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Pandemic-Proofing and General Development of an Electricity Distribution Course

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Abstract—The transition of courses based on the classic combination of lectures, calculation exercises and laboratory works to student-centred learning sessions and group assignments has been a typical transition for courses at Aalto University and elsewhere. The entirety of the course Electricity Distribution and Markets and its development over time is reviewed, covering the online content, lecture make-up, and the various parts of the assignment work, including the use of a multi-cultural group-forming algorithm, with reference to feedback from students. The methodology employed during the development of this course and in the assessments of group work and flipped classroom techniques made in this paper is trial and error, and the paper evaluates the efficacy of the various pedagogical methods that have been tried through the lens of student feedback.

Keywords—course development; electricity distribution; group-forming algorithms; group work; student feedback

I. INTRODUCTION

Some fundamental courses remain, content-wise, somewhat unchanged as the decades unfold, although hopefully develop as pedagogical innovations prove trustworthy and as the demographics and level of prior learning of incoming students change. Some courses must adapt rapidly to the changing environment or become obsolete, and some courses, for example Electricity Distribution and Markets (ED&M) at Aalto University must cover both extremes. The energy system is undergoing major changes, and this impacts the power grid, including electricity distribution networks. Nevertheless, fundamentals such as voltage drop/rise, thermal constraints for both normal and contingency operation, short-circuit levels, etc., remain as significant as ever and cannot be forgotten as the generation profile changes to increasing stochastic, weather dependent production, both centralised and distributed, and rapid electrification of other sectors such as transportation take place.

There have been four main drivers for the development of ED&M. The first driver is the research-based conviction that students learn best by doing [1]. The second is the loss of laboratory facilities for the power systems unit while merging the Helsinki University of Technology into the new Aalto University, which required action to compensate for the impact on the first driver. The third driver has been to both cope with the Covid pandemic and the fact that several of the students are in working life, with limited time to come to the campus or match online lecture schedules. The fourth and most important driver is student feedback. The latter driver, despite its importance, must be kept in perspective.

The author, henceforth referred to as the lecturer, inherited a very good course in 2005 and has developed it ever since, but discovered by 2021 that ED&M, while well-intended and with some good features, was confusing and unwieldy for some of the students, a few of whom reacted quite negatively to the course.

Accordingly, this paper relates some of the features of ED&M, including changes made between 2021 and 2022, which seem to have changed the students’ impression of the course for the better. One change, which is not further dealt with in this paper, has been the clarifying of the MyCourses (Aalto University’s implementation of the Moodle platform) course page, so that everything can be found from the main page and is more consistent with other courses.

Another action has been the removal of some previous unsuccessful innovations, such as extra Taking Things Further material intended for more advanced students, now given directly as links in the main course material, and Learning Packages, an attempt to create a flipped classroom, [2] and [3], by giving the students material to study, followed by a Q&A session where the lecturer would simply respond to the students’ questions.

While this paper provides a critical glimpse into a course that is reasonably successful, both pedagogically and content-wise, the aim of the paper can be expressed as laying out the methodology employed to achieve the claim of reasonable success (one of the better rated large courses in the department of Electrical Engineering and Automation at Aalto University), and backing up that claim with a sample of student feedback. The main novelty is the use of an original group-forming algorithm to create groups that are as diverse as possible whilst having the skill-set to be able to complete a rigorous network planning task. The methodology is trial and error, the trying of various pedagogical tricks and content formats, and eliminating those that do not work, based on the teacher’s perception and critical course feedback from the students.

The developments that are covered in the following sections include an overview of the course in Section II, and the compulsory course content, Section III, including the re-
conceptualising of the presentation of the distribution grid prior to teaching power flows and related subjects, which has meant that most of the technical content of the learning material is far clearer and digestible from the students’ point of view. The most successful part of the course from a student activation and learning point of view is the Assignment, which is covered in Section IV. Section IV gives an overview of a multi-cultural group-forming algorithm used to form the assignment groups (to be as diverse as possible in terms of personality, nationality, gender and academic background), the development of the essay topics to cover existential threats and give the students a voice to express their concerns, and the continued development of the main planning task to embrace at least one of the contemporary challenges. The paper concludes with a sober assessment of student feedback, which has motivated some of the most recent changes to the course and the writing of this paper, and a discussion.

