LOW-FREQUENCY MAGNETIC FIELDS IN SECONDARY SUBSTATIONS

Peter Leipold, Klaus-Peter Panzlaff
Bewag Aktiengesellschaft,
Puschkinallee 52, D-12435 Berlin
Tel.: +49 30 267 10 350 - Fax: +49 30 267 10 352 - E-mail: Panzlaff.Klaus-Peter@bewag.com

ABSTRACT

In 1997, a new regulation on emission protection (26th BImSchV) (amending the Act on protection of the environment against harmful effects through air pollution, noise, vibrations and similar factors) came into effect in Federal Germany. It includes directions for compliance with maximum permissible emission levels for electrical and magnetic fields. These requirements are intended as a precaution to protect the general public against potentially harmful effects of low-frequency fields. They are so low, that only multiples of these limits could have an influence on living organism. Damages to humans is inconceivable.

Investigations at secondary (h.v/l.v.) substations operated by Bewag have shown that these emission limits are, in general, not exceeded. But they are near the limit of the requirement. However, even though the legally required limits are respected, there are electromagnetic fields of much lower strengths that have an influence on PC's by reason of the kind of function of the PC. Therefore, it is recommended to make use of any available cost-effective means of reducing emissions to the lowest possible level when new secondary substations are built.

This is why EMF-optimized secondary substations have been developed in conjunction with switchgear manufacturers. The improvements are described in the present report. As a result of these efforts, magnetic fields generated in newly designed stations were reduced to values which represent only a fraction of the legally prescribed standard. For example, magnetic alternating fields which are measured 3.5 m above the station floor exhibit values which exclude any impact on even older personal computers.

The above-mentioned electromagnetic compatibility was achieved without any high cost increases for station equipment for new installed stations. However, where this effect is required to be built into existing facilities, the necessary reconstruction work will be quite cost intensive.

1 PROBLEM DESCRIPTION

Basic life has positively changed since electricity has been used in the form of mechanical work, heat or light. The use of electrical energy has brought on electrical and magnetic fields which mostly occur as alternating fields. An electric field is created under any energized electrical conductor. A magnetic field is created as soon as an electric current flows. The field strengths of both rapidly decrease as the distance to the source of their generation increases.

Natural fields have always existed on earth. For example, there is electric fields in the atmosphere - the cause of thunderstorms - or the natural magnetic field of the earth. In the low-frequency range, the technically generated fields are often much stronger than those natural fields which occur in the environment. They are created when electrical energy is generated, distributed and used.

Publications on the effects of electric and magnetic fields on man and electrical appliances as a result of the operation of electrical installations have caused insecurity and confusion among some people. *'Electrosmog'* is the term the media frequently uses, although it is physically incorrect.

According to the opinions of scientists, the fields caused by normal devices of which we are always surrounding ourselves cause no damage for humans. They are measurable by sensitive measurement devices.

2 GERMAN LEGISLATION

To protect human beings from harmful effects of electric and magnetic fields, the Federal German Law on Emission Protection stipulates consent limits. They are ultimately based on the recommendation given by the ICNIRP (International Committee on Non-Ionizing Radiation Protection) that the current densities caused by fields in the human body should be lower than 2 mA/m^2.

The above-mentioned precautionary base limit has been used to derive consent limits for exterior electric and magnetic field strengths at a frequency of 50 Hz for protection of the general public and the neighborhood against harmful environmental impacts. These limits are given in the above-mentioned German Emission Protection Act as follows:

Low-frequency facilities

	Effective value of electric field strength and magnetic flux density	
Frequency in Hertz (Hz)	Electric field strength in kilovolts per meter (kV/m)	Magnetic flux density in micro tesla (µT)
50 Hz fields	5	100
16 2/3 Hz fields	10	300

Table 1

This ordinance defines low-frequency facilities as 'stationary installations for transformation and transmission of electrical energy at a voltage including and above 1000 V'. Commissioning of such facilities has to be reported to authorities, and compliance with consent limits has to be proven to them (table 1).

After a three-year transitional period, the above-mentioned directions will also apply to existing installations already in operation.

With the low limits of the German legal requirements, we have the full protection of humans. Also, these are not very high hurdles for the beneficial use of electric energy.

