University of South-Eastern Norway

EXAMINATION INFORMATION PAGE
Written examination

Subject code: **IIA2017**	Subject name: Industrial IT	
Examination date: 25-MAY-20	Examination time from/to: 9:00 to 14:00	Total hours: 5
Responsible subject teacher: Nils-Olav Skeie		
Campus: Porsgrunn	Faculty: TNM	
No. of assignments: 36	No. of attachments: None	No. of pages incl. front page and attachments: 7

Permitted aids:

- Open books, all aids can be used,

Information regarding attachments:

Comments:

- Include/merge all information into one single pdf document (report),
- The format of this document **must** be pdf,
- The WISEFLOW system will do a plagiarism control of all pdf files so always do referencing when copy information from any source,
- **Any communication with others, electronically or oral, is cheating!**

Select the type of examination paper		
	Spreadsheets ☐	Line sheets ☐

Introduction (6%)

You are working as a system designer and your new project is to extend an existing process control system (PCS). The existing industrial system consists of a PCS connected to an Enterprise Resource Planning (ERP) system. Your extension will be a separate PCS consisting of a supervisory control and data acquisition (SCADA) module and a distributed I/O system consisting of several Remote Terminal Units (RTUs). These I/O devices are Distributed Computer System (DCS) and Programmable Logic Controllers (PLC). This extension will connect to the existing ERP system together with the existing PCS system. An upgrade of the ERP system is included for communication to an external cloud system for data storage and backup.

The distributed I/O system will consists of several sub systems with closed loop controllers. Each closed loop consists of either a PLC or a combination of DCS and PLC. These closed loop controllers are controlling the filling fraction and the temperature in a set of tanks using sensors, pumps, valves and heaters. The sensors will be radar sensors for level measurements and PT-100 sensors for temperature measurements.

You will be the project leader for this extension and will be responsible for making the necessary requirements and documentation for this extension. Information technology (IT) and operation technology (OT) are parts of an industrial system and a system designer should have knowledge about these parts.

The documentation of your PCS will be answers to the following tasks:

1. (3%) Illustrate with a sketch the interconnection of the existing industrial system and your new extension. Let the sketch focus on the overview of the main modules/devices in the industrial system. Use only a PCS module for the existing PCS system.
2. (1%) Indicate the difference of IT and OT systems, and illustrate in the sketch what will be the IT and OT parts.

Security is becoming more and more important for industrial systems and firewalls are important devices. Note that the upgraded ERP system now will be using an external cloud system.

3. (2%) Indicate the main functions of a firewall and extend the sketch from task #1 or task #2 with any firewalls that you will use in this system. Discuss why you have added any firewalls.

Analysis and design (4%)

The analysis and design steps will be to collect the requirements, making a prototype of the Human Machine Interface (HMI) part of the SCADA system, and defining the architectures.

4. (3%) Indicate the logical architecture of your PCS with focus on the data flow. Use any sketch from the introduction as basis, or make a new sketch suitable to show the logical architecture.
5. (1%) In your PCS, indicate what will be the main difference between the logical and physical architecture based on any sketch.

Communication (11%)

The Open System Interconnection Reference (OSI) model is a layered model and one way to get an overview of functions and services in a communication protocol. Figure 1 shows the seven-layered OSI model where the physical layer is layer #1 and the application layer is layer #7.

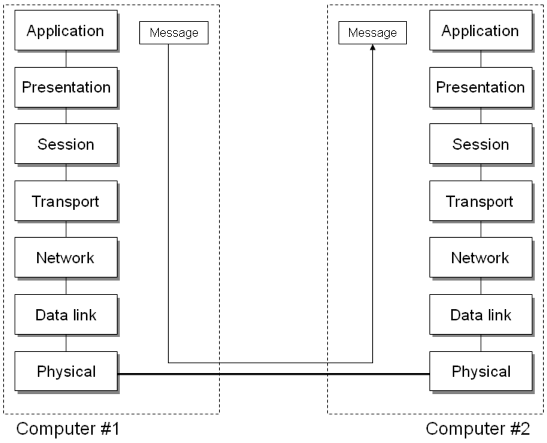

Figure 1: The OSI model for better describing the communication between two or several computers. Layer #1 is the physical layer and layer #7 is the application layer (Skeie n.d.a).

Firewalls are important communication devices for interconnection of network systems.

6. (2%) A firewall may support layer #3, #4 and #7 in the OSI model. Use the OSI model to indicate the functions and services that you need for the firewalls in your PCS according to your answer in task #3.

RTU devices will often be embedded device with network connection. Today Internet of Things (IoT) devices are popular devices and can be a RTU.

7. (3%) Use the OSI model to explain why an IoT device normally must connect to a cloud system.

