Safety Critical Dam control system

Introduction:

This report is an overview of the Dam control system program which is developed for the water gates management systems. This system is designed in such a way that the it responds in real time to various environmental factors which are water level, wind, pressure, seismographic readings, rain and snow. The main objective of this system is to maintain the safety and stability of the dam structure as its failure could be catastrophic, issues with the dams control systems like uncontrolled water release or dam collapse can put living beings and properties downstream at a major risk.

Key parameters that impact safety and influence the gate operation:

- **Water level (Threshold value:100m, Critical Value:80m):** Water level sensors monitor the height of the water behind the dam, high water levels will produce more pressure on the dam structure which might lead to overflow or structural failure.

Influence: If the water level exceeds the predefined threshold the system will activate the gates opening and open gates based on the user input to release the excess water.

- **Pressure (Threshold value:5 atm, Critical Value:2 atm):** Pressure sensors measure the force exerted on the dam structure, there might be multiple environmental factors which leads to pressure variation which indicates the changes in the flow of water and stress on the structure.

Influence: Increase in pressure beyond the predefined limits will prompt the system to assess the risk and consider the amount of water that needs to be released by adjusting the gates.

- **Wind Speed (Threshold value:15km/h, Critical Value:10km/h):** Wind sensors measure the wind speed and the wind direction which accounts the effect of wind on the water dynamics, high wind speed leads to large waves which in turn affects the water levels and cause stress on the dam structure. Influence: The system will evaluate the wind speed along with water level data to predict and respond to the potential disturbance.
- **Rain (Threshold value:100mm, Critical Value:80mm) and Snow (Threshold value:10cm Critical Value: 5cm):** Rain and snow sensor module will read the real time weather conditions. Rain and snow are responsible for the water inflow which affects the dam water level which potentially changes the pressure on the dam structure.

Influence: The system will monitor the level of precipitation and will adjust the gate operation based on the intensity of rain/snow.

- **Seismographic Readings (Threshold value:5Mw critical Value:2Mw):** These sensors measure the seismic activity in the area around the dam. Seismic events can directly affect the dam's structure. Influence: The system will monitor the seismographic readings and in case there is an event of seismic activity it will initiate the emergency protocols and implement safety measures.

Working of Dam control system:

This system works on the basis of real-time sensor readings which affects the safety and stability of the dam. The system takes the reading of all the parameters from the sensors and then make a decision on opening and closing of gates.

Here gates are opened in two methods:

1. **Manual Gate Control:**

The system will first take the sensor readings, these readings are displayed to the gate operator. The operator can open one or more gates by entering the gate number and the discharge rate based on their analysis of the scenario(Maximum number of gates is 3 and the discharge rates are from 1 to 5) the operator can also change the discharge rate of the gate which is already open by entering the gate number

and the new discharge rate, however the system will prompt that the "Gate is already open do you want to change the rate" this prevents simultaneous command on same gate, also the operator will have an option to close the gates post water release.

2. **Emergency Gate Control:**

Automatic gates Closing events:

- Gates closing will be activated automatically when there is a seismic event.
- When there is high rainfall, where rainfall measured is greater than the critical rainfall value and the dam water level measured is less than maximum water level, gates will be closed to avoid flood in the downstream.

Automatic gates opening events:

- When water and pressure level measured is greater than critical water and pressure levels respectively, gates will be opened automatically to maintain the stability of the dam structure.
- When there is water scarcity downstream and water level measured is more than critical water level and rainfall measured is low then few gates will be opened with low rate for the irrigation in downstream.

