

# THE OCCURRENCE OF TRANSIENT FIELDS AND ESD IN TYPICAL SELECTED AREAS

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*The occurrence rate of Electrostatic Discharges (ESD) depends extremely on the environment. Several parameters influence ESD and the severity of this interference. A special measurement system to measure the transient fields of ESD was designed. Measurements were done in different environments. A theoretical model was developed, helping to predict and to evaluate the severity level of an environment towards ESD.*

## 1. INTRODUCTION

Electrostatic Discharges (ESD) can cause temporary disturbances or even lasting destruction of electronic devices. The critical components of an ESD-event are both the current and the always associated transient E- and H-Field. The short rise times of the ESD-current can cause strong, steep-rising fields even at larger distances from the discharge location.

Due to the stochastic nature of ESD it is very difficult to determine the currents and the fields of ESD occurring under practice conditions. Many parameters influence the occurrence rate and the intensity of real ESD.

The direct environment of a device and the activities which happen in the environment determine the ESD threat. Each environment has its own average hazard potential. In the test standard IEC 1000-4-2 there are little considerations concerning the environment dependency of the ESD threat: It is however desirable to improve the ability to differentiate better the actually possible extent of the environmental hazard potential. If it is sure, that a certain threshold of a disturbance variable does not or only occur with infinitesimal probability, in certain cases the protection level can be reduced. However, only with knowledge of the occurrence rates and the intensities a decision can be made.

In reality ESD pulses can have a higher disturbance intensity than even the strongest pulses, which are prescribed with a test to meet the IEC 1000-4-2

standard. In the standard a negligible occurrence frequency of these strong disturbances is assumed. This is hardly provable so far.

Apart from study [1] published at the beginning of the 80's, there is no detailed information about ESD in practice so far. The mentioned study examined only two different environments and did not consider the fields of ESD. Due to the small number of examined environments and the disregard of the ESD field effects, the results of this investigation are incomplete and cannot be generalized.

In order to increase the knowledge base concerning the occurrence rate and the intensity of ESD events that really occurs in practice, long-term measurements of the transient fields at three different places were made by means of a new developed, complex measurement system [2]. The large variation of ESD and the necessity for further tools to determine the occurrence of ESD under practice conditions was confirmed.

A universal stochastic model of ESD can be helpful. It has to consider the substantial parameters of ESD, and it should be able to characterize ESD with a few, simple measurements and general considerations of the environment.

With the help of a stochastic model it would be possible with little effort to receive the ESD hazard potential that is possible in an environment. The stochastic model helps to determine suitable test procedures and also to select the really necessary protection measures.

A stochastic model for the occurrence rate of ESD considering the intensity distribution is presented here.

## 2. EXPERIMENTAL METHOD

The developed and applied measurement system consists of a specially designed circuit for the evaluation of fast transient pulses. The measurement system is

equipped with several field sensors. It is optimized for ESD long term measurements. The E- and H-fields are measured separately. This system automatically registers the amplitude of impulsive fields within the range of 20 V/m up to 1000 V/m or 0.05 A/m up to 2.7 A/m. The pulse width can thereby be smaller than 1 ns. Apart from the pulse amplitudes the system records important frequency components, environmental conditions (temperature, relative humidity) and time. The maximum repetition rate is higher than 25 kHz. A detailed description of the developed measurement system can be found in [2].

