Impact of the use of the Circuit Navigation System in the teaching of electrical engineering on the dropout rate and on the shortage of engineers

Prologue:

The following publication contains:
an overview of the distinctive key figures of the study of electrical engineering,
a description of the usual method of learning electrical circuits that has been used so far,
a description of the challenge to apply this method in studies
a presentation of a new method, and
an outlook on the impact of using the new method.

The content of this publication relates primarily to electrical engineering studies because the author has completed such studies and is therefore familiar with the processes and challenges therein. However, the content is essentially transferable to other forms of teaching, especially to professional training as an electrical technician.
Furthermore, it is transferable to other disciplines that have electrical circuits as a peripheral area. For example the mechanical engineering, where electrical drives are taught, or computer science, which deals with digital circuits.

The text was translated from german language. The statistics and key figures refer to the FRG, but the teaching methods for electrical engineering presented below as well as the conclusion are independent of the country.

Content

Impact of the use of the Circuit Navigation System in the teaching of electrical engineering on the dropout rate and on the shortage of engineers

The dropout rate in electrical engineering is even higher than in comparable courses

In electrical engineering bachelor's degree programs at German universities, about 46% of first-year students drop out, compared to 35% in mechanical engineering and 45% in civil engineering.

At universities of applied sciences, the dropout rate in electrical engineering is also higher than in mechanical engineering or civil engineering: There, the dropout rate for electrical engineering is 37%, for mechanical engineering 35% and for civil engineering 32%. [i]

These figures relate to the 2018 academic year, in which around 140,000 first-year students started an engineering degree at a German university or UAS. [ii]

The requirements are considered too high by dropouts

The dropouts in the engineering sciences, especially in electrical engineering and mechanical engineering, regard primarily the level of technical requirements as too high. In other subject groups, such as medicine, on the other hand, it was rather the amount of material to be learned that was considered too high. See the study by the DZHW [iii].

Electrical engineers are in demand in industry

According to the press release of the Association of Electrical Engineering (VDE), 100,000 electrical and information technology engineers are currently being sought. [iv]

Volker Brennecke, education expert from the Association of German Engineers (VDI) says, quote: "In view of the shortage of engineers, the high dropout rate cannot be accepted. It is ultimately a threat to further industrial development, to the location and to our prosperity if we do not fully utilize the potential of young talent."
(Original: „*Angesichts des Ingenieurmangels darf die hohe Abbrecherquote nicht hingenommen werden. Es ist letztlich eine Bedrohung für die industrielle Weiterentwicklung, für den Standort und für unsteren Wohlstand, wenn wir nicht das Potenzial an Nachwuchs vollständig ausschöpfen*“.)
He also says that not all dropouts abandon their studies because of the too high requirements.[v]

