AUTOMATION AND ELECTRIC DRIVES

A POWERFUL UNION FOR SUSTAINABILITY

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In recent years there has been moderate annual growth in global container handling volumes – reaching around 700 million TEU in 2017. Meanwhile, the capacity of the world container vessel fleet has increased considerably to over 20 million TEU. Because of this, shipping lines are increasingly operating in global alliances, giving them scope to optimize their services and increase their buying power.

For container terminals this has resulted in noticeable reductions in handling rates, larger operational peaks and more idle time in waterside operations. Shipping lines and inland transportation companies are requiring terminals to increase their handling performance and provide predictable, shorter turnaround times.

Further to this logistics are growing more complex. The greater power of the shipping lines and consignees is having a deleterious effect on landside stochastic oscillation due to last-minute changes and less predictable modal connections.

Furthermore, in the big picture governments, society and port authorities are demanding greater environmental control, sustainable design and the use of renewable energy. The use of casual labour is diminishing and terminal operators are under pressure to provide good working conditions, appropriate training and labour contracts that are drawn up according to agreed, clearly defined regulations.

In this rapidly evolving environment, many terminals are studying automation technology as a promising evolutionary path to improved cost control and better performance. As part of this evolutionary path, the application of state-of-the-art electric drive technologies will be instrumental in building sustainable automated container terminals that can meet future business and societal demands.

STATE-OF-THE-ART AUTOMATION

As of today, there are almost 30 terminals with a working automated container handling system, with (or without) automated horizontal transportation of containers, with centralized control systems and some kind of automated gate control incorporating features for automated container ID and X-ray inspection.

The most extensive terminal automation has been installed in CTA at the Port of Hamburg, LBCT at Long Beach, and ECT, Euromax, APMT and RWG in Rotterdam, where both the yard stacking and waterside transportation are fully automated and the landside interaction to rail and road is done via remote control.

Figure 1: Automated stacking in end-to-end arrangement

Figure 2: Konecranes Noell A-STRAD for the Port of Auckland during testing

The implementation of automation in terminals has developed slowly, despite the clear benefits from cost savings and predictable operations. Some terminals have selected a partly automated concept with an automated stacking yard and manually operated horizontal transportation at the waterside.

At greenfield terminals, the majority of automated stacking yards have been realized with automated rail mounted gantry (ARMG) cranes in an end-to-end, perpendicular configuration (see Figure 1 for an example in CTA, Hamburg).

In the Middle-East and Asia the configuration of automated stacking yards is often a parallel lay-out arrangement with cantilever RMGs, allowing a remote-controlled interchange (waterside and interchange).

In the years after the turn of the millennium, a terminal operator in Australia installed an automated straddle carrier operation. In more recent years two new, mid-sized terminals in Australia and one on the West Coast of the USA applied automated straddle carrier technology. Most recently, the next logical chapter in the automation of container terminals using straddle carriers has begun in at the Port of Auckland, New Zealand. Here 27 new, fully automated straddle carriers (A-STRADs) are being delivered (see Figure 2), and 21 existing manual straddle carriers are being upgraded to automated operation so that they can work hand-in-hand with the automated straddle carriers.

This highlights a key advantage of A-STRAD technology: the ability to convert existing, mid-size brownfield terminals to full automation. Every such terminal is a special case, however, requiring special study and unique measures.

The main drivers for adopting automation are:

- Greater control over logistics, supporting priority-based scheduling and last-minute changes
- More predictable and reliable operations, less dependence on the skills of crane operators
- Cost reductions, higher and more consistent service quality, less damage caused by accidents
- Reduced liability for injuries, reduced losses due to sickness, reduced vulnerability to labor shortages

To achieve full terminal automation, it is necessary to integrate the automated equipment and all of the related sub-systems into one efficient, reliable automated terminal system. This is a major, complex challenge. In the early days of terminal automation, terminal operators themselves took on the job of integrating all of the various parts. Recent terminal automation projects have emphasized the need for a well-planned, well-structured, timely integration of all sub-systems and components. Computer simulation tools have proven to be of great value in the planning, testing, and personnel training involved in the successful go-live of automated container terminals. Increasingly, terminals use specialized companies to do the integration.

The integration process requires well-defined, field-proven interfaces and protocols. Terminal operators are therefore increasingly interested in acquiring complete systems with field-proven, guaranteed performance thresholds. Obviously, the specification of such thresholds is a combined effort between customer and supplier.

