# Proposed Method for Determining Price Cap in the Korean Electricity Market Applicable to TWBP

**Dong-Joo Kang†, Young-Hwan Moon* and Balho H. Kim****

**Abstract** - This paper proposes the level of price cap in the TWBP(Two-Way Bidding Pool) market in Korea for which the draft of market design has been prepared by KPX. Max_GMCP(Maximum Generation Market Clearing Price) and APC(Administered Price Cap) would be separately applied as individual price caps for a normal period and a Price Capping period in TWBP. The level of price cap is determined for inducing optimal investment in the Korean Electricity Market considering the "electricity resource baseline plan" published by the Korean government in 2002 for maintaining government-leading resource planning in Korea. In this regard, Max_GMCP is calculated from the equilibrium condition of investment based on reliability standard and fixed cost of the peaking plant. For verifying the propriety of the proposed price cap, this paper compares the proposed value with the estimated VoLL(Value of Lost Load) based on Korea's GDP(Gross Domestic Product).

**Keywords**: APC, Max GMCP, price cap, VoLL

## 1. Introduction

Since the Korean Government unveiled "The Basic Plan for Restructuring of the Power Industry" in 1999, the Korean Electric Power Industry has been undergoing major restructuring. Consequently, the Cost Based Pool has been operated by the KPX (Korea Power Exchange) as of 2001, and market design of the Two Way Bidding Pool is coming to a close. According to market rules proposed for the TWBP, a price cap would be introduced to restrict the volatility of market pricing. Implementation of the price cap involves two phases, one is for normal dispatch periods and the other is for abnormal periods in which the market price has been kept too high. A price cap would not be necessary in an ideal market, but there have been inflexibilities on both the sides of producers and customers in the electricity market. Many generators have start-up and ramp-rate constraints, and few purchasers have the ability to control the amount of electricity they are taking from the wholesale market at any time. Furthermore supply and demand must be kept closely balanced at all times in order to protect the integrity and security of the power system. Thus the market operator needs to have the authority to cut off customer load when necessary [1]. Moreover, it has been accepted that a price cap is warranted in the early stages of the market to guard against the consequences of unmanageable risk. It is expected that price cap will be set by the Reliability Committee of the KEC(Korea Electricity Commission). However, it has been argued that too low a value of a price cap would deteriorate the overall level of system reliability through discouraging investment and encouraging mothballing. On the other hand, too high a value of price cap would increase risks and would probably result in over-investment in reserve plant and voluntary load interruption schemes [2]. This paper calculates the level of price caps for inducing optimal investment considering "electricity resource baseline plan" published by Korean government in 2002 for maintaining government- leading resource planning in Korea, and compares the result with the estimated VoLL based on Korean GDP. The proposed level of price cap and the used calculating method can be the guidance when the Reliability Committee of the KEC sets the Max_GMCP and APC, and periodically reviews these values.

† Corresponding Author: Electricity Market Research Group, KERI, (djkang@keri.re.kr)
* Electricity Market Research Group, KERI, (yhmoon@keri.re.kr)
** Dept. of Electrical and Electronic Engineering, Hong-ik University, Korea, (bhkim@hongik.ac.kr)
Received January 18, 2005 ; Accepted April 29, 2005

## 2. Price Caps in Electricity Market

### 2.1 Price cap design

Various forms of wholesale price cap regulations are noted in electricity markets around the world. Wholesale electricity price cap can be broadly summarized to fall into one of the following three categories [3,4].

- Hard price caps;
- Soft price caps; and

Bid caps.

### 2.1.1 Hard price caps: Australia, Singapore and Alberta

Hard price caps are regulatory-imposed maximum wholesale electricity prices that utilities or system operators will pay to generators.

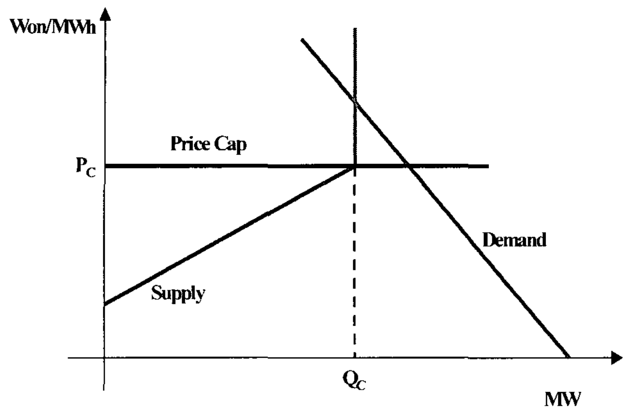



**Fig. 1** Hard Price Cap

The enforcement of hard price caps requires involuntary load curtailment during periods where supply is scarce.

