Discussion

M. Misakian (National Bureau of Standards, Gaithersburg, MD): This paper should be welcomed by workers responsible for accurately characterizing power frequency electric fields because it presents calculated results that address questions that previously could only be examined by experiment or by extrapolation of approximate theoretical models. This discussion compares several results in the paper with recommendations in the IEEE Standard, "Recommended Practices for Measurement of Electric and Magnetic Fields from AC Power Lines," (IEEE Std 644-1979), and finds good agreement as well as a need to revise a statement in the standard.

Parallel Plate Dimensions. The dimensions of the parallel plate system recommended in IEEE Std 644-1979 for calibrating field strength meters with side dimensions of less than 20 cm are 1.5 m × 1.5 m with a spacing of 0.75 m. These dimensions correspond to H/L equal to 0.25 in the paper and were determined, as the authors have noted, by assuming superposition of fringing field effects using a semi-infinite plate model [1]. With this assumption, the field at the center of the parallel plates is 0.4% less than the uniform field value, E_O, i.e., V/H. The good agreement between the calculated value for the finite parallel plates in Table 1 and the value assuming superposition of fringing fields is reassuring.

Model-type field strength measurements were also performed in a parallel plate system at NBS and it was found that there exists within the IEEE recommended parallel plate system, a central volume, 30 cm × 30 cm × 30 cm in which the field strength is within about 0.3% of the central field strength [2]. This experimental result appears to be consistent with the calculated curve in Fig. 6.

Proximity Effect of Fieldmeter Between Parallel Plates. The 0.75 m parallel plate spacing recommended in the IEEE standard was established, in part, by experimentally observing the interaction between a field strength meter with dimensions 18.2 cm × 5.1 cm × 14 cm and the plates of a large parallel plate system [2]. Observations of the analog display of the field strength meter, using a cathetometer, revealed no discernable proximity effect when the distance between the center of the fieldmeter and one of the plates was about 30 cm. Because of the experimental uncertainties (~1%), it was felt that a distance of 37.5 cm (0.75 m parallel plate spacing) would be adequate to keep the proximity effect to a negligible value. The proximity effect formula in the paper, $V/8D^3$, predicts an effect of 0.3% for the parallel plate spacing recommended in the IEEE standard and the field strength meter having the above dimensions, which again is reassuring. While fortuitous, it is worth noting that this predicted increase in field strength due to proximity effects is nearly canceled by the 0.4% decrease because of fringing field effects.

The authors have shown theoretically that the interaction between the field strength meter and the surface charge distributions on the parallel plates is proportional to the volume of the probe. The existing language in the IEEE standard notes that fieldmeters having *side dimensions* less than ~20 cm can be calibrated in the recommended parallel plate system. However, the calculated proximity effect of a field strength meter 20 cm × 20 cm × 20 cm would be 1.9%, which exceeds the 1% field uncertainty specified in the IEEE Standard. This indicates that the language in the IEEE standard should be "tightened" and it is being suggested that the wording in the standard, which is currently under review, be changed to read that the largest *diagonal dimension* of the field strength meter not exceed ~23 cm. This is the largest diagonal dimension of the field strength meter (mentioned above) which was used to experimentally determine the magnitude of proximity effects between parallel plates.

Proximity Effect of Nearby Vertical Ground Plane. The IEEE standard recommends that the minimum distance between nearby ground planes (e.g., a wall) and the parallel plates be 0.5 m. This corresponds to C/L equal to 0.33, using the notation in Fig. 9. It was determined experimentally [2] that a vertical ground plane 0.5 m away from the parallel plates (H/L equal to 0.25) led to no measurable proximity effect and the calculated results in Table 3 are consistent with this result.

REFERENCES

1. P. M. Morse and H. Feshbach, *Methods of Theoretical Physics, Part II,* p. 1245, McGraw Hill, New York, 1953.
2. F. R. Kotter and M. Misakian, "AC Transmission Line Field Measurements," NBS report prepared for U.S. Department of Energy, Report No. HCP/T-6010/E1 (1977). Available from NTIS, Springfield, VA 22161.

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T. Takuma, T. Kawamoto and **Y. Sunaga:** We would like to thank Dr. Misakian for his interest and valuable comments, especially for his useful comparison of the previous studies with our results.

The numerical field calculation now enables us to accurately analyze power frequency electric fields. Therefore, as Dr. Misakian suggests, the numerical evaluation of various effects is useful and important in electrostatic induction problems which could be examined until now only by experiment. Some of such problems that remain to be studied that are related to field strength meters, are the effects of insulating support or handles, and of leakage due to humidity in those parts.

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Discussion of paper, "Analysis of Calibration Arrangements for AC Field Strength Meters" by T. Takuma, T. Kawamoto, and Y. Sunaga in IEEE Transactions on Power Apparatus and Systems, Vol. PAS-104, pp. 489-496, February, 1985.