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Power Electronics Turing Test: A Path Toward Strong AI in Power Electronics

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Recording from Dak Cheng (Princeton ECE’25 Undergrad)

https://www.youtube.com/watch?v=Q_nJV8klBtk
Strong AI and Domain-Specific AI ...

- Artificial narrow intelligence (ANI)
  - "AI as a Tool"
    - Image Recognition
    - Speech Recognition
    - Alpha - Go

- Artificial general intelligence (AGI)
  - "General Purpose AI"
    - ChatGPT - Language
    - Sora - Vision
    - GitHub Copilot – Logic Thinking

- Artificial super intelligence (ASI)
  - "Domain Specific AI"
    - Medicine Expert
    - Materials Expert
    - Power Electronics?
Power Electronics + AI?

• Is *Strong* AI ready to learn Power Electronics? - Yes?
• Is Power Electronics ready for *Strong* AI? - No?

“Once data is ready, AI is ready!”

“Once question is ready, solution is ready!”

“How does human understand power electronics?”

“How does machine understand power electronics?”
Turing Test in Power Electronics?

Dr. Alan Turing (born June 23, 1912)
PhD in math, Princeton
Teach AI to Understand Power Electronics?

Figure 4.1  Half-wave phase-controlled rectifier with resistive load and desired waveforms.

current pulse (whose width is not critical) applied once every cycle of the line voltage waveform. The SCR is a regenerative device, that is, once it is conducting on — even after the gate pulse ends — and its anode current goes to zero (which, in this circuit, occurs at the zero-crossing of the line input voltage), the angle $\alpha$ is usually called the firing angle, the angle of delay, or the delay angle. Retard or delay is measured relative to the angle at which the device would have turned on if it were a diode. The resulting output voltage $v_{o}$ is shown, and from it we can infer the effect of gate control. The import of the rectifier voltage is its dc component:

$$v_{dc} = \frac{V_{L}}{2}\left(1 + \cos \alpha \right) = \frac{V_{dc}}{2}\left(1 + \cos \alpha \right)$$

where $V_{dc}$, the maximum possible value of $v_{o}$, is also the output of an equivalent diode rectifier. The voltage $v_{o}$ as a function of $\alpha$ is known as the control characteristic of the rectifier and is shown in Fig. 4.2.
We can obtain a simpler alternative by replacing the resistor in the circuit with the transformer. This simplifies the circuit, reduces the complexity, and makes it easier to analyze and understand.
Structured Abstraction in Power Electronics

**Circuit Schematic**

**Conceptual Abstract**

**Control Strategy**

Teach AI to understand/classify Basic Schematics?

- 90% of power electronics in use are designed following these topologies
- 90% of power electronics designs already “exist” and are just “fine-tuning” efforts
- Texas Instruments power topology catalog: https://www.ti.com/lit/ml/sluw001g/sluw001g.pdf
Training Data Preparation

ComponentNet
- 2544 hand-collected component images
- Machine-drawn and hand-drawn
- Semiconductor switches, capacitors, magnetics, controllers, labels, symbols

CircuitNet
- 200 hand-classified schematics
- Machine-drawn and hand-drawn

Open-Sourced: https://github.com/minjiechen/PowerVision
NetlistMaker – Convert Schematics to Netlists

Schematic Database (>100 schematics)

Component Detection (OpenCV)

Netlist / Incidence Matrix (SPICE Simulations)

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Component Database (2544 images in 11 categories)

Segmentation

Inference

Component Recognition (CNN in TensorFlow)

Classification

Netlist Generation
Performance of the NetlistMaker

>90% accuracy for component classification

Confusion Matrix

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Predicted label

Component Detection

<90%

Netlist Recognition

>90%

Hand-Assisted

Component Value Assignment

Vdry p0 PULSE (20 0 0 0 5.0 u 10.0 u)
### Advanced Understanding about the Schematic

#### Circuit Schematic

1. Circuit Functions
2. Key Patterns

#### Incidence Matrix

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#### Matrix Patterns <-> Circuit Functions

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Train on a Large Number of Pre-Labeled Circuits
A Failed Turing Test, but A Successful First Attempt ...

Power Electronic Topology “Fingerprints”

Classify and explain an existing circuit topology

Try to interpret a new, unknown circuit topology
End-to-End Cognitive Intelligence beyond Schematics
What is the true Artificial Intelligence in Power Electronics?

- Image + Language
- General Intelligence
- Domain-Specific Intelligence
COMPEL community should think ahead of AI!!!

- How to enable AI to pass Power Electronics Turing Test?
  - Where is data?
  - How to organize the data?
  - What questions shall we ask?
  - Which tools are ready?
  - Where are our collaborators?
  - Who cares?

Embrace and think ahead of AI!

Pathway to Strong AI
A Path Toward Strong AI in Power Electronics

- Most human-created information documented/processed as 1-D time sequences (natural language) or 2-D arrays (computer vision).
- Most advanced AI models focus on language or vision processing.
- Convert interesting power electronics problems into time sequence (language) or vision (image) problems.
- Create the database → migrate the tools → build an open-source community → advance the field collaboratively and competitively.

2023 PELS Magnet Challenge

2025 PELS TURIS Challenge

time-sequence processing (NLP) image processing (computer vision)
Rethinking Human and Machine in Power Electronics

2002 IEEE Workshop on Computers in Power Electronics
Proceedings
June 3-4, 2002
University of Puerto Rico at Mayagüez

IEEE Power Electronics Society

ENIAC - 1945
PC - 1980
GPU - 2024