ARTIFICIAL INTELLIGENCE PLANNING OF TWO REAL-LIFE MICROGRIDS

Age van der Mei
Duinn – The Netherlands
Age.vandermei[at]duinn.nl

Jan-Peter Doomernik
Enexis – The Netherlands
Jan-Peter.Doomernik[at]enexis.nl

ABSTRACT

This paper shows a real-life application of artificial intelligence for the planning of green-field microgrids and finds that an estimated 30% cost reduction is possible compared to the human grid design. The basic learning neural network is able to design both generation and transport/transmission for relatively large area's and number of users, but is not yet mathematically optimal.

INTRODUCTION

The **problem** is the optimal design of a new electricity network, given a set of objectives and constraints. In an earlier paper the authors present the results from a theoretical analysis, this paper follows-up with two real-life testcases where the artificial intelligence (AI) is applied and tested.

The two real-life cases are festivals held in The Netherlands during the summer of 2019: Welcome To The Village in Leeuwarden and Into The Great Wide Open on the island of Vlieland. Both festivals last for four days and host around 7.000 people every day, including campsites. These test-cases are chosen because of a number of reasons that make these cases relevant and valuable: (1) all installations are placed green-field, (2) the festivals are repeated every year, allowing multi-year learning to occur, (3) are flexible and day-to-day adjustments can be made, (4) batteries and hybrid-generators are available for use, and (5) it is non-mission critical infrastructure.

RESEARH QUESTION

Can tools and techniques be developed that utilize the progress in computational resources and machine learning to allow new electricity grids to be more optimally designed? And more specifically, **how can artificial intelligence assist with network design? How does artificial intelligence perform in real-life cases versus current human grid designs?** What are the current limitations of artificial intelligence? This paper seeks to uncover more of the answers to these questions by testing an artificial intelligence in two real-life applications.

In the longer-run, these questions assist in the development of being able to plan, in real-time, 'mobile electric assets', such as batteries, electrical vehicles and fuel cells.

METHOD

The method of addressing this problem is through the application of an earlier developed artificial intelligence algorithm [1]. This algorithm consists of a basic learning neural network which, step-by-step, plans the location of production and connection of users with production. The steps are described in [1]. Here the neural network algorithm is tested and compared against two green-field microgrids using human planners. The comparison is with the traditional design and the resulting structure, length, reliability and costs.

Artificial intelligence entails the designing and building of intelligent agents that receive input and instructions from the environment and take actions that affect that environment [2]. An intelligent agent is one that acts so as to achieve the best outcome or, in case of uncertainty, the best expected outcome. Authors endeavour here to apply artificial intelligence to the task of network planning, architecture and design. This paper applies a rational agent to the problem of designing a microgrid.

The problem is a combination of the Unit Allocation Problem and Transmission Problem. The Unit Allocation problem is concerned with optimal geographical location and sizing of the generator unit. The Transmission Problem is concerned with the optimal geographical location and sizing of the transmission and distribution cables. The goal is a design and architecture that scores high on efficiency, cost and reliability.

The method of addressing this problem is to test Artificial Intelligence techniques in designing and planning of new, greenfield grids. These new grids are comparable to large microgrids giving size and load. The authors work on developing and testing these new techniques for both theoretical problems and real-life grid cases. The method consists of comparing the actual grid with an artificial intelligence generated grid design.

The results and outputs are compared to the actual grid for two festival locations that design the grid yearly, without the availability of the existing grid. For transparency, the underlying data can be obtained from the relevant contacts.

Artificial intelligence for network planning

Authors co-designed an artificial intelligence algorithm to assist and for the Unit Commitment and Transmission

Problems using the following method [1]:

1. Determine demand (load, geographic location)
2. Set performance function (efficiency, costs, reliability)
3. Determine input variables (relevant investment, costs and losses)
4. Design expert systems (generator allocation, connecting, sizing of capacity, dispatching)
5. Design neural network that creates expert systems
6. Train neural network

Generate microgrid plan with trained neural network.

RESULTS

During the summer of 2019 the AI algorithm has been applied to assist in festival grid planning and outputs compared to real-life plans, operations and costs.

The two festivals each host around 7.000 people and have a music and cultural program. Campsites are available where most of the visitors stay over-night. The number of active and relevant electricity users are 113 for Welcome To The Village and 119 for Into The Great Wide Open. The electricity use and number of users is described in the table below.

