# DESIGN AND IMPLEMENTATION OF A FUZZY LOGIC-BASED VOLTAGE CONTROLLER FOR VOLTAGE REGULATION OF A SYNCHRONOUS GENERATOR

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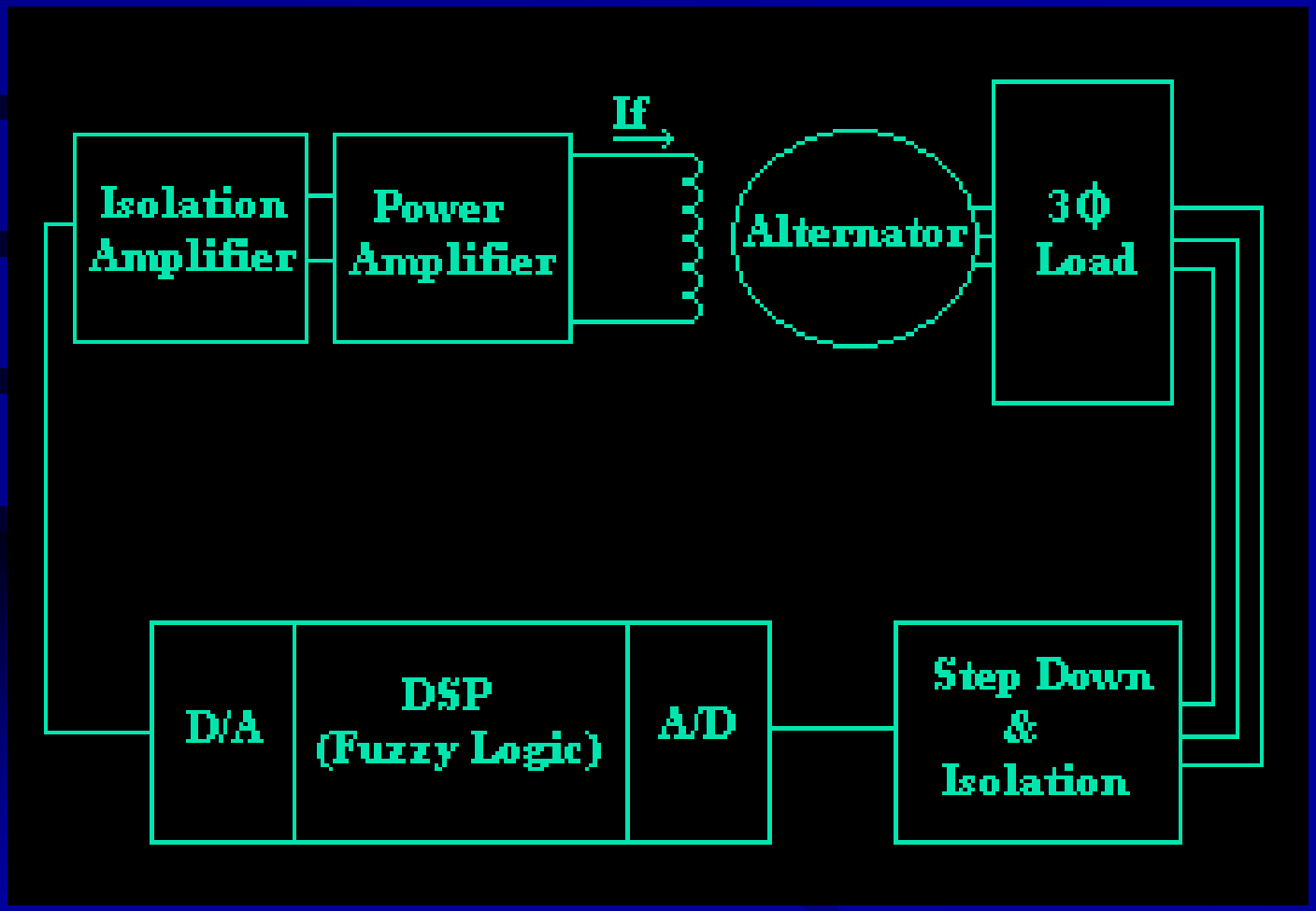
# Project Statement

- To develop an automated fuzzy logic controller to regulate the output voltage of a synchronous generator under varying loads.

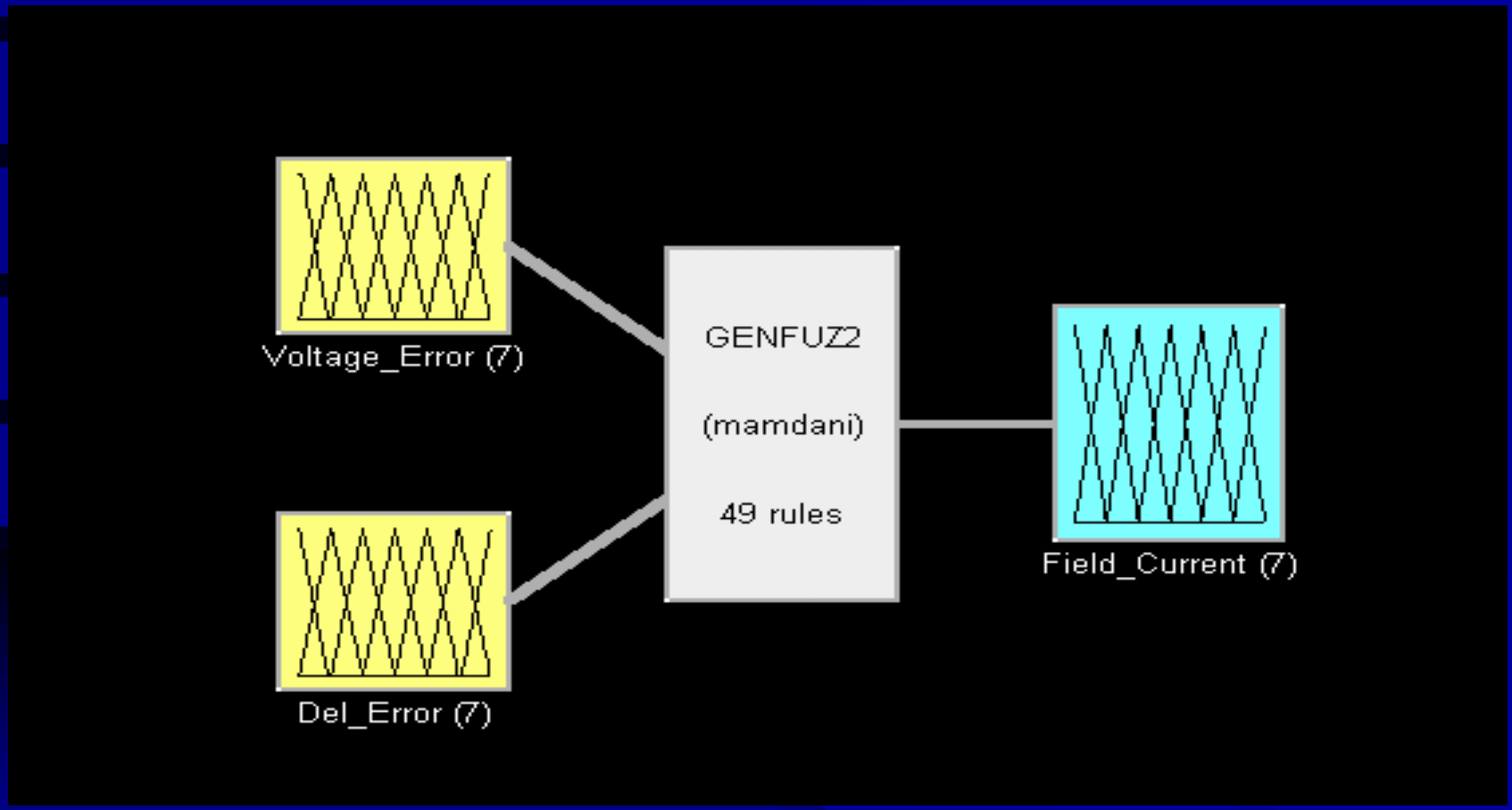
# Fuzzy Logic Control of a Synchronous Generator