### 2.1.2 Soft price caps: California

Soft price caps were introduced in California in December 2000 after hard caps increased the problem of scarcity in California in a couple of ways. In the Californian experience, the adoption of a soft price cap has been debated and is seen to raise current and forward electricity prices. Its enforcements remain a key issue where 'out of market' transfer or 'sale' can undermine any benefits.

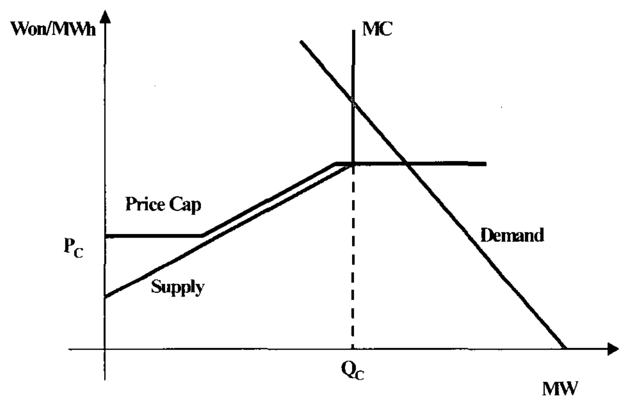



**Fig. 2** Soft Price Cap

### 2.1.3 Bid caps: New York, APX(AMSTERDAM), PJM, New England, ERCOT and Alberta

Bid caps are generator specific and are seen by some as compatible with a gradual transition to a workable competitive market and a more preferred way of market power mitigation as compared to the effects of hard price caps[5].

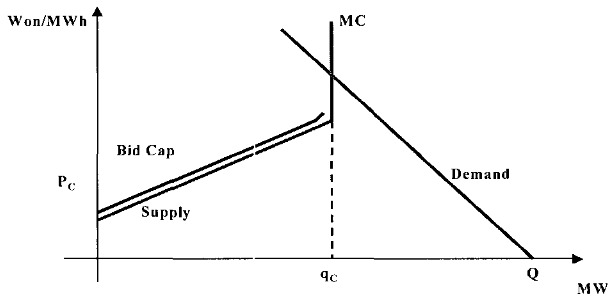



**Fig. 3** Bid Caps

## 2.2 The level of Price Caps in key electricity markets

Fig.4 summarizes the level of price caps of key electricity markets around the world.

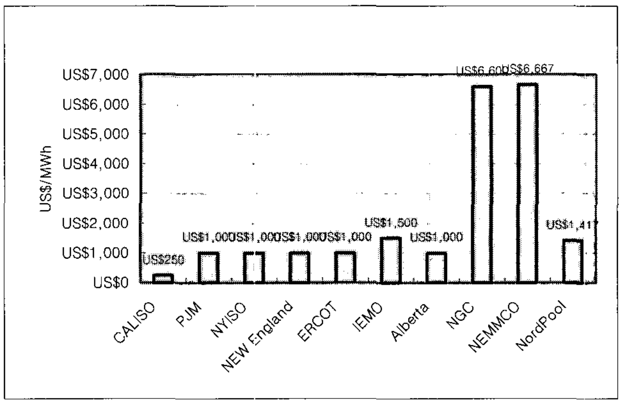



**Fig. 4** The price cap of key electricity markets

## 3. The Framework of Price Regulation in the TWBP

In the TWBP, the price cap would be introduced to restrict the instability of market pricing. This price cap is considered to be a hard price cap, and has two phases; one is for normal dispatch periods and the other is for abnormal periods where the market price has been kept too high. Fig.5 shows the outline of price regulation in the TWBP.

According to the market rules proposed for the TWBP, the GMCP which is the dispatch price for the reference node in the first dispatch period of an unconstrained dispatch schedule is equal to Max_GMCP if the dispatch price exceeds Max_GMCP. Moreover, if the arithmetic mean of the GMCP in the previous (12*24*7) dispatch periods, where 12 refers to the previous 12 dispatch periods, 24 refers to the number of hours in a day and 7 refers to seven days, exceeds the APT(Average Price Threshold), a dispatch period is to be a price capping period. During these price capping periods, the APC which is much lower than Max_GMCP is applied to the GMCP as a price cap. The dispatch period occurs in a trading day in which a prior dispatch period is a price capping period.