3 THE SECONDARY SUBSTATION AS A SOURCE OF MAGNETIC FIELDS

As electric fields do not reach considerable sizes even in old secondary substations, all further observations can be restricted to magnetic fields.

A secondary substation consists essentially of three components: the high-voltage switchgear, the transformer and the low-voltage distribution.

At nominal output, the individual components contribute to the emitted magnetic field in varying degrees .

As a result of the high voltage in the h. v. area, the currents flowing there are relatively small. The magnetic fields found there are therefore of low intensity.

The transformer similarly emits very small magnetic fields. This is due to the fact that it is built to keep down transformer losses as much as possible. To achieve this, it is necessary to chose transformer designs which generate a minimal stray field and consequently a minimum outgoing magnetic field.

This leaves the l.v. distribution switchboard and its connection to the distribution transformer as the main magnetic field-producing component in secondary substations. It is here where the high currents occur which are necessary for the generation of strong magnetic fields.
In its existing facilities, Bewag usually complies with legal requirements for magnetic field strengths of ≤ 100 µT outside the station rooms even without applying any special measures. This is demonstrated in the following schematic drawing (figure 1).

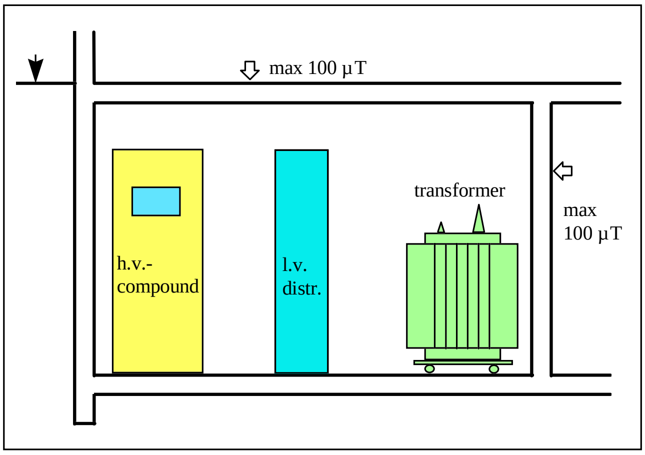
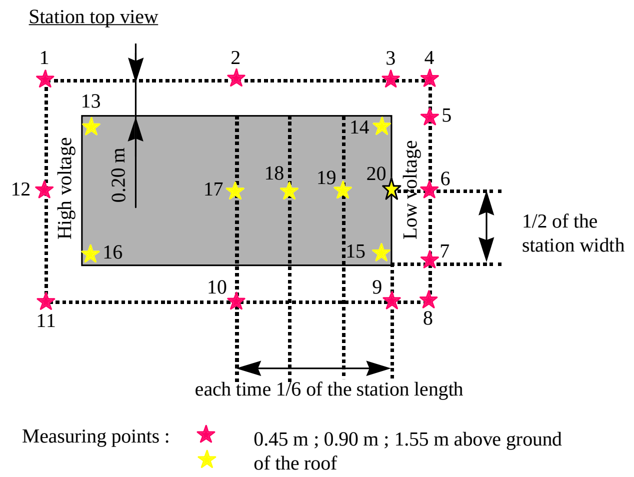


Figure 1

3.1 Measurement in a non-accessible substation with a 400 kVA distribution transformer

A magnetic field measurement, at a rated voltage of 6kV/0.231kV and a 556 A to 618 A transformer actual load current, revealed the following field distribution (table 2):



Meas.point	Height 1.55m		Height 0.9m		Height 0.5m	
	Magn. field µT	Current A	Magn. field µT	Current A	Magn. field µT	Current A
1	1.3	607	1.5	610	2.0	574
2	14.7	592	17.7	536	13.7	600
3	20,9	618	53.1	598	34.4	570
4	15.9	612	36.1	622	26.4	576
5	21.3	600	54.3	586	36.1	559
6	35.8	589	77.7	566	76.5	567
7	11.4	603	15.2	567	15.6	560
8	8.3	591	9.7	571	9.9	560
9	9.3	604	9.2	556	10.3	568
10	15.9	591	28.3	560	18.7	591
11	1.4	580	1.2	598	2.2	605
12	1.3	606	1.3	604	2.7	600
Meas.point	Station roof					
13	2.2	579				
14	28.1	582				
15	14.1	573				
16	51.7	562				
17	49.3	589				
18	86.0	630				
19	93.2	603				
20	52.5	579				

Table 2

3.2 Time characteristic of magnetic field strength and actual load current

In another measurement, the time characteristic of the magnetic field strength was recorded as a function of the actual load current at measuring point no. 6 at a height of 0.9 m (figure 2).