DEVELOPMENTS IN ELECTRIC DRIVE TECHNOLOGIES

Many port authorities and governmental transportation bodies are increasing the pressure on container terminals to use sustainable and environmentally-friendly technologies. This is prompting terminals to search for alternative drive technology for their container handling equipment.

For automated stacking operations, container crane suppliers provide electrically driven automated rail-mounted gantry cranes (ARMGs) and automated rubber-tired gantry cranes (ARTGs), connected to the public electrical grid through ‘busbar’ systems (RTGs) or cable reel systems via medium-voltage, flexible cables with optical fiber cores for high-speed data communication.

For free running container handling equipment the diesel engine is still the

Figure 3: Konecranes container handling equipment (RTG, AGV, straddle carrier)

dominant power source. For straddle carriers, RTGs (late 1970s) and AGVs (in the 2000s), diesel-electric drive trains improved energy consumption, reliability and reduced maintenance costs (see Figure 3).

The demand for better energy efficiency, emissions control and reduced fuel costs has resulted in the application of new technologies from other industries, such as:

- Energy recuperation through energy storage systems (e.g. batteries and super-caps in RTGs)
- Electric drive trains powered by on-board batteries, a proven technology for electric forklift trucks, warehouse vehicles and, more recently, AGVs and certain terminal tractors
- Combustion engines fueled with "environmentally friendly" Compressed Natural Gas (CNG) or Liquefied Natural Gas (LNG)
- Hybrid drives consisting of a combustion engine, a generator, a transmission, a smaller energy storage device and an electric motor

The selection of an appropriate drive train is a complex process. The exhaust gases (like NO_x) and CO_2 emissions, measurable from the Well-to-Wheel (WTW) pollution figures, should be minimized. The recent interest in CNG and LNG fueled engines comes from their lower CO_2 production per MJ of fuel (compared to regular diesel engines). However, the NO_x emissions and the lower energy-efficiency of CNG/LNG engines still limit their attractiveness.

The big picture of terminal economics is very affected by fuel consumption per operating hour, fuel cost, maintenance cost, equipment availability and the cost of fuel storage, fuel supply and safety measures. In this respect, a fully-electric drive train offers by far the best energy-efficiency and lowest maintenance cost. Nowadays, there is great scope to design equipment along eco-efficient lines, reducing or avoiding the use of fossil fuels. This is strongly supported by recent developments in electric drive technology.

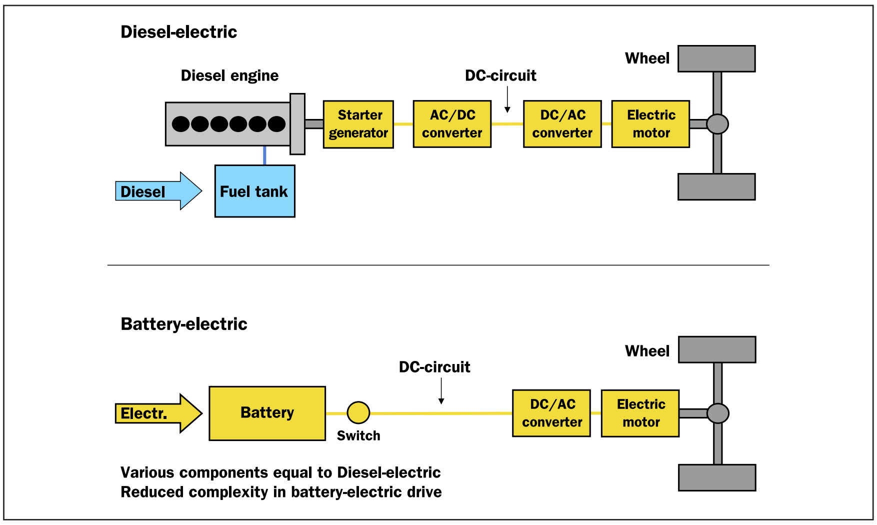

Figure 4: Diesel-electric and battery-electric drive train schematic

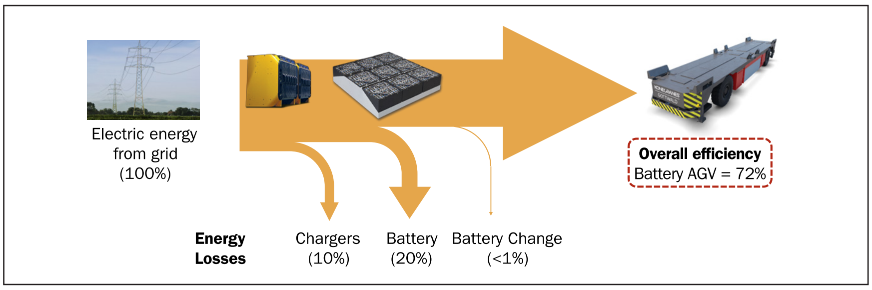

Figure 5: Energy transfer efficiency for battery charging of lead-acid batteries

Konecranes' experience with diesel-electric drive trains triggered the development of zero-emission, fully-electric drive trains, supplied with either lead-acid or Li-Ion batteries.

