ENERGETIC SYSTEM SIMULATOR

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1 INTRODUCTION

1.1 Context

The electricity network of a country is a complex system in which the government must supervise the quality and stability of the system and regulate it in order to be affordable for people and sustainable in the long term.

1.2 Objectives

This project aims to provide an advanced overview of Object-Oriented programming by developing a platform for administering a country's electrical network using advanced OOP concepts.

The following objectives are covered upon implementing the program:

- Develop basic abilities of organization and OOP design
- Develop the ability to write generic code
- Understand how and when to use design patterns
- Adopt specific coding design and style for Object Oriented Programming

2 PROPOSED SOLUTION

2.1 Solution presentation

The project aims to implement an energetic system simulator in which the assessed entities have to remain in business and avoid bankruptcy.

There are 3 entity categories:

- Producers - The entity considered to produce and sell energy
- Consumers - The entity that buys and uses the produced energy
- Distributors - The entity which acts as an intermediary between the Producers and the Consumers

These entities try to take action and finish their specific responsibilities over a specific number of rounds simulating the passing months. Each round comes with new updates for the simulator that are going to be applied at the start of each round. On a single round, the following actions are executed in order:

1. If it is the first round, the distributors choose the producers based on their choosing strategy
2. If it is not the first round
   (a) Checks if all distributors are bankrupt, in which case the simulation is finished
   (b) Adds new consumers and updates costs for distributors based on the round instructions
   (c) The consumers are checked for bankruptcy, in which case the corresponding actions are taken
3. Distributor prices are updated
4. Consumers receive their monthly salary
5. Distributors are checked for bankruptcy, in which case they are eliminated and their contracts closed
6. Assigns new contracts for consumers that are not bankrupt and have no contract
7. Consumers pay their bills and Distributors update their budgets
8. Consumers are checked again for bankruptcy, in which case the corresponding actions are taken
9. If it is not the first round
   (a) Producer's debit per distributor is updated based on the round instructions

(b) The distributors who seek new producers sign new contracts based on their chosen strategy

(c) Statistics about all entities are extracted

2.2 Round flow

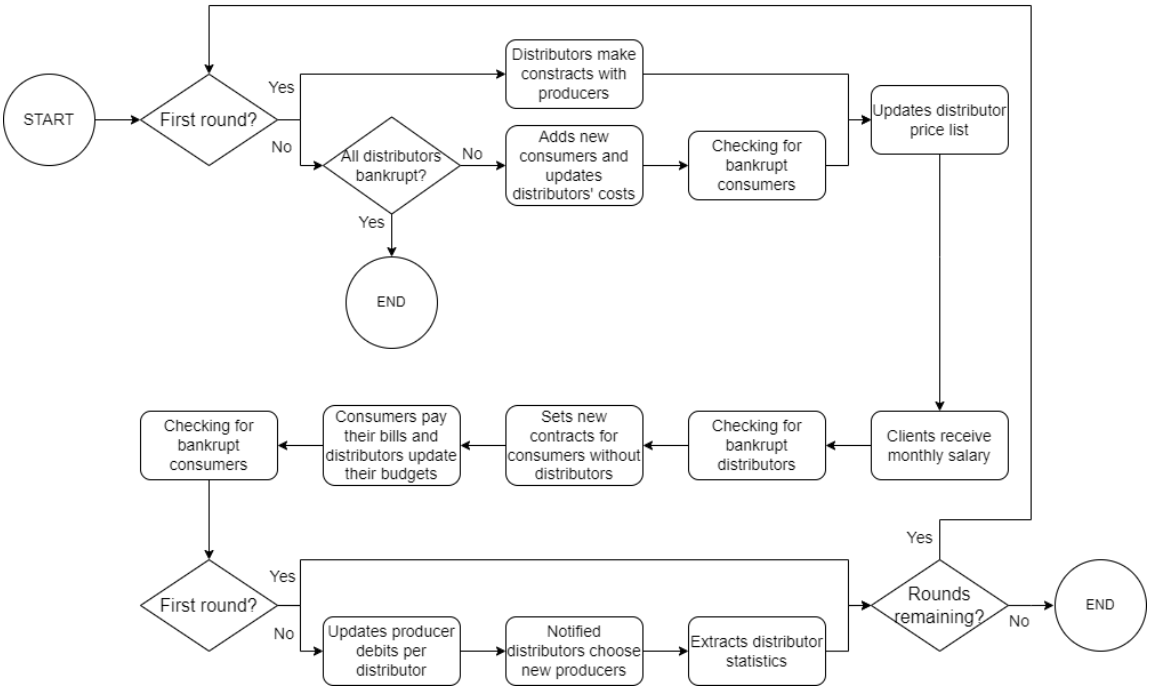

Figure 1: Round flow

3 IMPLEMENTATION DETAILS

The simulator starts its execution by reading from a provided input file, data about multiple producers, distributors, and consumers that are going to be registered. After initialization, the first round begins and it goes through the presented round flow [Fig. 1].

