CHAPTER 1

Introduction to the Injected-Absorbed-Current Method of Analysis

1-1 Theoretical Foundation

According to the classification of analysis methods shown in Figure P1-1, the injected-absorbed-current method belongs to the class of the simplest linear methods whose validity is limited to low-frequency, small-signal phenomena. As will be explained in Chapter 14, the low-frequency limitation can be made less stringent by including the discrete (sampled), injected-current waveform in the cell model. This chapter discusses the basic low-signal-frequency characterization of the switching cells, with the goal of establishing a foundation for the introduction of more accurate models.

The basic idea that leads to linearization is the introduction of the notion of average values of the quantities of interest (usually voltages and currents). The quantities change during a cycle of the switching frequency. Their average values are determined by averaging over a period (duration $T$) of the switching frequency:

$$q = \frac{1}{T} \int_{t_i}^{t_i+T} q(t)dt$$

(1-1)

where $q$ represents any quantity of interest and $t_i$ represents the time at which the averaging process begins.

The averaging eliminates the influence of the exact waveforms, during a period of the switching frequency, on the mathematical relationships among the averaged quantities. The result is a dramatic simplification of the mathematical expressions in the analysis.

Hereafter, the averaged quantities defined by (1-1) are referred to without the adjective “average,” for brevity.
Figure 1-1 shows the switching cell as a black box. Five quantities are marked at its ports: the input voltage and current, the output voltage and current, and a fifth quantity $x$, which is the controlled quantity. As mentioned in the Introduction and will be explained later, the controlled quantity can be any controllable parameter of the cell that is capable of influencing the cell’s energy transfer. Assume now that the average values of the input (or absorbed) current $i_e$ and the output (or injected) current $i_c$ can be expressed as functions of the average value $x$ of the controlled quantity and the average values of the cell input and output voltages. The relations

$$i_e = i_e(x, u, e)$$ \hspace{2cm} (1-2)

and

$$i_c = i_c(x, u, e)$$ \hspace{2cm} (1-3)

define these functions. They depend on the configuration and operating mode of the particular cell and can be fairly complicated.

In a linear model of the cell, a simple proportional relation exists among the small increments of the quantities. That relation, applied to the functions (1-2) and (1-3), corresponds to their total differentials

$$di_e = \frac{\partial i_e}{\partial x} dx + \frac{\partial i_e}{\partial u} du + \frac{\partial i_e}{\partial e} de$$ \hspace{2cm} (1-4)

and

$$di_c = \frac{\partial i_c}{\partial x} dx + \frac{\partial i_c}{\partial u} du + \frac{\partial i_c}{\partial e} de$$ \hspace{2cm} (1-5)