Norwegian University of Science and Technology

TPK5120

Elements of Model Engineering

Assignment 1: Train Braking System

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INTRODUCTION

Circuit Diagram

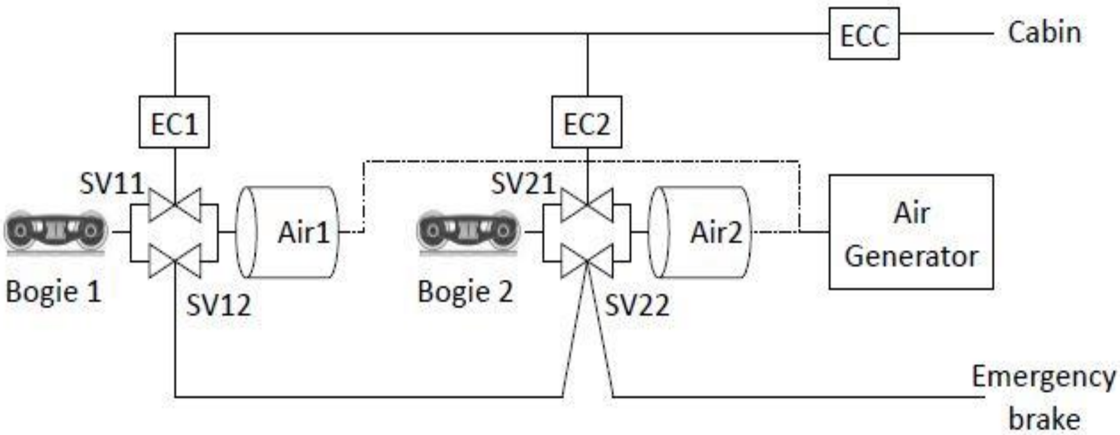

Figure 1: The circuit diagram

Description of the system

The circuit shows the braking system in two carriages of the train. The system consists of two safety system. One high demand train primary braking system and the second one is a low-demand emergency braking system. The high demand system is activated by the driver using a general electric controller (ECC) and two electronic controller EC1 and EC2 (one for each bogie). The system is operated using the electronic signals that are send to operate the brake using two solenoid valves (SV11 for the first bogie, SV21 for the second bogie). The braking is proportional to the signal applied by the driver. The system is energized to hold the brakes off. Output of the solenoid is de-energized to apply the brakes.

The emergency braking system had an electric wire that runs the full length of the train and is connected to an emergency button in the driver's cabin. The electric circuit normally hold the brakes off. The emergency valves SV12 and SV22 are de-energized to apply the full braking pressure to the brakes.

Each bogie has its own air reservoir topped up by an air generator. Air pressure is applied to operate the brakes and each bogie braking is independent. It is sufficient that the braking system on one of the bogies works for the train to be able to stop.

Assumptions

- Operator negligence is considered to be outside the system boundary, i.e., the driver always sends the correct signals.
- The solenoids, SV12 and SV22, and the wire are assumed to be independent, i.e., the breaking of the wire does not result in the solenoid being non-functional and will immediately trigger the brakes.
- The solenoid is assumed to be 2- position 3- way solenoid valve, which is in normally-closed position.
- The solenoids are powered by an external power source and is assumed to be out of the boundary of the system. The solenoid failure mentioned in the document is only the ability of the solenoid to detect the signal to de-energize.
- The breaks in the bogies are assumed to be failure-free. Considering otherwise would make that the critical component thus hampering the proper analysis of the rest of the system.
- Train is assumed to have only two carriages. For further calculations, the allocation of failure rate of the components gets stricter and is avoided in this analysis.
- The ECC, EC1, EC2 simply relays the signals it receives.

Understanding of the problem

The air braking system given is understood to work in the following way: -

In normal operation, the solenoid connects the air reservoir with the brakes thus maintaining the pressure in the brakes which holds the brake off, i.e., the circuit connecting the air reservoir to the brakes is connected and no braking action occurs. When the brakes are to be applied, air pressure is decreased and as the amount of air decreases, the valve allows air back into the reservoir tanks, while the brakes move to the applied position. This is achieved by powering the solenoid down, thus connecting the brakes to the other outlet of the solenoid valve where the pressure is bled-off to the atmosphere. For the brake to be released again, system must be pressurized with air before the brakes will release and this is achieved using the air reservoir. Once the system reaches its operating pressure, the brakes are freed and ready to use.