Rated voltage: 6 kV/0.231 kV
Rated power: 400 kVA
Rated current: 38.5 A / 1000 A

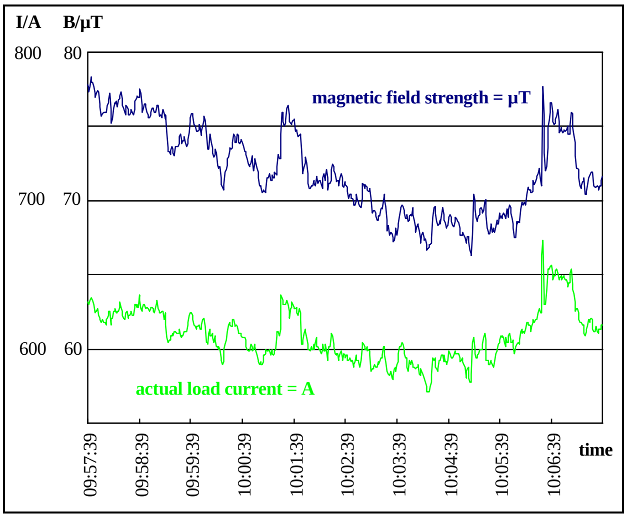


Figure 2

The safety of this kind of old secondary substation is not in question. It is impossible to effect people with the strength of magnetic fields of this substation.

4 SPECIAL MEASURES FOR REDUCING MAGNETIC FIELDS IN THE CONSTRUCTION OF NEW SECONDARY SUBSTATIONS

The emission of magnetic fields can be reduced by the following measures:

– Prevent creation of an outgoing magnetic field (by utilizing the balancing three-phase effect),
Measure type A

– Keep the distance between the emission source and the place of emission as large as possible,
Measure type B

– Keep the strength of currents flowing in the electrical installations and thus the generation of magnetic fields as low as possible,
Measure type C

– Keep the field-generating effective lengths of energized conductors as short as possible,
Measure type D

4.1 Increasing the distance between the bus bar and the ceiling of the room *(Measure type B)*

The maximum height of the unit should not exceed 1.6 m.

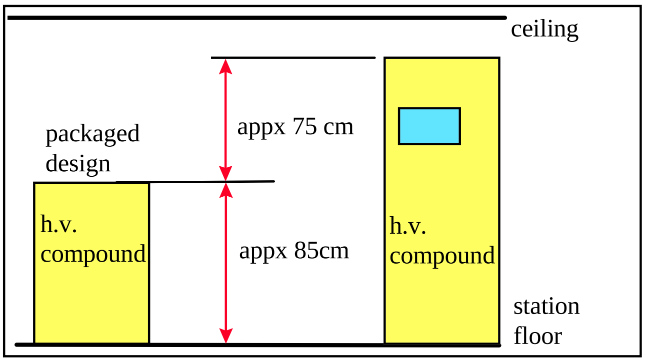


Figure 3

By way of increasing the space between the h.v. compound (emission source) and the room above of the station unit (place of emission), a lower magnetic field strength is experienced (figure 3).

4.2 Use of custom-designed transformers with connections fitted at the bottom (EMF transformer) *(Measure types B and D)*

An EMF reduction is achieved by using an EMF transformer.