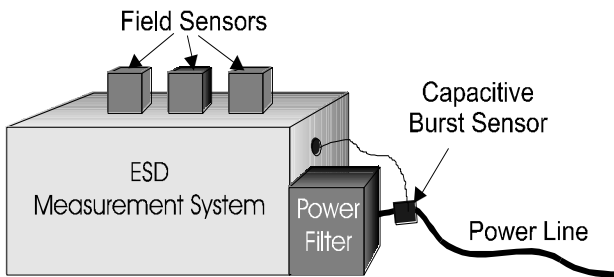


Fig. 1: Capacitive sensor connected to the power line for burst detection

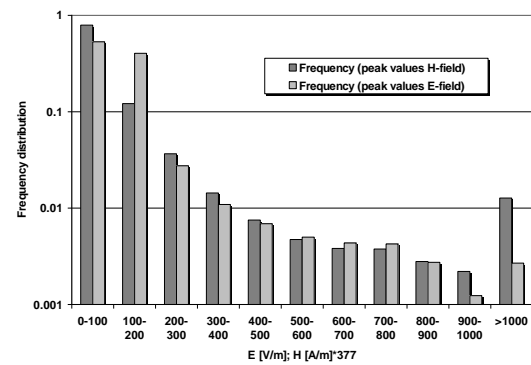
The often occurring burst fields (switching actions propagated by the power lines) can be mistaken for ESD events. For this reason a differential measurement method was implemented. Burst pulses were detected by a capacitive sensor placed on the power line of the

measurement system. If this burst sensor measures a pulse at the same time with the field sensors and a certain relation between the signals is exceeded, the measurement system rejects this event. With this method, the measurement of ESD by the observation of the transient fields is possible.

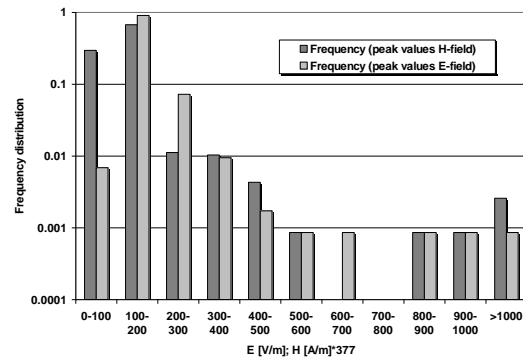
The measurements presented here were done without this burst sensor. The criterion for Burst rejection was the level of the pulses.

### 3. EXPERIMENTAL RESULTS

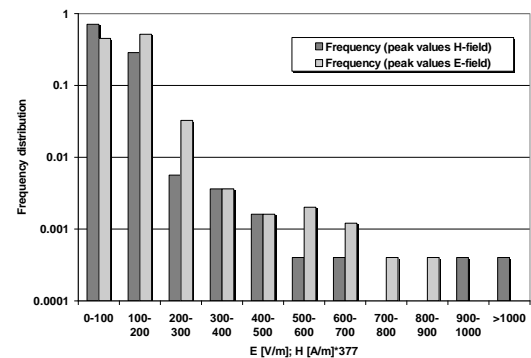
By means of three identical measurement systems at three different measuring locations long-term measurements of the impulsive fields were done. One location, the university library of the Technical University Berlin, was selected due to ESD promoting conditions there. ESD occur there very often. The device was placed in an arbitrarily chosen book shelf. The second measuring location was under a workstation, on the floor in a student electronics laboratory. The students there work with a lot of ESD-sensitive electronic components. The system was located in the middle of the room. The third location was a computer room equipped with 8 PCs. Here the device was placed in the middle of the room on the floor. The relative humidity during the entire measuring period ranged between 30% and 40%, the temperature was nearly constant with approx. 20°C.



a)



c)



b)

Fig. 2: Frequency and intensity of impulsive field events in three different environments

- a) Library; duration of measurement 20 days; 18620 events;
- b) Computer room; duration of measurement 14 days, 2488 events
- c) Electronics laboratory, duration of measurement 9 days, 1162 events

Histograms of the results of the measurements can be found in figure 2. The histograms show the relative frequency of the field pulses as a function of the amplitude. As expected in all three cases the weak field pulses occurred substantially more frequently than the stronger pulses.

Among the many impulsive events, which were recorded by the system, also many Burst (switching) actions can be found. Even though the ESD fields often differ from the fields generated by switching actions (frequency spectrum, repeating rate), nevertheless in practice it is very complex to execute this differentiation. The limited dynamic range of the used measurement setup and interference with the environment cause problems. With larger field strengths the necessary dynamic becomes available. In normal environments in larger distances large field strengths can be produced only by ESD. A minimum distance of 1 m was ensured between the measuring instruments and other electrical equipment. From investigations it could be determined that the switching actions occurring in the environments cause field strengths of less than 250 V/m or  $250/Z_0$  A/m. With the described differential measurements or an evaluation of the data with neural networks, a better distinction would be possible

In the examined library an ESD promoting carpet is laid. A high activity of students and staff further promotes the frequent occurring of ESD. Here an average number of 931 pulses per day was measured. In the computer room and the electronics laboratory an older linoleum floor is laid. This floor does not particularly promote ESD. Also less activities generating triboelectricity can be found there. Only 178 (computer room) or 129 (electronics work space) impulsive events per day could be measured in average. A lot of the pulses are generated by switching actions.

