EE5111/EE5061 Selected Topics in Industrial Control & Instrumentation
2021/2022 SEM 1

CA4: Fault diagnosis and fault-tolerant control
Assignment 2

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- What is fault-tolerant control? Please give one or two application examples.

Faults in an automated processes often results in undesired reactions and shut down of a controlled plant, impacting product yield, quality, plant infrastructure, personnel and the environment. With ever rising economy demand for higher plant availability, and an increasing awareness of the risks associated with system malfunction, fault tolerance control has been developed. Fault tolerance is a process that enables an operating system to respond to a failure in hardware or software. This fault-tolerance definition refers to the system's ability to continue operating despite failures or malfunctions. An operating system that offers a solid definition for faults cannot be disrupted by a single point of failure. It ensures business continuity and the high availability of crucial applications and systems regardless of any failures.

One of the applications of fault-tolerant control is in the aerospace applications. In modern commercial airliners, multiple engines were used. Generally, a single engine is generally all it requires to land the aircraft safely. With redundancy, failure of some engines will not pose any immediate threat to the safety. Another application of fault-tolerant control is in the process control industries. To be specific, Triconex has developed systems based on a triple modular redundant (TMR) architecture using two-out of three voting to provide high integrity. By employing ring-shaped communication networks, the system can achieve the capability of no single point of failure, as a break of the ring will not affect the data communications among distributed controllers.

- Please explain three soft-based fault-tolerant control methods, i.e., model-based fault-tolerant control methods, and draw the corresponding flowcharts, respectively.

The three soft-based fault-tolerant control methods are Passive FTC, Active FTC, and Hybrid FTC.

i) Passive FTC

Passive FTC systems do not rely on the fault information. This is because it is a robust control against a set of predefined faults, therefore there is no need for fault diagnosis. The advantage of passive FTC is that the robust control can be designed to achieve an acceptable performance while avoiding the time delay. However, passive FTC only allow limited number of faults to be tolerated and solution often conservative, which cannot meet certain defined performance requirements.

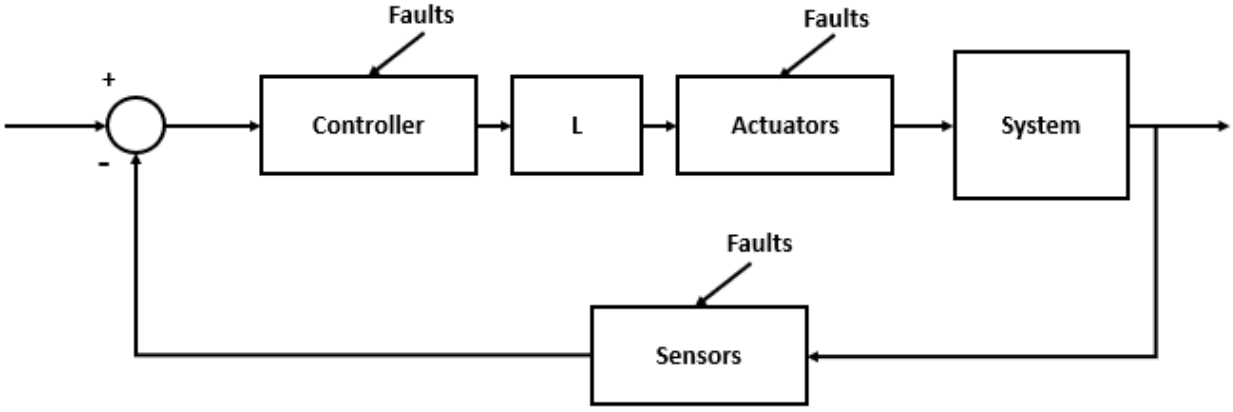

Fig 1. Flow charts of passive fault-tolerant control systems

ii) Active FTC

Opposite to passive FTC systems, active FTC systems react to each fault differently by reconfiguring control actions. Unlike passive FTC, active FTC system relies heavily on fault diagnosis to achieve fault tolerance. Fundamentally, active FTC reacts to the diagnosed faults by exercising the controls accordingly so that the stability can be maintained and the performance still within the acceptable level. An active FTC system generally more efficient in dealing with different type of faults. Yet, the controller performance is heavily dependent on the FDI unit in providing timely and accurate fault information.