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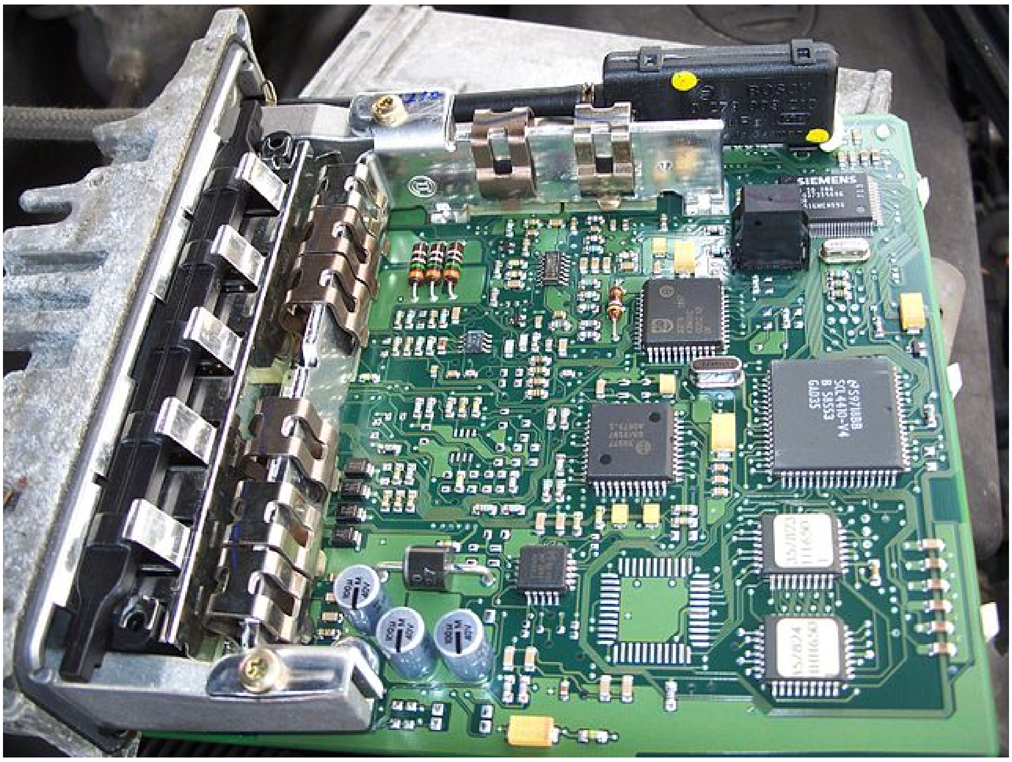
Reducing requirements is not a practicable solution

Although the requirements in the electrical engineering program seem too high, they cannot be lowered. That is because electrical engineers are responsible for devices on which human lives depend. Those who develop motor control units absolutely must ensure that the vehicle's electrical system functions properly. Because if mass-produced vehicles with faulty electrics were to come onto the market, the lives of millions of pedestrians on the roads would be at risk. When we pick up a kitchen appliance, we want it to be safe.
If one wants to have safe appliances, where the developer has also thought about the special cases, one cannot lower the study requirements. An electrical engineer has to be able to do that.



1st image: Human lives depend on motor control units like this one.

It is thus not a practicable solution to the problem outlined above to lower the requirements for electrical engineering studies. In this respect, a different solution, a practicable solution, is sought in the following. In order to get to the feasible solution, the next section first describes what the technical requirements in electrical engineering studies are.

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The usual method to understand circuits

A large part of the work of the electrical engineer is the design, adaptation or verification of electrical circuits. It therefore makes sense that the design of circuits is practiced in electrical engineering courses and that the typical structure of various circuits is taught. That is the major part of the electrical engineering curriculum.

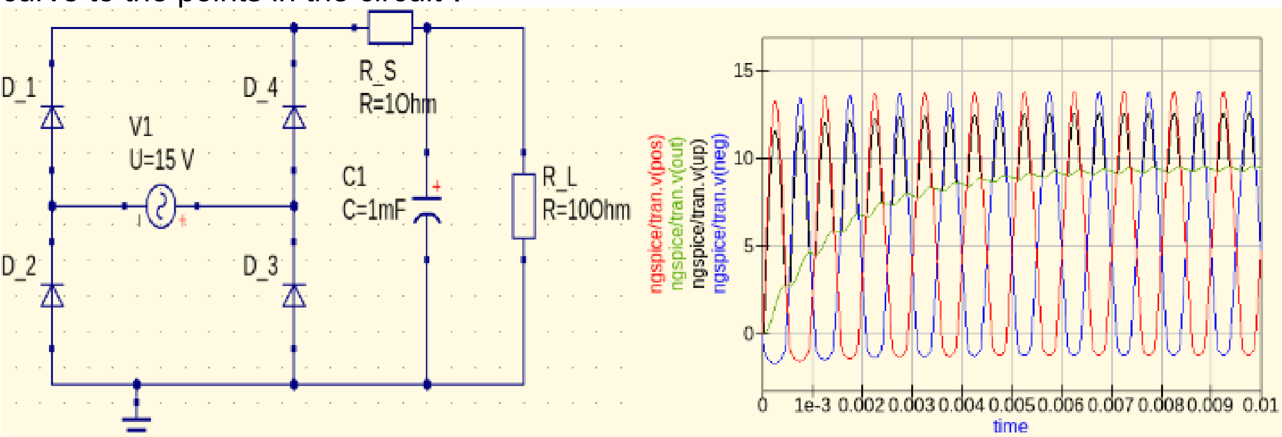
Students who try to understand the functional principle of a circuit usually do this with current and voltage curves:

- First, one assigns curves and components to each other.
- Then, one tries to recognize relations between the assigned values
- Finally, one has to identify the functional principle of the circuit from the relations.

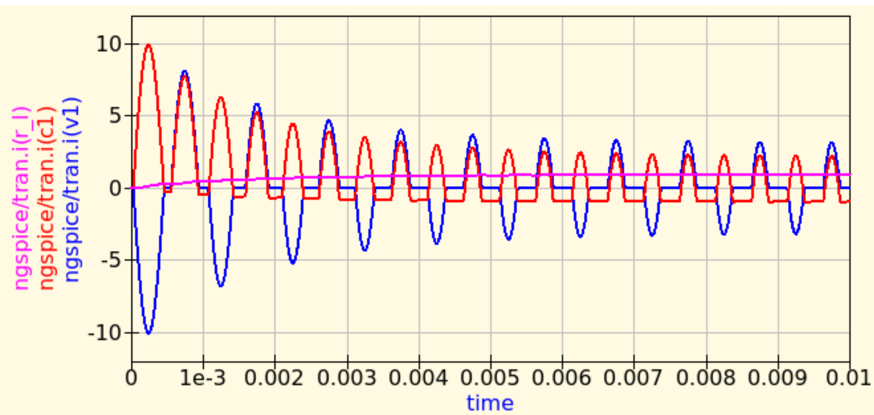
Each of these three steps takes time and is a source of possible errors. One can fail at each of the three partial steps.

<u>Example:</u>

As an example, one can try to figure out how the following diode rectifier works by means of voltage curves and current curves. To do this, one must first assign the appropriate curve to the points in the circuit[1].



2nd image: Circuit diagram of a diode rectifier, and the corresponding voltage curves.



3rd image: The current curves of the diode rectifier

1 Assignment: v(neg) is the voltage at the negative pole, v(up) is the voltage at the node above diodes D_1 and D_4, v(pos) is the voltage at the positive pole, v(out) is the output voltage across C1.
i(v1) is the current through the sinusoidal voltage source, i(c1) is the current through the capacitor C1, i(r_l) is the current through the load resistor R_L

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After one has assigned these curves, one has to compare the curves with each other to find relations[2] from the curves.
From these relations, one must then recognize the functional principle[3].

<u>Conclusion from the example:</u>
Maybe you understood the working principle of the diode rectifier when reading through this section and looking at the curve diagrams, maybe not. And maybe you already knew it before. In any case, you should have realized that schematic analysis using curve diagrams is exhausting and difficult.
Imagine that you were a student, and that you would be doing such schematic analyses all day long, and that for years. And that you have to understand circuits like these, but also more complicated ones, in order to pass your electrical engineering degree. Then you can certainly imagine why the dropouts described above are talking about requirements that are too high.

Easier learning is a practicable solution – by using a new method

We have seen in the previous section that curve diagrams do not provide optimal support for schematic analysis.
There is another way to represent schematics and their currents and voltages. A representation that better supports schematic analysis, so that one can learn faster, have less effort, and eliminate unnecessary sources of error:
The integrated representation in the Circuit Navigation System.

In this, the currents and voltages are drawn directly into the schematic as graphical elements. Example:

2 The relation in this circuit is that the output voltage v(out) always rises when v(up) has a high value, which in turn is exactly when v(pos) or v(neg) also have a high value. And that at these times also current peaks from the source flow into the capacitor.