The result of a solenoid failure is that the solenoid is de-energized and this results in the ports from brakes and the atmosphere being connected, thus resulting in a loss of pressure in the braking system.

ECC along with EC1 and EC2 sends a signal to the solenoid to regulate the braking pressure. Normally, they send a signal, let’s say, 1 to keep the solenoids energized and hold the brakes off. To apply controlled brakes, it sends a value between 0 and 1 where 0 means complete braking. So, if either of these 3 circuits fails, it sends a value 0 to the solenoid, resulting in a full-on braking in the system.

Architecture of the system

Functional Architecture

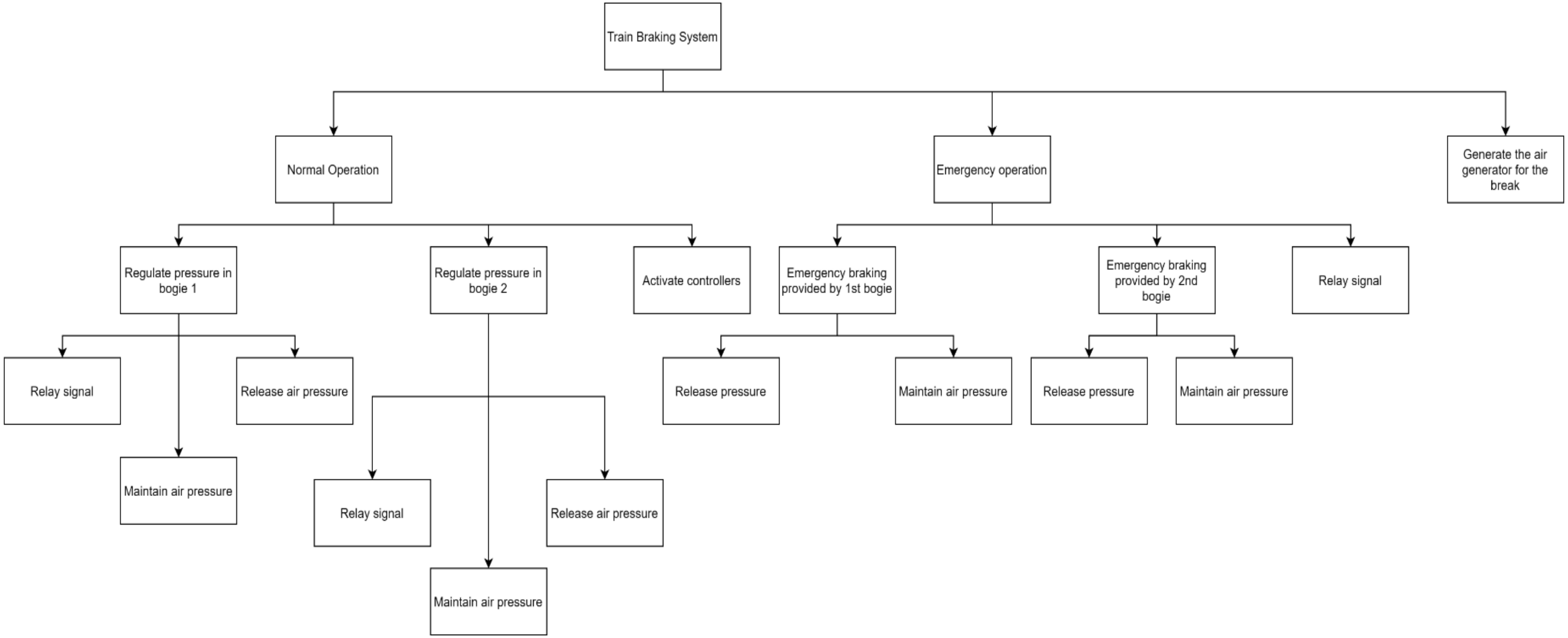

Figure 2: Functional architecture of the braking system

Physical Architecture

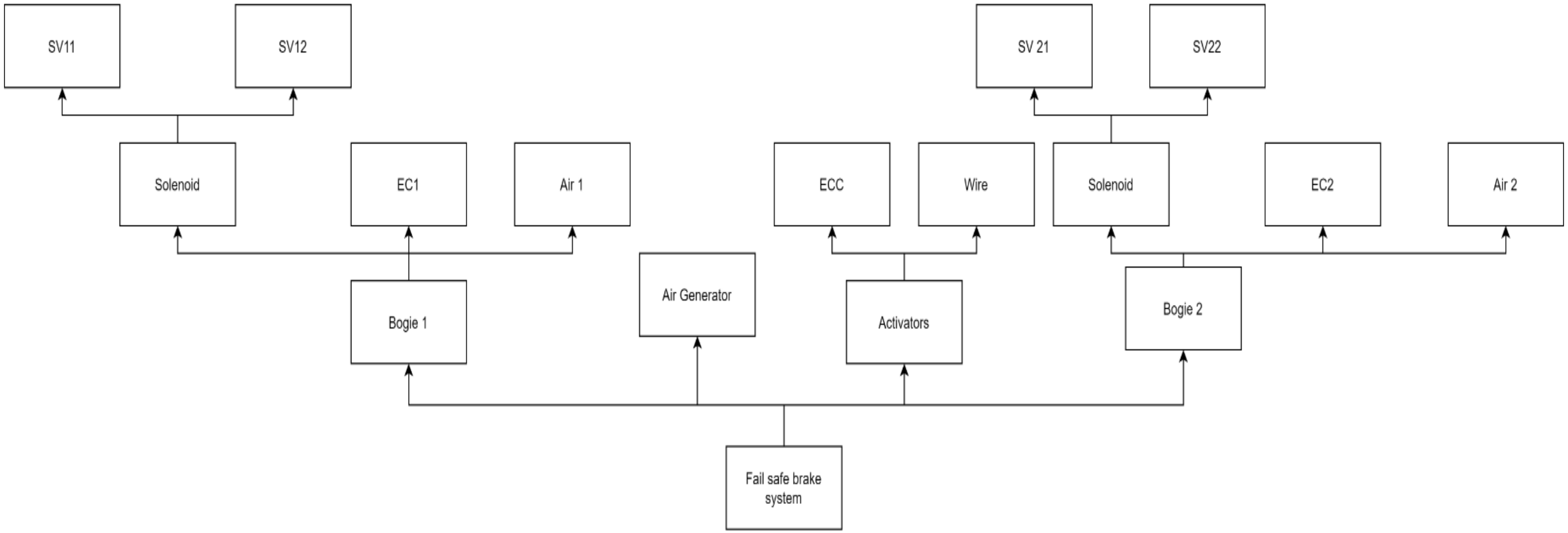

Figure 3: Physical Architecture

Linking the physical and functional architecture

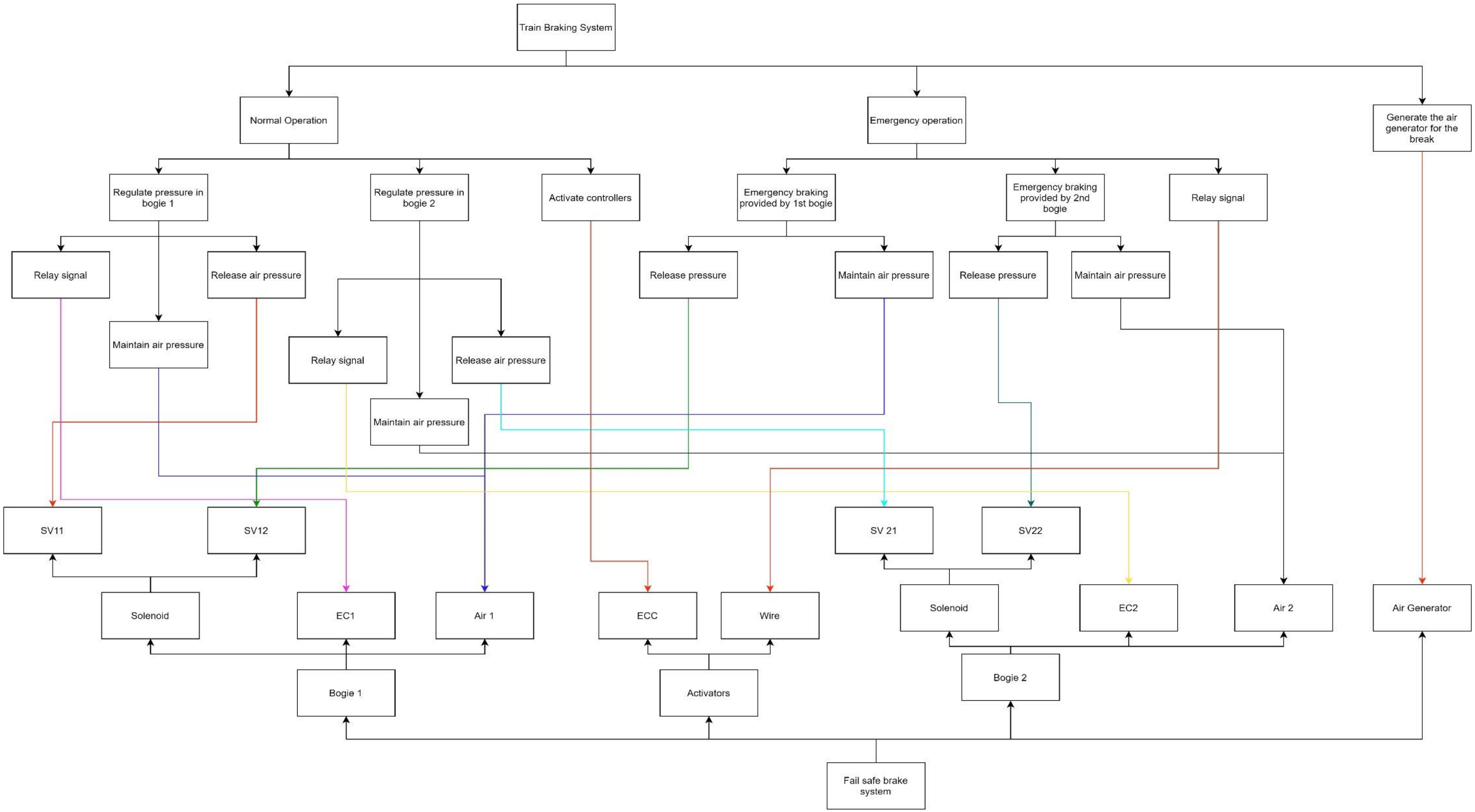

Figure 4: Functional - physical architecture

Fault Tree

In the system under study we can say that the safety function fails in two ways. One being the train braking when it is not supposed to (False braking) and the second one being not braking when it should, i.e., losing the braking capacity. False braking occurs whenever there is a pressure drop in the brakes. Here, both the sudden braking and speed reduction unwantedly are considered as failures. For losing the brakes, all the 4 solenoid has to fail. Even if ECC and both EC1 and EC2 fails, the emergency system works and hence we only lose the capacity to reduce speed, i.e., the accident could be prevented by triggering the emergency. However, if all the 4 solenoids do not recognize the signal to de-energize, then the pressure could not be bled-off and results in unwanted scenarios. Two different fault trees are set-up for these events since they are completely different scenarios.

