Fuzzy Fault Currents: Theory and Applications

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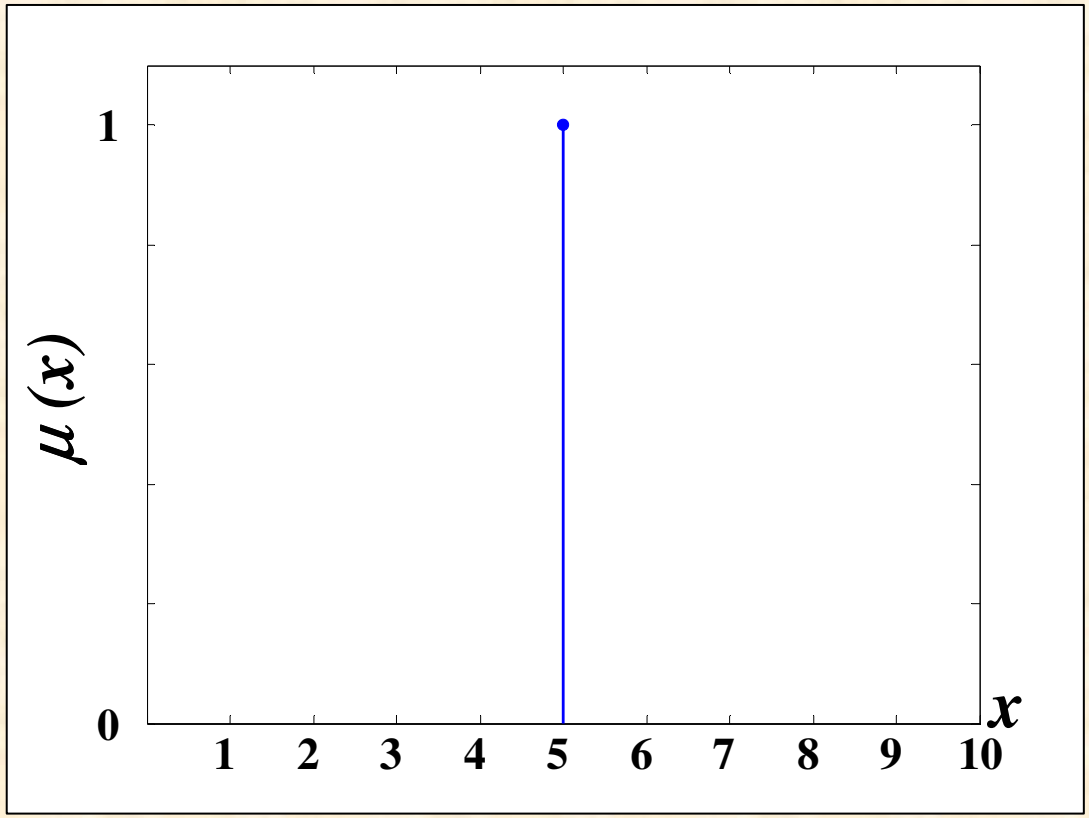
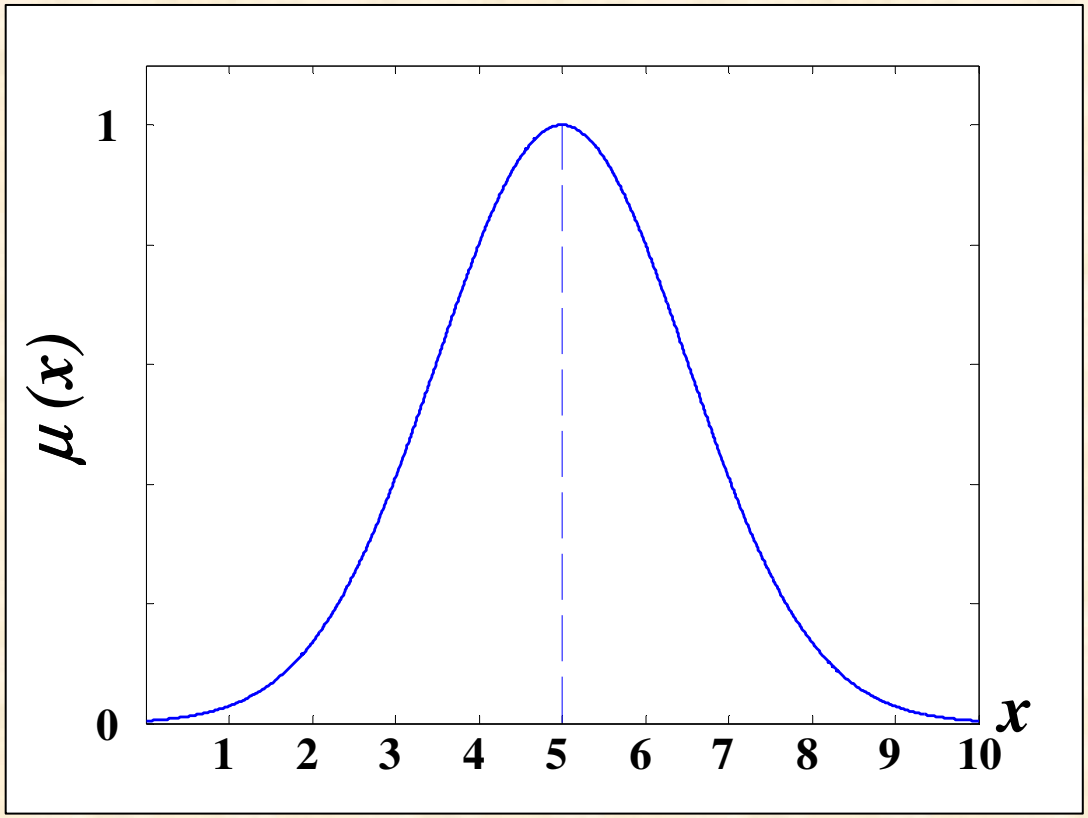
CRISP NUMBER

$$\mu_A(x) = \begin{cases} 1 \ \ if \ \ x \in A \\ 0 \ \ if \ \ x \notin A \end{cases}$$