3 The principle of operation is that the four diodes direct the flow of current so that it always flows into the capacitor, thereby increasing the voltage across the capacitor and thus building up a DC voltage across the capacitor.

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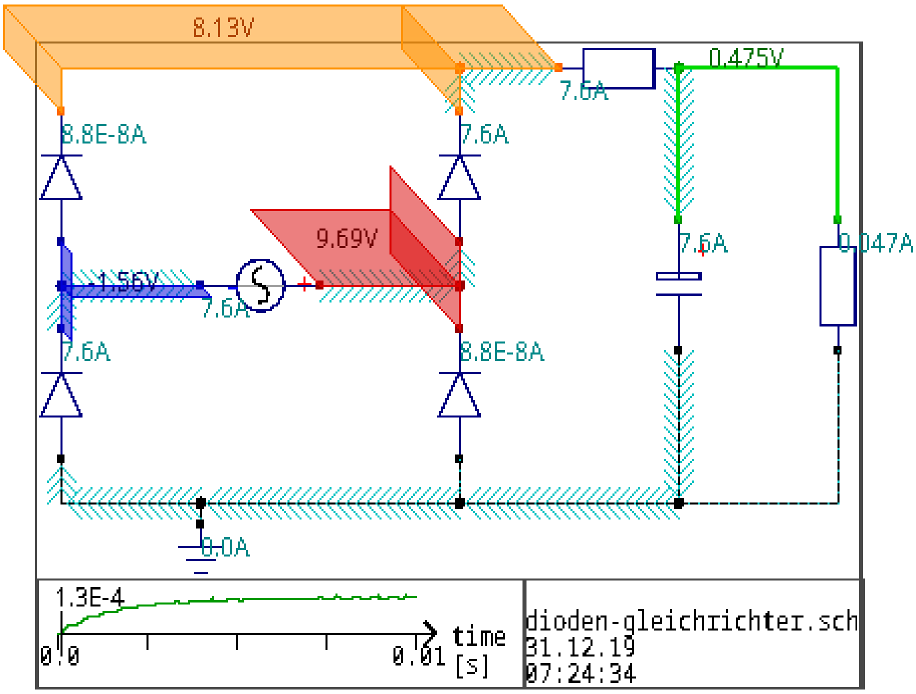
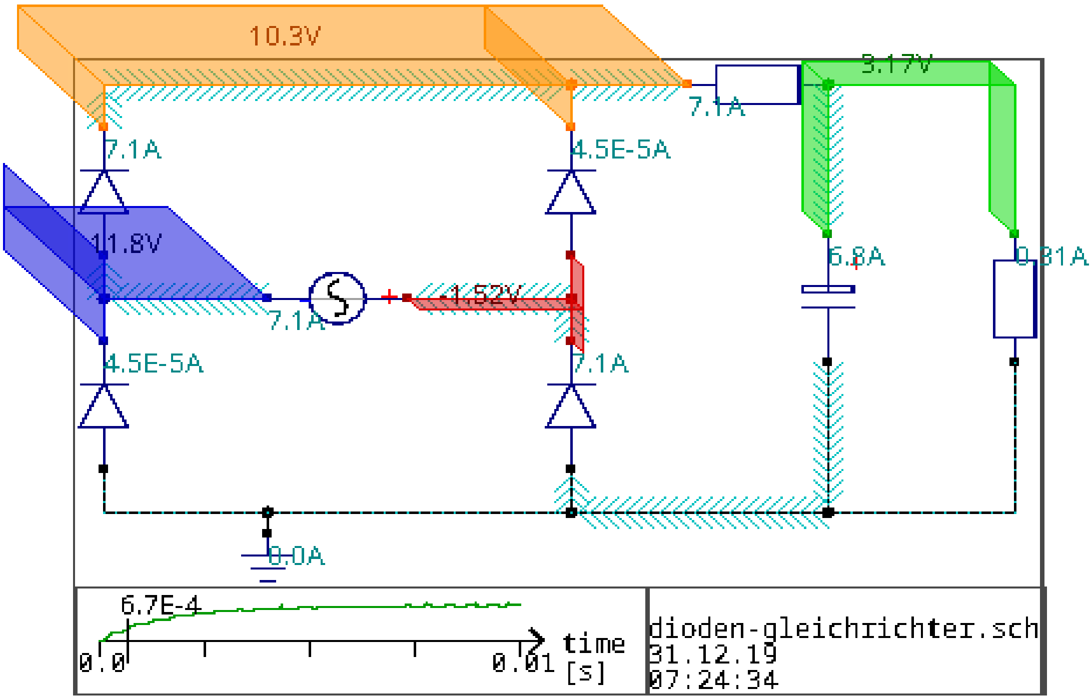