TCP/IP is a communication protocol used for Internet and many Intranets. TCP/IP is often using Carrier Sense Multiple Access and Collision Detect (CSMA/CD) as the Ethernet protocol. Figure 2 shows an activity diagram for the CSMA/CD protocol.

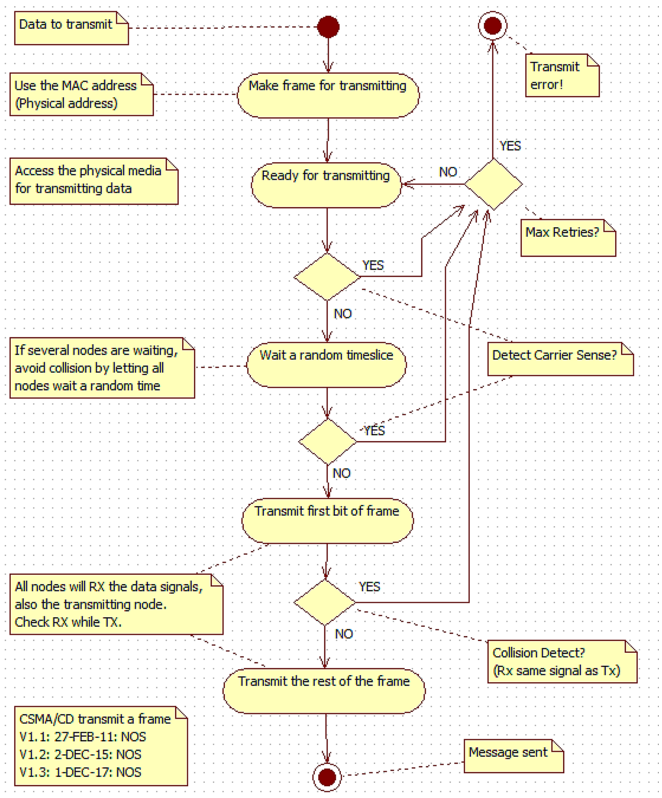

Figure 2: An activity diagram explaining the CSMA/CD protocol (Skeie n.d.a).

The Transport Control Protocol (TCP) provides services for systems to deliver and receive an ordered and error-checked stream of information over the network. However, the TCP protocol may fail in delivering the information.

8. (2%) Use Figure 2 to indicate the error situations for the CSMA/CD protocol, and suggest any solution(s) to minimize the probability for a transmission error.

A PCS may consists of many different communication protocols.

9. (2%) Use your sketch from the introduction (task #1, #2 or #3) to indicate the locations in your PCS where you will need a communication protocol.
10. (2%) Use the OSI model to indicate from which layers you will need functions and services for the communication protocols suggested in task #9.

OPC (10%)

OPC is one protocol that is suitable for your industrial system.

11. (4%) Explain and make pseudo code for how you can read data from an OPC DA server with C# using the features in Measurement Studio.
12. (3%) If the OPC DA server is located on internet, i.e., not on the same computer as the C# application, what do you need to do to be able to get access to the server? Explain and make a simple sketch. Do you have other options?
13. (3%) Assume we want to install or deploy the C# application using a Raspberry Pi with Linux installed. Will this solution work or not? Explain your answer.

Digitalization (10%)

Today there is a requirement for an increased use of digitalization in all computer systems, including PCS.

14. (1%) Describe with your own words what you mean by digitalization, and how digitalization may affect your industrial system.
15. (3%) Discuss the flow of information based on a sketch from the introduction (task #1, task#2 or task#3) on how to fulfill your requirements for digitalization in the industrial system.
16. (3%) Describe any useful file formats for importing/extracting information of the database management system in your PCS, for supporting digitalization.
17. (3%) Select one of these file formats and make an example with three samples containing values from minimum two tanks, and five minutes between each sample. Make your own assumptions for making these samples.

Human Machine Interface (HMI) (10%)

Design an HMI system based on the High-Performance HMI philosophy. The design should at least contain the following documentation:

18. (3%) A Level 1 display of the overall process. Assume that there are at least five tanks in the system.
19. (4%) A suggestion of a display hierarchy of Level 2, 3, and 4 displays, indicating what kind of information that should be shown on each level.
20. (3%) Discuss measures to increase the operator's situation awareness when using the Level 1 display.

Alarm System (11%)

The implementing of an alarm system should be according to an alarm standard and you have chosen the YA-710/YA-711 standard. Figure 3 shows this alarm standard.