II. OVERVIEW OF THE COURSE ED&M

Fig. 1 outlines the main components in the 2022 implementation of the course. Contact teaching is interactive, with Q&A sessions, flipped classroom techniques (used with mixed success), and traditional lectures, which encourage student participation where possible and profitable. The contact teaching content is summarized in short Panopto videos for each contact session, which have been available even before the Covid pandemic, although the technical content of the course received a radical upgrade for 2022, which meant renewal of these videos. In previous years, four of the learning sessions were converted into full flipped-classroom sessions, but somewhat unsuccessfully. The feedback from students was that the lecturer knows the subject, and having to listen to student groups and the lecturer only answering questions the students happen to ask was counterproductive. Elements of flipped classroom technique are still employed, albeit imperfectly, but in 2022 the use of this technique was reduced.

The main current drawback in the course (from the point of view of the students) has been the optional nature of the calculation exercises, despite an appeal to the students. The lecturer’s appeal to the students is to take responsibility for their learning. Many students optimize their workload in terms of time, and therefore only do tasks that are required and/or graded. In fact, automating these calculation exercises in MyCourses is on the author’s to-do list. The assignment is also optional, but it is a large task, worth up to 50% of each student’s grade, and the lecturer can prove, using previous years’ data, that the majority of students will get at least 1 higher grade, where the grading goes from 0 (fail) to 5 (excellent), if they do the assignment. This gives the option for genuinely overloaded students (especially those who are already working in industrial teams in working life) to skip the assignment, and pass the course on the exam only. The students in each assignment group are required to agree on each student’s participation as a proportion of, say, the recommended 30 hours per student. If a student only contributes 50% of time compared to other students in the same group, the assignment will only contribute half as much to their final grade.

III. COMPULSORY COURSE CONTENT

The course covers both planning and operational aspects of electricity distribution networks, although at a quite general level, as there tends to be a wide spectrum of students in addition to power systems students taking the course. For example, many students from the Advanced Energy Solutions Master’s programme take the course and while they are excellent and motivated students, they often lack fundamental knowledge in electrical engineering, so bridging material has to be supplied.

<table>
<thead>
<tr>
<th>TABLE I. CONTACT SESSION CONTENT</th>
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<tr>
<td>Contact Sessions</td>
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<td>9</td>
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<tr>
<td>Lecture 10</td>
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<tr>
<td>A break for several weeks for students to do the assignment. Lecturer morphs into consultant role and has at least 2 student-led meetings with each assignment group during this period</td>
</tr>
<tr>
<td>Lectures 11-13</td>
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</tbody>
</table>

![Fig. 1. Course requirements](image-url)
This course...

...is primarily concerned with electricity distribution networks, a subset of the power system, which connects nodes together (via lines), to enable the transfer of electricity from where it is produced (or delivered via the high voltage networks) to where it is needed, which changes over time...

The electric power system transfers energy, in the form of electricity, from where it is produced to where it is needed, hopefully prioritising the carbon-free sources and transferring the energy as efficiently as possible. This figure shows a rural medium voltage network, with trunk lines and radial spurs. The entire network is run radially, where the open joints are depicted with open green circles. The square nodes in the bottom left and upper right of the figure represent primary (high voltage to medium voltage) substations, and the other nodes represent secondary (medium voltage to low voltage) substations. What is a substation? Each outgoing line or main feeder from the primary substations is equipped with a main circuit breaker, which can break fault currents. The green nodes have manual switches, and the red nodes have remote-operated switches.

