utility
P5	Wind Energy	P17	Electricity Distribution Line
P6	Solar Energy	P18	Phasor Measurement Unit - PMU
P7	Onsite Wind Energy	P19	Measure Power Quality
P8	Roof Top Solar Energy	P20	Electricity Supply Substation
P9	Centralized Energy Storage	P21	Smart Appliances
P10	Distributed Energy Storage	P22	Smart Vehicles
P11	Centralized Electricity Generator	P23	Advance Metering Infrastructure
P12	Distributed Energy Resources	P24	Consumers

4.2.1.1. Safeness

If the number of tokens at the place is either 0 or 1, the reachability graph can be stated as safe. The graph shows that any of the places from top to bottom symbolize a combination of 0 (no token) and 1 (token) which means that, if the firing happens, then there will be a token at the position bit; otherwise, there is no token. Therefore, the reachability test shows that each place has a highest token count of 1 or 0 and that the net, as a whole, can be declared safe.

4.2.1.2. Liveness

The liveness property of a Petri Net is used to show continuous operation of the net model so that the system will not get into a deadlocked state. If any marking is present in the tree such that no transitions are enabled from that marking, then that marking signifies a deadlocked state, and the Petri Net model lacks the liveness property; otherwise, the Petri Net is declared live. Because the model requires executing the resource updating, some transaction-processing action will take place. To check whether the Petri-net model is live or not, we need to move along the markings of the reachability tree. For our case, no such deadlock situation appears at any place. Therefore, we call our model live.

CHAPTER 5. CONCLUSION AND FUTURE WORK

The smart grid will be our future electric-power grid. This work develops a model for smart grids to put the foundation for the functional and performance analysis of the smart-grid system for multiple consumers with different power consumptions and requirements at various time intervals. The design of smart-grid system is developed in a Petri Net, and to control the flow, Java code is used. To analyze the model's behavior, Petri-net simulation is used, comparing different features and functionalities of the actual smart-grid system.

This Petri-net model for smart grids also performs alternate power supply to the consumer in case of any fault or transmission-line failure to fulfill the consumer's electricity supply and protect the consumer from any blackout situation. The foundation of this model is based on Petri-net theory.

The standard firing of tokens has been studied and compared for different scenarios to analyze the system's behavior. The Petri-net model maintains all the characteristics of the smart grid and includes the possible use of technologies with the smart grid.

This Petri-net model can be used for analysis and experiments with the smart-grid system as well as the system's design, features, and functionalities. The model is initially built with four basic modules, electricity generation, electricity transmission, electricity distribution, and electricity consumption, and is furthered by integrating it into one complete model by using the Renew 2.4 tool and applying Java to control the flow of the system's power supply.

Several interesting observations were found in the model analysis. The Petri-net model did not have any boundary for the power supply, power storage, and distance-value evaluation, so the model output was largely dependent on contributions from the individual modules.

There are many areas where the current Petri Net Renew 2.4 model can be extended. As limited control is applied, the model can be extended by applying further conditions and analyses on actual corporate electrical power-supply data. The historical data can also be incorporated in the form of rules and conditions to further analyze the model. Valid rates can be assigned to the timed transitions, including exact weights to immediate transitions to include real scenarios which can be done by collaborating with an electric company. It can be also being validated on different electrical bus systems.

The concept of dynamic pricing can also be incorporated to verify the model's stability and balance in the real world. Including further functionalities in the model will make it highly complex, requiring professional tools and software to hold the entire smart electrical system.

REFERENCES

[1] C. A. Petri. Kommunikation mit Automaten. PhD thesis, Bonn: Institut fuer Instrumentelle, Mathematik, 1962.

[2] T. Murata. Petri Net: Properties, Analysis and Applications. Proceedings of the IEEE, April 1989.

[3] O. M. Dahl, S. D. Wolthusen; Modeling and Execution of Complex Attack Scenarios Using Interval Timed Colored Petri Net; 4th IEEE Int'l Workshop on Info. Assurance, 2006.

[4] E. Simmon, A. Griesser; Use Case Based Testing to Improve Smart Grid Development; New World Situation: New Directions in Concurrent Engineering, 2010.

[5] G. Deconinck; Metering, Intelligent Enough for Smart Grids?; Topics in Safety, Risk, Reliability, Securing Electricity Supply in the Cyber Age, 2010.

[6] P. P. Parikh, M. G. Kanabar, T. S. Sidhu; Opportunities and Challenges of Wireless Communication Technologies for Smart Grid Applications; IEEE Power and Energy Society General Meeting, 2010.

[7] Z. Jiang; Computational Intelligence Techniques for a Smart Electric Grid of the Future; Advances in Neural Networks, 2009.

[8] B. B. Sarkar, Nabendu Chaki; "Virtual Data Warehouse Modeling Using Petri Net for Distributed Decision Making"; JCIT, Vol. 5(5), pp. 8-21, July 2010.

[9] A. Hahn, M. Govindarasu; Smart Grid Cyber Security Exposure Analysis and Evaluation Framework; Power and Energy Society General Meeting, 2010.

[10] L. Zhang; Study of Applications Based on Measurement Technology in the Future Smart Grid; Advanced Intelligent Computing Theories and Applications, 2010.

[11] D. Xu, et. al., A Petri Net Based Software Architecture for UAV Simulation, Proc. of the Int'l Conf. on Software Engineering Research and Practice, 2004.

[12] W. Ruckdeschel, R. Onken; Modeling of Pilot Behavior Using Petri Net; 15th Int'l Conf. on Application and Theory of Petri Net, Spain, 1994.

[13] L. Napione et. al.; On the Use of Stochastic Petri Net in the Analysis of Signal Transduction Pathways for Angiogenesis Process; Int'l Conf. on Computational Methods, 2009.

[14] J. Liu, Kui Chen, Zhisheng Wang; Fault Analysis for Flight Control System Using

Weighted Fuzzy Petri Net, 2011.

[15] A. W. Colombo, R. Carelli, B. Kuchen; A Temporized Petri Net Approach for Design, Modeling and Analysis of Flexible Production Systems; International Journal of Advanced Manufacturing Technology, Springer, 2005.

[16] G. C. Dalton II, J. M. Colombi; Analyzing Attack Trees Using Generalized Stochastic Petri Net; Proc. of IEEE Workshop on Information Assurance, 2006.

[17] C. Zhuo, et. al.; Petri Net Based Workflow Access Control Model; Journal of Shanghai, 2004.

[18] N. Busi, G. M. Pinna; Process Discovery and Petri Net; Journal of Mathematics Structure in Computer Science, Cambridge Univ. Press, 2009.

[19] F. Dicesare, et. al.; The Application of Petri Net to the Modeling, Analysis and Control of Intelligent Urban Traffic Networks; Int'l Conf. on Application and Theory of Petri Net, 1994.

[20] N. Chaki, S. Bhattacharya; Performance Study of Multistage Interconnection Networks; Journal of System Architecture; Elsevier North-Holland, Inc., vol. 52(1), 2006.

[21] N. Akharware; PIPE2: Platform Independent Petri Net Editor, University of London, 2005.