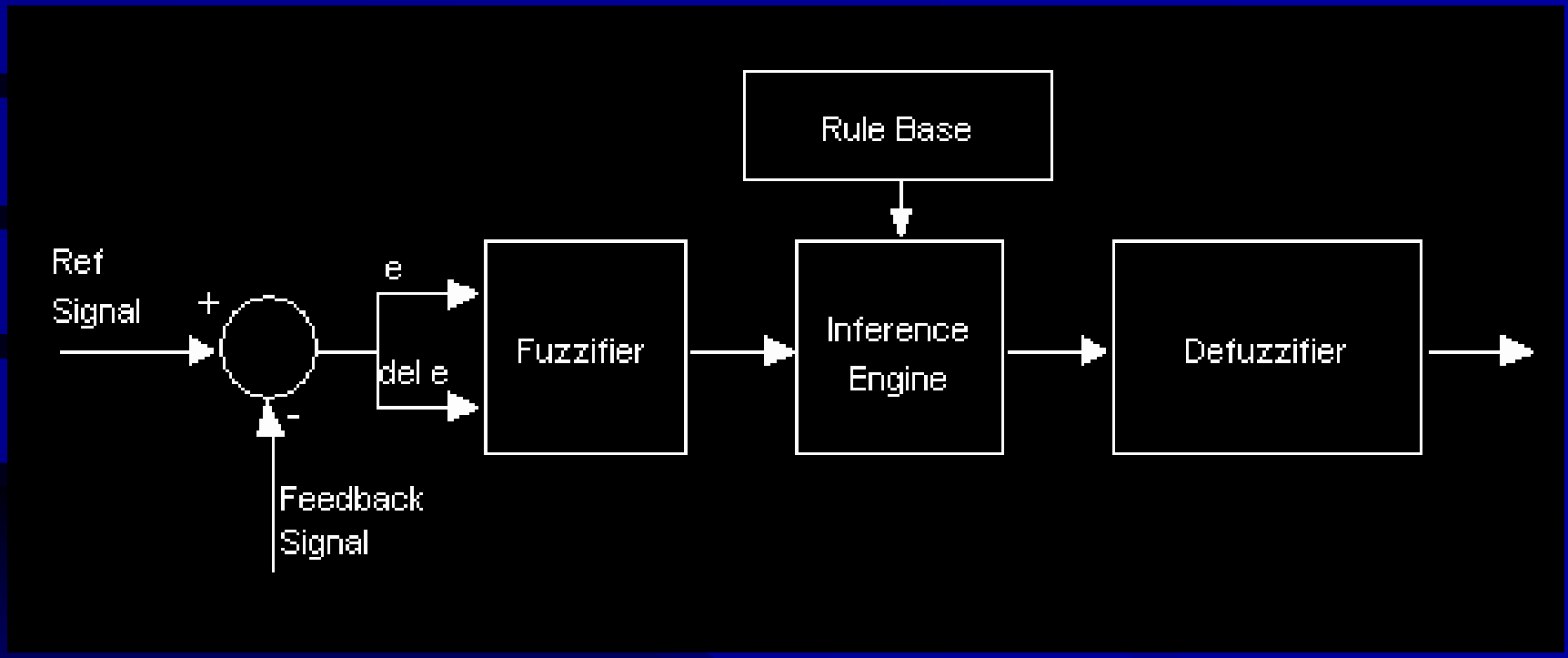
# Fuzzy Logic Controller

- This will increase or decrease the field current of the synchronous generator depending on the:
  - Voltage Error
  - Rate of Change of Voltage Error