The technical content of the course is standard fare, and needs no further elaboration. Some of the contemporary challenges are handled; for example, voltage rise in feeders where distributed generation (DG) provides higher peak power flows than demand and the challenges in terms of protection and changing grid topologies that DG and microgrids might require in the grids of tomorrow. A major conceptual clarification has recently been introduced in a significant reworking of the technical content. The entire power system is represented in terms of nodes and lines. This is hardly new in power systems, but the course is framed in these terms from the outset, e.g. as indicated in Fig. 2. The text in the yellow insert is, more or less, the text that is read in the concise Panopto videos. The idea of these videos is to provide concise content for revision purposes and for students who miss a lecture, but the slides also stand on their own for advanced students, in which case there is no need to spend time watching the videos. The online content makes the course pandemic-proof and in fact while a lot is lost in online contact sessions, group meetings with the lecturer have been expedited by the availability of online meeting tools and make meetings easier when groups contain members in working life. The challenges of hybrid learning will be briefly discussed in the final section of the paper.

The live lectures (regardless of whether they are face-to-face, online, or hybrid) are more verbose, where the lecturer encourages and sometimes forces debate, sometimes folding his arms and refusing to say anything until each group of students (groups are made from the assignment groups, but also, for class purposes, there are also a couple of non-assignment groups) has asked at least one question. The demographics of the classes are about 15% international, and 35% female. Gender equality is promoted in all fields of study at Aalto, and a diverse group of students always promotes learning and learning enjoyment. How individual groups are
made as (on average) diverse as possible is covered in the following section.

IV. THE ASSIGNMENT

A. The Group-Forming Algorithm

This was initially conceived in a simple form (at least one international student per group, but not more than one student from the same country, except the host country, Finland), but was comprehensively developed in the Tyylli project [7]. The coding accepts a multitude of parameters, mostly in terms of the personality tests available, but in practice only a few of these are used.

It must be stressed that students are given various ways to opt out of the entire questionnaire or parts they may feel uncomfortable with, in which case the questions ignored, or indeed the entire set of questions are given a neutral weighting. The country of origin provides data to generate intercountry-distances, which are derived from the dendrogram in Fig. 1 in [8]. The author feels these distances may be somewhat global-north-centric, and will be upgraded as research in this field progresses. Personality criteria based on the Big 5 [9] are derived from the following set of questions:

1. In a student group context, do you tend to be active (extravert) OR more passive (introvert)?
2. In a group setting, do you tend to be easy-going (agree, mediate, be 'nice') OR hypercritical (i.e., point out faults in yourself and/or others, challenge, suspect)?
3. Do you tend feel calm and relaxed OR anxious and worried with others?
4. Do you tend to be conscientious and on time, OR more spontaneous and tend to be late?
5. Do you like new experiences OR do you prefer predictability and dealing with what you are familiar with?

Gender is requested, in terms of male, female or other, and academic background is assessed as follows:

This scale is a playful attempt for you to assess how appropriate your previous education is for the assignment.

5 means you have passed Power Systems or some equivalent subject and 1 indicates that you feel your education is in quite another area - but you are especially valuable!

<table>
<thead>
<tr>
<th>Fine arts</th>
<th>General science</th>
<th>Basic physics</th>
<th>Electrical Engineering</th>
<th>Power Engineering</th>
</tr>
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Other categories that are coded but not used at the time of writing are the Enneagram [10] and work history relevance. The categories are represented to provide distances between students, which in turn can be weighted if one category is favoured over another. In addition, attributes can be stipulated. For example, in the course under discussion, at least one international student and one female is required in each group, but not more than one international student from the same country. It is clear that the author is interested in enhancing integration in the host country, which he has enjoyed as a human animal of New Zealand origin.

In addition, the algorithm can force the groups to be as homogeneous as possible or, to range from the most homogeneous to the most heterogeneous groups for large enough classes where the teacher is interested in pedagogical research.