TYPE-1 FUZZY NUMBER

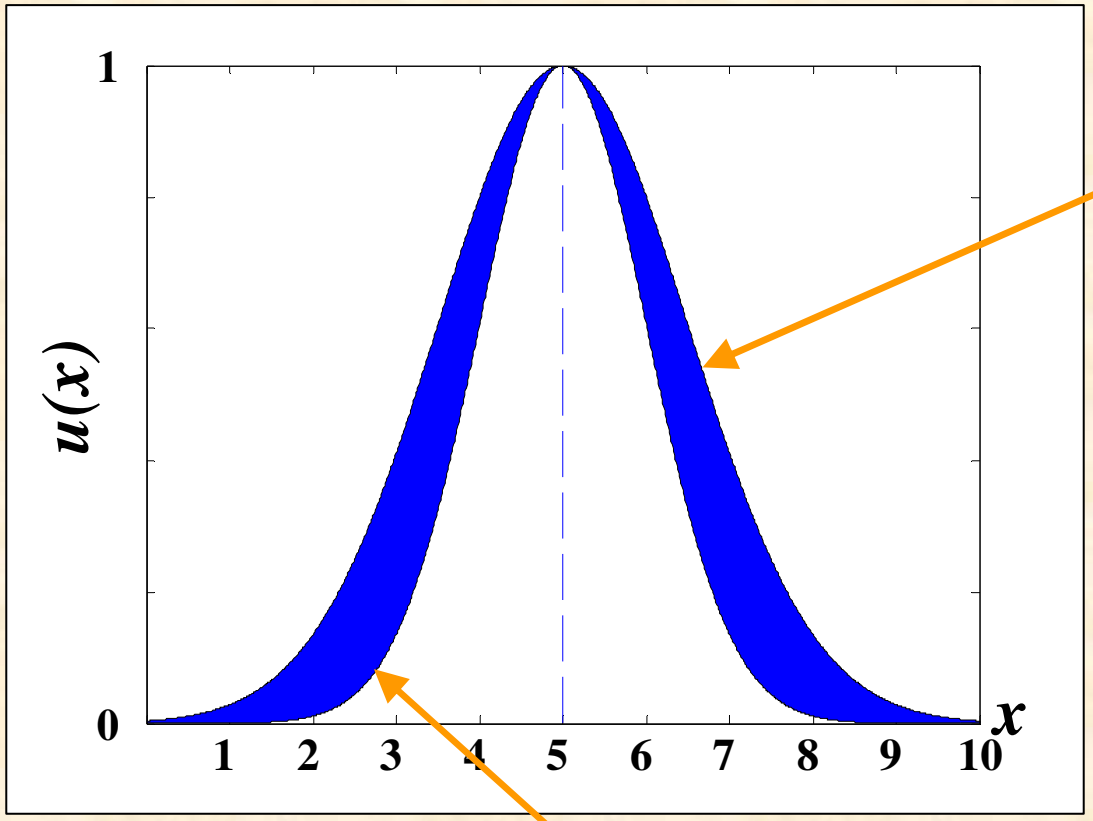
$$A = \int_{x \in X} \frac{\mu_A(x)}{x}$$