The advantages of simplicity (no diesel-generator and AC/DC converter) are shown in Figure 4. The much better energy-efficiency of fully-electric drives is another major advantage (Figure 5).

Compared with diesel-electric drives, the overall energy-efficiency is more than two times better (see Figure 6). On top of that, battery-powered AGVs have zero energy consumption during operational stand-still periods.

The availability of large Li-Ion batteries for industrial mobile equipment will further increase eco-efficiency. Current lead-acid batteries have a charging efficiency of 72% which will increase to about 85% for Li-Ion batteries.

Battery technology has the built-in advantage of recuperating braking energy. The Li-Ion battery technology increases the recuperation rate to a great extent.

To use AGVs heavily, a battery capacity of gross 360kWh is required, allowing 18-20 operating hours after which the battery has to be charged or exchanged with a fully charged one. Up to 2015, the large battery capacity needed for AGVs could not be met economically with Li-Ion batteries. Today, large Li-Ion batteries have become cheap enough to use in AGVs. Lead-acid batteries have stayed in the price range of 100-160 $/kWh, and Li-Ion-batteries have dropped to an acceptable 400-1200 $/kWh.

The high eco-efficiency of battery-powered drives gives a 50% decrease in Greenhouse Gases (GHG), compared with diesel-electric drives when powered with conventional energy sources (see Figure 7). Moreover, a fully-electric drive train will give zero emissions when powered by solar, hydro or wind turbine power.

BATTERY CHARGING CONCEPTS

Continuous (24/7) terminal operation requires the exchanging or recharging of empty batteries. Recharging takes 6-8 hours for lead-acid batteries and 1-2 hours for Lithium-Ion batteries, causing significant equipment downtime. There are two ways to ensure continuous operation:

1. Install quick-charge equipment and purchase more mobile equipment to compensate for equipment downtime during quick-charging. The quantity of additional equipment needed is determined by the ratio of battery recharging time to operating time. The quick-charge installations provide redundancy and their locations can be selected so as to minimize mobile equipment travel for charging purposes
2. Install a battery exchange station, preferably with automated battery exchange into and out of the mobile equipment. Due to the ratio of equipment investment/battery investment in the case of lead-acid batteries, this solution has proven to be more economical for container terminals as can be seen in four terminals recently equipped with some 200 battery-powered AGVs (see Figure 8)

As of 2010, the Port Authorities of Hamburg, Long Beach and Rotterdam required sustainable designs for their terminal expansion projects. Some terminals in these ports selected battery-powered AGVs for their automated waterside transport.

The selection of battery type and operating concept (battery exchange or recharging) was based on a total cost of ownership approach (TCO) that compared electric drives with diesel-electric drives, assessing the various electric parameters (battery type/size, charging provisions, operating time, planned outage algorithms, transformer capacities, peak loads, etcetera).

Since 2012 the TCO comparison analysis of diesel-electric vs. fully battery-powered vehicles clearly showed a much better result for the battery side. The reduced energy cost and the much lower maintenance cost strongly compensates for the slightly larger initial investment (see Figure 9).

Recently, the technology developed by the automotive industry for the quick-charging of public transport vehicles has been applied by Konecranes to terminal equipment. A first contract for the delivery of 25 Li-Ion battery-powered AGVs and 6 automated quick-chargers (Figure 10) for the fully automated CTA terminal in Hamburg is a new concept for battery-powered mobile equipment.