3.1 Producers

3.1.1 Description

The producers are entities that produce energy and deliver it to distributors. Energy can be produced in many ways thus producers can be categorized by the resource used for production which falls either into renewable energy (wind, solar, hydro) or non-renewable energy (coal, nuclear).

Additionally, the producers have an ID for identification, a price per kWh, the monthly quantity of energy it can offer to one distributor, and the maximum number of distributors it can set a contract with.

3.1.2 JSON representation

```
 {
    "id": 0,
    "energyType": "WIND",
    "maxDistributors": 10,
    "priceKW": 0.01,
    "energyPerDistributor": 2695
}
```

3.1.3 Actions

The producers offer the requested amount of energy to distributors based on the signed contracts. However, producers can change their monthly energy price based on the indications provided by the simulator and are going to notify the associated distributors about the price change, a mechanic implemented with the Observer Design Pattern.

3.2 Distributors

3.2.1 Description

The distributors act as intermediaries between producers and consumers. One distributor can sign contracts with multiple producers to fulfill its necessary energy debit. The way distributors choose their producers is based on one of the following 3 strategies:

- Green Strategy - Distributors prioritize producers with renewable energy, the ones with the lowest prices secondly, and the ones with the biggest quantity offered at last
- Price Strategy - Distributors prioritize producers by the price, and the quantity offered last
- Quantity Strategy - Distributors prioritize producers by the quantity offered

Distributors can also sign contracts with consumers when requested and get paid at a fixed price. If a consumer is unable to pay the bill, the distributor adds a penalty to the next month's bill. If the consumer is unable to pay the next bill, the contract is terminated and the consumer eliminated.

In addition, a distributor has an ID for identification, the number of months until the contract with the producer is due, an initial budget, an initial infrastructure cost, the amount of energy needed, and the strategy for selecting producers.

3.2.2 JSON representation

```
{
    "id": 0,
    "contractLength": 6,
    "initialBudget": 60,
    "initialInfrastructureCost": 24,
    "energyNeededKW": 1930,
    "producerStrategy": "GREEN"
}
```

3.2.3 Actions

The distributor strategies are implemented using the Strategy Design Pattern. Based on the provided strategy, the pattern sorts all producers accordingly and lets distributors set contracts with the best producers for their needs.

Additionally, distributors, as soon as they are notified by the producer of a price change, can

opt for choosing other producers. The listening mechanic for distributors is implemented using the Observer Design Pattern.

Moreover, distributors have a cost of infrastructure which reflects the cost of receiving, maintaining, and distributing energy. This cost is monthly and it is updated by the system.

In relationship with consumers, distributors set a penalty in case consumers can't pay their monthly bill, in addition to the next month's bill according to the following formula:

$$Math.round(Math.floor(1.2 * old_bill)) + new_bill$$

3.3 Consumers

3.3.1 Description

The consumer is the entity that buys energy from distributors for its benefit.

3.3.2 JSON representation

```
{
    "id": 0,
    "initialBudget": 150,
    "monthlyIncome": 28
}
```

3.3.3 Actions

The consumers, besides receiving salary and paying bills to the subscribed distributors can move to other distributors, but only when their contract has expired. In case a consumer opts for a new distributor, it has to pay the remaining penalties to the former distributor, in addition to the new bill. If it is unable to do so, it will be considered bankrupt.

3.4 Input & Output objects

The input is the information provided by the system. In the first round, the input provided will load all the entities with their corresponding data. In the next rounds, the following changes can take place based on the system's input:

- Monthly price changes for producers

- Monthly changes in infrastructure costs for distributors
- New clients added

One such example can be found below:


```
{
  "numberOfTurns": 6,
  "initialData": {
    "consumers": [
      {
        "id": 0,
        "initialBudget": 150,
        "monthlyIncome": 28
      }
    ],
    "distributors": [
      {
        "id": 0,
        "contractLength": 6,
        "initialBudget": 60,
        "initialInfrastructureCost": 24,
        "energyNeededKW": 1930,
        "producerStrategy": "GREEN"
      }
    ],
    "producers": [
      {
        "id": 0,
        "energyType": "WIND",
        "maxDistributors": 10,
        "priceKW": 0.01,
        "energyPerDistributor": 2695
      }
    ]
  },
  "monthlyUpdates": [
    {
      "newConsumers": [
        {
          "id": 0,
          "initialBudget": 140,
          "monthlyIncome": 24
```

```
    }
  ],
  "distributorChanges": [
    {
      "id": 0,
      "infrastructureCost": 20
    }
  ],
  "producerChanges": [
    {
      "id": 0,
      "energyPerDistributor": 6319
    }
  ]
},
{
  "newConsumers": [
    {
      "id": 0,
      "initialBudget": 56,
      "monthlyIncome": 97
    }
  ],
  "distributorChanges": [
    {
      "id": 0,
      "infrastructureCost": 25
    }
  ],
  "producerChanges": [
    {
      "id": 0,
      "energyPerDistributor": 4430
    }
  ]
},
{
  "newConsumers": [
    {
      "id": 0,
      "initialBudget": 188,
      "monthlyIncome": 43
```

```
    }
  ],
  "distributorChanges": [
    {
      "id": 0,
      "infrastructureCost": 17
    }
  ],
  "producerChanges": [
    {
      "id": 0,
      "energyPerDistributor": 9965
    }
  ]
},
{
  "newConsumers": [
    {
      "id": 0,
      "initialBudget": 55,
      "monthlyIncome": 65
    }
  ],
  "distributorChanges": [
    {
      "id": 0,
      "infrastructureCost": 17
    }
  ],
  "producerChanges": [
    {
      "id": 0,
      "energyPerDistributor": 2569
    }
  ]
},
{
  "newConsumers": [
    {
      "id": 0,
      "initialBudget": 163,
      "monthlyIncome": 27
```

```
        }
      ],
      "distributorChanges": [
        {
          "id": 0,
          "infrastructureCost": 13
        }
      ],
      "producerChanges": [
        {
          "id": 0,
          "energyPerDistributor": 9077
        }
      ]
    },
    {
      "newConsumers": [
        {
          "id": 0,
          "initialBudget": 140,
          "monthlyIncome": 85
        }
      ],
      "distributorChanges": [
        {
          "id": 0,
          "infrastructureCost": 16
        }
      ],
      "producerChanges": [
        {
          "id": 0,
          "energyPerDistributor": 4523
        }
      ]
    }
  ]
}
```


The output of each round will have evidence of all entities and some additional statistics. One such example can be found below:

```
{
  "consumers": [ {
    "id": 0,
    "isBankrupt": false,
    "budget": 178
  }, {
    "id": 0,
    "isBankrupt": false,
    "budget": 152
  }, {
    "id": 0,
    "isBankrupt": false,
    "budget": 446
  }, {
    "id": 0,
    "isBankrupt": false,
    "budget": 324
  }, {
    "id": 0,
    "isBankrupt": false,
    "budget": 208
  }, {
    "id": 0,
    "isBankrupt": false,
    "budget": 209
  }, {
    "id": 0,
    "isBankrupt": false,
    "budget": 213
  } ],
  "distributors": [ {
    "id": 0,
    "energyNeededKW": 1930,
    "contractCost": 12,
    "budget": 261,
    "producerStrategy": "GREEN",
    "isBankrupt": false,
    "contracts": [ {
      "consumerId": 0,
      "price": 22,
      "remainedContractMonths": 0
    }, {
```

```
      "consumerId": 0,
      "price": 19,
      "remainedContractMonths": 1
    }, {
      "consumerId": 0,
      "price": 9,
      "remainedContractMonths": 2
    }, {
      "consumerId": 0,
      "price": 14,
      "remainedContractMonths": 3
    }, {
      "consumerId": 0,
      "price": 4,
      "remainedContractMonths": 4
    }, {
      "consumerId": 0,
      "price": 12,
      "remainedContractMonths": 5
    }, {
      "consumerId": 0,
      "price": 12,
      "remainedContractMonths": 5
    } ]
  } ],
  "energyProducers": [ {
    "id": 0,
    "maxDistributors": 10,
    "priceKW": 0.01,
    "energyType": "WIND",
    "energyPerDistributor": 4523,
    "monthlyStats": [ {
      "month": 1,
      "distributorsIds": [ 0 ]
    }, {
      "month": 2,
      "distributorsIds": [ 0 ]
    }, {
      "month": 3,
      "distributorsIds": [ 0 ]
    }, {
      "month": 4,
```

```
      "distributorsIds": [ 0 ]
    }, {
      "month": 5,
      "distributorsIds": [ 0 ]
    }, {
      "month": 6,
      "distributorsIds": [ 0 ]
    } ]
  } ]
}
```

The input and output are created using the Factory Design Patterns since there is a common way of how these objects work. The input object gathers its data from an input file using the Jackson library[1] which parses the provided data into JSON readable data. The output object gathers the results from the simulation, represented as JSON, converts it to an output format using the same Jackson library[1], and puts it in the output files.

3.5 Testing

For testing the simulator, the following methods have been used:

- Checker - Used for testing general cases
- Manual testing - Used for testing corner cases

4 CONCLUSIONS

In conclusion, this program aims to provide an advanced overview of Object-Oriented programming by developing a platform for administering a country's electrical network. The app offers a great and practical example of using advanced techniques such as design patterns as well as attempting to design code with SOLID principles in mind making it easier to add more functionalities. This program provides a simulator for a country's electrical network that will keep the evidence of multiple consumers, distributors, and producers along with additional stats that facilitate the administration of such a complex system.

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