APPENDIX A. EXPERIMENT LOG

(67807)Putting [] into SmartGrid[0].Centralized Electricity Generator
(67807)-------- Synchronously --------
(67808)Removing [] in SmartGrid[0].Non - Renewable Source of Energy
(67808)Firing SmartGrid[0].T2
(67808)Putting [] into SmartGrid[0].Centralized Energy Storage
(67808)-------- Synchronously --------
(67809)Removing [] in SmartGrid[0].Wind
(67809)Firing SmartGrid[0].T5
(67809)Putting [] into SmartGrid[0].Centralized Energy Storage
(67809)-------- Synchronously --------
(67810)Removing [] in SmartGrid[0].Centralized Energy Storage
(67810)Firing SmartGrid[0].T9
(67810)Putting [] into SmartGrid[0].Centralized Electricity Generator
(67810)-------- Synchronously --------
(67811)Removing [] in SmartGrid[0].Smart Appliances 4
(67811)Removing [] in SmartGrid[0].Electric Vehicles 4
(67811)Firing SmartGrid[0].T29
(67811)Putting [] into SmartGrid[0].Advance Metering Infrastructure 4
(67811)-------- Synchronously --------
(67812)Removing [] in SmartGrid[0].Phasor Management Unit 3
(67812)Firing SmartGrid[0].T17
(67812)Putting [] into SmartGrid[0].P10
(67812)-------- Synchronously --------
(67813)Removing [] in SmartGrid[0].P10
(67813)Firing SmartGrid[0].T18
(67813)-------- Synchronously --------
(67814)Firing SmartGrid[0].Tz
(67814)Putting [] into SmartGrid[0].Non - Renewable Source of Energy
(67814)-------- Synchronously --------
(67815)Removing [] in SmartGrid[0].Solar
(67815)Firing SmartGrid[0].T6
(67815)Putting [] into SmartGrid[0].Centralized Energy Storage
(67815)-------- Synchronously --------
(67816)Removing [] in SmartGrid[0].Centralized Energy Storage
(67816)Firing SmartGrid[0].T9
(67816)Putting [] into SmartGrid[0].Centralized Electricity Generator
(67816)-------- Synchronously --------
(67817)Removing [] in SmartGrid[0].Non - Renewable Source of Energy
(67817)Firing SmartGrid[0].T4
(67817)Putting [] into SmartGrid[0].Roof-Top Solar Panels
(67817)Putting [] into SmartGrid[0].Solar
(67817)-------- Synchronously --------
(67818)Inhibiting [] at SmartGrid[0].P4

(67818)Removing [] in SmartGrid[0].Centralized Electricity Generator
(67818)Firing SmartGrid[0].T21
(67818)Putting [] into SmartGrid[0].Transmission Line - 1
(67818)-------- Synchronously --------
(67819)Removing [] in SmartGrid[0].Non - Renewable Source of Energy
(67819)Firing SmartGrid[0].T2
(67819)Putting [] into SmartGrid[0].Centralized Energy Storage
(67819)-------- Synchronously --------
(67820)Removing [] in SmartGrid[0].Transmission Line - 1
(67820)Firing SmartGrid[0].T1
(67820)Putting [] into SmartGrid[0].Advance Sensors Y
(67820)-------- Synchronously --------
(67821)Removing [] in SmartGrid[0].Advance Sensors Y
(67821)Firing SmartGrid[0].T23
(67821)Putting [] into SmartGrid[0].P4
(67821)-------- Synchronously --------
(67822)Removing [] in SmartGrid[0].Advance Metering Infrastructure 4
(67822)Firing SmartGrid[0].Immediate Transition 4
(67822)Putting [] into SmartGrid[0].CONSUMER D
(67822)-------- Synchronously --------
(67823)Firing SmartGrid[0].Tx
(67823)Putting [] into SmartGrid[0].Finite Source of Energy
(67823)-------- Synchronously --------
(67824)Firing SmartGrid[0].Tx
(67824)Putting [] into SmartGrid[0].Finite Source of Energy
(67824)-------- Synchronously --------
(67825)Firing SmartGrid[0].Ty
(67825)Putting [] into SmartGrid[0].Non - Renewable Source of Energy
(67825)-------- Synchronously --------
(67826)Inhibiting [] at SmartGrid[0].P1
(67826)Removing [] in SmartGrid[0].Centralized Electricity Generator
(67826)Firing SmartGrid[0].T11
(67826)Putting [] into SmartGrid[0].Transmission Line - 2
(67826)-------- Synchronously --------
(67827)Removing [] in SmartGrid[0].Non - Renewable Source of Energy
(67827)Firing SmartGrid[0].T2
(67827)Putting [] into SmartGrid[0].Centralized Energy Storage
(67827)-------- Synchronously --------
(67828)Firing SmartGrid[0].Tz
(67828)Putting [] into SmartGrid[0].Non - Renewable Source of Energy
(67828)-------- Synchronously --------
(67828)Setting time to 0.0

APPENDIX B. JAVA CODE

```
/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */
package smartgrid;

import java.io.File;
import java.io.FileOutputStream;
import java.io.OutputStreamWriter;
import java.util.Scanner;

/**
 *
 * @author Anand
 */
public class ControlFlow
{
   private static int customerADemand = 50;
   private static int customerBDemand = 50;
   private static int customerCDemand = 100;
   private static int customerDDemand = 150;
   private static int customerEDemand = 400;
   private static boolean T19failed = false;
   private static boolean T28failed = false;
   private static boolean T30failed = false;
   private static boolean T36failed = false;
   private static boolean T34failed = false;

   /**
    * @param args the command line arguments
    */

   public ControlFlow()
   {
      Init();
   }
   public static void Init()
   {
      File file = new File("c:\\renew2.4\\setting.txt");
      Scanner scan = null;

      try
      {
```

```
    scan = new Scanner(file);
    int tmp = 0;
    tmp = scan.nextInt();
    System.out.println("Read number " + tmp + "from file.");

    if (tmp != 0)
    {
       //initialize all static variables
       for (int i = 0; i < tmp; i++)
       {
          String tmpStr = scan.next();
          System.out.println("Read string " + tmpStr + " " + i);
          if (tmpStr.equals("T34"))
          {
             T34failed = true;
          }
          else if (tmpStr.equals("T36"))
          {
             T36failed = true;
          }
          else if (tmpStr.equals("T30"))
          {
             T30failed = true;
          }
          else if (tmpStr.equals("T28"))
          {
              T28failed = true;
          }
          else if (tmpStr.equals("T19"))
          {
              T19failed = true;
          }
       }
       scan.nextLine();
       InitializeConsumers(scan.next()/*"6to10"*/);
       scan.close();


       FileOutputStream fos = new FileOutputStream(file);
       OutputStreamWriter osw = new OutputStreamWriter(fos);
       osw.write(0);
       osw.close();
       fos.close();
       System.out.println("Wrote 0 to file.");
    }
}
```

```
    catch(Exception e)
    {
       e.printStackTrace();
    }


}

public static void InitializeConsumers(String time)
{
    if (time.equals("6to10"))
    {
       customerADemand = 50;
       customerBDemand = 50;
       customerCDemand = 100;
       customerDDemand = 150;
       customerEDemand = 400;
    }
    else if (time.equals("10to17"))
    {
       customerADemand = 200;
       customerBDemand = 250;
       customerCDemand = 300;
       customerDDemand = 350;
       customerEDemand = 1000;

    }
    else if (time.equals("17to22"))
    {
       customerADemand = 100;
       customerBDemand = 100;
       customerCDemand = 200;
       customerDDemand = 150;
       customerEDemand = 300;

    }
    else if (time.equals("22to6"))
    {
       customerADemand = 50;
       customerBDemand = 100;
       customerCDemand = 200;
       customerDDemand = 50;
       customerEDemand = 500;

    }
```

```
}


public static void ImmediateTransition1()
{
   if (customerADemand != 0)
   {
      customerADemand--;
   }
   System.out.println("ImmT1 called customer demand is currently " + customerADemand );
}

public static boolean IT1()
{
   if (customerADemand != 0)
   {
      return true;
   }
   else return false;

}


public static void ImmediateTransition2()
{
   if (customerBDemand != 0)
   {
      customerBDemand--;
   }
   System.out.println("ImmT2 called customer demand is currently " + customerBDemand );

}

public static boolean IT2()
{
   if (customerBDemand != 0)
   {
      return true;
   }
   else return false;

}


public static void ImmediateTransition3()
{
```

```
   if (customerCDemand != 0)
   {
      customerCDemand--;
   }
   System.out.println("ImmT3 called customer demand is currently " + customerCDemand );

}

public static boolean IT3()
{
   if (customerCDemand != 0)
   {
      return true;
   }
   else return false;
}


public static void ImmediateTransition4()
{
   if (customerDDemand != 0)
   {
      customerDDemand--;
   }
   System.out.println("ImmT4 called customer demand is currently " + customerDDemand );
}

public static boolean IT4()
{
   if (customerDDemand != 0)
   {
      return true;
   }
   else return false;
}

public static void ImmediateTransition5()
{
   if (customerEDemand != 0)
   {
      customerEDemand--;
   }
   System.out.println("ImmT5 called customer demand is currently " + customerEDemand );
}

public static boolean IT5()
```

```
    {
        if (customerEDemand != 0)
        {
            return true;
        }
        else return false;
    }

    public static boolean DistributionLine1()
    {
        if (customerADemand > 0 || customerBDemand > 0)
        {
            System.out.println("DL1 called customer demands are currently " + customerADemand +
" " + customerBDemand );
            return true;
        }
        else return false;
    }

    public static boolean DistributionLine2()
    {
        if (customerCDemand > 0 || customerDDemand > 0)
        {
            System.out.println("DL2 called customer demands are currently " + customerCDemand +
" " + customerDDemand );
            return true;
        }
        else return false;
    }

    public static boolean DistributionLine3()
    {
        if (customerEDemand > 0)
        {
            System.out.println("DL3 called customer demand is currently " + customerEDemand);
            return true;
        }
        else return false;
    }

    public static boolean T19()
    {
        return !T19failed;
    }

    public static boolean T34()
```

```
    {
        return !T34failed;
    }

    public static boolean T36()
    {
        return !T36failed;
    }

    public static boolean T30()
    {
        return !T30failed;
    }

    public static boolean T28()
    {
        return !T28failed;
    }

    public static boolean T49()
    {

        if (customerADemand > 0 && !T36())
            return true;
        if (customerBDemand > 0 && !T34())
            return true;
        if (customerCDemand > 0 && !T30())
            return true;
        if (customerDDemand > 0 && !T28())
            return true;
        if (customerEDemand > 0 && !T19())
            return true;

        return false;

    }
}
```