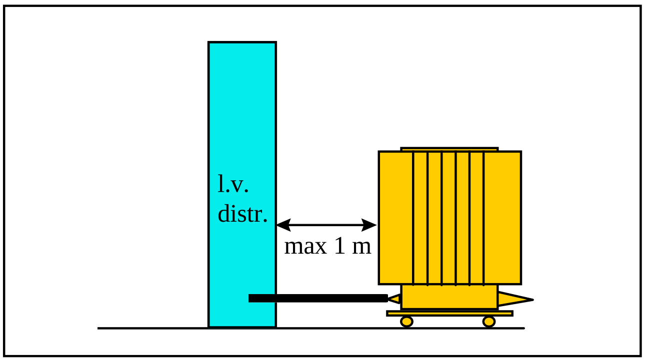


Figure 4

Current-carrying wires should be fitted in a maximum possible distance from the ceiling (see 4.1). Current-carrying connections between components, in this case the l.v. distribution and the outgoing unit of the l.v. transformer should be as short as possible. This is why the system components are put up close to each other, and the outgoing units on the l. v. side of the EMF-optimized transformer are fitted close to the bottom of the transformer rather than on the cover as usual (figure 4).

4.3 Decrease the length of the l.v. coupling between transformer and l. v. distribution box (max 1 m) *(Measure type B)*

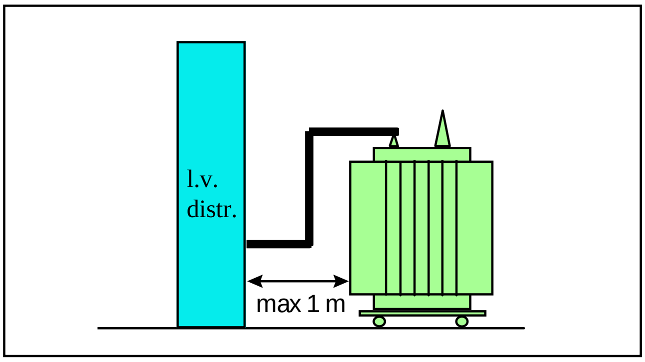


Figure 5

If no EMF-optimized transformer is available, it should at least be provided for connection lines to be kept as short as possible (figure 5).

4.4 Arrange conductors of l.v. connections in such a way that the fields cancel each other as much as possible, e.g. by twisting of the individual wires *(Measure types A and B* (Figure 6)

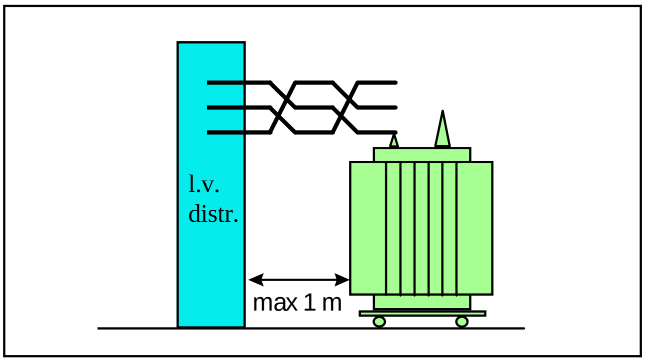


Figure 6

4.5 Three examples for how the distance between bus bars can be reduced *(Measure type B)*

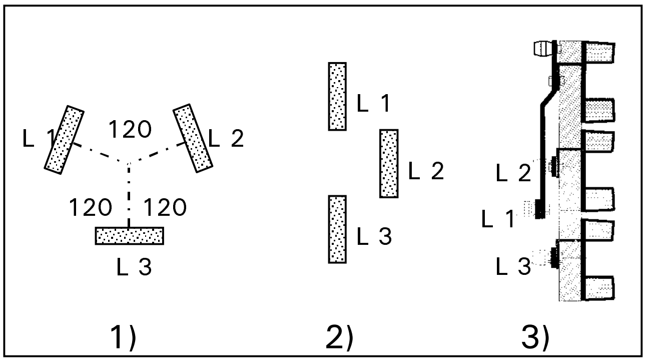


Figure 7

The emitted resulting magnetic field can be restricted by modifying the spatial arrangement of the bus bars of a three-phase current system on a l. v. switchboard.
This effect can be best achieved by turning the bus bars through 120° and arrange them in a staggered way. The second best effect is obtained by arranging bus bars with smaller spaces between them (figure 7).

