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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

$\delta$ = machine rotor angle (radian or degree), propagation error

$\omega$ = machine angular speed

$\omega_0$ = synchronous speed (rad/s)

$\eta$ = learning rate

$\varphi$ = activation function

$\theta$ = 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

$\tau, T$ = time constant

$t$ = target output

$\phi$ = flux

$x$ = reactance, input to neural network

$R$ = resistance

$T$ = torque, term set

$\underline{X}$ = fuzzy set

$U$ = universe of discourse

$\mu_x$ = membership function

$\alpha$ = 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

$\Delta$ = small change

$\sum$ = summation

$\times$ = multiplication

|| = parallel

$s$ = Laplace operator