The algorithm itself is written in C and will be the subject of a further publication. It takes text file inputs stipulating the preferred group size (and whether group sizes should be increased or reduced by 1 if necessary), and text file data formed from a .csv file produced from the Questionnaire plug-in in MyCourses. The groups are first ordered deterministically in terms of maximising (or minimising) inter-student distances, and then a random student-swapping routine is run until convergence, according to the stipulated criteria:

- highest average distance (greatest average diversity in all groups)
- lowest average distance (greatest average homogeneity in all groups)
- groups ranked in terms of the most divergent group possible from the class to the most homogeneous group

The output is a text file listing the groups. Once the groups are formed and the students are informed, it is stressed that the groups are purposefully as diverse as possible, which may lead to challenges, and solving those challenges mindfully is part of the learning objectives for the course. The idea is to expose the students to diversity (noting that all Master’s students are to some extent university conditioned) in a safe environment, where support is at hand, both from the lecturer, but also, if need be, from a study psychologist. The choice of essay topics, the subject of the next subsection, further increase the potential stress level inside a group, but, more significantly, increase the richness of the learning experience.

B. The Assignment Group Essay Topics

Prior to 2021, the lecturer gave the students a list of contemporary topics, one of which was allocated to each group chose, taking into account their list of preferred topics. The role of the essays was to motivate students to study relevant topics that were not fully covered in the core content. Starting from 2021, the lecturer gave each group the same topic or topics. These have been quite radical essay topics, not obviously related to the core content of the course.

In 2021 the topics were for the Finns in the group to explain the content of a television documentary (the lecturer also provided a rough English transcript) questioning whether the intended reasonable distribution tariffs were in fact unreasonable (Kohtuullinen siirtohinta on kohtuuton [11]), following some quite marked increases in distribution tariffs for rural customers in Finland. The first task was to write a critical assessment of the documentary. The second topic was an invitation for the student groups to vent their angst! They were asked to discuss the big existential issues of our time in their group, such as climate change, inequality, species
extinction, the risk of nuclear war, the constant wars waged on our precious planet... They were asked to identify the root causes of these woeful human abominations, and to write a group essay expressing their sentiments and opinions with the request that they be bold but sensitive, and suggest ways forward and solutions, both generally, and in our field – electricity. The inset below shows how the task was framed in 2022:

In 2022 the groups were formed and the single essay, same topic for all groups, was presented as in the green insert above.

C. The Distribution Network Planning Task

The course used to have two laboratory works, one on power quality and the other on a network information system (NIS). As computers got upgraded, the old NIS ceased to run on newer versions of Windows, and relocation activities and the merging of universities (otherwise an overwhelmingly positive development in the case of Aalto University) meant the loss of laboratory facilities for some research units. During this process the lecturer added a network planning assignment, mirroring his post-doctoral research activities. Initially it was planning on a blank sheet of paper, where the students were given demand and location data for secondary substations and the location of a feeding primary substation. Their task was to create a section of cost-reasonable but technically functional medium voltage network, with suitable levels of backup and switching. Over the years, the planning task has developed in complexity and in its contribution to the final grade. A geographical reference was added, where the students were given actual primary and secondary substation coordinates and falsified load data, and had to plan the networks considering the installed geographic conditions. In following years prosumer nodes were added, with significant distributed generation inspired by data from southern Germany.

In 2022, in deference to data protection laws, the students were given falsified primary substation locations, and secondary substations with prosumer load data and reliability indices, but no locations. The students had to look at a map interface, and sensibly locate the substations. This has had the downside that the lecturer cannot show actual depictions of the network from an NIS to compare with the student groups’ solution networks.

V. Student Feedback

The students are generally positive about the feedback the lecturer gives them, especially in terms of group-specific feedback for each assignment submission. The assignment feedback goes into each cost and technical parameter, provides comparison simulations for each group’s nodes, and discusses the group essays. Each group can earn back up to 2/50 points, which motivates the groups to review their work and learn from their errors.

The course divides students’ opinions. Some of the more radical content (the essay topics in recent years) doesn’t suit everyone, but the lecturer encourages students to dig deep and look at any aversion that may emerge, both generally in the course, and specifically in the assignment. The following relates, anonymously, 2021 course feedback comments from the students, many of which motivated a major reworking of the technical content:

“I am very satisfied with the course, although it has a lot of overlapping with the "power systems" course. I think the "angst essay" part of the group assignment was a bit far-fetched for a course about "electricity distribution and markets" but I still saw its point in the content.”