# Fuzzy Logic Controller



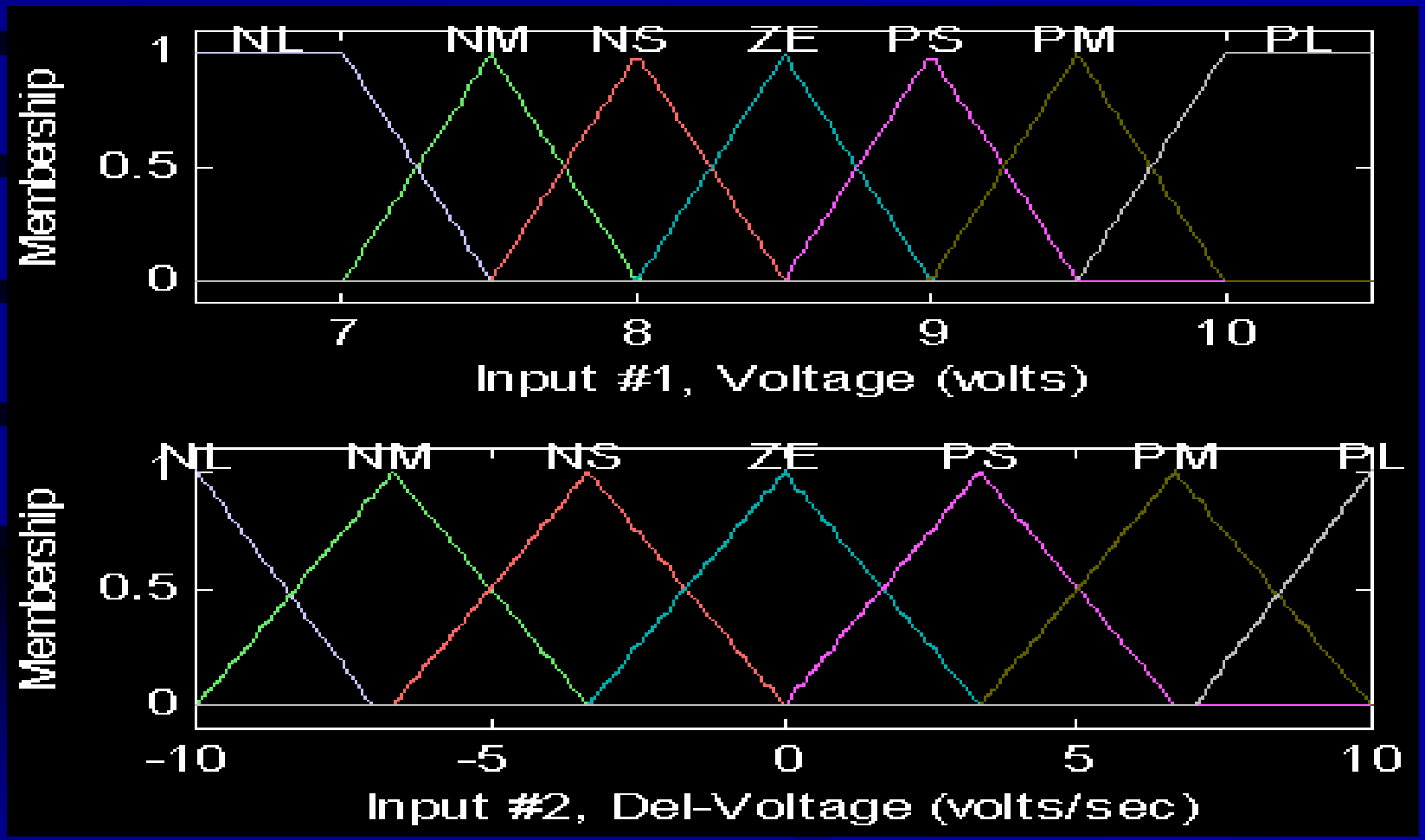
# Fuzzy Logic Strategy



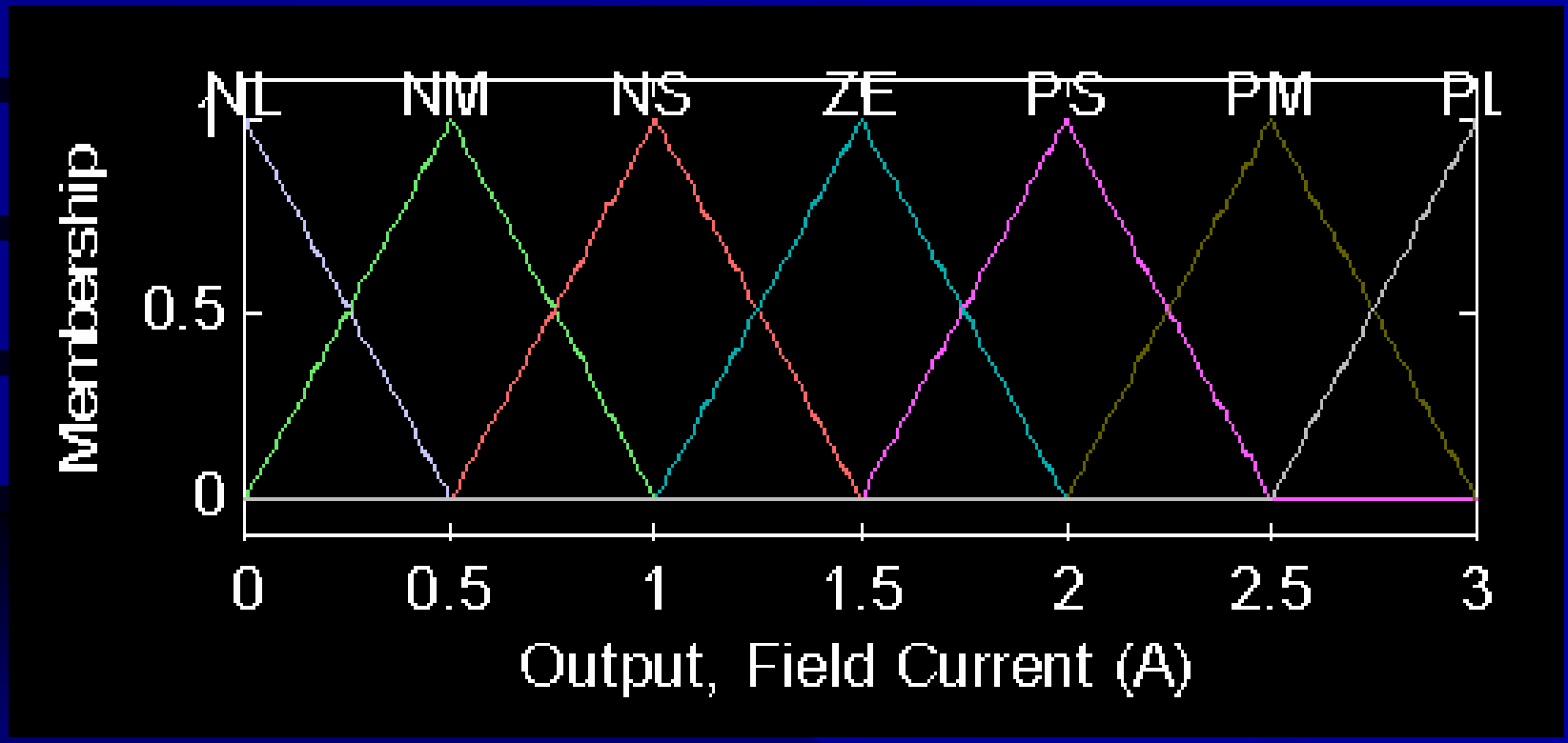
# Fuzzifier
## (Linguistic Labels)

- **NL Negative Large**
- **NM Negative Medium**
- **NS Negative Small**
- **ZE Zero**
- **PS Positive Small**
- **PM Positive Medium**
- **PL Positive Large**

