Chapter 5
Smart DC Microgrid:
A Cyber–Physical System Perspective

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ABSTRACT

The objective of this chapter is to elucidate on microgrid technologies, a comparison of direct current (DC) microgrid technology and alternating current (AC) microgrid technology, the role of the information and communication technology, demand response programs, and the evolution of Industry 4.0 in detail. The microgrid is a cyber-physical system. ICT is used for computing control algorithms and sending control information to actuators for physical processes. In a cyber-physical system, the physical processes, which are governed by the laws of physics, are controlled by computers. The computers are used for computing or executing the algorithms (i.e., the control logic) and the result is sent to the actuators in the form of control signal for actual control. In a microgrid, a consumer can act as a producer also, which is termed as the prosumer. This chapter explains the maximum power point tracking algorithm, software-defined battery, the operation of parallel converters, the working of prosumer, the demand response program, communication technologies, and the (industrial) Internet of Things.

INTRODUCTION

A cyber-physical system is a mechanism in which physical phenomena are controlled by algorithmic logic through computers. Physical phenomena are governed by the laws of physics. When these physical phenomena are controlled by algorithmic logic executed in computers, are called cyber-physical system. In a cyber-physical system, algorithms and physical phenomena are tightly coupled. Computers or communication units execute the algorithmic logic, and the outcome is used by the actuator to perform the physical phenomena. The term "cyber-physical system" is in mass consumption since 2007.

To understand algorithmic logic and physical phenomena coupling consider working of VLC media player (a program to play video or audio file) as shown in Figure 1. The VLC media player is a program which processes the media file (here mp3 file), and the VLC media program and data (mp3 file) are processed by the processor. A processor can do operations, such as addition, subtraction, multiplication, division, logical operations (e.g., and, not, or, shift, etc.). During these operations, the processor takes data and instructions from memory and again puts it into the memory.

This is the stored program and data computing model. The processor is capable to do some arithmetic and logical operations. So, the question is how these arithmetic and logical operations affect the physical world. Actually, when processor processes, it generates output voltage signal. Here, suppose a speaker is connected to the computer using a signal amplifier. VLC media player executes the mp3 file. It generates voltage level for the speaker, which is actually the audio sound (i.e., dialog, song, etc.). When the voltage is applied to the speaker, current flows through the wire connected to the speaker. Speaker is a device which has a coil and a magnet when current flows through the coil, it generates a magnetic field, and this magnetic field is opposite to the fixed magnet's magnetic field. The magnetic field generated by the coil depends on the amount of current flowing through it. By this variable current, the diaphragm in the speaker moves and generates longitudinal waves which are the sound waves. This way the VLC media program controls the movement of the diaphragm, whose movements generate controlled sound waves i.e., dialog or song. And human ear listens to that dialog or song. This is how an algorithmic logic affects the physical phenomena. When this algorithmic logic affects biological phenomena, it leads to the cyber biological system.

Above example is not directly related to the smart DC microgrid. But the simplicity of this example fascinates to be included in this chapter for the explanation of the concept of cyber-physical system as it spans across a very large area, such as energy, healthcare, manufacturing, transportation, aerospace, chemical processes, Quantum Information Science and Technology (QIST), etc. The next example also

Figure 1. VLC media player program execution to generate sound
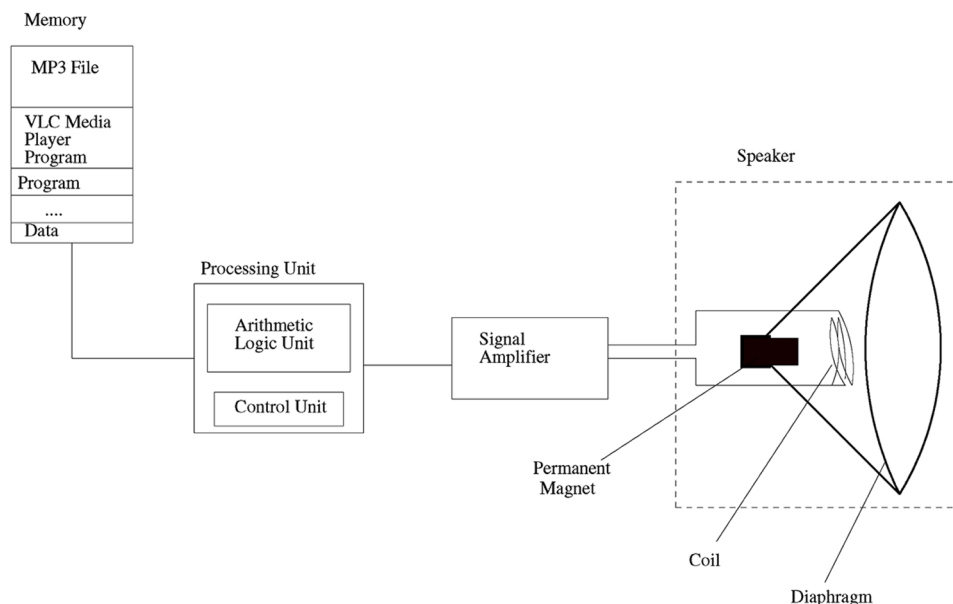
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