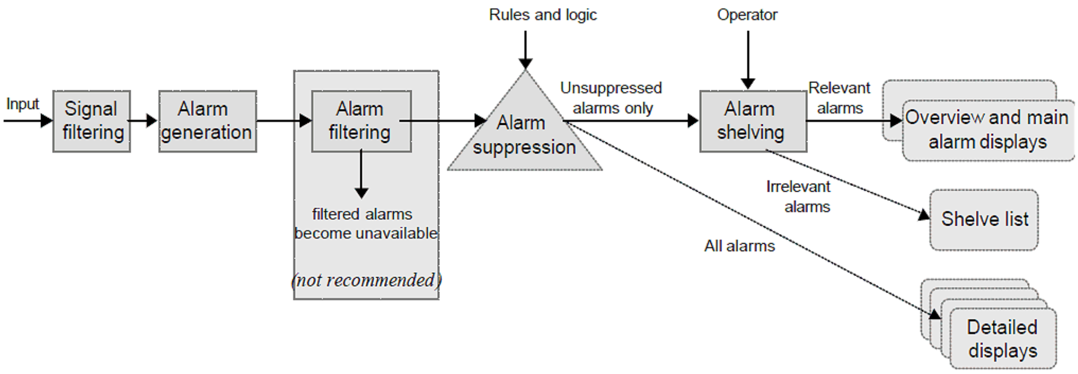

Figure 3: The YA710/YA711 alarm standard (Skeie n.d.a).

21. (2%) Indicate why an alarm philosophy is important, and especially with your solution in this industry system.
22. (5%) Make the outline of an alarm philosophy for your PCS. Include details for the design and operation of the alarm system like indication of alarms, how to acknowledge an alarm and number of alarm lists. Include also your decision if your system should support alarm filtering and/or alarm shelving.
23. (4%) Make pseudo code for the "alarm generation" module for the high temperature alarms in your system. Make your own assumption for the configuration values and other type of information. Note that the alarm philosophy should support these assumptions.

Database (14%)

Your PCS will need a database for the process system information, configuration data, may be run time data and historical data. You have decided to use a SQL database for storing all the information in your PCS, information for the SCADA system, RTU devices connected, and the sensors and actuators connected to these RTU's.

24. (2%) Based on the sketch from the introduction (task #1, #2 or #3), what will be the minimum number of databases in your industrial system?
25. (7%) Make an ER (Entity-Relationship) diagram according to the description of the system. Use suitable names on entities and attributes (column names).
26. (2%) Explain why stored procedures can make your system more secure.
27. (3%) Make an example of a stored procedure for your PCS, supported by your ER diagram.

Multitasking and Real-Time (11%)

In your "Multitasking and real-Time" assignment in this course you were running a small multitasking system with a set of threads, in two different states, with and without synchronization. Figure 4 shows a sequence diagram for these threads.

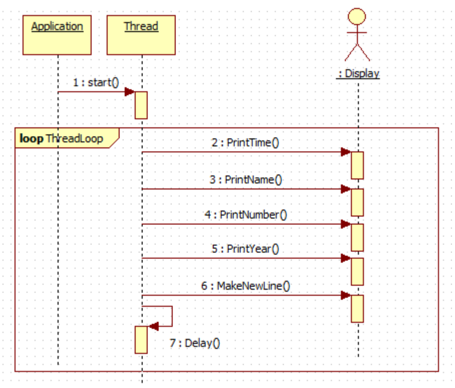

Figure 4: A sequence diagram for the threads in the small multitasking system (Skeie n.d.b).

Figure 5 shows the output from the threads running in this small multitasking system. This small multitasking system is using the standard Windows operating system scheduler together with all the other running applications for both running codes. The threads in this small multitasking system are using one single common resource.

