INSULATION COORDINATION

Insulation Coordination is defined by the values of test voltages which the insulation of equipment under test must be able to withstand. In the earlier days of electric power, insulation levels commonly used were established on the basis of experience gained by utilities. As laboratory techniques improved, so that different laboratories were in closer agreement on test results, an international joint committee, the Nema-Nela Committee on Insulation Coordination, was formed and was charged with the task of establishing insulation strength of all classes of equipment and to establish levels for various voltage classification. In 1941 a detailed document18 was published giving basic insulation levels for all equipment in operation at that time. The presented tests included standard impulse voltages and one-minute power frequency tests.

In today‘s systems for voltages up to 245 kV the tests are still limited to lightning impulses and one-minute power frequency tests, see section 5.3.Above 300 kV, in addition to lightning impulse and the one-minute power frequency tests, tests include the use of switching impulse voltages. Tables 5.2and 5.3 list the standardized test voltages for 245 kV and above ½300 kV respectively, suggested by IEC for testing equipment. These tables are based on a 1992 draft of the IEC document on insulation coordination.

Table 5.7 Standard insulation levels for Range II (Um > 245 kV) (From IEC document 28

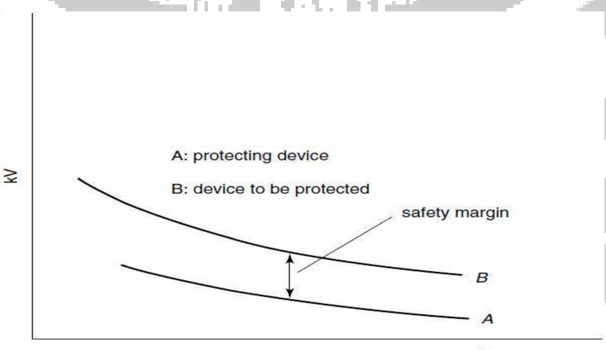
CO 58, 1992, Insulation coordination Part 1: definitions, principles and rules)

Highest Voltage for equipment Um KV (rms Value)	**Longitudinal Insulation (+) KV Peak Value**	**Standard lighting withstand voltage phase to earth value (Peak Value)**	**Phase to phase (ratio to phase to earth peak value)**	**Standard lighting withstand voltage (Peak Value)**
300	750	750	1.50	850 950
362	750	850	1.50	950 1050
420	850	850	1.50	950 1050
	850	950	1.50	1050 1175
	850	850	1.60	1050 1175
525	950	950	1.50	1175 1300
	950	1050	1.50	1300 1425

	950	950	1.70	1425 1425
	950	1050	1.60	1550 1800
	950	1175	1.50	1675 1800
	950	1300	1.70	1800 1425
765	1175	1425	1.60	1675 1800
	1175	1550	1.70	1800

Statistical approach to insulation coordination

In the early days insulation levels for lightning surges were determined by evaluating the 50 per cent flashover values (BIL) for all insulations and providing a sufficiently high withstand level that all insulations would withstand. For those values a volt–time characteristic was constructed. Similarly the protection levels provided by protective devices were determined. The upper curve represents the common BIL for all insulations present, while the lower represents the



protective voltage level provided by the protective devices. The difference between the two curves provides the safety margin for the insulation system. Thus the Protection ratio=Max. Voltage it permits/Max.

This approach is difficult to apply at e.h.v. and u.h.v. levels, particularly for external insulations. Present-day practices of insulation coordination rely on a statistical approach which relates directly the electrical stress and the electrical strength. This approach requires knowledge of the distribution of both the anticipated stresses and the electrical strengths. The statistical nature of over voltages, in particular switching over voltages, makes it necessary to compute a large number of over voltages in order to determine with some degree of confidence the statistical over voltages on a system. The e.h.v. and u.h.v. systems employ a number of non- linear elements, but with today‘s availability of digital computers the distribution of over voltages can be calculated. A more practical approach to determine the required probability distributions of a system‘s over voltages employs a comprehensive systems simulator, the older types using analogue units, while the newer.

Employ real time digital simulators (RTDS).For the purpose of coordinating the electrical stresses with electrical strengths it is convenient to represent the overvoltage distribution in the form of probability density function (Gaussian distribution curve as shown in Figure) and theinsulation breakdown probability by the cumulative distribution function. The knowledge of these distributions enables us to determine the _risk of failure‘. If Va is the average value of overvoltage, Vk is the kth value of over voltage, the probability of occurrence of overvoltage is p0Vk du, where as the probability of breakdown is PbVkor the probability that the gap willbreak down at an overvoltage Vk is PbVkp0Vk du. For the total voltage range we obtain for the total probability of failure or _risk of failure‘.