APPENDIX C. XML CODE

```
<pnml xmlns="RefNet">
  <net id="netId1381547479957" type="RefNet">
    <place id="12097">
      <name>
        <graphics>
          <offset x="-3" y="-33"/>
        </graphics>
        <text>Finite Source
of Energy</text>
      </name>
      <graphics>
        <position x="333" y="1533"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(112,219,147)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <transition id="12098">
      <name>
        <graphics>
          <offset x="13" y="-11"/>
        </graphics>
        <text>T1</text>
      </name>
      <graphics>
        <position x="447" y="1534"/>
        <dimension x="6" y="50"/>
        <fill color="rgb(112,219,147)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </transition>
    <place id="12099">
      <name>
        <graphics>
          <offset x="-1" y="-31"/>
        </graphics>
        <text>Non - Renewable Source
of Energy</text>
      </name>
      <graphics>
        <position x="328" y="1644"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(112,219,147)"/>
```

```
      <line color="rgb(0,0,0)"/>
    </graphics>
  </place>
  <transition id="12100">
    <name>
      <graphics>
        <offset x="12" y="-17"/>
      </graphics>
      <text>T3</text>
    </name>
    <graphics>
      <position x="443" y="1890"/>
      <dimension x="6" y="50"/>
      <fill color="rgb(112,219,147)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <place id="12101">
    <name>
      <graphics>
        <offset x="-1" y="-24"/>
      </graphics>
      <text>Wind</text>
    </name>
    <graphics>
      <position x="546" y="1889"/>
      <dimension x="32" y="32"/>
      <fill color="rgb(112,219,147)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </place>
  <arc id="12102" source="12100" target="12101">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <transition id="12103">
    <name>
      <graphics>
        <offset x="14" y="-13"/>
      </graphics>
      <text>T4</text>
    </name>
```

```
        <graphics>
          <position x="444" y="1990"/>
          <dimension x="6" y="50"/>
          <fill color="rgb(112,219,147)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
      <place id="12104">
        <name>
          <graphics>
            <offset x="1" y="-24"/>
          </graphics>
          <text>Solar</text>
        </name>
        <graphics>
          <position x="546" y="1990"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(112,219,147)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <place id="12105">
        <name>
          <graphics>
            <offset x="0" y="-31"/>
          </graphics>
          <text>Roof-Top
Solar Panels</text>
        </name>
        <graphics>
          <position x="543" y="2239"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(112,219,147)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <place id="12106">
        <name>
          <graphics>
            <offset x="0" y="-32"/>
          </graphics>
          <text>On-Site
Wind Turbines</text>
        </name>
        <graphics>
          <position x="545" y="2347"/>
```

```
      <dimension x="32" y="32"/>
      <fill color="rgb(112,219,147)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </place>
  <arc id="12107" source="12103" target="12104">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <transition id="12108">
    <name>
      <graphics>
        <offset x="16" y="-10"/>
      </graphics>
      <text>T2</text>
    </name>
    <graphics>
      <position x="446" y="1644"/>
      <dimension x="6" y="50"/>
      <fill color="rgb(112,219,147)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <transition id="12109">
    <name>
      <graphics>
        <offset x="18" y="7"/>
      </graphics>
      <text>T5</text>
    </name>
    <graphics>
      <position x="666" y="1890"/>
      <dimension x="6" y="50"/>
      <fill color="rgb(112,219,147)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <transition id="12110">
    <name>
      <graphics>
        <offset x="16" y="12"/>
      </graphics>
```

```
      <text>T6</text>
    </name>
    <graphics>
      <position x="666" y="1991"/>
      <dimension x="6" y="50"/>
      <fill color="rgb(112,219,147)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <transition id="12111">
    <name>
      <graphics>
        <offset x="16" y="-15"/>
      </graphics>
      <text>T7</text>
    </name>
    <graphics>
      <position x="667" y="2240"/>
      <dimension x="6" y="50"/>
      <fill color="rgb(112,219,147)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <transition id="12112">
    <name>
      <graphics>
        <offset x="16" y="12"/>
      </graphics>
      <text>T8</text>
    </name>
    <graphics>
      <position x="667" y="2348"/>
      <dimension x="6" y="50"/>
      <fill color="rgb(112,219,147)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <arc id="12113" source="12099" target="12108">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12114" source="12101" target="12109">
```

```
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12115" source="12104" target="12110">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12116" source="12105" target="12111">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12117" source="12106" target="12112">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <place id="12118">
      <name>
        <graphics>
          <offset x="45" y="-31"/>
        </graphics>
        <text>Centralized
Energy Storage</text>
      </name>
      <graphics>
        <position x="797" y="1776"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(112,219,147)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
```

```
    <arc id="12119" source="12108" target="12118">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <position x="664" y="1644"/>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12120" source="12109" target="12118">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12121" source="12110" target="12118">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <place id="12122">
      <name>
        <graphics>
          <offset x="12" y="-33"/>
        </graphics>
        <text>Distributed
Energy Storage</text>
      </name>
      <graphics>
        <position x="788" y="2288"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(112,219,147)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <transition id="12123">
      <name>
        <graphics>
          <offset x="16" y="16"/>
        </graphics>
        <text>T10</text>
```

```
  </name>
  <graphics>
    <position x="910" y="2289"/>
    <dimension x="6" y="50"/>
    <fill color="rgb(112,219,147)"/>
    <line color="rgb(0,0,0)"/>
  </graphics>
</transition>
<arc id="12124" source="12122" target="12123">
  <type>
    <text>ordinary</text>
  </type>
  <graphics>
    <line color="rgb(0,0,0)" style="solid"/>
  </graphics>
</arc>
<arc id="12125" source="12111" target="12122">
  <type>
    <text>ordinary</text>
  </type>
  <graphics>
    <line color="rgb(0,0,0)" style="solid"/>
  </graphics>
</arc>
<arc id="12126" source="12112" target="12122">
  <type>
    <text>ordinary</text>
  </type>
  <graphics>
    <line color="rgb(0,0,0)" style="solid"/>
  </graphics>
</arc>
<arc id="12127" source="12098" target="12118">
  <type>
    <text>ordinary</text>
  </type>
  <graphics>
    <position x="668" y="1533"/>
    <line color="rgb(0,0,0)" style="solid"/>
  </graphics>
</arc>
<transition id="12128">
  <name>
    <graphics>
      <offset x="19" y="16"/>
    </graphics>
```

```
          <text>T9</text>
        </name>
        <graphics>
          <position x="908" y="1777"/>
          <dimension x="6" y="50"/>
          <fill color="rgb(112,219,147)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
      <arc id="12129" source="12118" target="12128">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <line color="rgb(0,0,0)" style="solid"/>
        </graphics>
      </arc>
      <place id="12130">
        <name>
          <graphics>
            <offset x="0" y="-33"/>
          </graphics>
          <text>Distributed
Electrical Generator</text>
        </name>
        <graphics>
          <position x="1007" y="2288"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(112,219,147)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <arc id="12131" source="12123" target="12130">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <line color="rgb(0,0,0)" style="solid"/>
        </graphics>
      </arc>
      <arc id="12132" source="12103" target="12105">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <position x="444" y="2239"/>
```

```
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12133" source="12100" target="12106">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <position x="443" y="1937"/>
      <position x="404" y="1937"/>
      <position x="404" y="1975"/>
      <position x="404" y="2057"/>
      <position x="404" y="2347"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12134" source="12097" target="12098">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <place id="12154">
    <name>
      <graphics>
        <offset x="5" y="-25"/>
      </graphics>
      <text>Transmission Line - 2</text>
    </name>
    <graphics>
      <position x="1225" y="367"/>
      <dimension x="32" y="32"/>