Table 1: festival information

Items	Welcome To The Village	Into The Great Wide Open
Visitors (ticket holders)	7 500	7 000
Number of electricity users	113	119
Demand [kW] as provided by users	728	1389

Sources: Into The Great Wide Open organization 2018, Welcome To The Village technical team 2018.

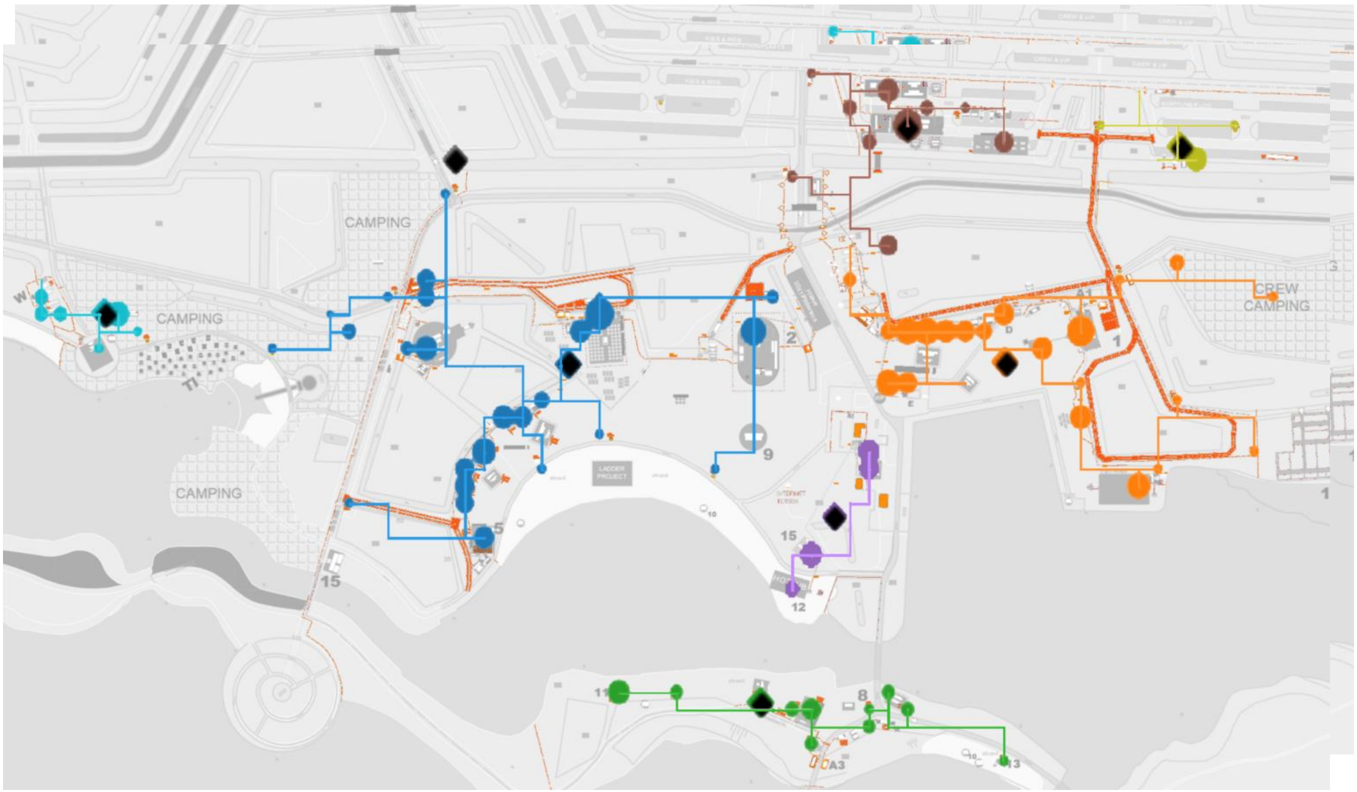
Figure 1: fixed grid design with three generators

Welcome To The Village festival area with human grid design (orange) and AI design (coloring) for a similar number of grid zones (three)

The two festivals cordially provided the input for the AI algorithm. The artificial intelligence algorithm generated different designs, depending on the number of producers. The information is first transferred to a linear rectangular grid, describing each electricity user and the requirements. The restricted areas are provided as input and the detail level is 10 meter. Other input is the redundancy amount, set to 1,2 for the festivals compared to the required kW of power which is provided by users.