Site	Number of pulses/day	Number of pulses >500 V/m/day	Number of pulse >500/377 A/m/day	notes
library	931	19	28	-many activities -flooring
computer room	178	0,9	0,4	-less discharge locations
electronic laboratory	129	0,7	0,8	-less critical activities

Table 1: Comparison of the average number of strong field pulses in the different sites

The higher frequency of large H-field amplitudes measured in the library compared to the frequency of E-field amplitudes can be explained by the fact that most

of the strong discharges were probably caused by a discharge in a door handle located in a distance of approximately 2 m from the measurement instrument. The E-field probe was shielded in this direction by a metal book shelf.

In table 1 the environments are compared. In the university library an average number of 19 to 28 ESD serious events per day occur, which cause a field strength of more than 500 V/m or 500/377 A/m at a quite arbitrarily selected measuring point. In the other environments less than 1 serious ESD event could be measured in average per day. The ESD promoting conditions in the library like the floor and the activities caused such big differences.

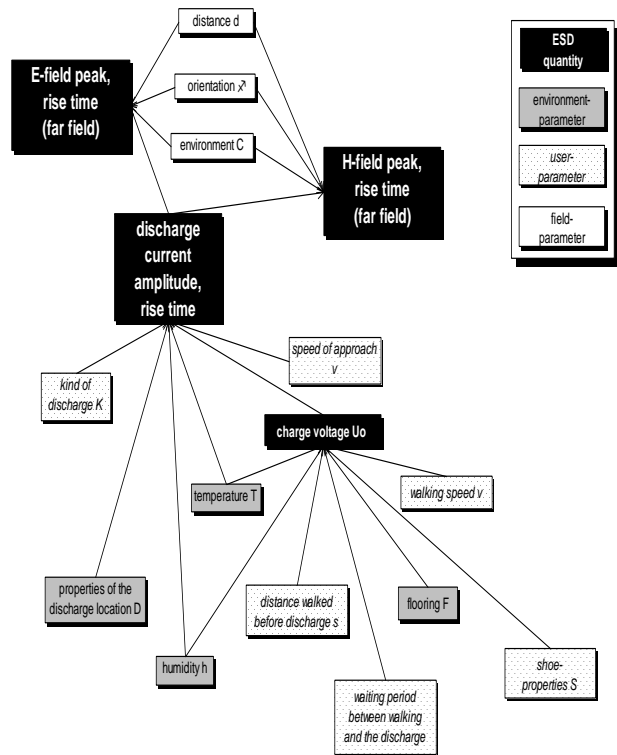


Fig.3: Dependency of ESD from the 'environment'

### 3. A STOCHASTIC MODEL OF THE OCCURRENCE OF ESD

The actually interesting parameters of ESD are the currents and the fields, but the always preceding charging process can be characterized by the generated charging voltage. To describe the severity of an ESD, the charging voltage is however an unsuitable quantity. For the same charging voltage, e.g. the amplitudes of the currents can vary to up to three orders of magnitude. The current derivatives, the amplitudes and the derivatives of the fields can vary even up to three orders of magnitude [3].

	Parameter	Abbreviation	Example	Possible Probability Density Function	f()
1	distance walked before discharge	s	0-20 m	Exponential Distribution	
2	walking speed	v <sub>L</sub>	0-1 m/s	Normal Distribution	
3	flooring	F			
4	shoe-, garment properties furniture properties...	S			
5	delay between walking and the discharge	t			
6	rel. humidity	h	10-90%	Normal Distribution	
7	temperature	T	0-35°C	Normal Distribution	
8	charge voltage	U <sub>0</sub>	0-20 kV	Exponential Distribution	s,v <sub>L</sub> ,F,S,t,h,T
9	kind of discharge	K	finger, metal piece		
10	speed of approach	v		Normal Distribution	
11	properties of the discharge location	D	impedance Z of the current path		
12	discharge current	$i_{\max}, \frac{di}{dt}_{\max}$		Exponential Distribution	U <sub>0</sub> ,h,T,K,v,D
13	distance	d	0-3m	Exponential Distribution	
14	orientation	φ	0-90°	Normal Distribution	
15	environment	C	reflection		
16	E-field (far field)	$E_{\max}, \frac{dE}{dt}_{\max}$		Exponential Distribution	i,d,φ,C
17	H-field (far field)	$H_{\max}, \frac{dH}{dt}_{\max}$		Exponential Distribution	i,d,φ,C

