CASE HYDROELECTRIC POWER PLANT

The municipality of Emmen, impressed by the technological advancements in renewable energy solutions, has asked you to write the software for a new hydroelectric power plant being constructed near the Great Dam. Due to strict environmental deadlines, the software must be completed within three hours.

The hydroelectric power plant consists of a **reservoir**, **turbines**, and a **generator**. The reservoir stores water, with its capacity measured in cubic meters (m³). The reservoir includes the method addWater() to add a random amount of water coming to the reservoir. This technique, of course, should have a limit to avoid any possible risks, the range of water capacity must be around 6000m3-10000m3.The reservoir acts as a potential energy source, and water is released from the reservoir to power the turbines. The rate of water release, or **discharge**, is measured in cubic meters per second (m³/s). This flow is regulated based on operational requirements.

. The turbines have an efficiency percentage that indicates how effectively they can convert the energy of flowing water into mechanical energy. This efficiency starts at 100% and decreases over time due to wear and tear. The turbine keeps track of its heat by calculating the turbine heat.

Turbine heat = discharge \* efficiency \* 0.01;

The turbines also calculate water discharge (in m³/s) and rotational speed (in RPM). The calculation parameters are water pressure (P, in Pascals) and time (t, in seconds). There are two types of turbines. Table 1 outlines their properties.

Table 1 Properties of turbine types TURBINE PROPERTIES

KAPLAN TURBINE: The efficiency decreases by 0.05% per second of operation.

If the water pressure is less than 150,000 Pascals, the water discharge is calculated as P / 500 ∗ t ∗ 0.85. The rotational speed is then t ∗ 2.

For higher pressures ( > 150.000 Pascals), the water discharge is 0.85 ∗ ((P ∗ 0.75) / t) ∗ √2 ∗ t, and the rotational speed is P / 100.

FRANCIS TURBINE: The efficiency decreases by 0.0001 ∗ P ∗ t + 0.0005 percent. If the water pressure is below 100,000 Pascals, the efficiency does not decrease. The water discharge is calculated as 40 ∗ P. The rotational speed is t ∗ 0.4 ∗ 50.

The hydroelectric power plant also contains a generator. This generator converts the mechanical energy from the turbines into electrical energy (kWh). The conversion is performed using the generateEnergy method, which returns the energy output in kWh. The energy output is calculated as m³/s ∗ 9.81. The generator also keeps track of the total energy produced.

Additionally, the plant has a cooling system to regulate turbine temperatures. The cooling system’s coolTurbine method reduces the heat generated by the turbines. It keeps track of the cooling water temperature, which starts at 0°C. The cooling water temperature is calculated as turbine heat ∗ 0.45.

All these systems integrate into the power plant. The power plant consists of three main components: the reservoir, turbines, and generator. The power plant’s main operation is controlled by the run method, which takes water pressure and time as input parameters. This method initiates the entire process: the turbines calculate discharge and rotational speed, which are then used by the generator to produce energy. The cooling system regulates the heat generated. The run method ultimately returns the total energy output in kWh.

Your colleague has already created a foundation with the class diagram. This can be found in Appendix 1. Unfortunately, he spilled his coffee.

ASSIGNMENT 1 Build the software based on the class diagram and the text above.

ASSIGNMENT 2 Despite being renewable, hydroelectric power plants can still pose dangers, such as mechanical failures in turbines.

1. Create a TurbineFailureException.
2. b) Throw the TurbineFailureException in the following cases during operation:

Kaplan Turbine: If the time exceeds 120 seconds and the water pressure is above 200,000 Pascals. Also, if the turbine efficiency drops below 0.1%.

Francis Turbine: If the water pressure exceeds 300,000 Pascals.

ASSIGNMENT 3 To ensure safety and performance, the hydroelectric plant requires a control room to monitor the status of all its components. This is done using the getStatus() method, which must be implemented in all components except the control room itself. The getStatus() method can only return one of the following three values: Stable, Needs Attention, and Unstable.

a) Add this method to the components. Follow the criteria below:

| **COMPONENT** | **NEEDS ATTENTION** | **UNSTABLE** |
| --- | --- | --- |

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| --- | --- | --- |
| **Reservoir** | If water level drops below 30% of minimum water capacity. | - |

|  |  |  |
| --- | --- | --- |
| **Turbines** | If efficiency falls below 15%. | - |

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| --- | --- | --- |
| **Generator** | - | If more than 1,000 kWh were produced in a single run. |

|  |  |  |
| --- | --- | --- |
| **Cooling System** | If the cooling water temperature is between 50°C and 60°C. | If the temperature exceeds 60°C. |

b) Create the control room. It must monitor all the components.

c) This method returns false if any component is not Stable. Otherwise, it returns true.

1. d) Add the control room to the hydroelectric power plant.

ASSIGNMENT 4 Write a Unit Test for the Francis Turbine to validate its behavior and calculations.