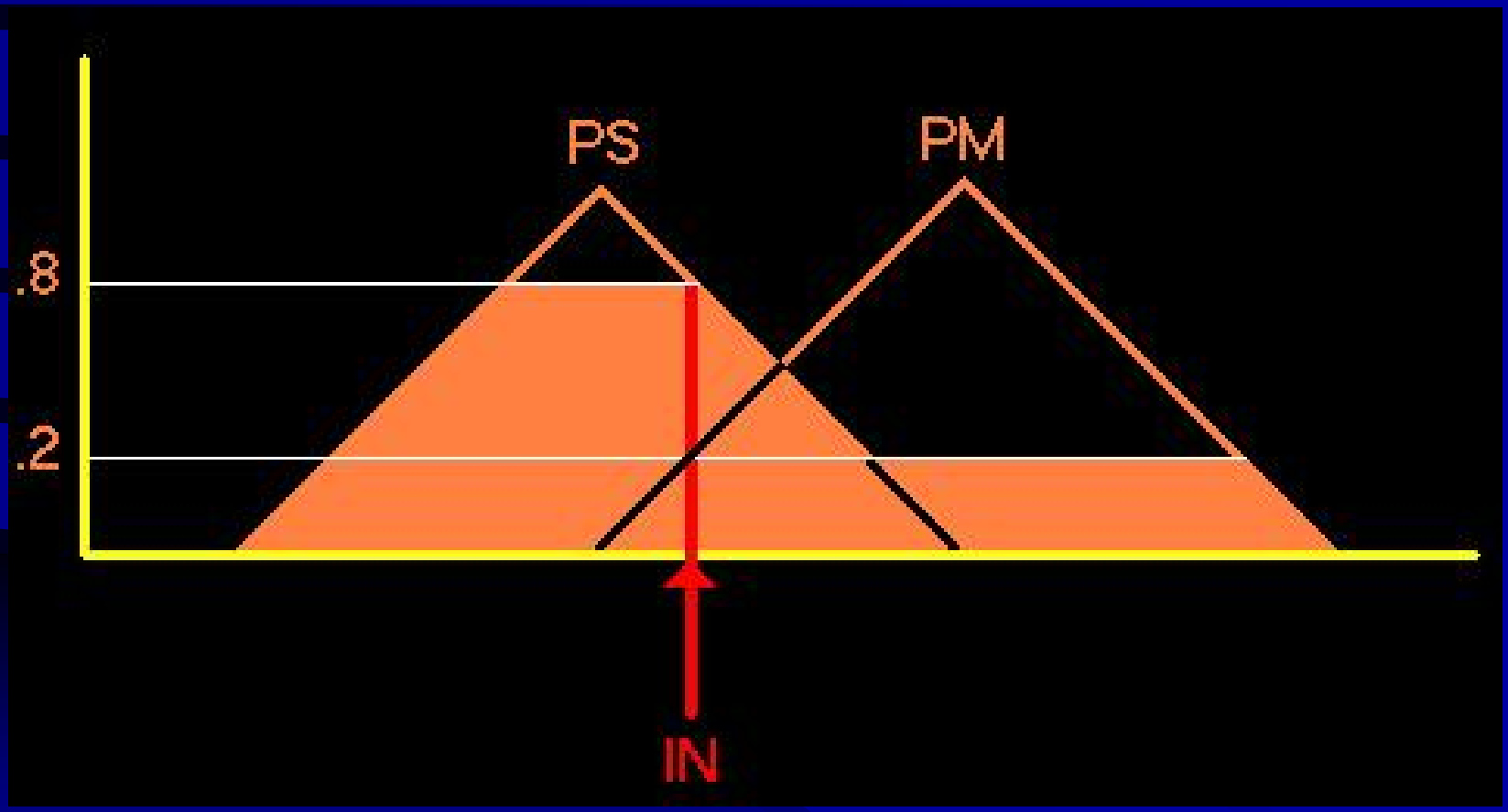
# Input Membership Functions



# Output Membership Functions



# Fuzzifier



# Fuzzy Logic Control Rules

- The *intelligence* of a fuzzy logic controller comes from its programming in the form of Control Rules.
- A more experienced programmer will develop a more efficient controller.
- Control rules are linguistic statements describing a desired output from a certain set of inputs.

  *Ex) if the voltage error is negative large and the rate of change of voltage is negative large, then the field current is positive large*

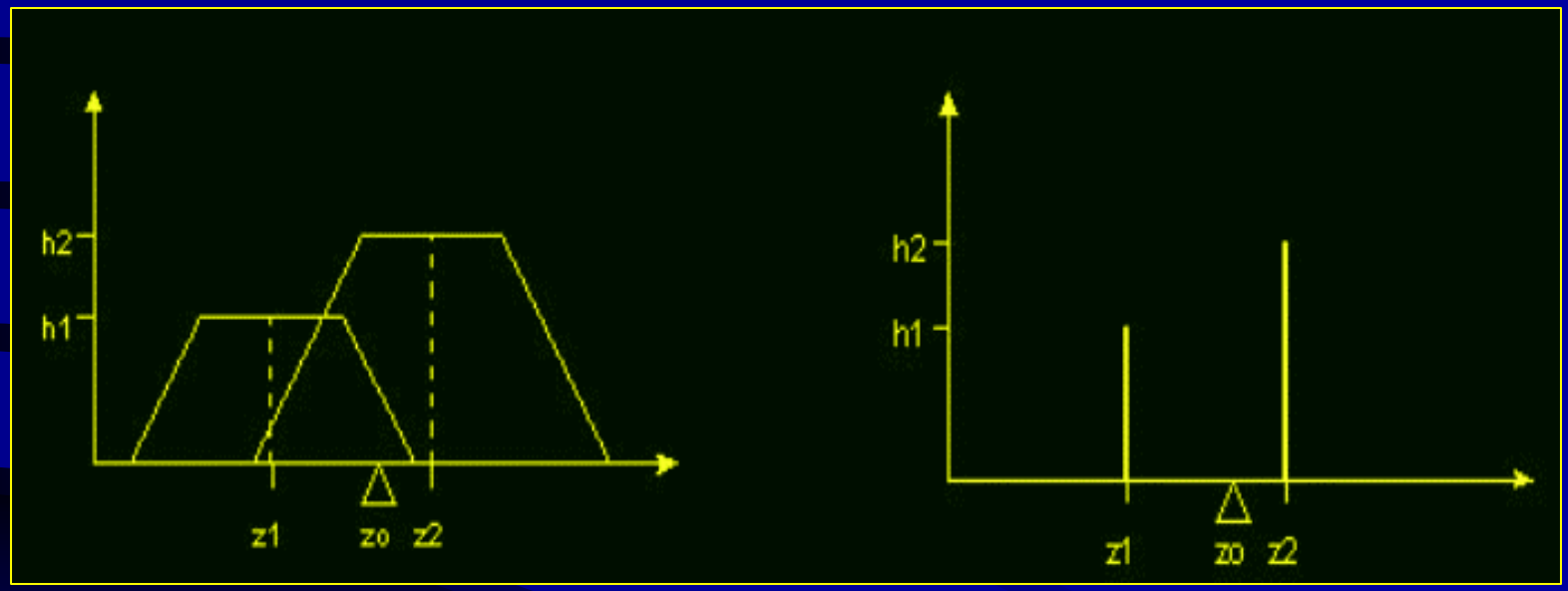
# Fuzzy Logic Control Rules

- Voltage Error

| Del Error | NL | NM | NS | ZE | PS | PM | PL |
|---|---|---|---|---|---|---|---|
| NL | PL | PL | PL | PL | PM | PS | ZE |
| NM | PL | PL | PM | PM | PS | ZE | NS |
| NS | PL | PM | PS | PS | NS | NM | NL |
| ZE | PL | PM | PS | ZE | NS | NM | NL |
| PS | PL | PM | PS | NS | NS | NM | NL |
| PM | PM | ZE | NS | NM | NM | NL | NL |
| PL | ZE | NS | NM | NL | NL | NL | NL |