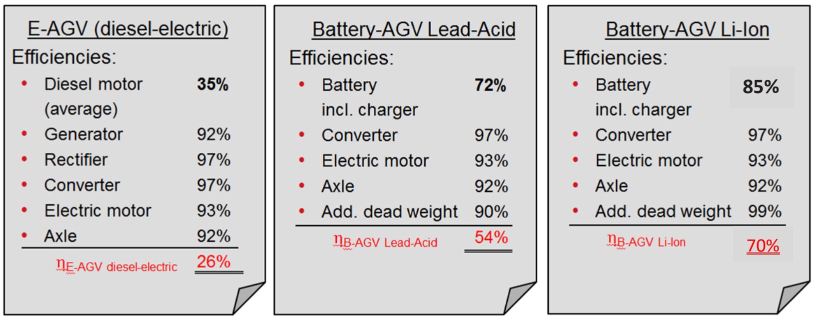

Figure 6: Overall drive train efficiency (tank-to-wheel)

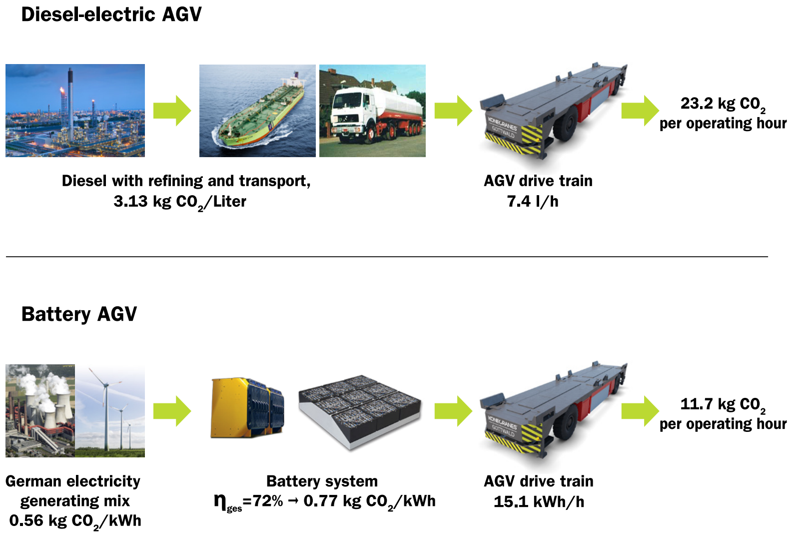

Figure 7: AGV well-to-wheel GHG production for diesel-electric (DE) and battery drive train

A TCO analysis for this case was carried out and it was learned that the reduced battery cost of the next-generation Li-Ion batteries and the improved automated quick-charger design outperformed the current concept of lead-acid batteries and battery exchange stations.

In the future, I anticipate that the TCO results for battery-powered vehicles will become even more favorable. The choice between lead-acid batteries and battery exchange stations or Li-Ion batteries and automated quick-chargers depends upon many variables. Case-by-case, TCO analyses will need to be carried out. Both concepts are viable and valuable in transferring operations away from fossil fuels towards renewable energy sources.

CONCLUSIONS

Automation in container terminals has been established over the last 25 years. Port Authorities and container terminal operators, driven by the need to reduce costs and reduce their carbon footprint, are increasingly turning to automated container handling systems and electric drive technology.

Regardless of automation, the container handling industry is increasingly focusing on electric drive technology in order to reduce costs and improve sustainability. This will increase the purchasing volumes of electric drive train components and reduce their cost. Li-Ion and other battery technologies will develop further and become even more applicable to large industrial vehicles. The development of Li-Ion technology is already very promising thanks to its short recharging time and greater capacity. However, the selection of battery technology type and size should always be made on the basis of a careful TCO analysis.

It is to be expected that fossil fuel prices will steadily increase over the long-term due to growing scarcity and higher taxation. Therefore, we can expect a growing trend of investment in renewable energy sources, which will make it more economically feasible to transfer to fully-electric, battery-powered drives. Today's technology makes zero emission operation possible when the

Figure 8: Battery exchange station with 2 AGVs, rack feeder, battery chargers, battery rack and maintenance area