      <fill color="rgb(153,153,255)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </place>
  <transition id="12155">
    <name>
      <graphics>
        <offset x="16" y="18"/>
      </graphics>
      <text>T12</text>
    </name>
    <graphics>
```

```
          <position x="1311" y="368"/>
          <dimension x="6" y="50"/>
          <fill color="rgb(255,255,0)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
      <arc id="12156" source="12154" target="12155">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <line color="rgb(0,0,0)" style="solid"/>
        </graphics>
      </arc>
      <place id="12157">
        <name>
          <graphics>
            <offset x="-28" y="-24"/>
          </graphics>
          <text>Advance
Sensors
X</text>
        </name>
        <graphics>
          <position x="1406" y="367"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(153,153,255)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <arc id="12158" source="12155" target="12157">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <line color="rgb(0,0,0)" style="solid"/>
        </graphics>
      </arc>
      <place id="12159">
        <name>
          <graphics>
            <offset x="0" y="0"/>
          </graphics>
          <text>P2</text>
        </name>
        <graphics>
```

```
      <position x="1582" y="367"/>
      <dimension x="32" y="32"/>
      <fill color="rgb(153,153,255)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </place>
  <transition id="12160">
    <name>
      <graphics>
        <offset x="17" y="16"/>
      </graphics>
      <text>T16</text>
    </name>
    <graphics>
      <position x="1671" y="368"/>
      <dimension x="6" y="50"/>
      <fill color="rgb(255,255,0)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <arc id="12161" source="12159" target="12160">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <transition id="12162">
    <name>
      <graphics>
        <offset x="19" y="17"/>
      </graphics>
      <text>T13</text>
    </name>
    <graphics>
      <position x="1492" y="367"/>
      <dimension x="6" y="50"/>
      <fill color="rgb(255,255,0)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <arc id="12163" source="12157" target="12162">
    <type>
      <text>ordinary</text>
    </type>
```

```
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12164" source="12162" target="12159">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <transition id="12165">
    <name>
      <graphics>
        <offset x="16" y="19"/>
      </graphics>
      <text>T11</text>
    </name>
    <graphics>
      <position x="1124" y="368"/>
      <dimension x="6" y="50"/>
      <fill color="rgb(153,153,255)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <arc id="12166" source="12165" target="12154">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <transition id="12167">
    <name>
      <graphics>
        <offset x="20" y="13"/>
      </graphics>
      <text>T14</text>
    </name>
    <graphics>
      <position x="1406" y="411"/>
      <dimension x="55" y="6"/>
      <fill color="rgb(255,255,0)"/>
      <line color="rgb(0,0,0)"/>
```

```
    </graphics>
  </transition>
  <transition id="12168">
    <name>
      <graphics>
        <offset x="20" y="11"/>
      </graphics>
      <text>T15</text>
    </name>
    <graphics>
      <position x="1582" y="297"/>
      <dimension x="55" y="6"/>
      <fill color="rgb(255,255,0)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <place id="12169">
    <name>
      <graphics>
        <offset x="0" y="0"/>
      </graphics>
      <text>P1</text>
    </name>
    <graphics>
      <position x="1406" y="472"/>
      <dimension x="32" y="32"/>
      <fill color="rgb(153,153,255)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </place>
  <transition id="12170">
    <name>
      <graphics>
        <offset x="16" y="15"/>
      </graphics>
      <text>T25</text>
    </name>
    <graphics>
      <position x="1488" y="473"/>
      <dimension x="6" y="50"/>
      <fill color="rgb(153,153,255)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <arc id="12171" source="12157" target="12167">
    <type>
```

```
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12172" source="12159" target="12168">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12173" source="12168" target="12157">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <position x="1406" y="297"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12174" source="12167" target="12169">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12175" source="12169" target="12170">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <place id="12176">
    <name>
      <graphics>
        <offset x="8" y="-28"/>
      </graphics>
      <text>Transmission Line - 1</text>
    </name>
```

```
      <graphics>
        <position x="1222" y="1776"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(153,153,255)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <transition id="12177">
      <graphics>
        <position x="1308" y="1777"/>
        <dimension x="6" y="50"/>
        <fill color="rgb(255,255,0)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </transition>
    <arc id="12178" source="12176" target="12177">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <place id="12179">
      <name>
        <graphics>
          <offset x="-25" y="-26"/>
        </graphics>
        <text>Advance
Sensors
Y</text>
      </name>
      <graphics>
        <position x="1403" y="1776"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(153,153,255)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <arc id="12180" source="12177" target="12179">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
```

```
</arc>
<place id="12181">
  <name>
    <graphics>
      <offset x="0" y="0"/>
    </graphics>
    <text>P5</text>
  </name>
  <graphics>
    <position x="1579" y="1776"/>
    <dimension x="32" y="32"/>
    <fill color="rgb(153,153,255)"/>
    <line color="rgb(0,0,0)"/>
  </graphics>
</place>
<transition id="12182">
  <name>
    <graphics>
      <offset x="16" y="15"/>
    </graphics>
    <text>T25</text>
  </name>
  <graphics>
    <position x="1668" y="1777"/>
    <dimension x="6" y="50"/>
    <fill color="rgb(255,255,0)"/>
    <line color="rgb(0,0,0)"/>
  </graphics>
</transition>
<arc id="12183" source="12181" target="12182">
  <type>
    <text>ordinary</text>
  </type>
  <graphics>
    <line color="rgb(0,0,0)" style="solid"/>
  </graphics>
</arc>
<transition id="12184">
  <name>
    <graphics>
      <offset x="18" y="18"/>
    </graphics>
    <text>T22</text>
  </name>
  <graphics>
    <position x="1489" y="1776"/>
```

```
      <dimension x="6" y="50"/>
      <fill color="rgb(255,255,0)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <arc id="12185" source="12179" target="12184">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12186" source="12184" target="12181">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <transition id="12187">
    <name>
      <graphics>
        <offset x="17" y="18"/>
      </graphics>
      <text>T21</text>
    </name>
    <graphics>
      <position x="1121" y="1777"/>
      <dimension x="6" y="50"/>
      <fill color="rgb(153,153,255)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <arc id="12188" source="12187" target="12176">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <transition id="12189">
    <name>
      <graphics>
```

```
        <offset x="20" y="13"/>
      </graphics>
      <text>T23</text>
    </name>
    <graphics>
      <position x="1403" y="1824"/>
      <dimension x="55" y="6"/>
      <fill color="rgb(255,255,0)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <transition id="12190">
    <name>
      <graphics>
        <offset x="21" y="11"/>
      </graphics>
      <text>T24</text>
    </name>
    <graphics>
      <position x="1579" y="1706"/>
      <dimension x="55" y="6"/>
      <fill color="rgb(255,255,0)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <place id="12191">
    <name>
      <graphics>
        <offset x="0" y="0"/>
      </graphics>
      <text>P4</text>
    </name>
    <graphics>
      <position x="1403" y="1882"/>
      <dimension x="32" y="32"/>
      <fill color="rgb(153,153,255)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </place>
  <transition id="12192">
    <name>
      <graphics>
        <offset x="16" y="17"/>
      </graphics>
      <text>T30</text>
    </name>
```

```
    <graphics>
      <position x="1485" y="1883"/>
      <dimension x="6" y="50"/>
      <fill color="rgb(153,153,255)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <arc id="12193" source="12179" target="12189">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12194" source="12181" target="12190">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12195" source="12190" target="12179">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <position x="1403" y="1706"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12196" source="12189" target="12191">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12197" source="12191" target="12192">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
```

```
      </graphics>
    </arc>
    <place id="12198">
      <name>
        <graphics>
          <offset x="-58" y="-34"/>
        </graphics>
        <text>Centralized