# Defuzzification

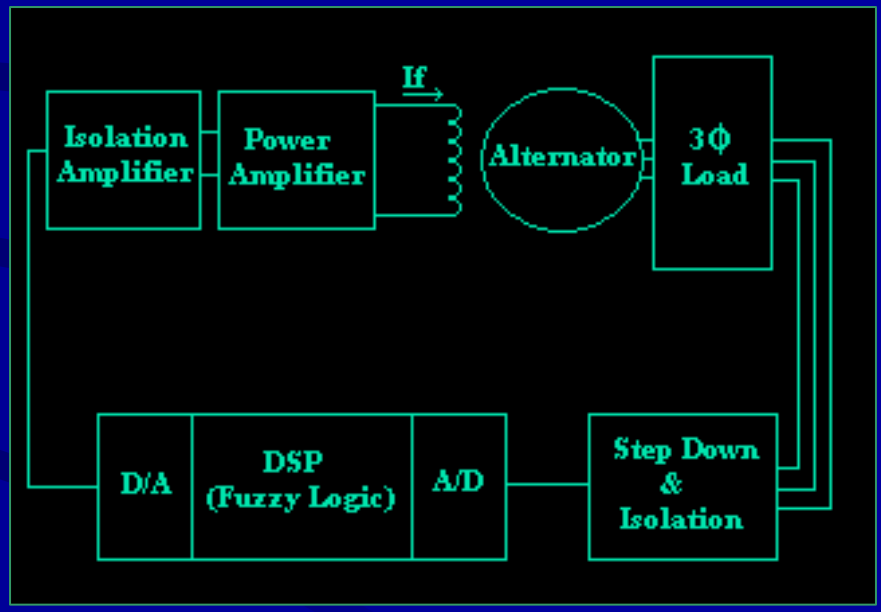
(Weighted Average)




$$Z_O = \frac{Z_1 \cdot h_1 + Z_2 \cdot h_2 + \cdots + Z_n \cdot h_n}{h_1 + h_2 + \cdots + h_n}$$

# Experimental Setup

- Alternator
- Three Phase Load
- Step Down and Isolation
- DSP (A/D, D/A)
- Isolation Amplifier
- Power Amplifier

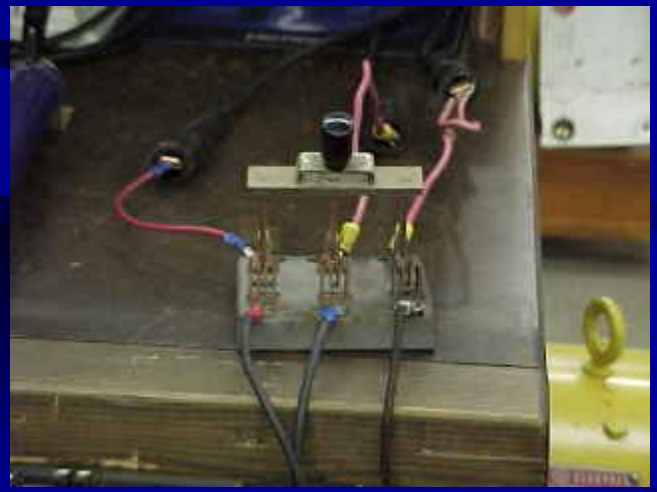


# Alternator

- 5kVA Alternator.
- Induction motor serves as prime mover.

# Three Phase Load

- Delta Formation
- R, RC, & RL



# Step Down & Isolation

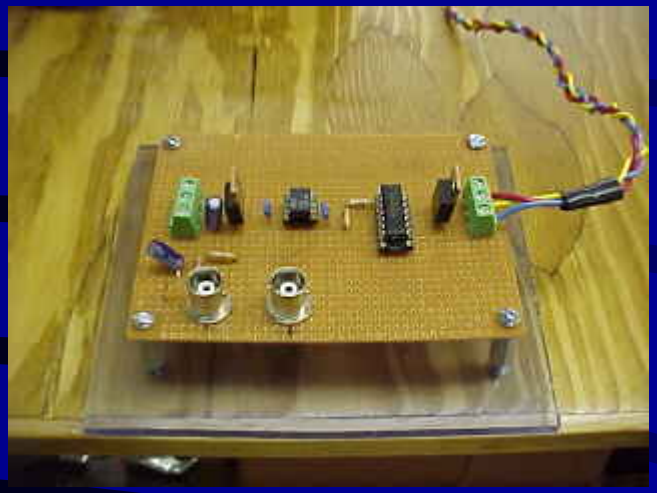

- *Probe Master* 20/1 Attenuator
- Provides analog saturation around 160 Vrms.

# DSP

(Digital Signal Processor)

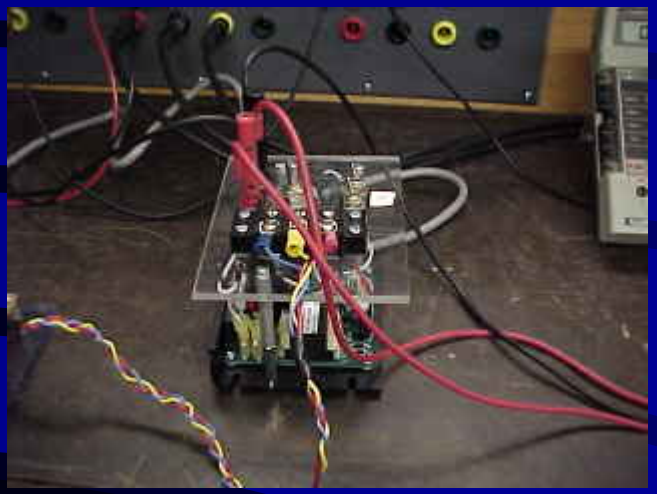
- 40 MHz processor.
- 12 bit signed A/D converter with 10 channels of sample and hold. (-10 < Vin < +10)
- Two 12 bit signed D/A converters. (-10 < Vout < +10)