It is expected that the Reliability Committee of the KEC sets the Max_GMCP and APC including APT according to the market rules. This paper proposes the level of Max_GMCP.

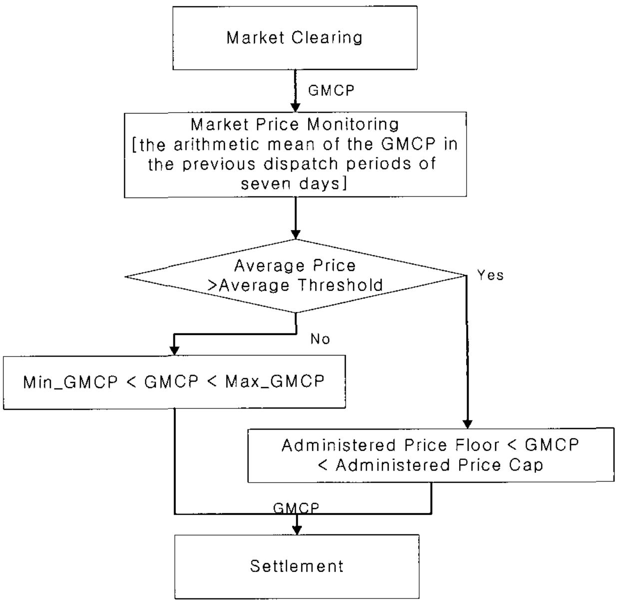



**Fig. 5** Comparison of price caps in the TWBP market

According to the market rules proposed for the TWBP, the GMCP, which is the dispatch price for the reference node in the first dispatch period of an unconstrained dispatch schedule, is equal to Max_GMCP if the dispatch price exceeds Max_GMCP. Moreover, if the arithmetic mean of the GMCP in the previous (12*24*7) dispatch periods, where 12 refers to the previous 12 dispatch periods, 24 refers to the number of hours in a day and 7 refers to seven days, exceeds the APT(Average Price Threshold), a dispatch period is to be a price capping period. During these price capping periods, the APC which is much lower than Max_GMCP is applied to GMCP as a price cap. The dispatch period occurs in a trading day in which a prior dispatch period is a price capping period.

It is expected that the Reliability Committee of the KEC sets the Max_GMCP and APC including APT according to the market rules. This paper proposes the level of Max_GMCP.

## 4. Max_GMCP Determination Based on the Condition of Optimal Investment

### 4.1 Considerations for setting Max_GMCP

A value for Max_GMCP is mathematically necessary to ensure that a GMCP can be set in the market when there is insufficient generation to meet non-scheduled load, and so the dispatch price is not well defined. However, it is also economically important to ensure a well-behaved and rational market during times of supply scarcity. There can be some issues like followings to consider when determining a value for Max_GMCP.

a) The value that consumers place on supply reliability and continuity; or, conversely, the cost to consumers of supply interruptions.
b) The level of supply reliability that is required by the Reliability Committee under the Power System Security and Reliability Standards(PSSRS)
c) The prudential and financial risks implied by the potential for extreme price outcomes.
d) The use of a price cap as a mechanism for mitigating generator market power.

The setting of Max_GMCP will be a trade off between the theoretical efficiency of maintaining required levels of supply reliability with KPX intervention and the practical impact of extreme and volatile prices on trading risks and market power. From this viewpoint of this view, VoLL (Value of Lost Load) has been recommended as the reasonable level of price cap; Max_GMCP because the system operator must purchase power on behalf of load when demand exceeds supply and instructs it to pay VoLL whenever some load has been sheded.

### 4.2 Market equilibrium

Fig.6 describes the relationship of market equilibrium. The core of that equilibrium process is the loop of casual links from the market through prices, investment, installed capacity and back to market. This circularity determines the long-term market equilibrium. If prices are high, investment will be encouraged, and installed capacity will increase. With more installed capacity, prices will fall. The system is in equilibrium if installed capacity, combined with exogenous factors, causes prices that are just profitable enough to cover the fixed cost of the installed capacity [6].

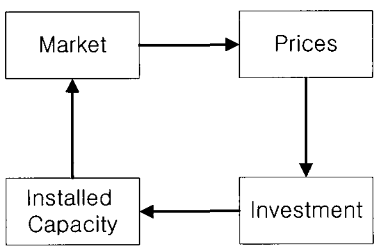



**Fig. 6** Relationship of market equilibrium

From the market equilibrium, the condition for optimal installed capacity can be described as follows.

$$VoLL * D = FC \qquad (1)$$

Where VoLL is Value of lost load, D is duration of lost load, and FC is fixed cost. From this condition VoLL can be calculated by FC/D.

