Reducing Electricity Costs of Ship to Shore Container Cranes

Developing new operational policies to reduce the peak electricity demand of a cluster of ship to shore container cranes. Which will increase economically attractiveness of the cranes, while enabling local greenhouse gas emissions reductions.

By

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Introduction Electrification is suggested as a promising solution to limit greenhouse gas (GHG) emissions in container terminals (CT) [1]. As a result, CTs are recently switching from fossil fuel-powered equipment to electrified equipment along with the use of electricity generated by renewable energy sources (RES) in the CT itself [2,3]. However, due to the electrification of equipment, the electricity grid in ports are or are likely to be in the near future overcrowded. The Port of Amsterdam is an example of a port experiencing grid congestion [9]. To guarantee a stable grid, grid operators charge clients extra based on the height of their peak load. Since a smoothed power demand, leads to an increases of the available capacity of the gird and prevents the need for expansion.

Problem Description Terminal operators pay high grid feeds because of their peak load. In 2015 Geerlings et al. [4] reported that the **peak electricity consumption in ports accounts for 25-30% of the monthly electricity bill**. Those cost are anno 2023 assumed to be higher since the charges per kW have almost doubled since 2015 [7]. Without effective solutions for this challenge, electrification of equipment will become economically unattractive causing a slowdown in the electrification and local GHG reduction.

Objective Peak loads in CTs are primarily caused by ship to shore container cranes (STSCC) [5,6]. The power profile of a STSCC is shown in Figure 1. The highest power demand occurs when lifting a container (1954 kW). Simultaneously lifting of multiple STSCCs will cause an overall peak load. The objective of this project is to suggest operational measures to control the power demand of STSCC, **granting operational efficiency and cost savings related to electricity peaks**.

Figure 1. Power Profile of one cycle

Analysis In literature some work is published aiming to reduce the peak power of STSCC, with operational measures, energy storage systems (ESS) or a combination of both. In the philosophy of reducing the overall footprint operational measures are preferable over material intensive ESS. In literature the following operational measures are suggested: fixed delay between duty cycles [5], optimized variable delay between duty cycles [5], limit on the amount of STSCCs hoisting simultaneously [4], and a limit on the power demand [4]. Only for the last two operational measures the impact on the STSCC's productivity is taken into account, of which the last operational measures shows the best results on the peak power reduction and the impact on the STSCC's crane productivity.

An independent investigation is conducted into the peak power of an group of six average dual-hoist post-panamax STSCCs hoisting 40ft containers. The highest possible peak, when hoisting a 40 ton container, is 1954 kW. Via a discrete-event simulation, the peak power of a group of six STSCC operating for three hours is analyzed for 14 replications. The outcomes show an average peak power of 4940 kW. Of the power values registered, 0.9% exceeded 4000 kW, 5.7% exceeded 3000 kW, 24.3% exceeded 2000 kW, and 71.1% exceeded 1000 kW (Figure 2).

These findings support the idea that the elimination of the highest observed powers, due to their low frequency of occurrence, are unlikely to have a significant impact on the STS crane productivity (TEU/hour).

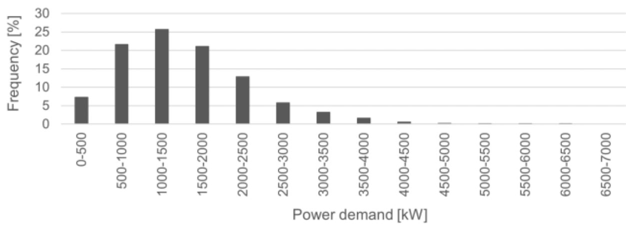

Figure 2. Frequency of the power demand

Geerlings et al. [4] developed a policy containing a power limitation to coordinate the STSCC's duty cycles. This policy is illustrated in Figure 3. An certain piece of equipment (i.e. spreader) makes a request to start an action. The to be consumed power is estimated. Thereafter it is check if the collective power demand is below a limitation. If it is, the action can start, if not, the action is postponed with one second.

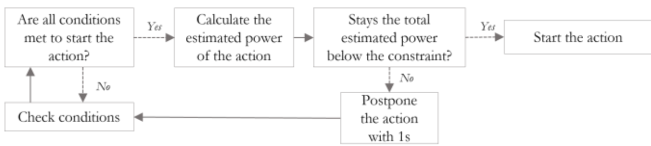

Figure 3. Policy limiting the power demand

This policy has been reproduced by means of simulation, via the discrete event simulation tool eM-plant. The effect of placing a power limitation on the STSCC's productivity and the peak related costs are show in Figure 4. At a power limitation of 2000 kW the productivity decreased with 12.2% and the peak power related costs decreased with 59.5%. Which raises the question: **How can the productivity be kept up when applying a power limitation?**

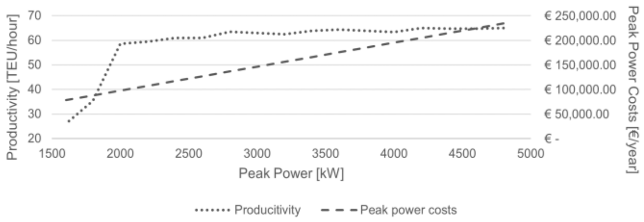

Figure 4. Effect of limiting the maximum power demand for 6 STSCCs

Solution A new policy aiming to reduce the decline in the productivity was developed and tested on the power limitation of 2000 kW. This new policy is illustrated in Figure 5. This policy checks whether other acceleration, velocity and deceleration values fit within the power limitation. A Simulated Annealing Metaheuristic is developed to find near-optimal combinations of acceleration, velocity and deceleration [8], with a constraint allowing only combinations that have a maximum increase in their action time of 20% and an objective of minimizing the action time.

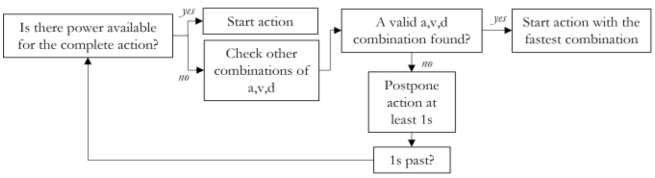

Figure 5. Policy limiting the power demand in combination with varying dynamic profiles

Results The productivity for a power limitation of 2000 kW improved to a decrease of 9.3% (Figure 5) compared to the scenario without a power limitation (unlimited), while the productivity for a power limitation without the allowance of varying dynamic profiles decreased with 12.2% (Figure 3 and 4). **Applying a power limitation of 2000 kW reduces the peak power related costs with 59.5%, while the increase in the productivity is limited till 9.3%**. The loss of productivity does not have to lead to longer berthing times, because idle time is used.

Future Steps The next step is integrating the proposed policy in the Terminal Operating System (TOS) and to do a simulation on a digital twin of an actual CT. This will give a good indication of the potential of the policy in reality.

Additionally future research can be done. The allowance of different dynamic profiles, when a power limitation is applied, is granting operational efficiency and cost savings related to electricity peaks. Policy ideas to be investigated in the future can be:

- Power limitation based on the available power generated by renewable energy sources.
- Power limitation in combination with the possibility of utilizing regenerated energy.
- Power limitation in combination with the arrival of automated guided vehicles (AGV) (i.e. if it is known that the AGV is arriving a t than the trolley can apply a slower profile such that it arrives exactly at t).
- (In case of a dual-hoist STSCC) Power limitation in combination with the fullness of the transport platform (i.e. if the transport platform is full of a loading STSCC crane, the landside trolley and spreader can apply a slower profile and smoothen their power demand).

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