# Isolation Amplifier



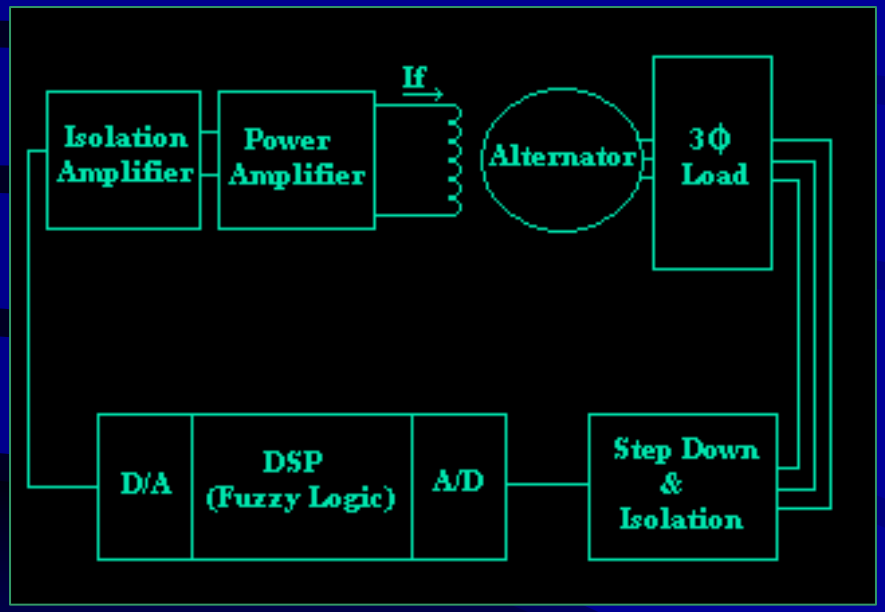
- Provides a way to link a fixed ground to a floating ground.
- Isolates the DSP from the high voltage associated with the power amplifier.

# Power Amplifier



- Will take in a voltage from 0 to +5 volts and in turn, supply a voltage of 30 to 160 volts to the field of the generator.

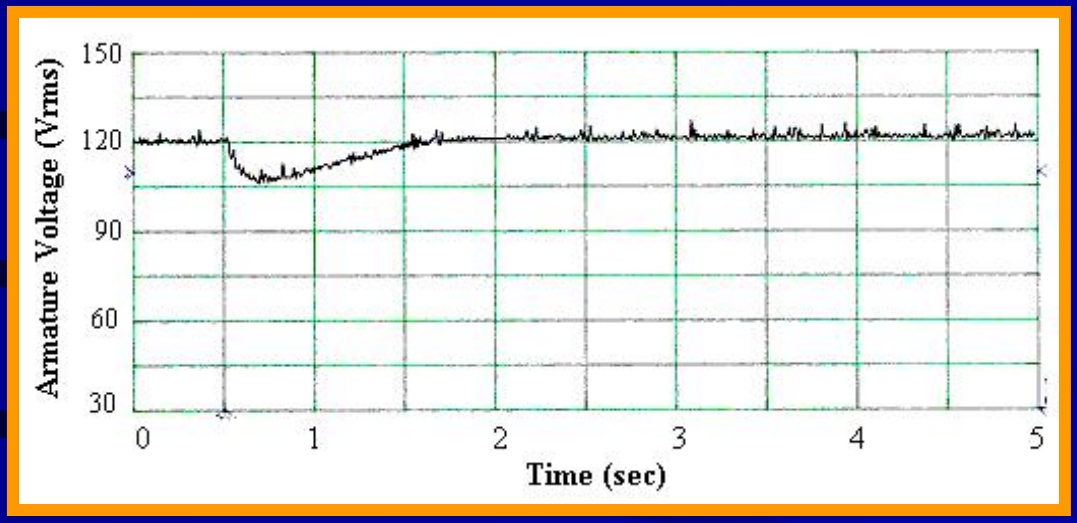
# Closed Loop Control System

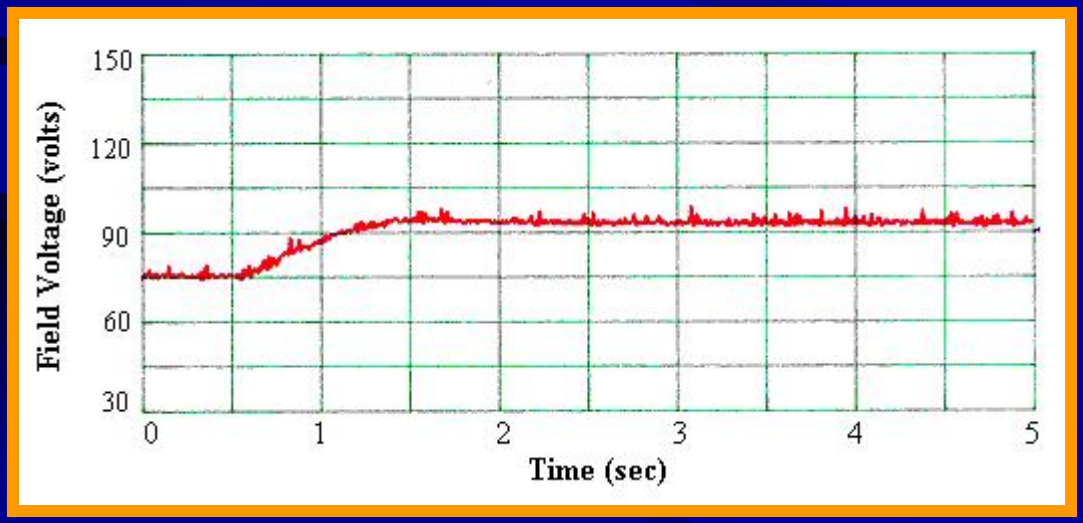



# Experimental Results

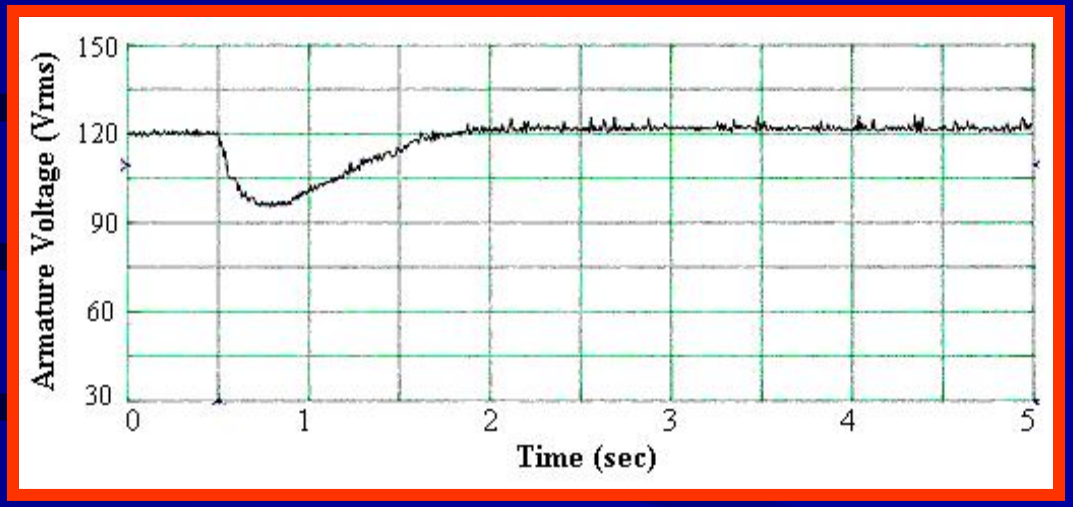
- The controller was tested under five different situations:
  - a light resistive load.
  - a heavy resistive load.
  - a capacitive load.
  - an inductive load.
  - generator start-up.