4th image: Integrated display of the diode rectifier in the Circuit Navigation System "CirNavSys" version 0.3.42 with positive input voltage

In this image above, one can see what happens at a positive input voltage(red): Two of the four diodes guide the current (light blue) in that way, that it flows into the capacitor. Therefor the output voltage (green) across the capacitor increases.



5th image: Integrated display with negative input voltage

In this lower figure we see what happens with a negative input voltage (dark blue): the current (light blue) flows here through the other two diodes, but just as in the upper figure from above into the capacitor. Therefore, the voltage at the output (green) continues to build up.

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From these two pictures you can see how - independent of the input voltage - the current is guided into the capacitor, so that the voltage rises at the capacitor until the DC voltage is built up. You can see this even more clearly than in these two figures by watching an animation video, for example at https://vimeo.com/386196137 or at https://www.youtube.com/watch?v=clJJMBWNeaI

Conclusion from the example:
With the help of the Circuit Navigation System, it becomes much easier for learners to understand circuits:
The first step, the assignment, is taken over by the computer.
The second step, recognizing relations, is made easier by the fact that the currents and voltages in the circuit diagram are assigned to their locations and one can see directly where the currents flow along and which voltages are next to each other and how these voltages influence each other.
Only the third step, the deduction of the functional principle, still has to be done by humans.

Easier learning even leads to less workload for teachers

One might assume that it would take a lot of time and effort to create such animated videos. So that electrical engineering teachers would have more effort to prepare lectures. In fact, it is the other way around: it is less effort.

Because for the traditional line diagrams the teacher has to define which currents and which voltages should be included in the diagram, has to pass these quantities to the analysis program, find suitable names for the quantities1 and then run a schematic simulation from the program (e.g. qucs).

With the Circuit Navigation System, all you have to do is run the simulation from CirNavSys, and then save the result to a video file. This can be done by anyone with a few clicks. How to do this is explained in a CirNavSys introduction video at https://www.youtube.com/watch?v=6_YSKPtffQU in less than four minutes.[4]

In addition, as an electrical engineering teacher, you can save a large part of the explanation in the lecture: You don't need component names anymore and therefore you don't have to explain component names. Previously, component names were used to assign currents and voltages via the names.

The teachers no longer have to explain the assignment by means of words, because they are graphically prepared and displayed and thus the values assigned in the circuit diagram are directly recognizable.

4 The video makes two time jumps, at the points where the computer calculates and makes the user wait. In this respect, it is rather realistic that not four minutes, but an additional minute of computing time is needed to create an animation video of a circuit.

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Conclusion

A consistent, widespread use of the Circuit Navigation System in teaching can help to reduce the dropout rate in electrical engineering in the future without having to lower the study requirements.

Thus, the use of the program can not only make it easier for thousands of young people to achieve their life dream of successfully studying electrical engineering. It can also counteract the shortage of engineers and thus take a part in securing Germany's future as an industrial location.

The program can be downloaded free of charge as a freemium program at cirnavsys.com/download.

Achieving these two goals of fulfilling life dreams and securing the industrial location should be worth trying out the program and using it in electrical engineering teaching.