TYPE-2 FUZZY NUMBER

Upper membership function

$$\bar{\mu}_A(x)$$



$$\tilde{A} = \int_{x \in X} \frac{\mu_{\tilde{A}}(x)}{x}$$

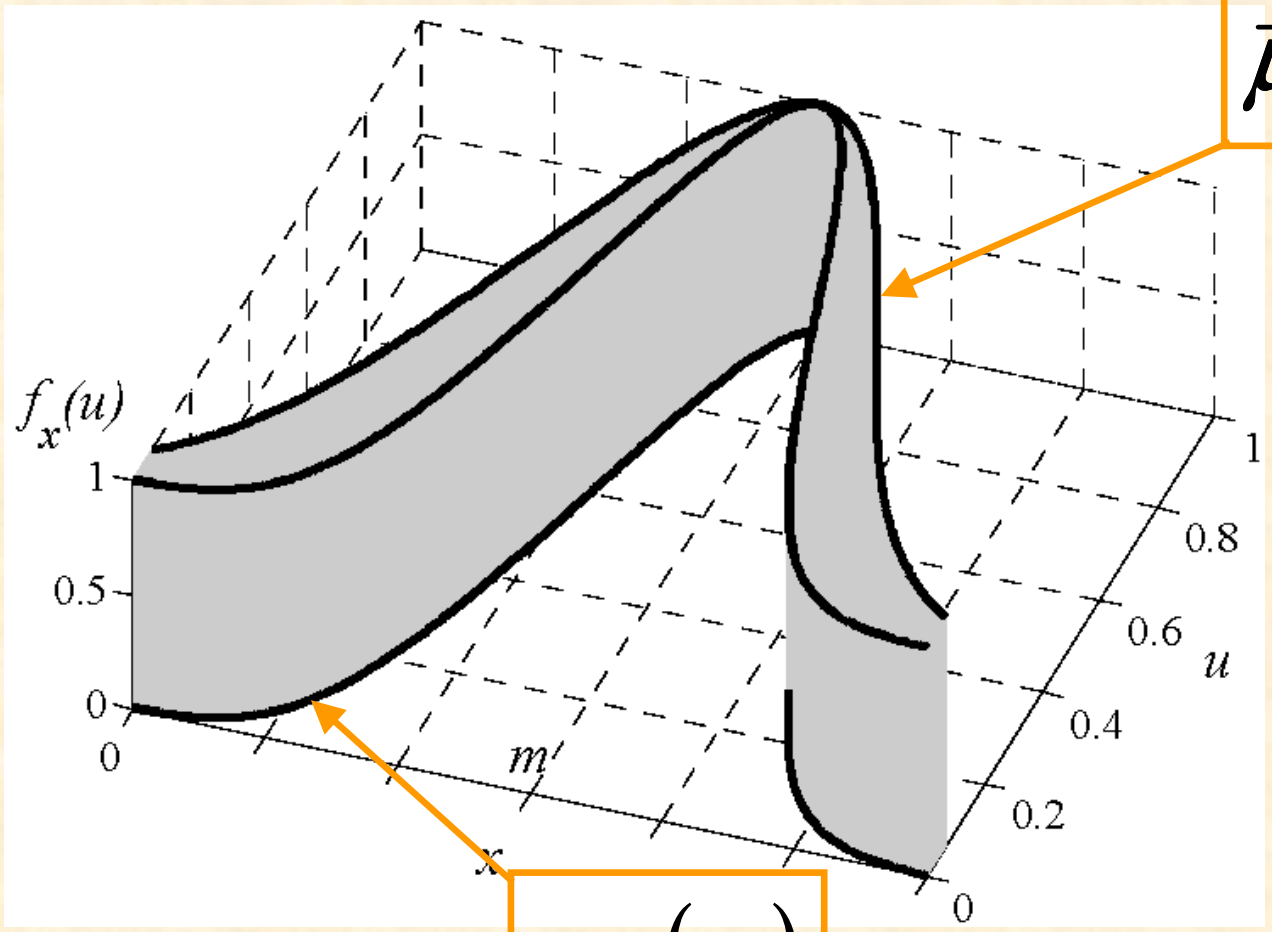
$$\underline{\mu}_A(x)$$

Lower membership function

INTERVAL TYPE-2 FUZZY NUMBER

Upper membership function

$\bar{\mu}_A(x)$



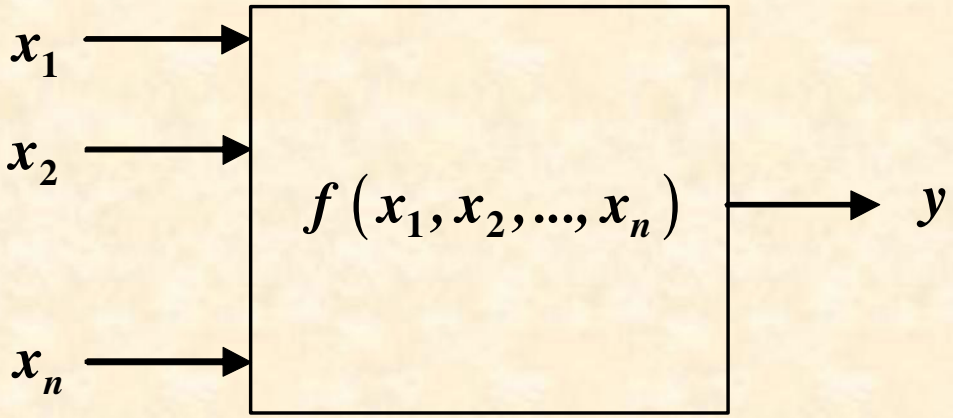
$\underline{\mu}_A(x)$

Lower membership function

$$\tilde{A} = \int_{x \in X} \frac{\mu_{\tilde{A}}(x)}{x}$$

FUZZY EXTENSION PRINCIPLE

Mathematical tool for calculating functions of fuzzy variables



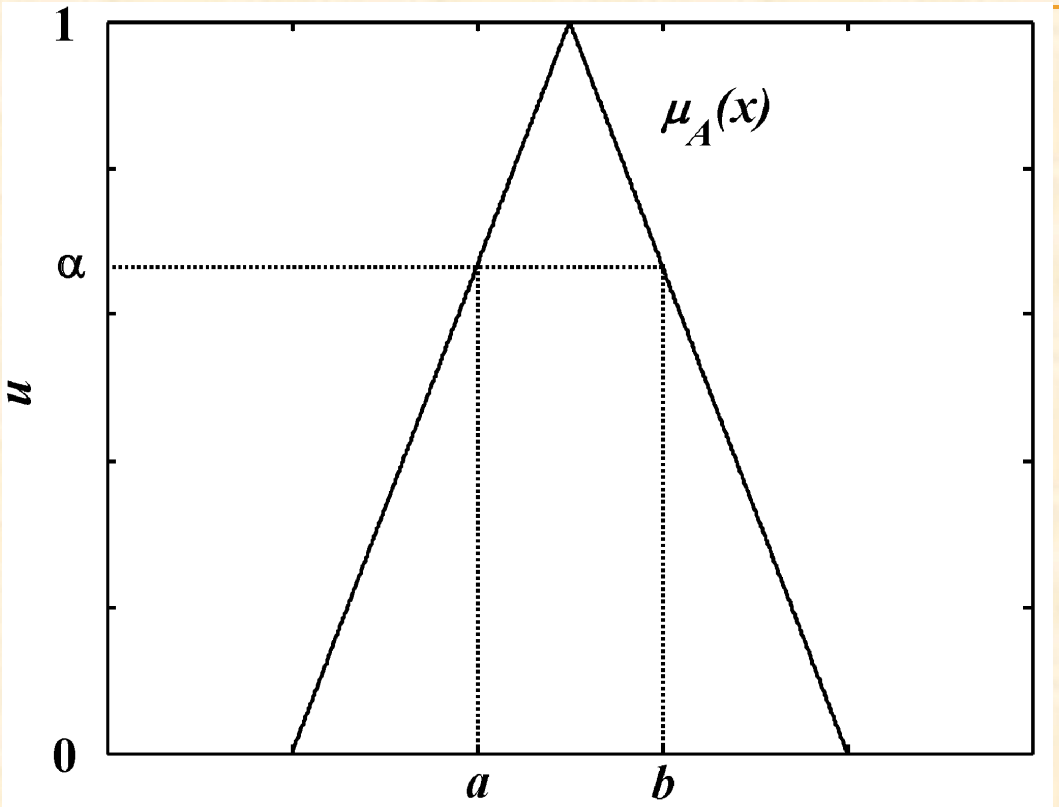
For type-1 fuzzy numbers:

The fuzzy extension principle is implemented by using the vertex method

For interval type-2 fuzzy numbers:

The fuzzy extension principle is implemented by using the vertex method and performing calculations only with the upper and lower membership functions

VERTEX METHOD



$$r = 2$$

$$c_1 = (a_1, b_1)$$

$$c_2 = (a_1, b_2)$$

$$c_3 = (a_2, b_1)$$

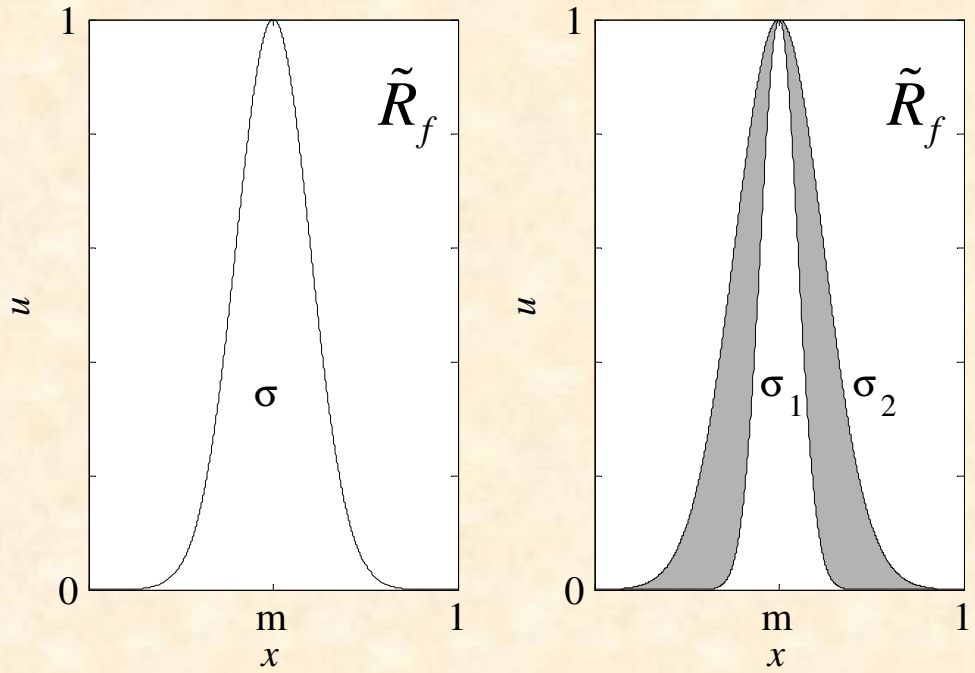
$$c_4 = (a_2, b_2)$$

$$I_{i\alpha} = [a_i, b_i], \quad i = 1, 2, \ldots r \qquad N = 2^r, \quad j = 1, 2, \ldots, N$$

$$B_\alpha = f(I_{1\alpha}, I_{2\alpha}, \ldots, I_{r\alpha}) = \left[\min_j \left(f(c_j) \right), \max_j \left(f(c_j) \right) \right]$$

FUZZY FAULT CURRENTS (FFC)