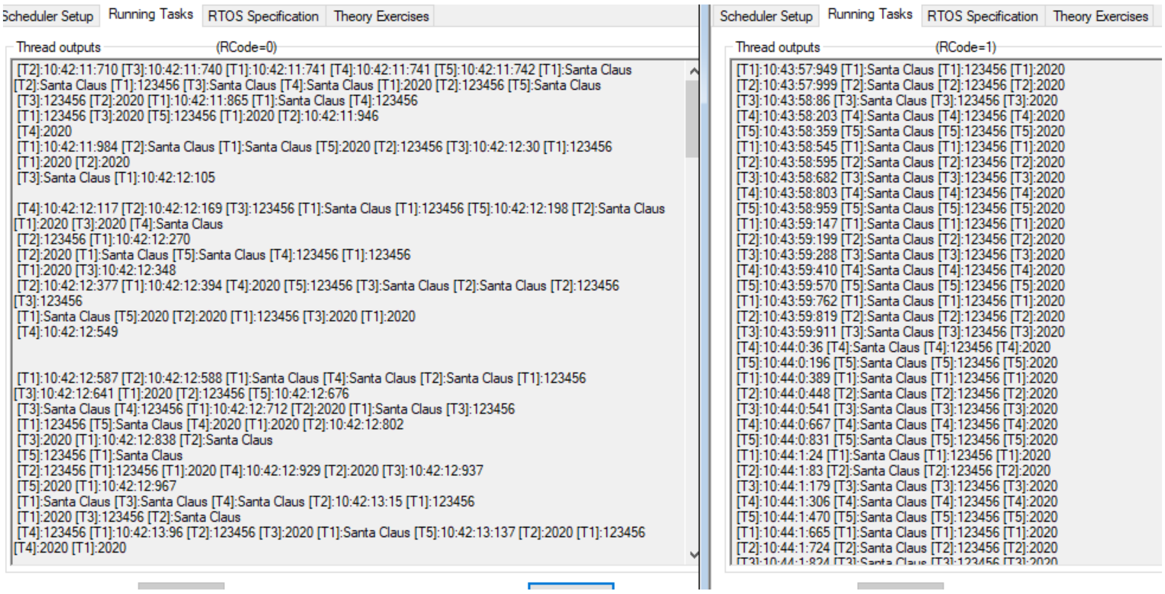

Figure 5: The output from the threads of the multitasking systems, running code 0 to the left and running code 1 to the right.

28. (1%) Indicate the common resource, and why this must be a common resource.

Some sort of synchronization mechanisms must be included in a multitasking operating system for protecting common resources.

29. (2%) Explain some of types for synchronization mechanisms in a multitasking operating system.
30. (1%) Discuss the usage of synchronization for running code 0 and running 1 in your "Multitasking and real-time" assignment, as shown in Figure 5.
31. (2%) Running code 0, the left part of Figure 5, has a faster execution time than running code 1. Why?
32. (3%) Use pseudo coding to show how a thread can share a common resource as shown in Figure 5. Focus only on the code section for sharing the common resource, no need to include all the code for the thread. Make your own assumption for the type of resource.
33. (2%) If you have real-time requirements in your new PCS, will the running code 0 or running code 1 solution be the best solution for your PCS?

Hardware-in-the-Loop (HIL) Simulation and Testing (10%)

The main purpose with the HIL Simulation is to test the hardware device on a simulator before we implement it on the real process. You want to use an industrial PID controller, like the Fuji PXG5 used in the HIL lab assignment, to control the level in a liquid tank process. The liquid tank process is shown in Figure 6.

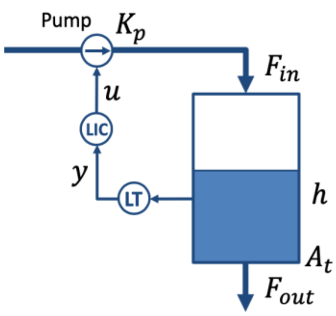

Figure 6: Liquid tank process

The model of the liquid tank process is as follows:

$$\dot{h} = \frac{1}{A_t}(K_p u - F_{out})$$

Where

$h\ [cm]$ is the level in the water tank. $0cm \leq h \leq 20cm$.

$u\ [V]$ is the pump control signal to the pump. $0V \leq u \leq 5V$

$A_t\ [cm2]$ is the cross-sectional area in the tank

$K_p\ [(cm3/s)/V]$ is the pump gain. The flow into the tank is $F_{in} = K_p u$, i.e. we control the flow into the tank using a pump.

$F_{out}\ [cm3/s]$ is the outflow through the valve. The outflow can be manually adjusted with a handle.

34. (4%) Illustrate with a sketch (use e.g., PowerPoint) and shortly explain how you can perform Hardware-in-the-Loop (HIL) Simulation and Testing for this use case.
35. (6%) Make a LabVIEW program where you control the system using the mathematical model for the liquid tank process. You may use the built-in PID controller in LabVIEW. You may also reuse some of your previous code to save time.
    You can assume the following values in your simulations:
    $$A_t = 78.5\ cm$$
    $$K_p = 16.5\ cm^3/s$$
    Explain your program and deliver relevant screenshots (you shall not deliver the source code).

Backup (3%)

The ERP system will use a cloud-based system for storage and backup. Ransomware is a subclass of malware, often as an attachment to emails or malicious links on web sites. Ransomware will encrypt information on an online disk drive, either at file-level or disk-level. A decryption key must be used to recover the information. Today most backup systems are based on online systems and these backup systems are affected highly by ransomware.

36. (3%) Indicate why there may be an advantage of using a tape drive as the backup drive instead of an online disk drive in relation to the ransomware challenge.

Bibliography

Skeie, N.-O. (n.d.a) 'IIA2017 Industrial Information Technology (IIT)', Lecture notes for the master course at the University of South-Eastern Norway (USN).

Skeie, N.-O. (n.d.b) 'Multitasking and real-time assignment (GuiSw)', Task description for an assignment in the IIA2017 Industrial IT course at the Industrial IT and Automation master program at the University of South-Eastern Norway.