### 4.3 Calculation of VoLL (unit : Won/kWh)

In this paper, VoLL is calculated from the condition for optimal installed capacity; VoLL=FC/D. For doing this, duration of lost load is taken from LOLP (Loss of Lost Probability); '0.5day/yr' applied in "the 1st electricity resource baseline plan" published by the Korean government in 2002 for maintaining government-leading resource planning in Korea. Generally, the fixed cost of a generating unit is calculated by the following equation.

$$FC = CC*\{r*(1+r)^n\}/\{(1+r)^n-1\} \qquad (2)$$

Where CC is capital cost of investment, r is discount rate, and n is generator lifetime(yr).

In the Korean electricity market, the Gas–Turbine generating unit is usually a marginal peaking unit. So, the fixed cost of the Gas –Turbine unit is used to calculate VoLL. Table 1 summarizes the cost information of the Gas–Turbine unit used to calculate the fixed cost.

**Table 1** Cost information of Gas–Turbine unit(300MW)

| Capital cost of investment | Fixed O&M | Generator lifetime | Discount rate |
|---|---|---|---|
| 300,000won/kW | 375won/kw-month | 30 years | 8% |

Based on the values of the duration of lost load, and fixed cost above, VoLL is calculated like follows.

$$VoLL = FC/D = 31{,}148[won/kW\text{-}yr]/12[hr/yr] = 2{,}596[won/kWh] = 2{,}163^1[US\$/MWh] \qquad (3)$$

In this paper, this VOLL is proposed as the level of Price Cap; Max_GMCP in TWBP.

## 5. Review of the Proposed Price Cap

According to the actual results of market(cost based Pool) operation published by KPX in 2002, the annual average of the marginal market price was about 47.35 [won/kWh]; 39.46[US$/MWh]. So the proposed level of price cap is as high as about 50 times of the annual average of marginal market price. This ratio is lower than that of the National Electricity Market in Australia which is about 300, and higher than that of electricity markets in the USA, which are about 20~40. Considering that the capacity reserve has been managed and will be maintained by the Korean government in at least the early stages of the TWBP at least, price cap should be set to stabilize electricity market rather than to induce new investment when the TWBP is opened. In addition, Korean price cap needs to have a great margin than that in the USA because there is only the energy spot market exists and market participants must recover all their costs from the energy spot market in the TWBP[7,8].

In addition to this, this paper compares the proposed price cap with the estimated value of VoLL based on the GDP. CRIEPI(Central Research Institute of the Electric Power Industry) has estimated the VoLL using this method in 1982, and 1987. In this method, VoLL was estimated by the following equation.

$$VoLL = GDP[\$]/\text{Sum of consumed electric power}[kWh] \qquad (4)$$

Table 2 presents the estimated VoLL based on this relation in Korea.

**Table 2** Estimated VoLL based on Korean GDP

| Year | GDP ($*10^9$ won) | Electric Power sold(GWh) | Estimated VoLL (won/kWh) |
|---|---|---|---|
| 1991 | 216,511 | 104,374 | 2,074 |
| 1992 | 245,700 | 115,243 | 2,132 |
| 1993 | 277,497 | 127,733 | 2,172 |
| 1994 | 323,407 | 146,540 | 2,207 |
| 1995 | 377,350 | 163,270 | 2,311 |
| 1996 | 418,479 | 182,470 | 2,293 |
| 1997 | 453,276 | 200,783 | 2,258 |
| 1998 | 444,367 | 193,470 | 2,297 |
| 1999 | 482,744 | 214,214 | 2,254 |
| 2000 | 521,959 | 239,535 | 2,179 |
| 2001 | 551,558 | 257,731 | 2,140 |

From the results of Table 2, the level of VoLL is estimated to be about 2,000~3,000[won/kWh], and this level corresponds to the proposed value of Max_GMCP in this paper.

## 6. Conclusion

This paper calculated VoLL from the condition for optimal investment in the electricity market, and proposes this as the level of Max_GMCP which will be introduced into the Korean electricity market as a price cap when the TWBP is opened. This paper also verified the proposed level of Max_GMCP by comparing it with the estimated

[1] 1,200won/US$

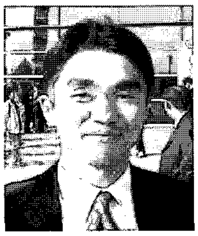
VoLL based on Korean GDP. Price cap is a very strong mechanism to regulate market price, and it has a direct effect on reliability and risks in the electricity market, so its level must be set considering various timely statuses of the electricity market, and reliability policy of the regulator etc. Therefore, it is very important to periodically review the level of price cap. The proposed level of price cap and the used calculating method used in this paper can act as guidelines for this.