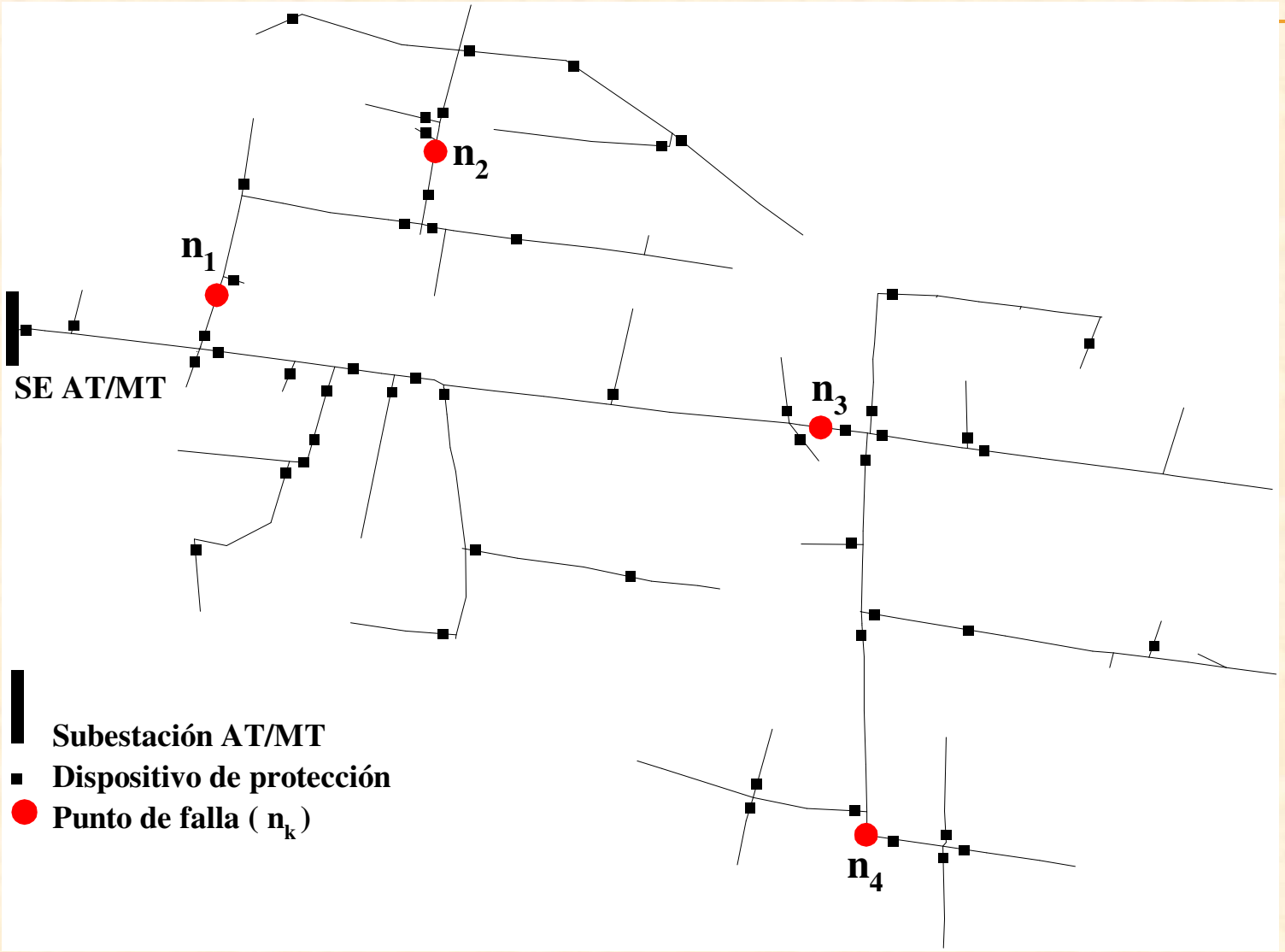
R_f and U_{pf} are modelled as type-1 or interval type-2 fuzzy numbers



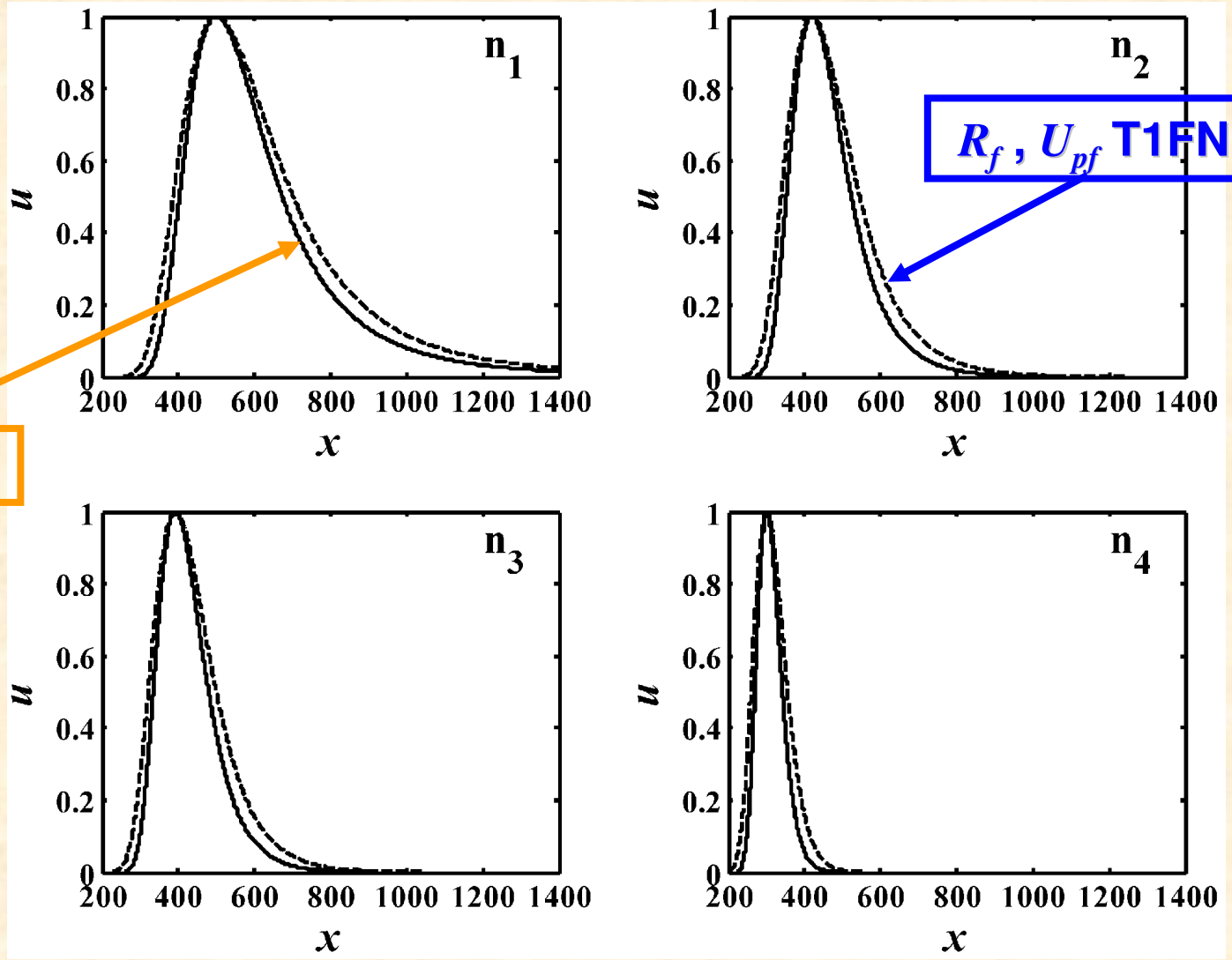
Then the fuzzy extension principle and vertex method are used to calculate fault currents using classical fault equations