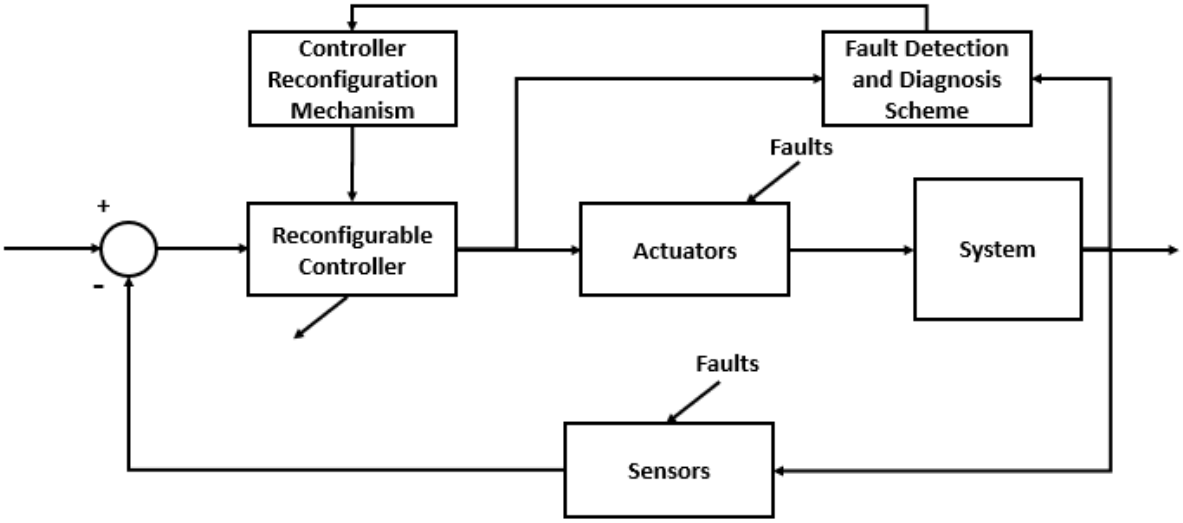

Fig 2. Flow charts of active fault-tolerant control systems

iii) Hybrid FTC

The bottleneck in any active FTC is the real-time fault detection/diagnosis scheme. Since the control system must operate in a real-time environment with a limited number of measurements, noise often will corrupt this information and results in possibility of wrong judgement made. Thus, Hybrid FTC, a mixture of passive and active FTC system will be a solution. A passive FTC will be employed in active FTC system to provide stability cushion while the active FTC to further improve the system performance.

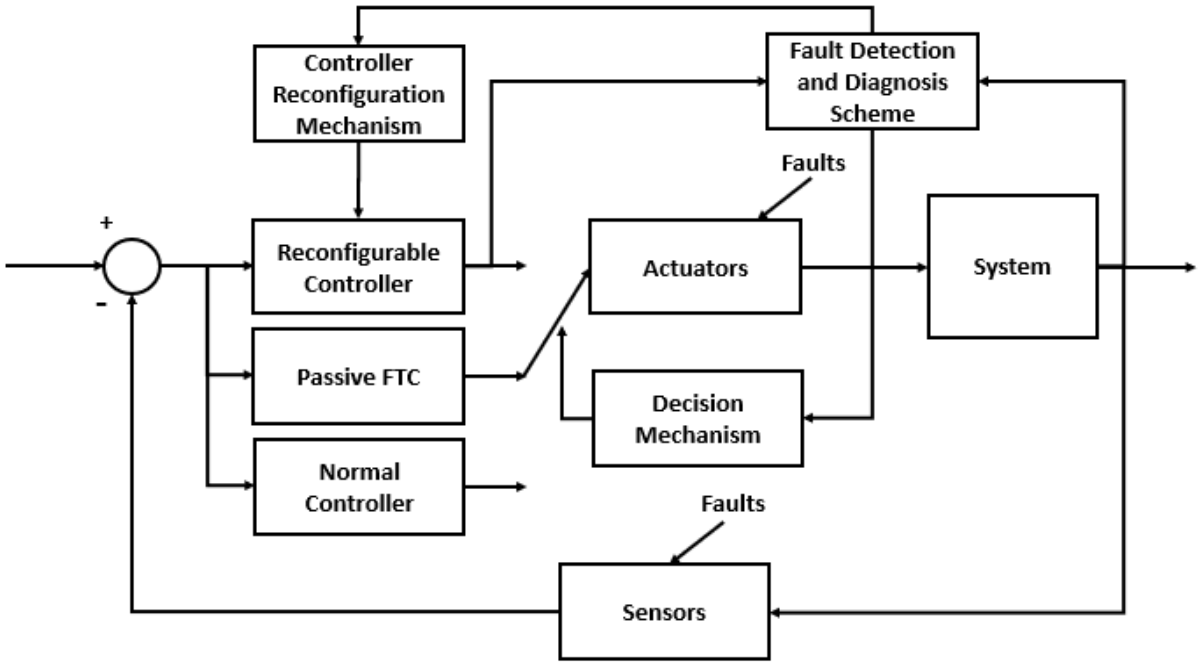

Fig 3. Flow charts of hybrid fault-tolerant control systems