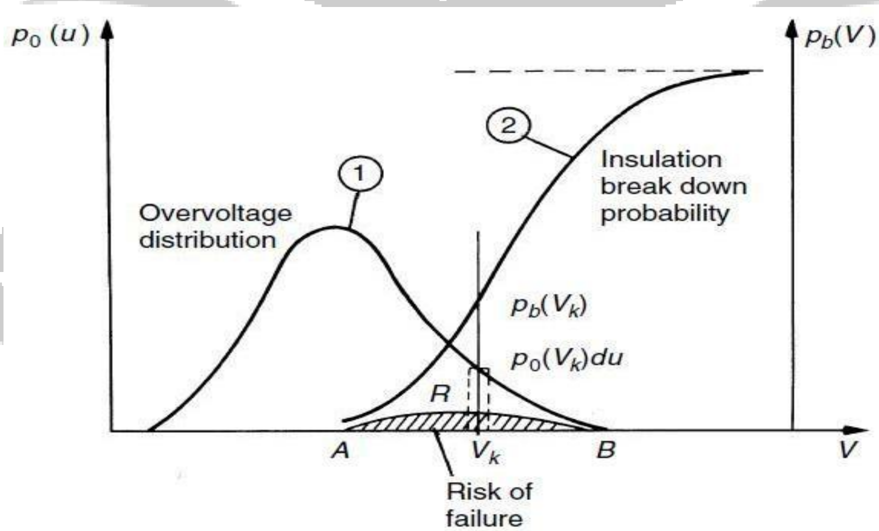


Figure: Method of describing the risk of failure.

1. over voltage distribution–Gaussian function. 2. Insulation breakdown probability–cumulative distribution)

$$R = \int_0^\infty Pb(Vk)P0(Vk)du$$

The risk of failure will thus be given by the shaded area under the curve R. In engineering practice it would become uneconomical to use the complete distribution functions for the occurrence of overvoltage and for the withstand of insulation and a compromise solution is accepted as shown in Figs 5.18 (a) and (b) for guidance. Curve (a) represents probability of occurrence of over voltages of such amplitude Vs that only 2 per cent (shaded area) has a chance to cause breakdown. VS are known as the _statistical overvoltage‘. In Fig. 5.18(b) the voltage Vw is so low that in 90 per cent of applied impulses, breakdown does not occur and such voltage is known as the _statistical withstand voltage‘ Vw.

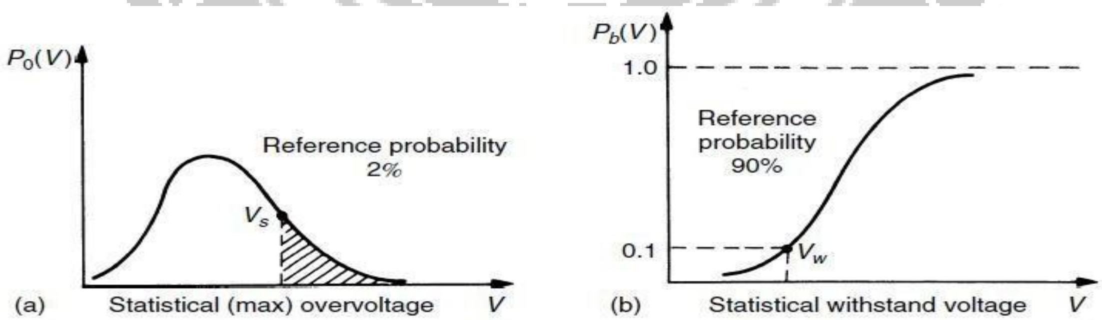


Figure: 5.18 Reference probabilities for overvoltage and for insulation withstand strength

In addition to the parameters statistical overvoltage _VS‘ and the statistical withstand voltage _VW‘ we may introduce the concept of statistical safety factor 4. This parameter becomes readily understood by inspecting Figs 5.19(a) to (c) in which the functions Pb V and p0Vk are plotted for three different cases of insulation strength but keeping the distribution of overvoltage occurrence the same. The density function p0Vkis the same in (a) to (c) and the cumulative function giving the yet undetermined withstand voltage is gradually shifted along the V-axis towards high values of V.

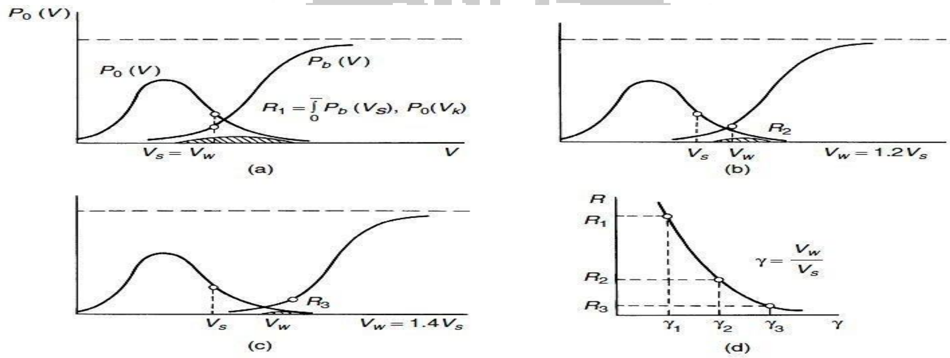


Figure: 5.19 The statistical safety factor and its relation to the risk of failure

This corresponds to increasing the insulation strength by either using thicker insulation or material of higher insulation strength. As a result of the relative shift of the two curves [PbV and p0Vk] the ratio of the values Vw/Vs will vary. This ratio is known as the statistical safety factor.