The output of the algorithm is a location and capacity for the generators (also called producers) and location and capacity for the cabling required. The resulting output is shown below, for a fixed design, where the number of generators is taken to be similar to the festival plan, and a more flexible design where the number of generators is flexible.

Figure 2: flexible design by AI
Welcome To The Village festival area with human grid design (orange) and flexible AI design (coloring)



The AI output results in somewhat higher power, compared to the human designs, mainly due to the redundancy factor applied, as well achieving as a saving on the grid length. For both festivals, the savings on grid length exceed 40% compared to the realised planning (see table 2 and 3). The cost savings versus the realized plans is around 30%.

Table 2: grid design Welcome To The Village [3]

Items	Power [kW]	AI design
Human Design	578	4625
AI design	641	2490
Difference	+11%	-46%

The output for the Into The Great Wide Open festival is similar, but less interesting from a planning perspective. The reason is that the festival locations are much further apart geographically. This situation is structuring in its own sense, still a reduction on cabling could be achieved, especcialy by applying smaller grids and avoiding big, expensive connecting cables.

Table 3: grid design Into The Great Wide Open [4]

Items	Power [kW] n	AI design
Human Design	728	7335
AI design	762	4150
Difference	+5%	-43%

An observation to share is that there is a 10% observed additional cable length between human plan and execution, reflecting additional cable use compared to planning and for provisioning of back-up cables.

A key learning is that there is a large amount of human tacit knowledge involved in (festival) grid planning. The tacit knowledge involved specific knowledge about users, about the location, about the regulations etc. Therefore, on the short-term, the most relevant next steps appear to assist the human planners by providing a blue-print, which can then be modified to reflect local specifics and tacit knowledge of the locations and users. The longer-term step under development is to have self-learning algorithms that can are capable to change plans on a day-by-day basis.

Figure 3: flexible design by AI
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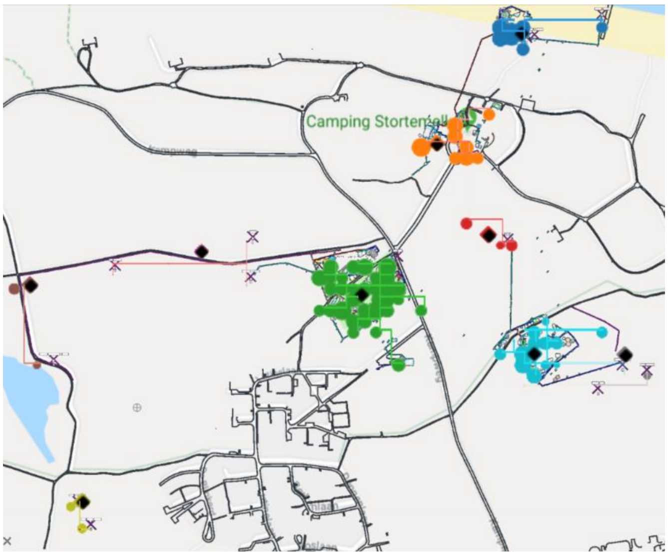

CONCLUSIONS

This paper shows a real-life application of artificial intelligence for the construction of green-field electric grid construction and finds that an estimated 30% cost reduction is possible compared to the human grid plan and 40% cable length reduction compared to the realised grid plan, highlighting there is a small but significant difference between a grid plan and a realised grid. The artificial intelligence is able to plan both generation and transport/transmission for relatively large area's and number of users, but is not yet optimal and shows a number of mistakes which are easily corrected by a human. At the current stage of artificial intelligence development, the best approach seems to *assist* human planners not relegate them to the role of 'checking' such as in certain legal and medical tasks.

DISCUSSION

The findings consist of comparisons to green-field grid plans and realisations, and not yet against other algorithms. In order to provide the possibility for replication the underlying data can be obtained from the relevant contacts. In a future paper a newer version of the artificial intelligence will be benchmarked against widely used algorithms, using large number of simulations.

The most interesting finding is how AI can assist human planners, the findings are not The application of artificial intelligence is currently in economic optimisation of the Transmission and Unit Commitment Problem. These are valuable activities in their own right, however there is a potential within the AI algorithms to greatly increase reliability and resilience. These topics will be research and developed in the future.

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