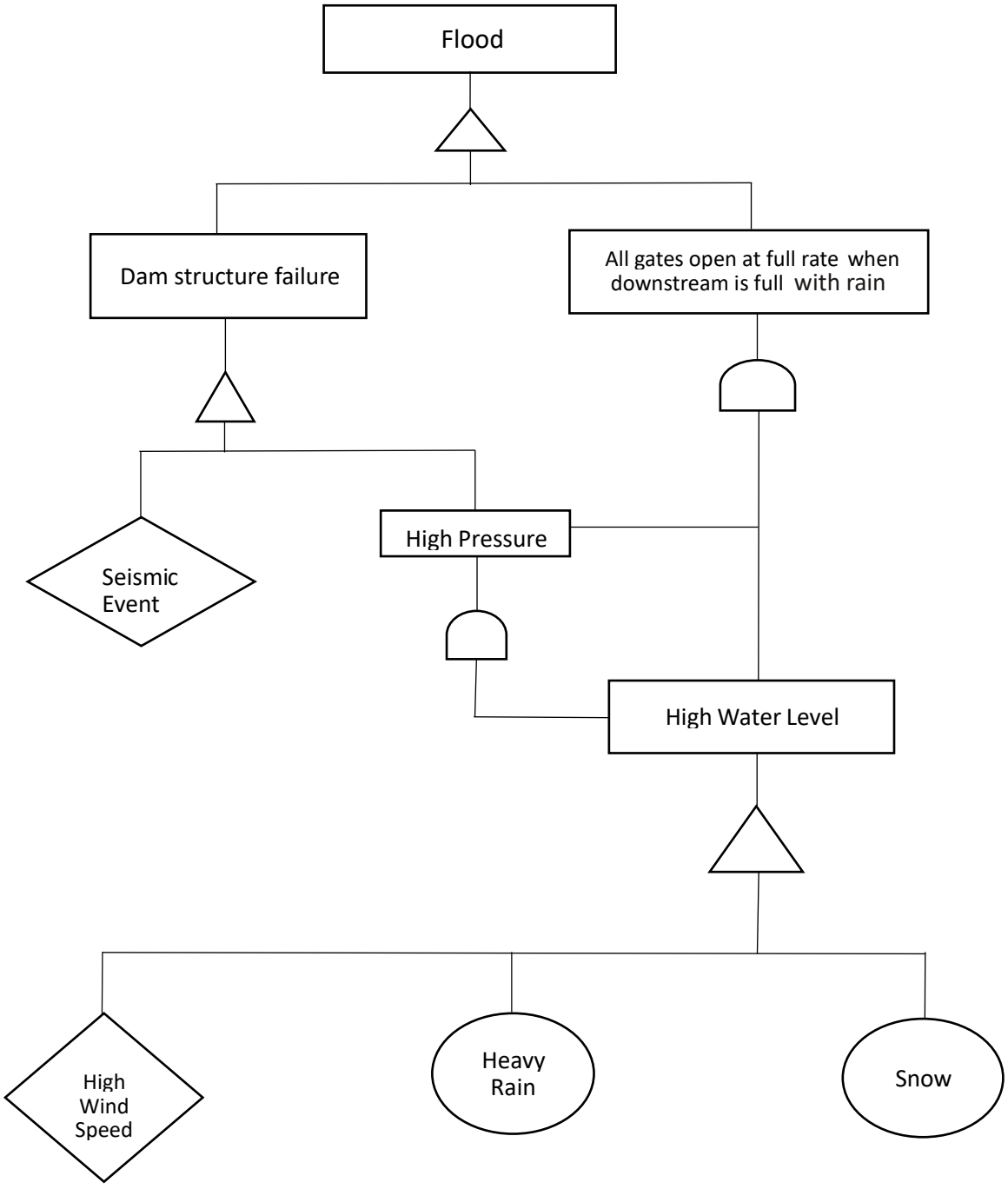
Safety critical system design principles:

- **Consequences of failure:** Uncontrolled water release or failure of dam structure will significantly affect human life and property.
- **Realtime response to Environmental factors:** System responds to real time environmental parameters and influences the operation/control of gates.
- **Emergency protocols against unpredictable events:** The system will respond immediately to unpredictable extreme events such as earthquakes. The response to such natural calamities is very important for maintaining the dam safety.
- **Preventive measures for overflow and structural failure:** The main objective of the system is to regulate and control the gate operation to prevent overflow and failure of dam structure, system will actively monitor the parameters to identify the risk and take preventive measures.
- **Manual and Emergency gate control features:** Manual gate control allows human operator to make critical decision on sensor readings. The system also incorporates emergency gate control which automatically activates the gates in response to seismic events.
- **Prompting for operator confirmation:** System will prompt for operator confirmation when attempting to change the rate of already open gates, this ensures that operator is aware of the current status of the gates.

Conclusion: The dam control system is clearly a safety critical system as it is vital for protecting the dam, lives downstream, nearby areas from potential disaster. This control system is focused on safety, it has a backup automatic emergency protocol. The system always stays alert and constantly scans the sensor readings which helps to take immediate preventive actions. This system serves as a critical safeguard against the dam failures and safeguard human life during emergency

B. Hazard analysis: Fault tree analysis

Boolean tree analysis:



- The possible accident considered in the program is “Flood” in the dam control system.
- The identified events causing flood in this system are Dam structural failure and when All gates open at full rate when downstream is full due to rain. Here the condition is disjunctive because if one of the conditions is satisfied the accident/event occurs.
- In the next sequence of event is Dam structural failure is caused due to earth quakes (seismic events) or high pressure on the Dam structure, this event is also disjunctive because if any one of the conditions is satisfied will lead to dam structure failure.
- All gates open at full rates when the downstream is full, this event occurs when the pressure and water level is high, this event is conjunctive as all the conditions should be satisfied in order for this event to occur.

- Seismic event is not fully traced as the cause is unknown but it is taken as input.
- High pressure is caused due to high water level.
- High water level is caused due to high wind speed, rain and snow, this event is disjunctive as the event occurs if any one of the conditions is satisfied.
- Here “OR” gate is used in case of disjunctive event.
- “AND” gate is used in case of conjunctive event.

Cut sets:

Boolean Formula:

((Seismic event and Condition) ∨ (High wind speed) ∨ (Rainfall) ∨ (Snow))

(Note: Here the “condition” is identified by continuing the fault tree below the rhombus)

Omit conjunctions is implied by shorter once:

(A ∧ B) ∨ (C)∨ (D) ∨ (E)

Where, (A ∧ B) and (C) can be omitted.

Here,

A: Seismic Event.

B: Condition.

C: High wind speed.

D: Rainfall.

E: Snow.

Each conjunctions determines a minimal sequence of events which leads to an accident. The minimal cut sets are conjunctions.