Table 2: Parameter influencing the occurrence rate and the intensity of ESD (assumption: electrification by walking)

With some additional assumptions statements concerning the severity level of ESD can be derived from the charging voltage distribution.

ESD depends on many parameters. The table prepared by Ryser [4] was extended in table 2 with further important parameters. In figure 3 the dependencies are presented graphically. It must be kept in mind that it is impossible to consider all influencing parameters. Only the most important ones are specified here.

The generation of charge and the charging voltage mainly depend on the parameters specified in table 1, line 1-7. The exact functional dependencies between the parameters and the value of the charging voltage can hardly be determined by analytical calculation, since the conditions are too complex. However based on measurements the necessary dependencies can be determined. By measurements a table can be made with the approximate charging voltage as a function of the individual parameters. A function:

$$U_0 = f(s, v_L, F, S, h, t)$$

can be generated from this table, which determines U<sub>0</sub>.

The occurrence of each single parameter, specified in table 2, is determined by the respective probability density distribution for each environment.

#### 4.1 Calculation of the resulting probability function from the individual probability functions

If the probability density functions  $f(x_i)$  of the individual parameters are known, the total probability function can be determined by simple multiplication of the functions (1), due to the stochastic independence of the individual ESD influencing parameter:

$$f(x_1, x_2, \dots, x_n) = \prod_{i=1}^n f(x_i) \quad (1)$$

An area of the n-dimensional density function may represent, e.g. the probability of a certain current amplitude.

In many cases the distribution function is of special interest, i.e. the function, which determines the probability that a disturbance quantity  $g(x_1, \dots, x_n)$  is bigger than a certain threshold  $g_0$ . If a constant distribution of the densities is assumed, the distribution function can be determined (2):

$$F(g_0) = P(g \geq g_0) =$$

$$\iint \dots \int_{g(x_1, x_2, \dots, x_n) \geq g_0} f(x_1, x_2, \dots, x_n) dx_1 dx_2 \dots dx_n \quad (2)$$

## 5. DISCUSSION

The measured distributions in figure 1 can be approximated by an exponentially dropping function. This corresponds with the assumption that the different charging voltages occur with an exponential distribution (acceptance: the walking distances are exponentially distributed and on the average are the charging voltage is a function of the distance). This dependency was already determined empirically in [1]. It is also obvious that ESD events far away from the measuring point appear more often than ESD events close to the measurement system (uniform distribution of the discharge locations assumed). This is just determined by the available space. Even if an exponential distribution is assumed here, the resulting function is again an exponential distribution.

The measured dependency can thus be explained by theoretical considerations. Considering ESD as a complex stochastic process it is possible to determine the intensity and frequency of the ESD in an environment with a few measurements and observations. A necessary prerequisite is the knowledge of the individual dependencies.

Even if the accuracy of such an estimation will not be very well in many cases, this will cause less problems. The variations that occur with almost all measurements concerning ESD, they do not influence a stochastic model. As long as the kind of distribution, the expected value and the variance correspond, the result does not change or it changes only insignificantly. This agreement can be achieved with some measurements and basic considerations.

## 6. CONCLUSION

At selected locations measurements of the transient fields were done. A stochastic model for ESD was presented. With some measurements and basic considerations the average intensity and frequency of ESD can be determined.

A lot of the data, which is necessary for the modeling of ESD as a stochastic process, does unfortunately not yet exist. This will be an important aspect of our future work. Further a simulator program, which describes an environment concerning its ESD behavior, will be developed.

## ACKNOWLEDGMENT

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## 7. REFERENCES

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