Electricity Generator</text>
      </name>
      <graphics>
        <position x="1040" y="1777"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(153,153,255)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <arc id="12199" source="12198" target="12187">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12200" source="12198" target="12165">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <position x="1040" y="1495"/>
        <position x="1040" y="931"/>
        <position x="1040" y="367"/>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12223" source="12128" target="12198">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <transition id="12224">
      <name>
```

```
          <graphics>
            <offset x="-67" y="21"/>
          </graphics>
          <text>Electricty Distribution
Line - 1</text>
        </name>
        <create>
          <graphics>
            <offset x="3" y="64"/>
          </graphics>
          <text>cf = new ControlFlow();
guard cf.DistributionLine1();
</text>
        </create>
        <graphics>
          <position x="1901" y="1869"/>
          <dimension x="6" y="56"/>
          <fill color="rgb(255,204,204)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
      <place id="12225">
        <name>
          <graphics>
            <offset x="-24" y="-22"/>
          </graphics>
          <text>Utility 1</text>
        </name>
        <graphics>
          <position x="1770" y="1776"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(255,204,204)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <place id="12226">
        <name>
          <graphics>
            <offset x="0" y="34"/>
          </graphics>
          <text>Phasor Management
Unit 1</text>
        </name>
        <graphics>
          <position x="2000" y="1868"/>
          <dimension x="32" y="32"/>
```

```
        <fill color="rgb(255,204,204)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <place id="12227">
      <name>
        <graphics>
          <offset x="0" y="0"/>
        </graphics>
        <text>P10</text>
      </name>
      <graphics>
        <position x="2000" y="1719"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(255,204,204)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <transition id="12228">
      <name>
        <graphics>
          <offset x="26" y="14"/>
        </graphics>
        <text>T32</text>
      </name>
      <graphics>
        <position x="2000" y="1793"/>
        <dimension x="59" y="7"/>
        <fill color="rgb(255,255,0)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </transition>
    <transition id="12229">
      <name>
        <graphics>
          <offset x="4" y="41"/>
        </graphics>
        <text>Measure Power
Quality 1</text>
      </name>
      <graphics>
        <position x="2131" y="1868"/>
        <dimension x="6" y="50"/>
        <fill color="rgb(255,255,0)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
```

```
</transition>
<arc id="12230" source="12225" target="12306">
  <type>
    <text>ordinary</text>
  </type>
  <graphics>
    <position x="1770" y="1194"/>
    <line color="rgb(0,0,0)" style="solid"/>
  </graphics>
</arc>
<arc id="12231" source="12225" target="12224">
  <type>
    <text>ordinary</text>
  </type>
  <graphics>
    <position x="1770" y="1868"/>
    <line color="rgb(0,0,0)" style="solid"/>
  </graphics>
</arc>
<arc id="12232" source="12224" target="12226">
  <type>
    <text>ordinary</text>
  </type>
  <graphics>
    <line color="rgb(0,0,0)" style="solid"/>
  </graphics>
</arc>
<arc id="12233" source="12226" target="12228">
  <type>
    <text>ordinary</text>
  </type>
  <graphics>
    <line color="rgb(0,0,0)" style="solid"/>
  </graphics>
</arc>
<arc id="12234" source="12228" target="12227">
  <type>
    <text>ordinary</text>
  </type>
  <graphics>
    <line color="rgb(0,0,0)" style="solid"/>
  </graphics>
</arc>
<arc id="12235" source="12226" target="12229">
  <type>
    <text>ordinary</text>
```

```
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <transition id="12236">
    <name>
      <graphics>
        <offset x="24" y="-12"/>
      </graphics>
      <text>T33</text>
    </name>
    <graphics>
      <position x="2000" y="1648"/>
      <dimension x="59" y="7"/>
      <fill color="rgb(255,204,204)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <arc id="12237" source="12227" target="12236">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12242" source="12182" target="12225">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <transition id="12243">
    <name>
      <graphics>
        <offset x="15" y="22"/>
      </graphics>
      <text>T37</text>
    </name>
    <graphics>
      <position x="2575" y="1791"/>
      <dimension x="6" y="61"/>
      <fill color="rgb(35,142,104)"/>
```

```
        <line color="rgb(0,0,0)"/>
      </graphics>
    </transition>
    <place id="12244">
      <name>
        <graphics>
          <offset x="-42" y="-31"/>
        </graphics>
        <text>Smart
Appliances 1</text>
      </name>
      <graphics>
        <position x="2488" y="1791"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <place id="12245">
      <name>
        <graphics>
          <offset x="1" y="-31"/>
        </graphics>
        <text>Advance Metering
Infrastructure 1</text>
      </name>
      <graphics>
        <position x="2661" y="1791"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <place id="12246">
      <name>
        <graphics>
          <offset x="-33" y="32"/>
        </graphics>
        <text>Electric
Vehicles 1</text>
      </name>
      <graphics>
        <position x="2484" y="1959"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
```

```
      </graphics>
    </place>
    <transition id="12247">
      <name>
        <graphics>
          <offset x="2" y="45"/>
        </graphics>
        <text>Immediate
Transition 1</text>
      </name>
      <create>
        <graphics>
          <offset x="-1" y="-73"/>
        </graphics>
        <text>cf = new ControlFlow();
action cf.ImmediateTransition1();
guard cf.IT1()</text>
      </create>
      <graphics>
        <position x="2749" y="1791"/>
        <dimension x="6" y="61"/>
        <fill color="rgb(255,255,0)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </transition>
    <place id="12248">
      <name>
        <graphics>
          <offset x="0" y="-32"/>
        </graphics>
        <text>CONSUMER A</text>
      </name>
      <graphics>
        <position x="2835" y="1791"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <transition id="12249">
      <name>
        <graphics>
          <offset x="14" y="-36"/>
        </graphics>
        <text>T36</text>
      </name>
```

```
        <create>
          <graphics>
            <offset x="-59" y="-51"/>
          </graphics>
          <text>cf = new ControlFlow();
guard cf.T36();
</text>
        </create>
        <graphics>
          <position x="2392" y="1868"/>
          <dimension x="6" y="61"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
      <arc id="12250" source="12249" target="12244">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <line color="rgb(0,0,0)" style="solid"/>
        </graphics>
      </arc>
      <arc id="12251" source="12249" target="12246">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <line color="rgb(0,0,0)" style="solid"/>
        </graphics>
      </arc>
      <arc id="12252" source="12244" target="12243">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <line color="rgb(0,0,0)" style="solid"/>
        </graphics>
      </arc>
      <arc id="12253" source="12243" target="12245">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <line color="rgb(0,0,0)" style="solid"/>
        </graphics>
```

```
    </arc>
    <arc id="12254" source="12245" target="12247">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12255" source="12247" target="12248">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <place id="12256">
      <name>
        <graphics>
          <offset x="-21" y="32"/>
        </graphics>
        <text>Electricity
Substation 1</text>
      </name>
      <graphics>
        <position x="2265" y="1868"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <arc id="12257" source="12256" target="12249">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12258" source="12256" target="12291">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <position x="2265" y="1543"/>
```

```
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12259" source="12246" target="12243">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <position x="2574" y="1959"/>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12266" source="12229" target="12256">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <place id="12267">
      <name>
        <graphics>
          <offset x="0" y="-32"/>
        </graphics>
        <text>Distributed
Energy Resources</text>
      </name>
      <graphics>
        <position x="1217" y="2287"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(112,219,147)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <transition id="12268">
      <name>
        <graphics>
          <offset x="16" y="19"/>
        </graphics>
        <text>T49</text>
      </name>
      <create>
        <graphics>
          <offset x="-88" y="59"/>
        </graphics>
```