$$I_{fk} = 3U_{pfk} \Big/ \sqrt{\left(2R_k^+ + R_k^0 + 3R_f\right)^2 + \left(2X_k^+ + X_k^0\right)^2}$$

RESULTS


n2
n1
SE AT/MT
n3
n4
Subestación AT/MT
Dispositivo de protección
Punto de falla (nk)

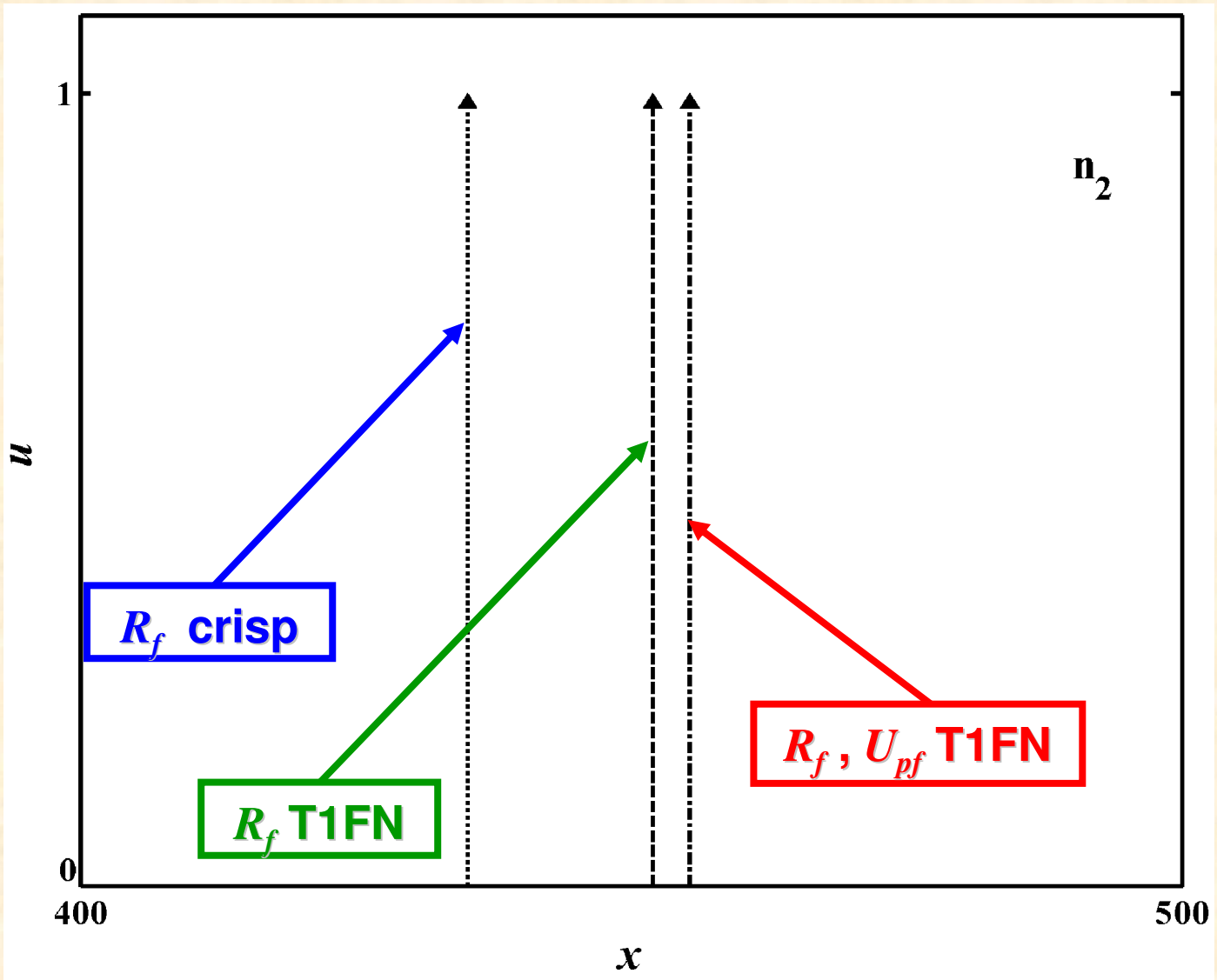
TYPE-1 FUZZY FAULT CURRENTS



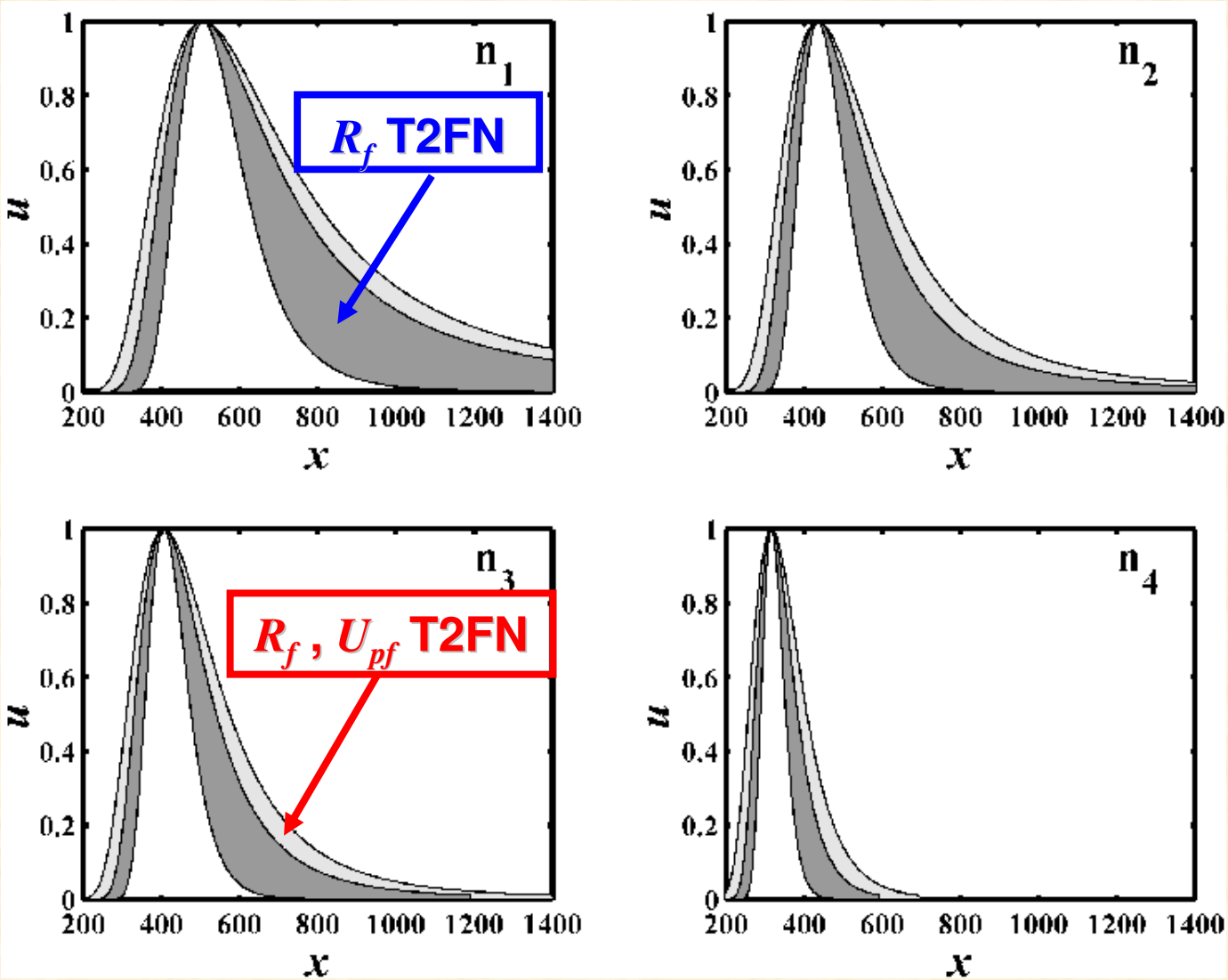
R_f T1FN

R_f , U_{pf} T1FN

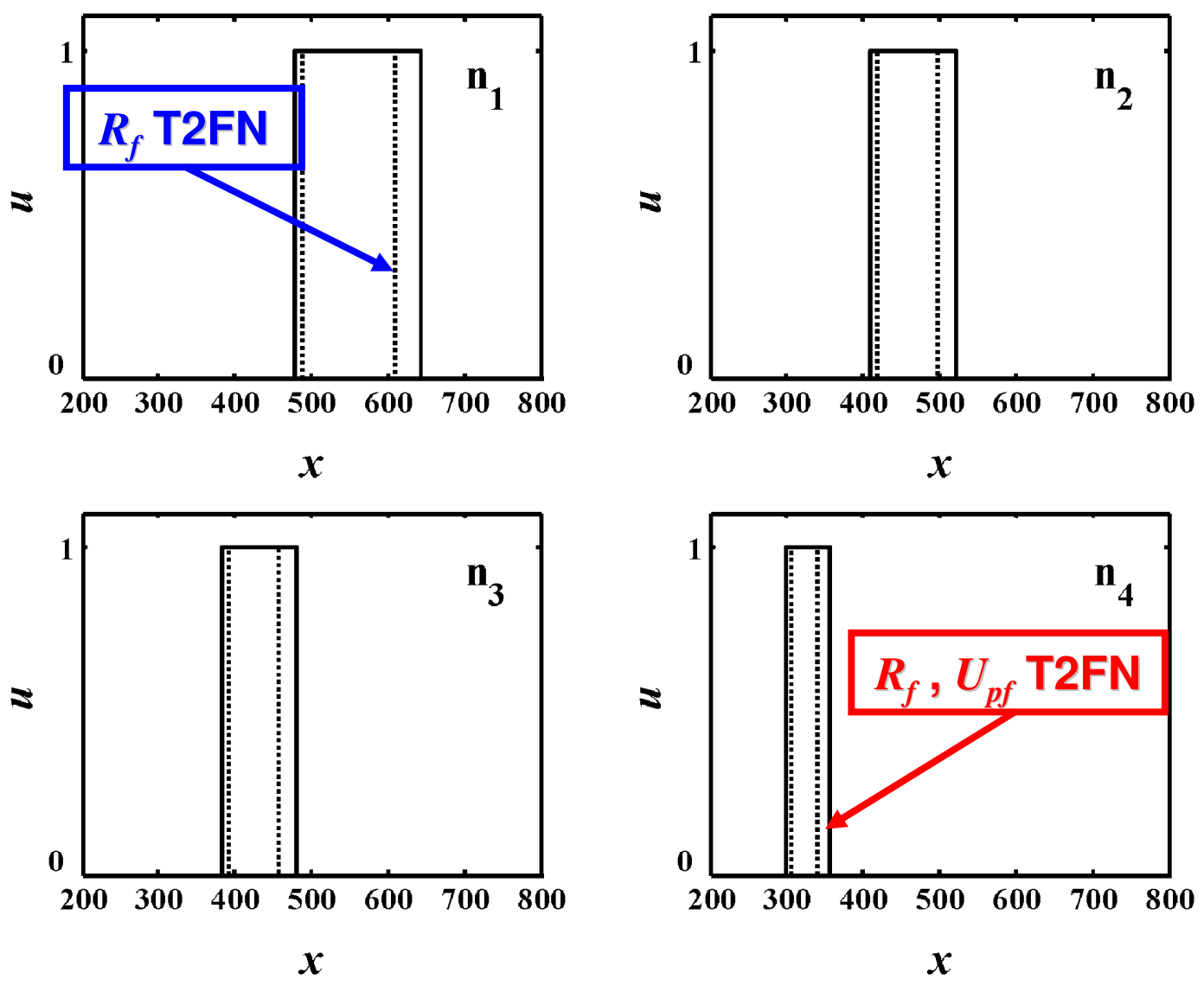
DEFUZZIFIED VALUES (TYPE-1 FFC)