## Acknowledgements

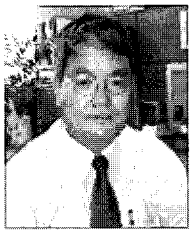
This work was sponsored by KPX(Korea Power Exchange).

## References

[1] "Proposed Market Rules for Two-Way Bidding Pool in Korea", KPX, March 2003.
[2] Steven Stoft, "Power System Economics", IEEE Press, 2002.
[3] "International Experience with Wholesale Electricity Price Cap Regulation", CRA, July 2003.
[4] "Review of VoLL in the National Electricity Market - Issue Paper", NECA, September 2003.
[5] "Review of VoLL in the National Electricity Market - Final Report", NECA, July 1999.
[6] "National Electricity Code", NEMMCO, 2003
[7] "Actual result of market operation in 2002", KEC, January 2003.
[8] "Market Price Caps in TWBP–Guidelines for Determination", IBM, April 2003



**Dong-Joo Kang**
He received his B.S. and M.S. degrees in Electrical Engineering from Hongik University, Korea in 1999 and 2001, respectively. He has been with KERI since 2001. His interests include analysis of power industry restructuring, game theoretic analysis to power transactions, and development of an electricity market simulator. He is a Member of KIEE.



**Young-Hwan Moon**
He received his B.S. and M.S. degrees from Seoul National University, Korea in 1979 and 1981, respectively, and his Ph.D. degree from the University of Texas at Arlington in 1990, all in Electrical Engineering. He has been with KERI since 1981 where he now holds the position of Principal Research Engineer. His interests include modeling of power systems, application of power system stabilizers, and control of HVDC transmission. He is a member of IEEE and Tau Beta Pi.

**Balho H. Kim**
He received his B.S. degree from Seoul National University, Korea in 1984, and his M.S. and Ph.D degrees from The University of Texas at Austin in 1992 and 1996, respectively. He was with KEPCO between 1984 and 1990, and joined Hongik University in 1997. His research fields include Distributed Optimal Power Flow, Public Pricing, B/C Analysis, and Power System Planning & Operation.

## GENERAL MANUSCRIPT PREPARATION

*A. Typing Specifications*

Manuscripts should be typed double spaced on one side of a sheet only, with margins of about 2.5 cm on each side of each page.

*B. Consecutive Numbering of Parts*

All manuscript pages, footnotes, equations, and refer-ences should be labeled in consecutive numerical order. Illustrations and tables should be cited in text in numer-ical order.

*C. Manuscript Formats*

Full length papers generally consist of the title, byline, author affiliation, footnote (including any financial support acknowledgment), index terms, abstract, nomenclature if present, introduction, body, conclusions, reference list, list of figures and table captions, and original figures and tables for reproduction. A paper may also include appendixes, a glossary of symbols, and an acknowledgment of nonfinancial support.

*D. Abstract*

The abstract should be limited to 50–200 words and should concisely state what was done, how it was done, principal results, and their significance. The abstract will appear later in various abstracts journals and should contain the most critical information of the paper.

*E. References*

A numbered list of references must be provided at the end of the paper as a separate page or pages of the manuscript. The list should be arranged in the order of citation in text, not in alphabetical order. List only one reference per reference number.

Each reference number should be enclosed by square brackets. In text, citations of references may be given simply as "in [1] . . . ", rather than as "in reference [1] . . . ". Similarly, it is not necessary to mention the authors of a reference unless the mention is relevant to the text. It is almost never useful to give dates of references in text. These will usually be deleted by Staff Editors if included.

Footnotes or other words and phrases that are not part of the reference format do not belong on the reference list. Phrases such as "For example," should not introduce references in the list, but should instead be given in parentheses in text, followed by the reference number, i.e., "For example, see [5]."

Sample correct formats for various types of references are as follows.

*Books:*

[1] G. O. Young, "Synthetic structure of industrial plastics," in *Plastics*, 2nd ed., vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.

[2] W.-K. Chen, *Linear Networks and Systems*. Belmont, CA: Wadsworth, 1993, pp. 123–135.