<text>cf = new ControlFlow();
guard cf.T49();
</text>
</create>
<graphics>
<position x="1303" y="2288"/>
<dimension x="6" y="50"/>
<fill color="rgb(255,255,0)"/>
<line color="rgb(0,0,0)"/>
</graphics>
</transition>
<arc id="12269" source="12267" target="12268">
<type>
<text>ordinary</text>
</type>
<graphics>
<line color="rgb(0,0,0)" style="solid"/>
</graphics>
</arc>
<transition id="12270">
<name>
<graphics>
<offset x="16" y="19"/>
</graphics>
<text>T48</text>
</name>
<graphics>
<position x="1116" y="2288"/>
<dimension x="6" y="50"/>
<fill color="rgb(255,255,0)"/>
<line color="rgb(0,0,0)"/>
</graphics>
</transition>
<arc id="12271" source="12270" target="12267">
<type>
<text>ordinary</text>
</type>
<graphics>
<line color="rgb(0,0,0)" style="solid"/>
</graphics>
</arc>
<arc id="12272" source="12130" target="12270">
<type>
<text>ordinary</text>
</type>
<graphics>

```
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12273" source="12268" target="12246">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <position x="2484" y="2287"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12274" source="12268" target="12244">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <position x="1303" y="2353"/>
      <position x="1385" y="2353"/>
      <position x="1469" y="2353"/>
      <position x="1634" y="2353"/>
      <position x="1966" y="2353"/>
      <position x="2626" y="2353"/>
      <position x="2626" y="2210"/>
      <position x="2626" y="2069"/>
      <position x="2626" y="1897"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12282" source="12169" target="12165">
    <type>
      <text>inhibitor</text>
    </type>
    <graphics>
      <position x="1124" y="472"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12283" source="12191" target="12187">
    <type>
      <text>inhibitor</text>
    </type>
    <graphics>
      <position x="1121" y="1882"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
```

```
    </arc>
    <arc id="12284" source="12227" target="12224">
      <type>
        <text>inhibitor</text>
      </type>
      <graphics>
        <position x="1901" y="1781"/>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <transition id="12285">
      <name>
        <graphics>
          <offset x="15" y="22"/>
        </graphics>
        <text>T35</text>
      </name>
      <graphics>
        <position x="2577" y="1466"/>
        <dimension x="6" y="61"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </transition>
    <place id="12286">
      <name>
        <graphics>
          <offset x="-42" y="-31"/>
        </graphics>
        <text>Smart
Appliances 2</text>
      </name>
      <graphics>
        <position x="2490" y="1466"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <place id="12287">
      <name>
        <graphics>
          <offset x="1" y="-31"/>
        </graphics>
        <text>Advance Metering
Infrastructure 2</text>
```

```
        </name>
        <graphics>
          <position x="2663" y="1466"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <place id="12288">
        <name>
          <graphics>
            <offset x="-40" y="32"/>
          </graphics>
          <text>Electric
Vehicles 2</text>
        </name>
        <graphics>
          <position x="2486" y="1634"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <transition id="12289">
        <name>
          <graphics>
            <offset x="2" y="45"/>
          </graphics>
          <text>Immediate
Transition 2</text>
        </name>
        <create>
          <graphics>
            <offset x="15" y="-57"/>
          </graphics>
          <text>cf = new ControlFlow();
action cf.ImmediateTransition2();
guard cf.IT2()</text>
        </create>
        <graphics>
          <position x="2751" y="1466"/>
          <dimension x="6" y="61"/>
          <fill color="rgb(255,255,0)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
```

```
    <place id="12290">
      <name>
        <graphics>
          <offset x="0" y="-32"/>
        </graphics>
        <text>CONSUMER B</text>
      </name>
      <graphics>
        <position x="2837" y="1466"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <transition id="12291">
      <name>
        <graphics>
          <offset x="14" y="-36"/>
        </graphics>
        <text>T34</text>
      </name>
      <create>
        <graphics>
          <offset x="-63" y="-53"/>
        </graphics>
        <text>cf = new ControlFlow();
guard cf.T34();
</text>
      </create>
      <graphics>
        <position x="2394" y="1543"/>
        <dimension x="6" y="61"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </transition>
    <arc id="12292" source="12291" target="12286">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12293" source="12291" target="12288">
      <type>
```

```
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12294" source="12286" target="12285">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12295" source="12285" target="12287">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12296" source="12287" target="12289">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12297" source="12289" target="12290">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12298" source="12288" target="12285">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <position x="2576" y="1634"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
```

```
    </arc>
    <transition id="12306">
      <name>
        <graphics>
          <offset x="-67" y="21"/>
        </graphics>
        <text>Electricty Distribution
Line - 2</text>
      </name>
      <create>
        <graphics>
          <offset x="-90" y="-18"/>
        </graphics>
        <text>cf = new ControlFlow();
guard cf.DistributionLine2();
</text>
      </create>
      <graphics>
        <position x="1904" y="1194"/>
        <dimension x="6" y="56"/>
        <fill color="rgb(255,204,204)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </transition>
    <place id="12307">
      <name>
        <graphics>
          <offset x="0" y="34"/>
        </graphics>
        <text>Phasor Management
Unit 2</text>
      </name>
      <graphics>
        <position x="2003" y="1193"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(255,204,204)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <place id="12308">
      <name>
        <graphics>
          <offset x="0" y="0"/>
        </graphics>
        <text>P11</text>
      </name>
```

```
      <graphics>
        <position x="2003" y="1044"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(255,204,204)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <transition id="12309">
      <name>
        <graphics>
          <offset x="26" y="14"/>
        </graphics>
        <text>T26</text>
      </name>
      <graphics>
        <position x="2003" y="1118"/>
        <dimension x="59" y="7"/>
        <fill color="rgb(255,255,0)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </transition>
    <transition id="12310">
      <name>
        <graphics>
          <offset x="4" y="41"/>
        </graphics>
        <text>Measure Power
Quality 2</text>
      </name>
      <graphics>
        <position x="2134" y="1193"/>
        <dimension x="6" y="50"/>
        <fill color="rgb(255,255,0)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </transition>
    <arc id="12311" source="12306" target="12307">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12312" source="12307" target="12309">
      <type>
```

```
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12313" source="12309" target="12308">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12314" source="12307" target="12310">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <transition id="12315">
    <name>
      <graphics>
        <offset x="24" y="-12"/>
      </graphics>
      <text>T27</text>
    </name>
    <graphics>
      <position x="2003" y="973"/>
      <dimension x="59" y="7"/>
      <fill color="rgb(255,204,204)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <arc id="12316" source="12308" target="12315">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <transition id="12321">
    <name>
```

```
          <graphics>
            <offset x="15" y="22"/>
          </graphics>
          <text>T31</text>
        </name>
        <graphics>
          <position x="2578" y="1116"/>
          <dimension x="6" y="61"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
      <place id="12322">
        <name>
          <graphics>
            <offset x="-44" y="-31"/>
          </graphics>
          <text>Smart
Appliances 3</text>
        </name>
        <graphics>
          <position x="2491" y="1116"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <place id="12323">
        <name>
          <graphics>
            <offset x="1" y="-31"/>
          </graphics>
          <text>Advance Metering
Infrastructure 3</text>
        </name>
        <graphics>
          <position x="2664" y="1116"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <place id="12324">
        <name>
          <graphics>
            <offset x="-34" y="32"/>
```

```
          </graphics>
          <text>Electric
Vehicles 3</text>
        </name>
        <graphics>
          <position x="2487" y="1284"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <transition id="12325">
        <name>
          <graphics>
            <offset x="2" y="45"/>
          </graphics>
          <text>Immediate
Transition 3</text>
        </name>
        <create>
          <graphics>
            <offset x="14" y="103"/>
          </graphics>
          <text>cf = new ControlFlow();
action cf.ImmediateTransition3();
guard cf.IT3()</text>
        </create>
        <graphics>
