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Title of Thesis: **STABILITY ENHANCEMENT OF MULTI-MACHINE POWER SYSTEMS
BY HYBRID NEURAL FUZZY-LOGIC CONTROL**

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ABSTRACT

This thesis presents a hybrid modeling technique for designing intelligent controllers for multimachine power systems using artificial neural networks (ANNs) and fuzzy logic (FL). ANNs are unstructured numerical estimators that can learn, generalize and adapt. FL is a structured representation of knowledge. An ANN–FL controller is designed in Chapter 5 for speed–tracking control of a DC motor. Simulation studies have shown that the newly–designed ANN–FL controller outperforms fixed parameter PID control when the DC motor experiences a load or a reference speed change.

This technique is then utilized to design supplementary excitation control for a two–machine infinite–bus power system. Two ANN–FL power system stabilizers (PSSs), one using speed deviation as input and the other using accelerating power, are designed. As ANN–FL PSSs have no dynamics themselves, and require only simple algorithms, they respond instantly to changes in the state variables and are robust to changes in the operating conditions. This research has led to an innovative design technique for supplementary excitation control of synchronous generators. An ANN–FL PSS synthesized using this technique can be employed on different generators without customized design.

Finally, an innovation to programming transient simulation has been achieved in this research. Difficulties in handling generator saliencies have been overcome in designing a simulation algorithm implemented by using the Transient Stability Simulation Package (TSSP) under SIMULINK.

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LIST OF PRINCIPAL SYMBOLS

Rotor angles of synchronous generators are with reference to the infinite-bus synchronous frame. Parameters of transmission lines are in per unit (pu) based on the system base 100 MVA. Machine impedance is in per unit based on its own rated capacity. All time constants are in seconds. Machine inertial H is also in seconds based on the machine capacity.

Abbreviations:

deg	= degree
rad	= radian
s	= second
ANN	= Artificial Neural Network
AI	= Artificial Intelligence
FL	= Fuzzy Logic
PR	= Probabilistic Reasoning
AVR	= Automatic Voltage Regulator and Exciter
AGC	= Automatic Generation Control
CPSS	= Conventional Power System Stabilizer
STC	= Self-Tuning Control
MRAC	= Model Reference Adaptive Control
RLS	= Recursive Least Squares
CMAC	= Cerebeelar Model Arithmetic Computer
ATO	= Automatic Train Operation at Sandai, Japan
FFT	= Fast Fourier Transform
G	= Generator
DC	= Direct Current

AC	= Alternating Current
PID	= Proportional, Integral, and Derivative
PE	= Processor/Processing Element
HVDC	= High Voltage Direct Current
A/D	= Analog/Digital
D/A	= Digital/Analog
RAM	= Random Access Memory
DSP	= Digital Signal Processing
TGR	= Transient Gain Reduction
TSSP	= Transient Stability Simulation Package
FDLF	= Fast Decoupled Load Flow
STCC	= Short Circuit Calculation
WPLOT	= Plotting Program

Symbols:

\rightarrow	= mapping
\int	= fuzzy union(continuous), integral
\sum	= fuzzy union(discrete)
$\cup, \cap, -$	= union, intersection, complement, respectively
\in	= belong to
δ	= machine rotor angle (radian or degree), propagation error
ω	= machine angular speed
ω_0	= synchronous speed (rad/s)
η	= learning rate
ϕ	= activation function
θ	= threshold, mechanical angle
E	= voltage, error function

e	= error function
E'	= voltage behind transient reactance
E''	= subtransient voltage
f	= frequency
i, I	= current
P, Q	= active and reactive power
v, V	= voltage
H	= machine inertial constant (s)
k	= saturation factor
K	= gain of transfer function
D	= machine damping coefficient
τ, T	= time constant
t	= target output
ϕ	= flux
x	= reactance, input to neural network
R	= resistance
T	= torque, term set
\underline{X}	= fuzzy set
U	= universe of discourse
μ_x	= membership function
α	= firing strength
u	= control variable
v	= net internal activation
L	= Laplace transform
A, B	= label of membership function

Superscripts:

- ' = transient
- “ = subtransient
- (0) = unsaturated value
- l = layer

Subscripts:

- a = armature
- e = electrical
- m = mechanical
- D, Q , or
- d, q = direct and quadrature axes
- l = leakage, power losses
- t, T = terminal
- s = supplementary signal
- f, fd = field
- i, j = index
- ref = reference
- err = error
- min = minimum
- max = maximum
- o = open circuit, initial value
- p = pattern, product
- ad, aq = mutual
- x, y = x and y coordinates
- w = washout, weight
- 0 = initial value

Operators:

\wedge = intersection

\oplus = bounded product

\cap = drastic product

$x \cdot y$ = algebraic product

\bullet = fuzzy composition

Δ = small change

\sum = summation

\times = multiplication

\parallel = parallel

s = Laplace operator