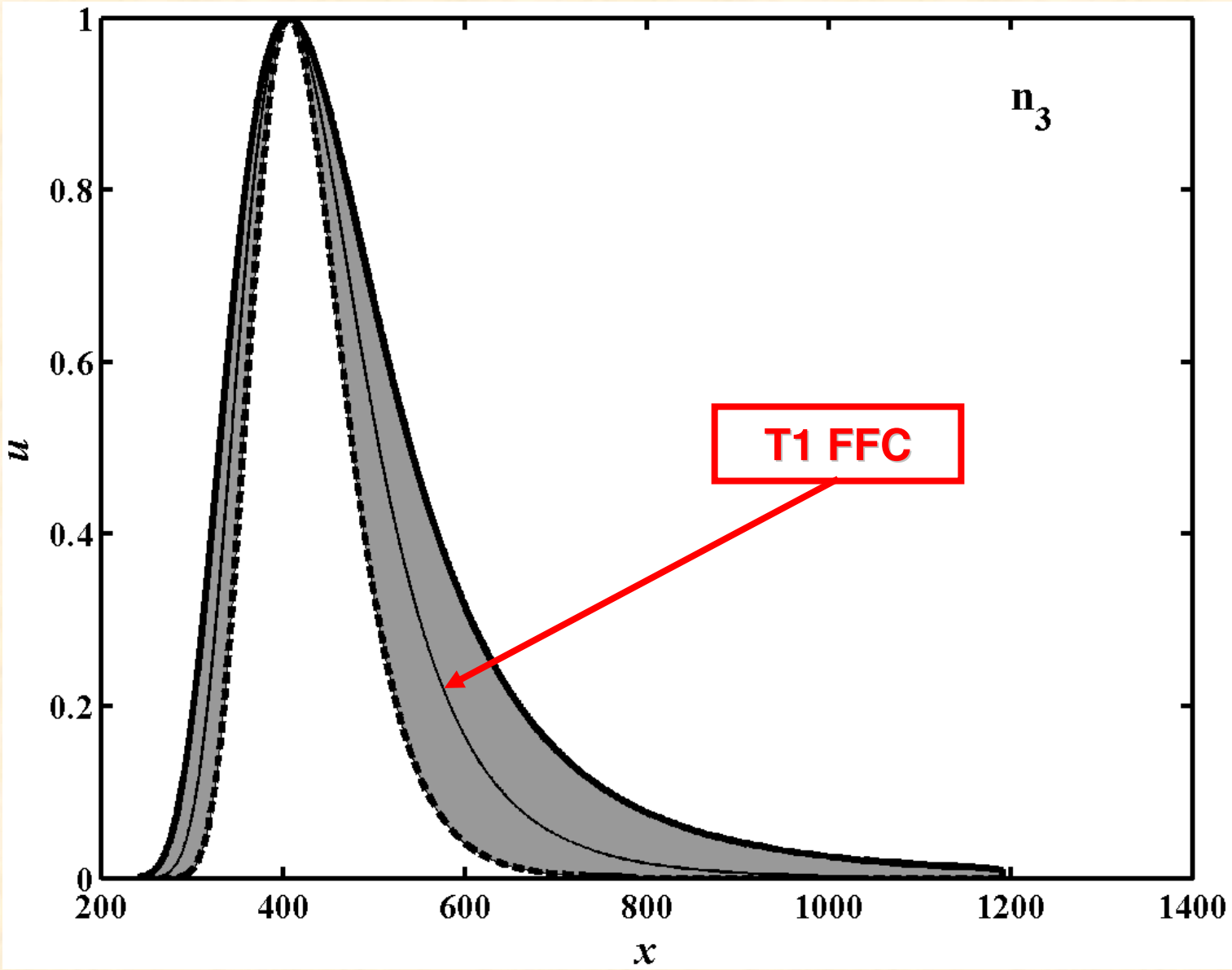
TYPE-2 FUZZY FAULT CURRENTS



CENTROIDS (TYPE-2 FFC)



COMPARISSON BETWEEN TYPE-1 AND TYPE-2 FFC



COMPARISON BETWEEN CRISP, TYPE-1 AND TYPE-2 FFC