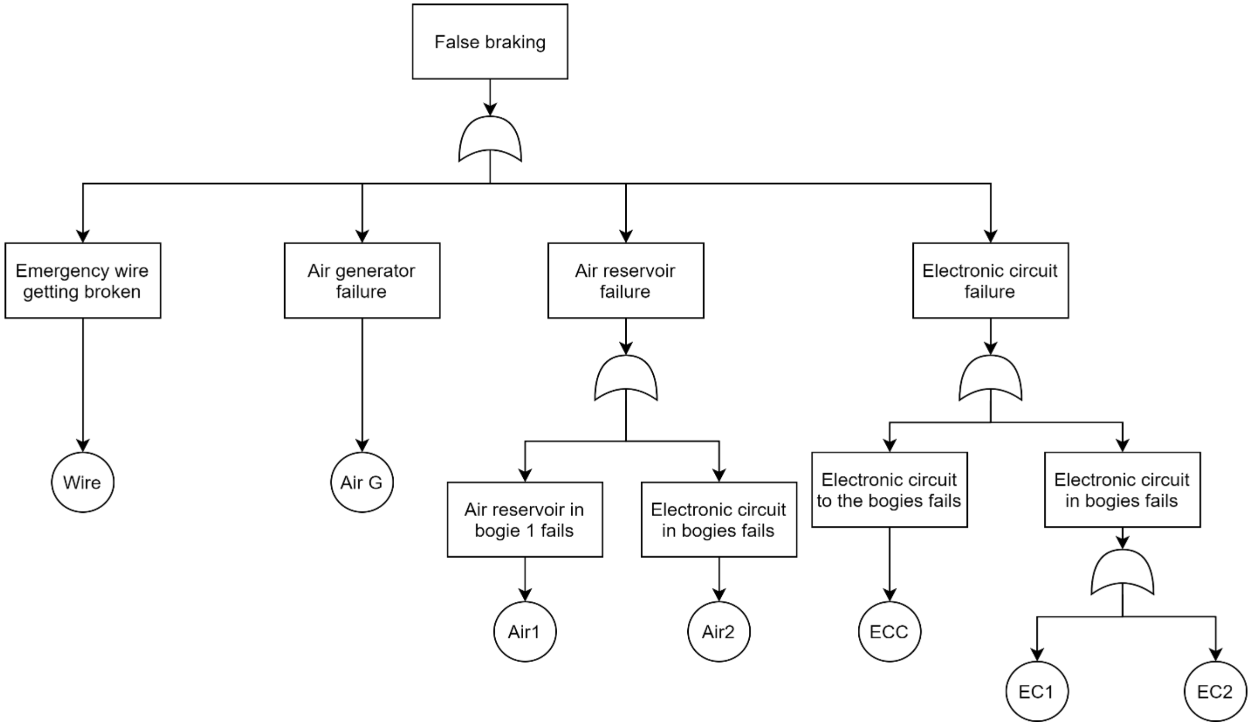

Figure 5: Fault tree for false braking

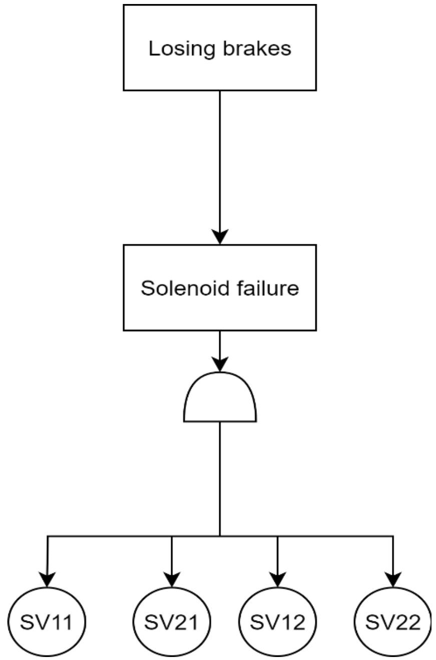

Figure 6: Fault tree for loosing braking capacity

Cassis model

The cassis model for the two system is implemented and attatched in the file named “TrainBrake.pbc” and the corresponding commands file in “TrainBrake.cassis” files. The .pbc file consists of the different elements created as classes, such as Solenoids, AirReservoir, ElectricCircuit, ElectricCircuitControl, AirGenerator and Wire. A class is also created called bogie to represent the connection in each bogie that could trigger the two scenarios. In the main block the final connection between the common elements and the bogie elements are made and two top events are created called falseBraking and loseBraking, corresponding to the two fault trees.

Assessments

The target failure rate for the components were assessed using the models. The results were: -

Air 1, Air 2 = 0.004 per million kilometres

SV11, SV12, SV21, SV22 = 0.105 per million kilometers

ECC = 0.003 per million kilometres

EC1 and EC2 = 0.0034 per million kilometres

Emergency Wire = 0.03 per million kilometres

Air Generator = 0.0034 per million kilometres

Probability that the train is stopped due to a problem of the braking system = 4.9911e-02

Probability of an accident due to a loss of the braking capacity = 9.8708e-05

The accuracy of these values is questionable. For one, possible values were not found from the internet. All the values obtained were in terms of per hours of operation and not in terms of distance travelled. But the main reason could be the wrong understanding or assumption regarding the working of the system. For instance, the ECC may not work like the way illustrated above. Since no accurate description of the system was available, the assumptions made to do the calculations could have led to the errors in the calculation.

Since, the objective was to create a model of the system, that has been done in accordance to object-oriented principle. Also, it is a representation of the fault tree that is derived from the functional-physical analysis.