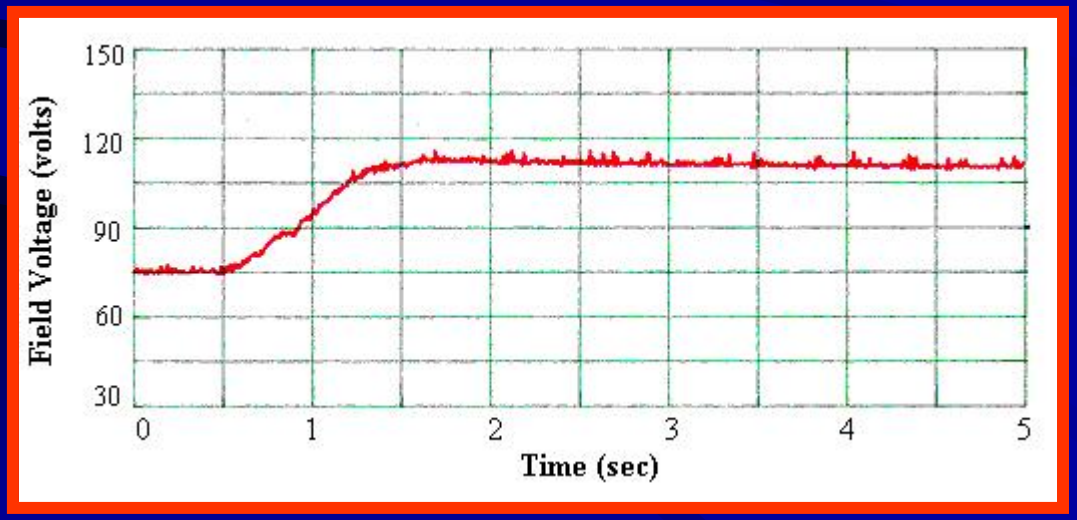
# Resistive Load (20%)



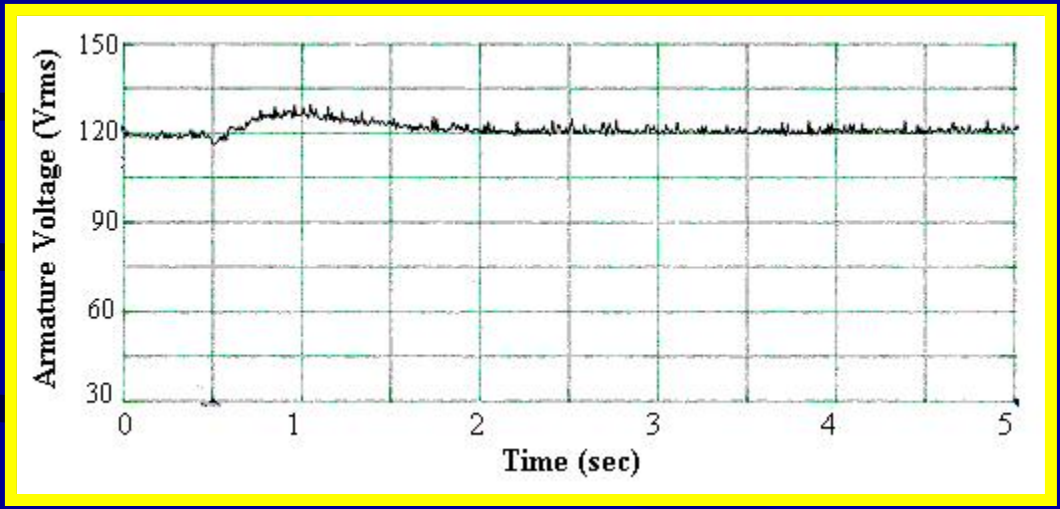



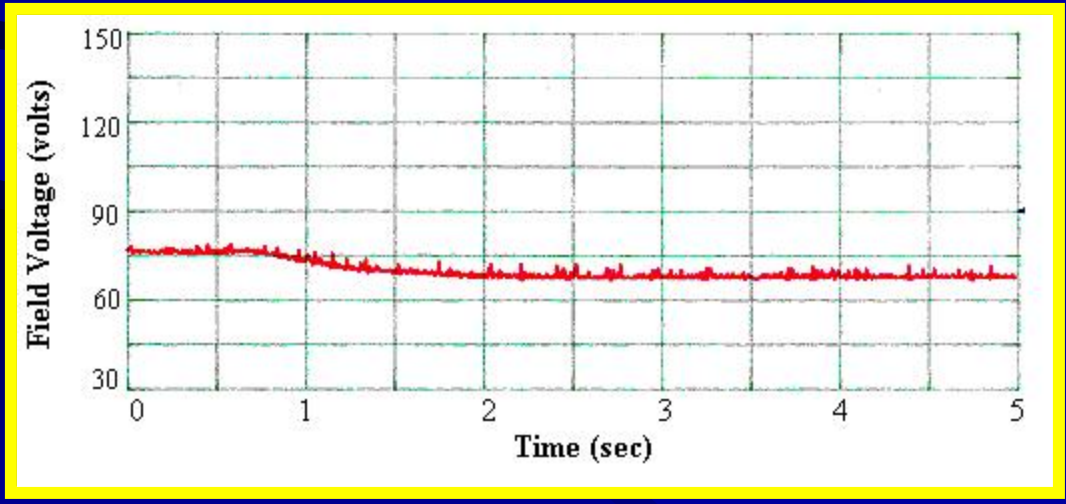
# Resistive Load (85%)