*Periodicals:*

[3] J. U. Duncombe, "Infrared navigation—Part I: An assessment of feasibility," *IEEE Trans. Electron Devices*, vol. ED-11, pp. 34–39, Jan. 1959.

[4] E. P. Wigner, "Theory of traveling-wave optical laser," *Phys. Rev.*, vol. 134, pp. A635–A646, Dec. 1965.

[5] E. H. Miller, "A note on reflector arrays," *IEEE Trans. Antennas Propagat.*, to be published.

*Articles from Conference Proceedings (published):*

[6] D. B. Payne and J. R. Stern, "Wavelength-switched passively coupled single-mode optical network," in *Proc. IOOC-ECOC*, 1985, pp. 585–590.

*Papers Presented at Conferences (unpublished):*

[7] D. Ebehard and E. Voges, "Digital single sideband detection for interferometric sensors," presented at the 2nd Int. Conf. Optical Fiber Sensors, Stuttgart, Germany, 1984.

*Standards /Patents:*

[8] G. Brandli and M. Dick, "Alternating current fed power supply," U.S. Patent 4 084 217, Nov. 4, 1978.

*Technical Reports:*

[9] E. E. Reber, R. L. Mitchell, and C.J.Carter,"Oxygen absorption in the Earth's atmosphere," Aerospace Corp., Los Angeles, CA, Tech. Rep. TR-0200 (4230-46)-3, Nov. 1968.

*F. Figures, Tables, and Captions List*

All graphics should be submitted as separate items from the body of your paper on separate sheets of paper or on disk. KIEE Transactions/Journals Department does not provide drafting or art services. Thus, the better the quality of the material submitted, the better the published result.

*G. Section Headings*

Primary section headings within papers are enume-rated by Roman numerals and are centered above the text. For the purpose of typing them manuscript only, primary headings should be capital letters. Sample:

## I. PRIMARY HEADING

(TEXT)

Secondary section headings are enumerated by capital letters followed by periods ("A.", "B.", etc.) and are flush left above their sections. The first letter of each word is capitalized. In print the headings will be in italics. Sample:

### *A. Secondary Heading*

(TEXT)

Tertiary section headings are enumerated by Arabic numerals followed by a parenthesis. They are indented, run into the text in their sections, and are followed by a colon. The first letter of each important word is capital-ized. Sample:

*1) Tertiary Heading:* (TEXT)

Quaternary section headings are rarely necessary but are perfectly acceptable if required. They are identical to tertiary headings except that lowercase letters are used as labels and only the first letter of the heading is capital-ized. Sample:

*a) Quaternary heading:* (TEXT)

Enumeration of section headings is often desirable, but is not a requirement. If an author does choose to enumerate section headings, then ALL levels of section headings in the paper should be enumerated. Similarly, if section headings are not to be enumerated, the choice should be consistent for all headings in the paper. In either case, the remaining style rules for each level of section heading should be followed.

### *I. Mathematical Notation*

To avoid errors in editing and typesetting, authors should clearly identify subscripts, superscripts, Greek letters, and other symbols. Add margin notes or other explanations wherever necessary. It is especially important to distinguish clearly between the following terms.

a) Capital and lowercase letters when used as symbols.
b) Zero and the letter "O."
c) The lowercase letter "l," and numeral one (1), and prime sign (′ ).
d) The letters "k" and κ (kappa), "u" and μ (mu), "v" and ν (nu), and "n" and η (eta).

A wavy line under a character or letter indicates boldface type. (Bold type should be indicated for certain vectors and matrices.)

A straight line under a character or letter indicates italic type. (Italic type should be indicated for all text variables.)

Avoid ambiguities in equations and fractions in text through careful use of parentheses, brackets, solidi (slants), etc. Note that in text, fractions are usually "broken down" to fit on one line and confusion can result if terms are not properly labeled. The convention nal order of brackets is {[()]}.

For simplicity in international usage, KIEE practice is to separate numbers of more than four digits into groups of three on either side of the decimal point, separated by a space. If the magnitude of a number is less than zero, the decimal sign should be preceded by a zero. Examples:

12 531 7465 9.2163 0.102 834

Use of the multidot (·) rather than the multi when multiplying by powers of ten in equations or text is at the author's discretion.

### *H. Units and Abbreviations*

The International System of Units (SI units) is advocated for use in KIEE publications. Unit symbols should be used with measured quantities, i.e., 1 mm, but not when unit names are used in text without quantities, i.e., "a few millimeters."

Acronyms and abbreviations should be defined the first time they are used in text.