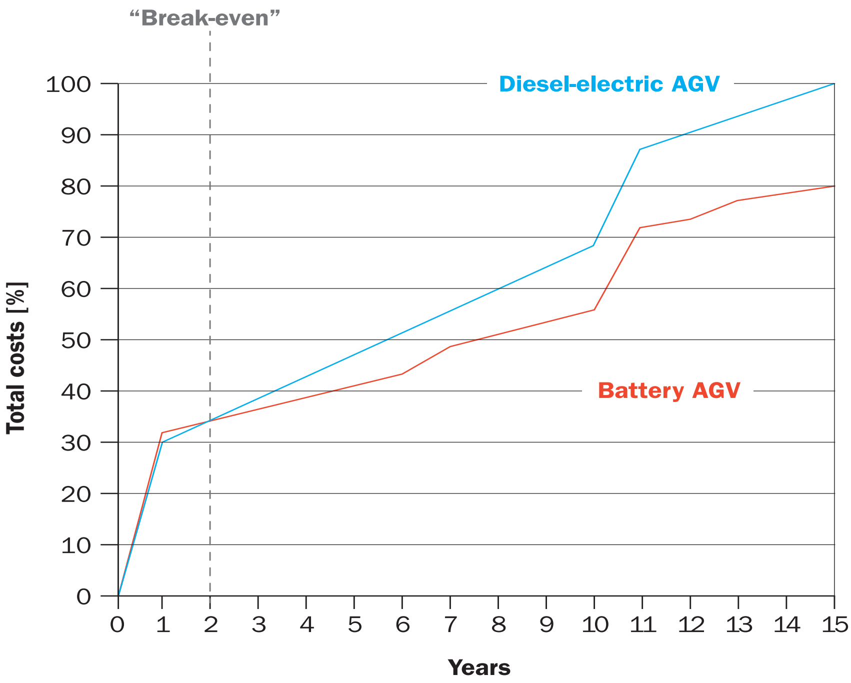

Figure 9: Total Cost of Ownership results

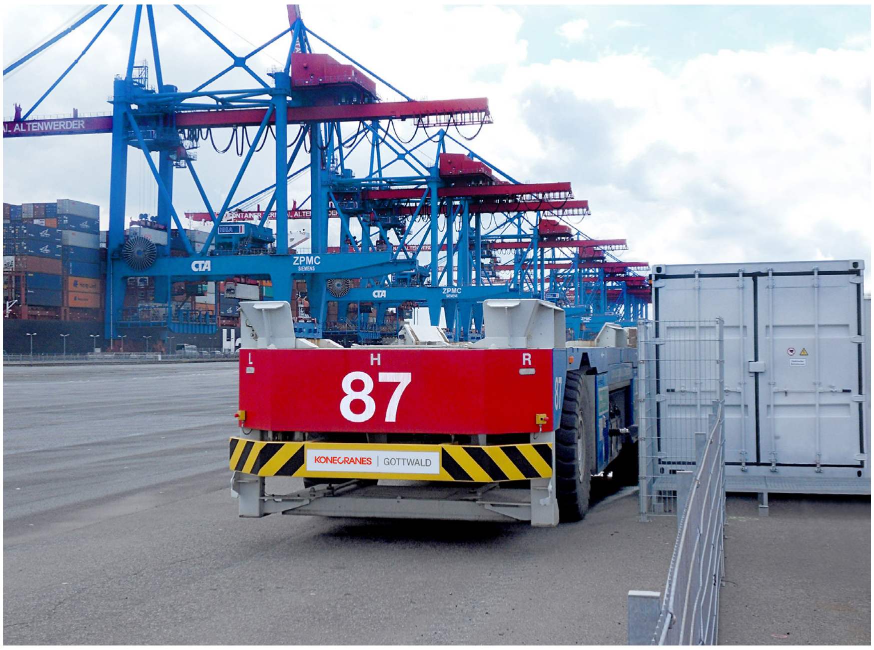

Figure 10: Li-Ion Battery AGV at an automated quick-charger at CTA, Hamburg

electricity is supplied from hydro, solar or wind power sources.

Fully-electric operation allows safe, reliable, high-density data transfer between container handling equipment and the TOS, making possible a higher level of logistical control, remote operation and equipment monitoring.

Terminal operators are increasingly interested in acquiring automation systems with guaranteed performance levels based on field-proven interfaces and processes. This is a great challenge and opportunity for container handling equipment suppliers.

ABOUT THE AUTHOR

After finishing a Master's degree in Mechanical Engineering and attaining a Doctor's Degree from the Technical University of Aachen, Dr-Ing Wieschemann joined Gottwald Port Technology, which was taken over by Terex Port Solutions, which in turn recently merged with Konecranes. Dr-Ing Wieschemann manages a team of engineers who are responsible for the planning and design of handling systems, the improvement of existing systems and the development of new technologies for terminals.

ABOUT THE ORGANISATION

Konecranes is a world-leading group of lifting businesses, serving a broad range of customers, including manufacturing and process industries, shipyards, ports and terminals. Regardless of your lifting needs, Konecranes is committed to providing you with lifting equipment and services that increase the value and effectiveness of your business.

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