University of Buea

Faculty of Engineering and Technology

Department of Electrical and Electronic Engineering

Option: Power Systems

Course Code/Title: EEF485: Sequence Control Lab

Course Type: Compulsory (C)   Credit Value (CV): 4

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OBJECTIVES

At the end of this practical course, students should be able to:

- Have hands-on mastery of different automats such as PLCs and Microcontrollers
- Program and run industrial PLCs
- Automate systems using PLCs and microcontrollers

OUTLINE

Experiment 1: Scheduling of power generators

Experiment 2: Control of a mixer

Experiment 3: Traffic light control

Experiment 4: Control of an elevator

Experiment 5: Electronic implementation of sequence controllers

Materials:

- Elevator (**ASC-89 DIDACTIC LIFT)**
- Laptop or Desktop with step 7 software pre-installed.
- Siemens PC Adapter USB A2
- One PLC (Mod. PLC–V7/EV) S7 300 with CPU 314C-2 PN/DP
- The elevator’s input / output interface
- Arduino Uno microcontroller
- LEDs
- DC Motors
- Cables
- Switches

The PLC in the laboratory (Figure 1) is the S7 300 mod. PLC-V7/EV with CPU S7-314C-2PN/DP. It provides many digital inputs (24) and outputs (16) on the front panel of the PLC. Twelve special digital inputs are used for fast counting, process alarms, frequency measurement and positioning. Regarding the digital outputs, they are available as relay and transistor (for fast applications) outpust. The logic state of the digital inputs and outputs is displayed via LED diodes on the PLC. Four analog inputs and two analog outputs are available for exercises involving process control. With four rotating potentiometers and an inner stabilizer, one can adjust the voltages or current levels at the analog inputs, eliminating the need of external power supply.

Figure 1: PLC (Mod. PLC–V7/EV)

Programming of the PLC is done with SIMANTIC STEP 7 version 11 in Totally Integrated Automation (TIA) Portal. It is the most known and used software in the world for industrial automation and is up to standard. SIMANTIC STEP 7 V11 embedded in TIA portal succeeds the SIMANTIC STEP 7. This software enables the users to write programs test and make the troubleshooting of all modular PLCs and SIMANTIC PLCs for PC based control.

The program consists of a number of instructions and can be written in any of the following languages: Ladder Logic Diagram (**LD**), Sequential Function chart (**SFC**), Function Block Diagram (**FBD**), Structured Text (**ST**) and Instruction List (**IL**). The software equally offers four (4) different types of programming blocks:

- The Organizational block (**OB**) for repeating programs
- The Data Block (**DB**) for creating internal variables and can either be global (accessible by all FCs or FBs) or assigned (instance DB) to a specific FC/FB.
- The function (**FC**) is a block that does not have a memory and must be associated a DB if storage is needed.
- The Function Block (**FB**): Whenever a FB is created, its associated instance DB is created as well. This is the advantage they have over FCs. FCs do not have associated DBs and these must be created if there is any need. This is very important if you want to forward Data from one OB cycle to the next. In complex programming however, this advantage is also their week points because they cannot be created without being associated to a DB, yet it is not every Function that needs a DB.

All experiments will be carried out using the PLC described above and the Arduino Uno as the main automats.

Experiment 1: Scheduling of power generators

The main purpose of an electrical power system is to efficiently deliver reliable electricity to consumers. The simplest electrical power system consists of a single electric generator and a load. However, power systems are usually much larger with several interconnected generators and loads.

Consider a power system made up of 5 generators which are Hydro (H), Thermal (T), Open Cycle Gas Turbine (OCGT), Solar (S), Wind (W). For reliable operation of this power system, the generators require automatic scheduling as shown in Table 1. The capacities of the generators are shown in Table 2.

Table 1: Generators scheduling based on load profile

Time (H)	0-2	2-4	4-6	6-8	8-10	10-14	14-16	16-18	18-21	21-23	23-0
Load (MW)	6	4	5	7	10	14	13	10	12	8	6
Scheduled Generators	H	H	H	H	H+W+S	H+W+S+ T+OCGT	H+T+S+W	H+W+S	H+T+W	H+W	H

Table 2: Generators and their capacities

Generators	H	T	OCGT	S	W
Capacity (MW)	8	3	3	1	1

The sequence begins when the START push button is pressed.

Note: For the purpose of this exercise, we assume that power production from solar and wind is constant. This is not the case in real systems where solar and wind are involved. These renewable sources are variable and their power production can only be determined through forecasting which will not be covered here.

Work Required

1. Study the load profile carefully and draw the GRAFCET Level 2 for the scheduling process
2. Identify the base loads, medium load and peak load generators
3. Write the ladder program for the scheduling process
4. Draw the state transition diagram for the scheduling process
5. Using the Arduino Uno microcontroller as the automat, implement this scheduling process by simulation and practically.
6. Using SIMATIC STEP 7 Professional, implement the scheduling process and run it with the SIEMENS PLC-V7/EV module.

