The induction motor model has been in use for many years and is well characterized both experimentally and theoretically. For control purposes the model is often expressed in an arbitrary two-axis rotating reference frame. This makes it easier for the control

designer to fix the reference frame to a particular motor quantity and adjust the model accordingly.

As induction motors are used in a wide range of applications, analysis of the machine during transient conditions has become important.

**4.3.3 Transient or Dynamic Equivalent Circuit**

The complexity, method of derivation, and ultimate adequacy of the transient equivalent circuit depend to a large extent upon the uses to which it is likely to be put. There are two particular operational conditions for which such a circuit is uniquely applicable. In the first case the results primarily concern the machine designer or applications engineer; the second case is of greater interest to the power systems analyst.

These circumstances are:

1. *Three-phase short circuit at the machine terminals.* The machine may be operating as either a motor or an induction generator, but in either event it is the stator current which will flow into the fault from the machine that is of concern here. At the instant of the short circuit there will be rotor current that



**Figure 4.58** Transient equivalent circuit

will decay, reaching zero when the initial stored energy is dissipated. The decaying current in the rotor generates

voltages in the stator windings and the machine is transiently analogous to a short-circuited alternator. This is reflected by the equivalent circuit of Fig. 4.58, where *R*1 is the stator resistance per phase and the transient reactance per phase is



the various parameters being as defined in Section 4.3.2. Vw1 is the prefault terminal voltage and Ew1 is known as the initial voltage behind the transient reactance of the machine. The procedure for calculation of fault current [17, 18] is then to calculate Ew1 from the prefault stator phase current, short circuit the stator terminals, and determine the initial current fed into the fault. The short-circuit time constant also follows approximately from the quotient:



where is the referred rotor resistance

The initial short-circuit current may be of the order of three or four times the rated value, but, with a short time

constant, the fault current usually decays to zero within less than ten cycles of the supply frequency. It is thus considered acceptable to neglect any change in speed during the transient.

Machines for which such transient analysis is considered appropriate are usually large devices, that is, in the megawatt range, and may well be provided with deep rotor bars. This somewhat complicates the estimate of transient reactance but it is possible to produce a transient equivalent circuit based on the treatment of double-cage motors to which deepbar rotor machines may be considered analogous.

2. *Power system fault conditions.* The behavior and influence of induction motor loads following a power system

fault can be assessed by the use of the transient equivalent circuit of Fig. 4.58. In fact, power system engineers use various models to represent induction motor loads in transient stability studies, the complexity of the models depending upon the degree of refinement required and the degree of influence (orsignificance) assigned to this dynamic component of the load. A simple impedance representation may sometimes be adopted or as an alternative, the steady-state equivalent circuit of Fig. 4.55 or 4.56 may be deemed adequate, either with or without consideration of the load inertia and mechanical transients. The use of the transient equivalent circuit, with suitable account being taken of mechanical transients, is then a further option with time-stepping, finite element techniques for a complete transient solution being available if necessary.