Further reading

The Circuit Navigation System in Teaching - Benefits for Teachers and Students
https://www.cirnavsys.com/cns-for-students-and-teachers

A general project, not limited to electrical engineering, by the OECD, to support the development of learning:
https://www.oecd.org/education/2030-project/contact/OECD_Lernkompass_2030.pdf

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Sources of the images

Name: Engine control VW Golf TDI interior
Description: Interior view of an motor control unit from a Golf III TDI. On the left is the connector strip, directly next to it the power semiconductors mounted on the cooling plate. Via the hose and the MAP sensor the boost pressure of the turbocharger is measured. The black component below the Siemens chip is the altitude sensor or absolute pressure sensor. The two chips at the bottom right of the image contain the engine map.
Author: Cschirp in Wikipedia in german
License: This file is licensed under the Creative Commons Attribution-Share Alike 3.0 Germany License. See https://creativecommons.org/licenses/by-sa/3.0/de/deed.de
Source: https://de.wikipedia.org/wiki/Datei:Motorsteuerung_VW_Golf_TDI_innen.jpg

Name: Circuit diagram of a diode rectifier, and the associated voltage curves.
Description: The circuit diagram of a diode rectifier with four diodes, a series resistor to simulate conductor resistance, a load resistor to simulate a load on the rectifier, and a smoothing capacitor to smooth the output voltage. Created using "Quite Universal Circuit Simulator", qucs for short. Next to it the voltage curves from a simulation calculation of the circuit using SPICE simulation.
Author: Benedikt Sessler
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Name: current curves of a diode rectifier.
Description: the current curves from a simulation calculation of the circuit of a diode rectifier using SPICE simulator.
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Name: Diode rectifier in CirNavSys with positive input voltage in the Aqueduct model.
Description: A diode rectifier in the Circuit Navigation System. Shown at analysis time 0.13ms at negative input voltage of sinusoidal voltage source. The colored areas at the connections indicate which voltage is applied to the respective connection with respect to the mass level.
Author: Benedikt Sessler
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Name: Diode rectifier in CirNavSys with negative input voltage in the Aqueduct model.
Description: A diode rectifier in the Circuit Navigation System. Shown at analysis time 0.67ms at negative input voltage of sinusoidal voltage source. The colored areas at the connections indicate which voltage is applied to the respective connection with respect to the mass level.
Author: Benedikt Sessler
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Sources of the text

i DZHW publication:
"The Development of Dropout Rates at German Universities".
(Original:„*Die Entwicklung der Studienabbruchquoten an den deutschen Hochschulen*“)
U.Heublein, J.Richter and R.Schmelzer
https://www.dzhw.eu/pdf/pub_brief/dzhw_brief_03_2020.pdf

ii Statistics from the Federal Statistical Office on first-year students in the first semester of higher education by subject group:
https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bildung-Forschung-Kultur/Hochschulen/Tabellen/studierende-erstes-ht-faechergruppen.html

iii DZHW publication:
"Causes of dropout in bachelor and traditional degree programs".
(Original: „*Ursachen des Studienabbruchs in Bachelor- und in herkömmlichen Studiengängen*“)
U.Heublein, C.Hutzsch, J.Schreiber, D.Sommer and G.Besuch (2010) ISBN 1863-5563
https://www.dzhw.eu/pdf/pub_fh/fh-201002.pdf
especially page 95, Abb.9.8: " Perception of the Requirement Level of Dropouts sorted by Study Discipline Group."
(Original: „*Einschätzung des Anforderungerungsniveaus der Studienabbrecher nach Fächergruppen*“)

iv Press release of the VDE on student numbers:
https://www.vde.com/de/presse/pressemitteilungen/studienanfangerzahlen-e-technik-bleiben-stabil

v Online-Article:
"Only one got through - dropout in engineering".
(*„Nur einer kam durch - Studienabbruch in den Ingenieurwissenschaften“*)
S.Schader (2008)
https://www.studis-online.de/Studieren/art-768-studienabbruch-ing.php

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