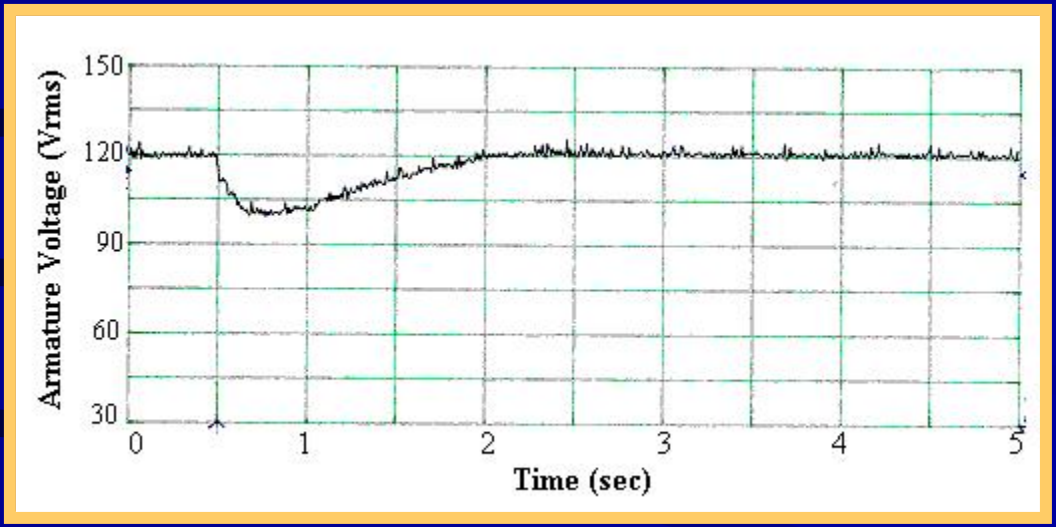



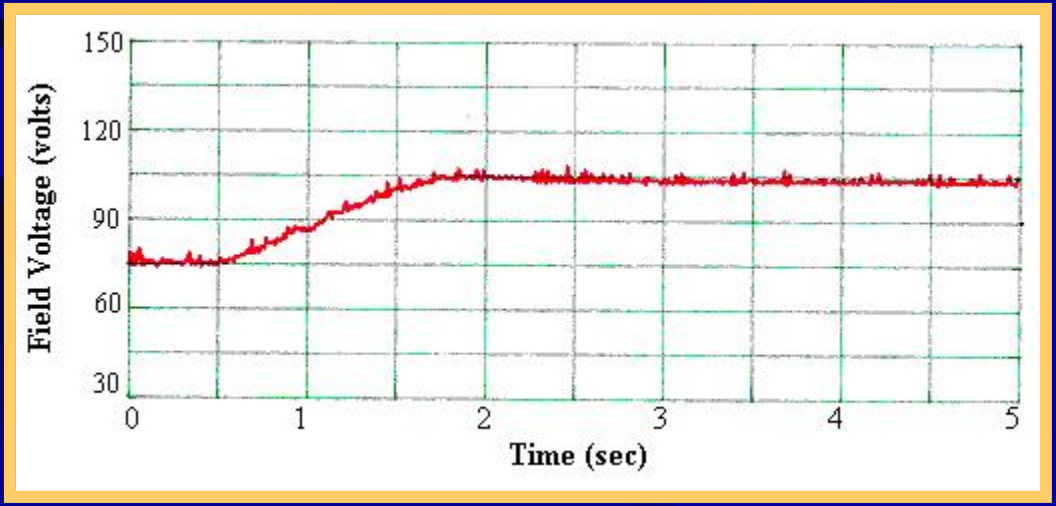
# Capacitive Load



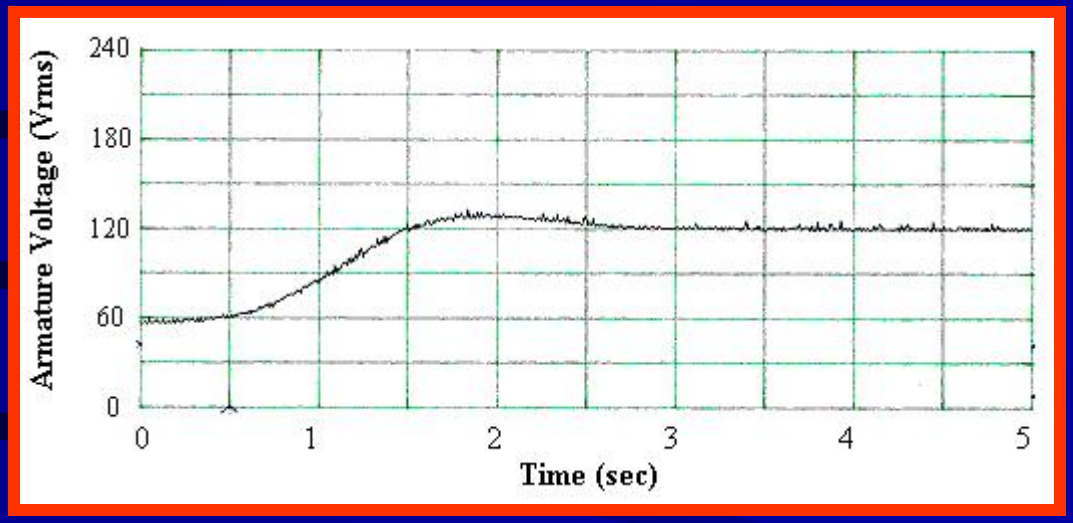



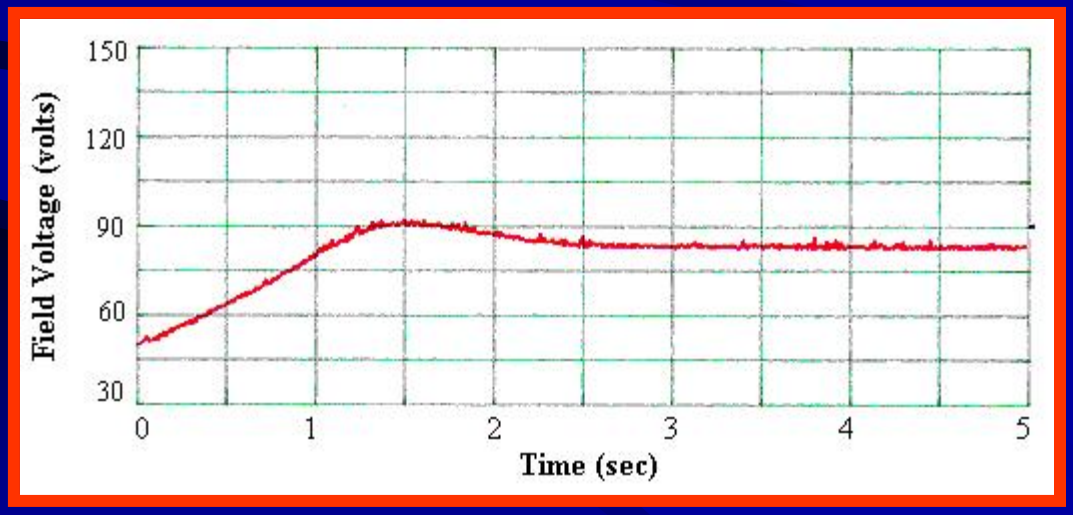
# Inductive Load (20%)



# Generator Start-Up



# Conclusion

- The fuzzy logic controller performed exceptionally well.
- A high power  system was linked to a low power system in a single closed control loop.
- A DSP was used as the control engine for a power application.

# Project Highlight

- Published in April's issue of
  "IEEE Computer Applications In Power"

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Questions?