Experiment 2: Control of a mixer

In a small chemical factory, two products A and B are required to be mixed. The system is shown Figure 2.

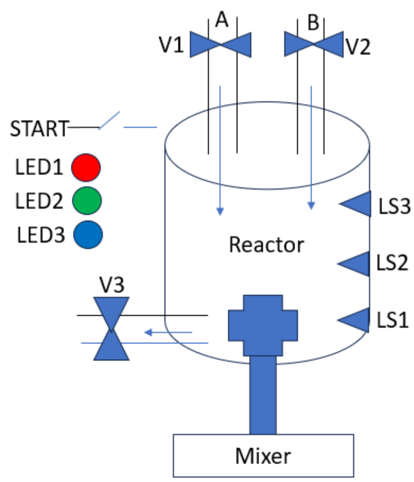

Figure 2: Product mixing system

- Level detectors LS1, LS2, and LS3 detect when the reactor is empty, half-full, and full respectively.
- Light emitting diodes LED1, LED2, and LED3 indicate when the reactor is empty, half-full, and full respectively.
- V1, V2, and V3 are respectively valves for product A, product B, and drainage.

The sequence of operations is as follows:

- When the operator presses the START button, product A is fed into the reactor until LS2 is activated. This stops the inflow of product A.
- The mixer is then operated and product B is admitted into the reactor until LS3 is activated to end the admission of product B.
- The mixing continues for another 2 minutes.
- The reactor is then drained until it is empty.

Work Required:

1. Draw the level 2 GRAFCET for the system
2. Draw a ladder network for the system
3. Using an Arduino microcontroller, implement this process.

4. Using a PLC, implement this process

Experiment 3: Traffic light control

Part I: Consider Figure 3 below. Both roads A and B are unidirectional.

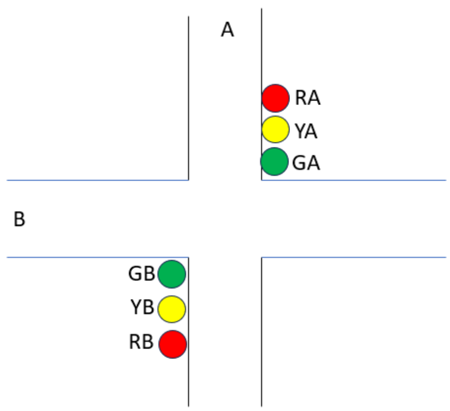

Figure 3: Traffic lights

RA and RB are the green lights for roads A and B

YA and YB are the yellow lights for roads A and B

GA and GB are the green lights for roads A and B

Each red light has a duration of 60 seconds

Each yellow light has a duration of 10 seconds

Each green light has a duration of 50

Note: The durations chosen for the lights in this exercise are for illustration purposes. In practice, these durations may be different.

Work to be done:

1. Draw the GRAFCET level 2 for the system
2. Draw the state transition diagram for the system
3. Draw the timing diagram for the system
4. Draw the ladder network for this system
5. Simulate and implement this system using the Arduino microcontroller

6. Use a PLC to implement this system

Part II: Consider Figure 4 below.

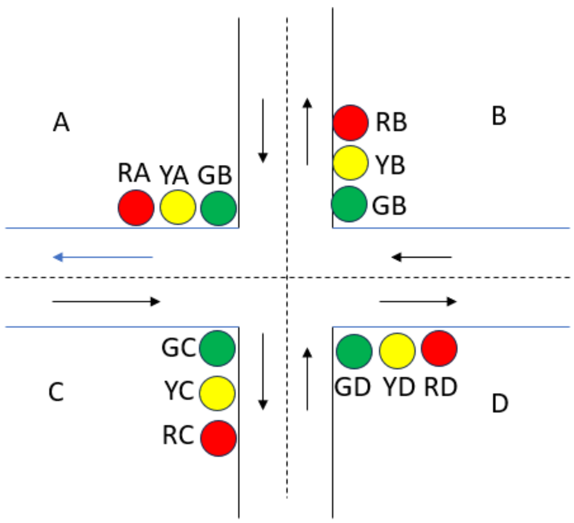

Figure 4: Traffic light system 2

Table 3 shows the different times in seconds for each light to stay ON.

Table 3: Traffic light timing sequence with times in seconds

Sequence states	A			B			C			D		
	RA	YA	GA	RB	YB	GB	RC	YC	GC	RD	YD	GD
1	5s					5s			5s	5s		
2	2s				2s			2s		2s		
3			5s	5s			5s					5s
4		2s		2s			2s				2s	
1	5s					5s			5s	5s		

Work to be done:

1. Draw the GRAFCET level 2 for the system
2. Draw the state transition diagram for the system
3. Draw the ladder network for this system
4. Simulate and implement this system using the Arduino microcontroller
5. Use a PLC to implement this system