“The slides were a bit too messy and the lectures too long. Sometimes there was so much stuff said, unrelated to the lecture, that it was hard to filter out the important things. Even with listening to all the lectures and exercise sessions, writing a summary and a collection of formulas, the exam and exercise questions were formulated in such a broad way that it's hard to know what is expected in the question. It's overall sometimes very hard to put apply the learnt knowledge on the exercise/exam when you never learnt on how to connect certain points. (maybe I’ve missed it in the lectures, but I also re-watched them, so i am very sorry if I did miss this)”

2021 was the first Covid year and the feedback from the largely online course was the harshest the lecturer had ever received, and the overall grading of the course by the students dropped from about 4/5 to 3.5/5. There was particular concern from the students about the untidy lecture material, the complexity of the course layout, the fact that lectures often went overtime… This inspired the lecturer to devote some time to reworking and tightening up the course content, as described in the previous sections. In 2022 the feedback from the students was much more positive:

This was undeniably one of the most well-constructed and executed courses. Lectures were interesting and involved lots of topical discussion i.e. Finnish networks currently. Same continued in the exercises. The project work and overall weighting of the course was very good since the project had a lot of weight but overall was a lot of work as well. Gaining any less weight from the project would feel like an insult. The only negatives of the course are also from the project. First, it was very good idea to send emails per group since it was easy to gather the group together after. Essay related to own interests is rarely seen in the university and was very welcome. Now, the only negative is about the project work itself (network planning). Considering each group had two weeks to complete it and present it right after was too tight of a schedule.
Personally, I had quite a lot of stress because of this since I had other courses also loading my schedule. Also, in some groups it's really hard to get in touch with people and it can usually take several days to even agree on something. Fortunately, our group was very good and answered in couple of days. Providing at least 3-4 weeks for the project itself (network planning) would be much better considering the possible load of other courses and passive group members.

The feedback was as positive for 2022 as it had been negative for 2021. The main critique for 2022 was about the calculation exercises, which the students feel should be worth something (the lecturer’s logic has been to stress that doing the exercises makes the planning task in the assignment easier, which is worth a lot, and will in turn help the student in the final exam). It seems the course is out of step in that regard, but with more than 70 students, the weekly grading of calculation exercises, which would have to be changed every year and individualised for each student, would over-burden the lecturer, and so this part of the course must be automated. It would apparently help the students if the assignment was delivered to the groups earlier (the essay part was, in 2022, but they felt the more time-consuming planning task was too tightly scheduled).

VI. DISCUSSION

Whilst there is nothing very radical in the course structure discussed in this paper, it is felt that the course is becoming fit for purpose and the course does have some unique and unexpected elements. Incremental additions and innovations over the years resulted in a course that was confusing to many students by 2021. The high level of criticism in 2021 motivated the lecturer to simplify the course layout and entirely rework the contact sessions and lecture material.

Some students feel that they are sufficiently examined in the assignment tasks and that the final exam could be dispensed with. This is also an aspiration for the lecturer, who at the time of writing feels that the exam is still the best way to evaluate individual performance, and that in-group assessment would have to be considerably refined before the final exam can be dropped.

In 2022 the essay topic was refined and given more context by the lecturer, who noticed the students found method in the lecturer’s madness! Engineers need context and mindfulness as much as any other sector of society, and whilst aspects of engineering might be considered by some males to be in the male domain, that is likely to be because it is males who have been the major influence as a continuation of causal chains of behaviour going back millennia. The world is now rather different than it was during the bulk of our evolution, and we are in need of new narratives and memes to guide us out of our present morass!

Notwithstanding the incredible leaps in living quality technology has brought to the global north, it has been at a devastating environmental cost. While gender and ethnic inclusivity will require more discussion and compromise, it is to be hoped that we will transition to an engineering culture that better considers consequences, and that takes much better care of the global environment.