4.6 Symmetrical structure of the low-voltage distribution with central supply *(Measure type C)*

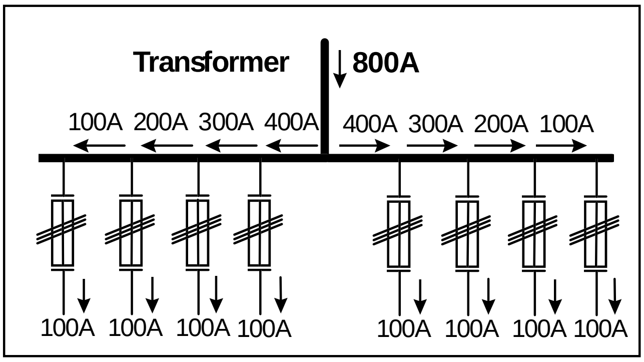


Figure 8

Central supply to bus bars of the l. v. distribution helps at best to halve partial currents on bus bar sections (figure 8).

4.7 Arrange the most-loaded feeders directly beside the supply point *(Measure types C and D)*

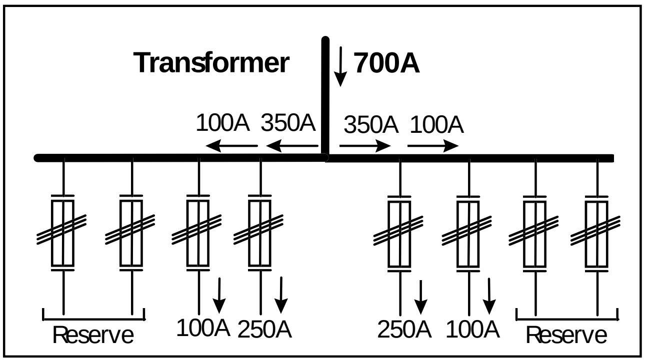


Figure 9

When the highest-power outgoing feeders are arranged close to the supply point of the bus bar system, the length of those bus bar sections which carry heavy currents is reduced (figure 9).

5 PROOF OF THE REDUCTION OF MAGNETIC FIELDS IN AN EMF-OPTIMIZED LOCAL AREA NETWORK STATION

To compare, the differences are shown in the magnitude of the magnetic fields for 1) a conventional EMF Non-Optimized Network Station, 2) for an EMF Optimized Station with a Conventional Distribution Transformer and 3) for an EMF-Optimized Station with EMF- Optimized Distribution Transformer. Proportionally, EMF Optimized stations indicate significantly smaller magnetic field strengths.

5.1 Non EMF-Optimized Station with a 630 kVA Distribution Transformer

Calculated Voltage: 10/0,4 kV
Calculated Current: 1000 A
Measuring Point Reference: Height of the station floor

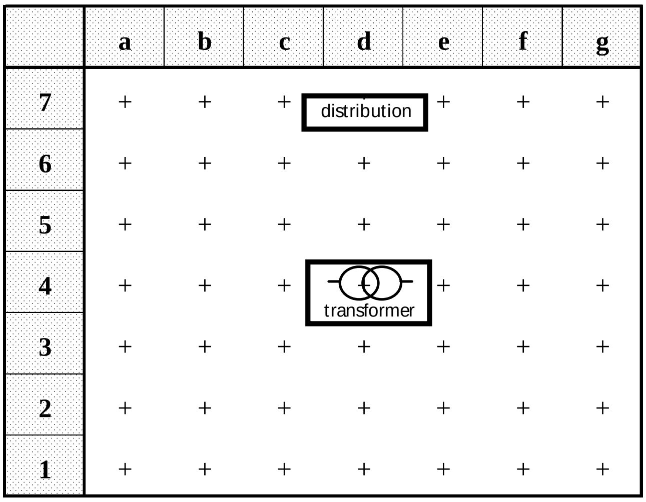


Figure 10: Measuring Points (Measured Distance = 1 m)

The maximum values occur within the area of the low-voltage distribution board at the measuring points 7/d. They are represented in Table 3 in relation to the given height over the station floor.