          <position x="2752" y="1116"/>
          <dimension x="6" y="61"/>
          <fill color="rgb(255,255,0)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
      <place id="12326">
        <name>
          <graphics>
            <offset x="0" y="-32"/>
          </graphics>
          <text>CONSUMER C</text>
        </name>
        <graphics>
          <position x="2838" y="1116"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
```

```
      </graphics>
    </place>
    <transition id="12327">
      <name>
        <graphics>
          <offset x="14" y="-36"/>
        </graphics>
        <text>T30</text>
      </name>
      <create>
        <graphics>
          <offset x="-33" y="-64"/>
        </graphics>
        <text>cf = new ControlFlow();
guard cf.T30();
</text>
      </create>
      <graphics>
        <position x="2395" y="1193"/>
        <dimension x="6" y="61"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </transition>
    <arc id="12328" source="12327" target="12322">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12329" source="12327" target="12324">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12330" source="12322" target="12321">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
```

```
      </graphics>
    </arc>
    <arc id="12331" source="12321" target="12323">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12332" source="12323" target="12325">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12333" source="12325" target="12326">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <place id="12334">
      <name>
        <graphics>
          <offset x="-21" y="32"/>
        </graphics>
        <text>Electricity
Substation 2</text>
      </name>
      <graphics>
        <position x="2268" y="1193"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <arc id="12335" source="12334" target="12327">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
```

```
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12336" source="12334" target="12356">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <position x="2268" y="868"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12337" source="12324" target="12321">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <position x="2577" y="1284"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12344" source="12310" target="12334">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12349" source="12308" target="12306">
    <type>
      <text>inhibitor</text>
    </type>
    <graphics>
      <position x="1904" y="1106"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <transition id="12350">
    <name>
      <graphics>
        <offset x="15" y="22"/>
      </graphics>
      <text>T29</text>
    </name>
    <graphics>
```

```
          <position x="2580" y="791"/>
          <dimension x="6" y="61"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
      <place id="12351">
        <name>
          <graphics>
            <offset x="-47" y="-31"/>
          </graphics>
          <text>Smart
Appliances 4</text>
        </name>
        <graphics>
          <position x="2493" y="791"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <place id="12352">
        <name>
          <graphics>
            <offset x="1" y="-31"/>
          </graphics>
          <text>Advance Metering
Infrastructure 4</text>
        </name>
        <graphics>
          <position x="2666" y="791"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <place id="12353">
        <name>
          <graphics>
            <offset x="-38" y="32"/>
          </graphics>
          <text>Electric
Vehicles 4</text>
        </name>
        <graphics>
          <position x="2489" y="959"/>
```

```
          <dimension x="32" y="32"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <transition id="12354">
        <name>
          <graphics>
            <offset x="2" y="45"/>
          </graphics>
          <text>Immediate
Transition 4</text>
        </name>
        <create>
          <graphics>
            <offset x="10" y="94"/>
          </graphics>
          <text>cf = new ControlFlow();
action cf.ImmediateTransition4();
guard cf.IT4();</text>
        </create>
        <graphics>
          <position x="2754" y="791"/>
          <dimension x="6" y="61"/>
          <fill color="rgb(255,255,0)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
      <place id="12355">
        <name>
          <graphics>
            <offset x="0" y="-32"/>
          </graphics>
          <text>CONSUMER D</text>
        </name>
        <graphics>
          <position x="2840" y="791"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <transition id="12356">
        <name>
          <graphics>
            <offset x="14" y="-36"/>
```

```
          </graphics>
          <text>T28</text>
        </name>
        <create>
          <graphics>
            <offset x="-75" y="-56"/>
          </graphics>
          <text>cf = new ControlFlow();
guard cf.T28();
</text>
        </create>
        <graphics>
          <position x="2397" y="868"/>
          <dimension x="6" y="61"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
      <arc id="12357" source="12356" target="12351">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <line color="rgb(0,0,0)" style="solid"/>
        </graphics>
      </arc>
      <arc id="12358" source="12356" target="12353">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <line color="rgb(0,0,0)" style="solid"/>
        </graphics>
      </arc>
      <arc id="12359" source="12351" target="12350">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <line color="rgb(0,0,0)" style="solid"/>
        </graphics>
      </arc>
      <arc id="12360" source="12350" target="12352">
        <type>
          <text>ordinary</text>
        </type>
```

```
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12361" source="12352" target="12354">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12362" source="12354" target="12355">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12363" source="12353" target="12350">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <position x="2579" y="959"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12371" source="12268" target="12288">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <position x="1302" y="2370"/>
      <position x="2095" y="2370"/>
      <position x="2968" y="2370"/>
      <position x="2968" y="1690"/>
      <position x="2486" y="1690"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12372" source="12268" target="12286">
    <type>
      <text>ordinary</text>
    </type>
```

```
      <graphics>
        <position x="1303" y="2390"/>
        <position x="2163" y="2390"/>
        <position x="3014" y="2390"/>
        <position x="3014" y="1387"/>
        <position x="2490" y="1387"/>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12373" source="12268" target="12322">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <position x="1304" y="2423"/>
        <position x="2216" y="2423"/>
        <position x="3127" y="2423"/>
        <position x="3127" y="1042"/>
        <position x="2491" y="1042"/>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12374" source="12268" target="12351">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <position x="1303" y="2466"/>
        <position x="2242" y="2466"/>
        <position x="3187" y="2466"/>
        <position x="3187" y="1587"/>
        <position x="3187" y="1147"/>
        <position x="3187" y="708"/>
        <position x="2493" y="708"/>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <transition id="12375">
      <name>
        <graphics>
          <offset x="-37" y="43"/>
        </graphics>
        <text>Electricty Distribution
Line - 3</text>
      </name>
      <create>
```

```
          <graphics>
            <offset x="20" y="111"/>
          </graphics>
          <text>cf = new ControlFlow();
guard cf.DistributionLine3();
</text>
        </create>
        <graphics>
          <position x="1907" y="367"/>
          <dimension x="6" y="56"/>
          <fill color="rgb(255,204,204)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
      <place id="12376">
        <name>
          <graphics>
            <offset x="0" y="-27"/>
          </graphics>
          <text>Utility 2</text>
        </name>
        <graphics>
          <position x="1776" y="367"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(255,204,204)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <place id="12377">
        <name>
          <graphics>
            <offset x="0" y="34"/>
          </graphics>
          <text>Phasor Management
Unit 3</text>
        </name>
        <graphics>
          <position x="2006" y="366"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(255,204,204)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <place id="12378">
        <name>
          <graphics>
```

```
            <offset x="0" y="0"/>
          </graphics>
          <text>P10</text>
        </name>
        <graphics>
          <position x="2006" y="217"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(255,204,204)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <transition id="12379">
        <name>
          <graphics>
            <offset x="26" y="14"/>
          </graphics>
          <text>T17</text>
        </name>
        <graphics>
          <position x="2006" y="291"/>
          <dimension x="59" y="7"/>
          <fill color="rgb(255,255,0)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
      <transition id="12380">
        <name>
          <graphics>
            <offset x="4" y="41"/>
          </graphics>
          <text>Measure Power
Quality 3</text>
        </name>