The foray into flipped classroom didn’t really work in previous years, probably due to unclear self-learning material, but also due to the nature of the content-rich course, much of which is non-negotiable. The methodology described in [2] would seem idealistic in a learning environment where students must optimize their time and are still conditioned to be educated or at least entertained by the sage on the stage. The lecturer fully agrees with the principle that students learn deeply by analysing, discussing and doing, but contends that most engineering students want sound information and principles on which to base their doings. Given the tight course schedule and the fact that the students are concurrently taking other courses at the same time, the intention expressed in [2] that (the flipped classroom model) allows students to learn in their own pace seems optimistic and, at least in Finland’s case, runs counter to the intention that students should attain their masters’ degrees in five years. Another consideration is that many of the students are already working, sometimes full-time, in companies.

The scepticism expressed in the previous paragraph is, however, challenged by the findings in [3], which provides a quantitative comparative study between traditional learning and the flipped learning method. Given that the core content of the course has been improved, the flipped classroom will be explored again in a more controlled way, where the students will have to self-study (in their groups) one of the core subjects in the course, and the lecturer will take a responsive and facilitative role in the subsequent class session. This will be followed by a student poll, to gather a more quantitative assessment of the efficacy of the technique.

Whilst the course is now able to be completed entirely online, the calculation exercises are lagging behind, pedagogically speaking, and it is clear the students feel they should be rewarded for doing them.

Towards the end of the spring semester in 2022, the Covid pandemic seemed to be abating and we were invited to give lectures on campus again. This only affected the last few contact sessions (the Markets part of the course). While the students voted that they would prefer on-campus activities, in fact only 1-3 (out of 76) students showed up in the lecture halls, and the total number of students attending the activities (~25 students) was lower than when the sessions were only online (~40 students) or prior to the Covid pandemic when everything was done live (~35 students). So, the lecturer’s experience of hybrid teaching was not so positive, even though the lecture-hall equipment had been upgraded to make hybrid teaching relatively easy on campus. These observations seem to concur with many lecturers at Aalto.

Another topic worth mentioning is assignment overload. Assignments, in particular group assignments, are seen by many as a great way to activate students, and so every year there are more professors and lecturers implementing group assignments in their courses. Added to that are the successful implementation of major project work courses at Aalto. This necessitates the coordination of such activities between courses on the same study paths, and giving the students more flexibility. The students consistently report, sometimes years later, that the assignment in this course is well-structured and
Feedback was a strong motivation to clarify the course content, in fact it entailed some months of work to generate new, more ordered, material. Nevertheless, student feedback should be kept in perspective. In live situations, a strong personality can sway large numbers of students to favour a course and its lecturer or not. This effect is presumably downplayed when most students are in isolation during a pandemic. There has also been tremendous improvement in teaching at the university level, and the expectations of the students have risen accordingly. Trial and error has whittled the course down to what works, which entails clearly presenting and illustrating the content, and activating the students via whatever means are appropriate and possible.

The core result gleaned in this exploration of teaching at a university has been that one should be aware of pedagogical innovations and be prepared to experiment, but also allow for the aptitudes of the lecturer, who cannot be all things to all people, and also be mindful of the situational aspects of the teaching environment, namely the demographics and aptitudes of the student body. Not everything need be put into every course! Put bluntly, the group assignment has been very successful in ED&M according to student feedback and feedback from alumni, whereas the use of flipped classroom technique has not.

A personal motivation of this lecturer is not to reinforce biases in students but to help divest students of fixed views and engineering tribalism. The students are this lecturer’s greatest motivation.

ACKNOWLEDGMENT

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REFERENCES


BIOGRAPHY

John Millar is a senior lecturer at Aalto University School of Electrical Engineering. He graduated in 1984 from Auckland University, New Zealand with a BE (Mech.), 2002 from Helsinki University of Technology (now part of Aalto) with an M.Sc (Elec.) and in 2006 with a D.Sc. (Tech.). He has worked on underground cable rating, distribution network planning and transmission grid modelling and teaches the course"Electricity Distribution and Markets at Aalto University."