Height	Maximum Value
1.0 m	760.5 µT
2.0 m	387.9 µT
3.0 m	170.4 µT
3.5 m	98.0 µT

Table 3: Maximum Values in µT

	a	b	c	d	e	f	g
7	14.1	30.4	60.5	**98.0**	60.1	30.7	15.1
6	25.4	49.1	88.2	90.0	87.9	48.9	25.4
5	16.7	30.2	57.9	87.5	58.1	30.1	17.3
4	11.2	25.7	58.4	88.5	59.2	28.4	12.1
3	8.7	22.1	46.1	58.7	45.9	22.7	9.5
2	4.0	14.8	30.7	31.5	30.4	11.2	4.3
1	2.5	3.2	7.9	18.5	8.1	3.2	2.1

Table 4: Field Distribution (µT) at 3.5 m High

5.2 EMF-Optimized Station with 630 kVA Distribution Transformer

Calculated Voltage: 10/0,4 kV
Calculated Current: 1000 A
Measuring Point Reference: Height of the station floor

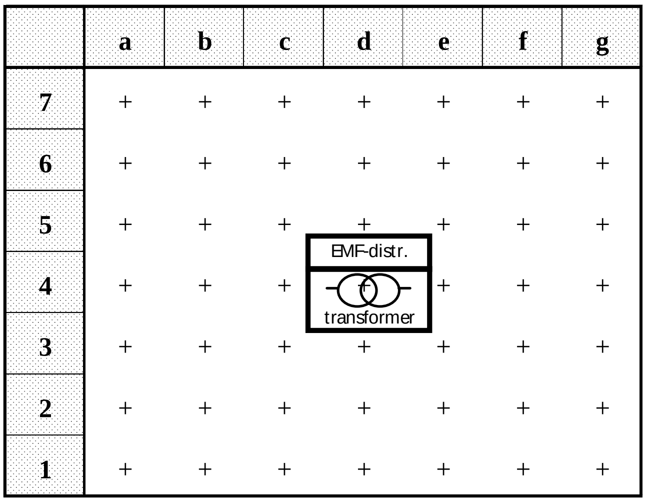


Figure 11: Measuring Points

The maximum values occur within the area of the low-voltage distribution board at the measuring point 4/d. They are represented in Table 5 in relation to the relative highest values of Table 3, section 5.1. The values are given in percentages.

Height	Maximum Value
1.0 m	12.47 %
2.0 m	11.70 %
3.0 m	2.58 %
3.5 m	1.90 %

Table 5: Maximum values, in percent, as relative to Table 3 in section 5.1

5.3 EMF-Optimized Station with 630 kVA EMF-Transformer

Calculated Voltage: 10/0,4 kV
Calculated Current: 1000 A
Measuring Point Reference: Height of the station floor

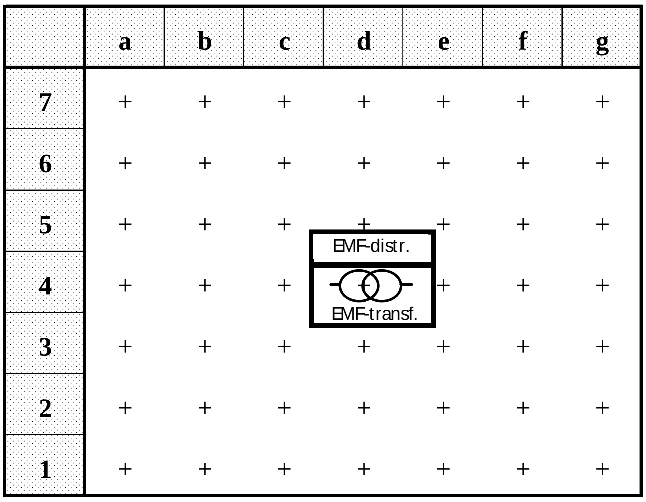


Figure 12: Measuring Points

The maximum values occur within the area of the low-voltage distribution board at the measuring point 4/d. They are represented in Table 6 in relation to the relative highest values of Table 3, section 5.1. The values are given in percentages.

Height	Maximum Value
1.0 m	5.64 %
2.0 m	4.62 %
3.0 m	1.15 %
3.5 m	1.00 %

Table 6: Maximum values, in percent, as relative to Table 3 in section 5.1