        <graphics>
          <position x="2137" y="366"/>
          <dimension x="6" y="50"/>
          <fill color="rgb(255,255,0)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
      <arc id="12381" source="12376" target="12375">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <line color="rgb(0,0,0)" style="solid"/>
```

```
  </graphics>
</arc>
<arc id="12382" source="12375" target="12377">
  <type>
    <text>ordinary</text>
  </type>
  <graphics>
    <line color="rgb(0,0,0)" style="solid"/>
  </graphics>
</arc>
<arc id="12383" source="12377" target="12379">
  <type>
    <text>ordinary</text>
  </type>
  <graphics>
    <line color="rgb(0,0,0)" style="solid"/>
  </graphics>
</arc>
<arc id="12384" source="12379" target="12378">
  <type>
    <text>ordinary</text>
  </type>
  <graphics>
    <line color="rgb(0,0,0)" style="solid"/>
  </graphics>
</arc>
<arc id="12385" source="12377" target="12380">
  <type>
    <text>ordinary</text>
  </type>
  <graphics>
    <line color="rgb(0,0,0)" style="solid"/>
  </graphics>
</arc>
<transition id="12386">
  <name>
    <graphics>
      <offset x="24" y="-12"/>
    </graphics>
    <text>T18</text>
  </name>
  <graphics>
    <position x="2006" y="146"/>
    <dimension x="59" y="7"/>
    <fill color="rgb(255,204,204)"/>
    <line color="rgb(0,0,0)"/>
```

```
      </graphics>
    </transition>
    <arc id="12387" source="12378" target="12386">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <transition id="12392">
      <name>
        <graphics>
          <offset x="15" y="22"/>
        </graphics>
        <text>T20</text>
      </name>
      <graphics>
        <position x="2581" y="289"/>
        <dimension x="6" y="61"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </transition>
    <place id="12393">
      <name>
        <graphics>
          <offset x="-42" y="-31"/>
        </graphics>
        <text>Smart
Appliances 5</text>
      </name>
      <graphics>
        <position x="2494" y="289"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <place id="12394">
      <name>
        <graphics>
          <offset x="1" y="-31"/>
        </graphics>
        <text>Advance Metering
Infrastructure 5</text>
```

```
        </name>
        <graphics>
          <position x="2667" y="289"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <place id="12395">
        <name>
          <graphics>
            <offset x="-33" y="32"/>
          </graphics>
          <text>Electric
Vehicles 5</text>
        </name>
        <graphics>
          <position x="2490" y="457"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(35,142,104)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <transition id="12396">
        <name>
          <graphics>
            <offset x="2" y="45"/>
          </graphics>
          <text>Immediate
Transition 5</text>
        </name>
        <create>
          <graphics>
            <offset x="26" y="-76"/>
          </graphics>
          <text>cf = new ControlFlow();
action cf.ImmediateTransition5();
guard cf.IT5()</text>
        </create>
        <graphics>
          <position x="2755" y="289"/>
          <dimension x="6" y="61"/>
          <fill color="rgb(255,255,0)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </transition>
```

```
    <place id="12397">
      <name>
        <graphics>
          <offset x="0" y="-32"/>
        </graphics>
        <text>CONSUMER E</text>
      </name>
      <graphics>
        <position x="2841" y="289"/>
        <dimension x="32" y="32"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </place>
    <transition id="12398">
      <name>
        <graphics>
          <offset x="14" y="-36"/>
        </graphics>
        <text>T19</text>
      </name>
      <create>
        <graphics>
          <offset x="-37" y="-57"/>
        </graphics>
        <text>cf = new ControlFlow();
guard cf.T19();
</text>
      </create>
      <graphics>
        <position x="2398" y="366"/>
        <dimension x="6" y="61"/>
        <fill color="rgb(35,142,104)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </transition>
    <arc id="12399" source="12398" target="12393">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12400" source="12398" target="12395">
      <type>
```

```
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12401" source="12393" target="12392">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12402" source="12392" target="12394">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12403" source="12394" target="12396">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12404" source="12396" target="12397">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <place id="12405">
      <name>
        <graphics>
          <offset x="-21" y="32"/>
        </graphics>
        <text>Electricity
Substation 3</text>
      </name>
```

```
    <graphics>
      <position x="2271" y="366"/>
      <dimension x="32" y="32"/>
      <fill color="rgb(35,142,104)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </place>
  <arc id="12406" source="12405" target="12398">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12407" source="12395" target="12392">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <position x="2580" y="457"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12414" source="12380" target="12405">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12419" source="12378" target="12375">
    <type>
      <text>inhibitor</text>
    </type>
    <graphics>
      <position x="1907" y="279"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12420" source="12160" target="12376">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
```

```
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12421" source="12268" target="12395">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <position x="1303" y="2480"/>
        <position x="2270" y="2480"/>
        <position x="3234" y="2480"/>
        <position x="3234" y="1481"/>
        <position x="3234" y="550"/>
        <position x="2490" y="550"/>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <arc id="12422" source="12268" target="12393">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <position x="1303" y="2496"/>
        <position x="2285" y="2496"/>
        <position x="3293" y="2496"/>
        <position x="3293" y="1291"/>
        <position x="3293" y="731"/>
        <position x="3293" y="169"/>
        <position x="2494" y="169"/>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <declaration>
      <graphics>
        <offset x="3042" y="132"/>
      </graphics>
      <text>import smartgrid.ControlFlow;
ControlFlow cf;
</text>
    </declaration>
    <place id="12438">
      <name>
        <graphics>
          <offset x="-1" y="-31"/>
        </graphics>
        <text>Non - Renewable Source
```

```
of Energy</text>
        </name>
        <graphics>
          <position x="327" y="1942"/>
          <dimension x="32" y="32"/>
          <fill color="rgb(112,219,147)"/>
          <line color="rgb(0,0,0)"/>
        </graphics>
      </place>
      <arc id="12440" source="12438" target="12100">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <line color="rgb(0,0,0)" style="solid"/>
        </graphics>
      </arc>
      <arc id="12441" source="12438" target="12103">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <line color="rgb(0,0,0)" style="solid"/>
        </graphics>
      </arc>
      <arc id="12444" source="12268" target="12353">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <position x="1303" y="2445"/>
          <position x="3157" y="2445"/>
          <position x="3157" y="1012"/>
          <position x="2489" y="1012"/>
          <line color="rgb(0,0,0)" style="solid"/>
        </graphics>
      </arc>
      <arc id="12445" source="12268" target="12324">
        <type>
          <text>ordinary</text>
        </type>
        <graphics>
          <position x="1304" y="2405"/>
          <position x="3074" y="2405"/>
          <position x="3074" y="1874"/>
          <position x="3074" y="1348"/>
```

```
      <position x="2487" y="1348"/>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <transition id="12446">
    <name>
      <graphics>
        <offset x="-15" y="18"/>
      </graphics>
      <text>Tx</text>
    </name>
    <graphics>
      <position x="203" y="1533"/>
      <dimension x="6" y="50"/>
      <fill color="rgb(112,219,147)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <transition id="12448">
    <name>
      <graphics>
        <offset x="-15" y="18"/>
      </graphics>
      <text>Ty</text>
    </name>
    <graphics>
      <position x="202" y="1644"/>
      <dimension x="6" y="50"/>
      <fill color="rgb(112,219,147)"/>
      <line color="rgb(0,0,0)"/>
    </graphics>
  </transition>
  <arc id="12450" source="12446" target="12097">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
    </graphics>
  </arc>
  <arc id="12451" source="12448" target="12099">
    <type>
      <text>ordinary</text>
    </type>
    <graphics>
      <line color="rgb(0,0,0)" style="solid"/>
```

```
      </graphics>
    </arc>
    <transition id="12452">
      <name>
        <graphics>
          <offset x="-15" y="18"/>
        </graphics>
        <text>Tz</text>
      </name>
      <graphics>
        <position x="209" y="1942"/>
        <dimension x="6" y="50"/>
        <fill color="rgb(112,219,147)"/>
        <line color="rgb(0,0,0)"/>
      </graphics>
    </transition>
    <arc id="12454" source="12452" target="12438">
      <type>
        <text>ordinary</text>
      </type>
      <graphics>
        <line color="rgb(0,0,0)" style="solid"/>
      </graphics>
    </arc>
    <name>
      <text>SmartGrid</text>
    </name>
  </net>
</pnml>
```