Chapter 6

SPACE VECTOR BASED TRANSFORMER MODELS

6.1 Introduction

This chapter considers an extension of the single phase transformer (ITF) model to a two-phase space vector based version. The introduction of a two phase (ITF) model is instructive as a tool for moving towards the so-called ‘ideal rotating transformer’ ‘IRTF’ concept, which forms the basis of machine models for this book. The reader is reminded of the fact that a two-phase model is a convenient method of representing three-phase systems as was discussed in section 4.6 on page 89. The development from ITF to a generalized two inductance model as discussed for the single phase model (see chapter 3) is almost identical for the two-phase model. Consequently, it is not instructive to repeat this process here. Instead, emphasis is placed in this chapter on the development of a two-phase space vector based ITF symbolic and generic model.

6.2 Development of a space vector based ITF model

The process of moving from a single phase ITF model to a space vector based version is readily done by making use of figure 3.1, which is modified to a two-phase configuration as shown in figure 6.1.

A comparison between the single phase (figure 3.1) and two-phase (figure 6.1) shows that there are now two windings on the primary and two on the secondary side of the transformer. The primary and secondary ‘alpha’ winding pair are orthogonal to the ‘beta’ winding pair. The number of ‘effective’ primary and secondary turns is equal to $n_1$ and $n_2$ respectively. Note that the windings are shown in symbolic form in order to show where the winding majorities are located. The primary and secondary phase windings are assumed to be sinusoidally distributed. A discussion on the concept of sinusoidally distributed
windings and ‘effective’ number of turns is given in appendix A. The currents in the primary and secondary windings are defined as $i_{1\alpha}$, $i_{1\beta}$ and $i_{2\alpha}$, $i_{2\beta}$ respectively. A complex plane with a real and imaginary axis is also introduced in figure 6.1. Also shown in this figure is the circuit flux distribution which is linked to a flux space vector $\vec{\psi}_m = \psi_{m\alpha} + j\psi_{m\beta}$. The complex plane is purposely tied to the orientation of the primary windings of the transformer, as can be explained by considering the two-phase model in a single phase form. If we ignore, for the purpose of this discussion, the windings which carry the currents ($i_{1\beta}$, $i_{2\beta}$), then a primary current $i_{1\alpha}$ (formerly $i_1$ in the single phase model) leads to a primary MMF $n_1 i_{1\alpha}$. This primary MMF must, for reasons discussed in chapter 3, correspond to a secondary MMF $n_2 i_{2\alpha}$, where $i_{2\alpha}$ is now used instead of $i_2$ (as used in the single phase model). Furthermore, the circuit flux vector $\vec{\psi}_m$ is under these circumstances oriented along the horizontal axis, which is precisely the chosen direction for the ‘real’ axis of the new complex plane in which case $\vec{\psi}_m = \psi_{m\alpha}$.

The relationship between currents and flux-linkages for the two-phase ITF model proceeds along similar lines as discussed for the single phase ITF model. The relationship between the primary and secondary currents is given as

$$n_1 i_{1\alpha} - n_2 i_{2\alpha} = 0 \quad (6.1a)$$
$$n_1 i_{1\beta} - n_2 i_{2\beta} = 0 \quad (6.1b)$$