Fleets of Terex Gottwald Lift AGVs and automated stacking cranes (ASCs) operating in a fully automated terminal

TERMINAL AUTOMATION

CHALLENGES IN SYSTEMS INTEGRATION

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Over the last 25 years, automation has entered into the operations of container terminals and today almost 30 terminals have installed automated handling and/or transportation of containers through centralised control systems and combined them with some kind of automated gate control and features for automated container ID and X-ray inspection. The most elaborate automation has been installed in terminals in Hamburg (CTA), Long Beach (LBCT) and Rotterdam (Euromax, APMT and RWG), where both the stacking and waterside transportation is fully automated and the landside delivery/receipt to the road is done by remote control. Even the transportation to the railhead could be automated (APMT with automated guided vehicles designed as active Lift-AGVs).

Notwithstanding the large benefits from cost savings and reliable, well-planned operations, the implementation of automation in terminals has developed rather slowly. Some terminals have even decided to take a risk-avoiding approach and selected a partly automated concept, limited to an automated stacking yard and a control system for the scheduling of manually operated transportation equipment between ship-to-shore (STS) cranes and the stack area (e.g. sprinter carriers).

Generally speaking, an automated horizontal transportation system for waterside operations in a multi-million terminal is the most challenging automated terminal sub-system. It includes a sophisticated scheduling and dispatching module, position monitoring, dead-lock control and heavy-duty vehicles, capable of running more than 5,000 hours per year with a large MTBF.

TPS SETTING THE PACE

Right from the beginning in 1989, Terex Port Solutions (TPS) – with its legacy Gottwald brand in those days – has been instrumental for all major terminal projects with both automated and unmanned transportation between STS cranes and automated stacking cranes (ASCs). After the delivery of 48 automated guided vehicles (AGVs) for the first automated terminal (ECT, Rotterdam) during 1991-1992, TPS recognised the importance of systems integration for the overall AGV-system productivity and started the development of a fleet management system and well-defined interfaces to terminal operating systems. The advantage of such a complete automated transport module resulted in the delivery of over 600 AGVs for 6 world class terminals.

In the majority of these pioneering automation projects TPS has supported the design stage with their know-how and tools for system simulations and emulation packages provided by their systems development department and by TBA, a daughter company specialised in simulation and control software. In the design stage, experience with automated operations and the availability of system analysis tools are especially important to determine a system that will fulfil the customer's demands for productivity and cost savings.

LARGER VESSELS, NEW CHALLENGES

After the year 2000, an extra complication entered the automating of horizontal transport at larger terminals with the

Manual Terex straddle carriers for horizontal container transport working hand in hand with Terex Gottwald automated stacking cranes

introduction of container vessels carrying more than 10,000 TEU.

In the 1990s, an overall berth productivity of 100 moves/hour/vessel with 4-5 STS cranes was a good service to shipping lines. However, after the arrival of 14,000 TEU vessels, and now the up to 21,000 TEU vessels, shipping lines require a berth productivity of 150-225 moves/hour/vessel with 6-8 STS cranes, which is a real challenge for an automated transportation system between so many STS cranes per vessel and the (large) stacking yard.

A proper scheduling and dispatch for all the transport vehicles and dynamic logistics, caused by the reversing push (discharge operation) and pull (loading) processes between STS cranes and the stacking yard, now require an intelligent vehicle fleet control system with smart interfaces and well defined priority rules. The earlier mentioned automated multi-million TEU terminals have shown their potential in supporting high-berth productivity when handling three ultra large container vessels simultaneously.

Some terminals have taken a step-by-step approach and started their automation with the stacking yard only connected with manual horizontal transportation to the STS cranes. Existing terminals decided to continue running their straddle carrier fleet (thus avoiding labour union disputes) with most greenfield terminals opting for sprinter carriers. In the latter cases it was not only the risk avoidance (no automated horizontal transport) but also a (short-term) saving in apron depth. The assumption that such manual carrier systems can be automated in a later stage is premature. Still, it is not yet proven that such automated sprinter systems will be capable of delivering an equal productivity on the same apron depth. The longstanding experience from TPS in the area of straddle/sprinter carriers and the simulation and analysis capabilities of TBA has been combined to respond to customer demands.

Partly automated rail-mounted gantry cranes (RMGs) were already developed in the early 1970s (Hamburg Eurokai, Hong Kong MTL, Rotterdam ECT) for 11-14 wide/4-high stacking. Gantry and trolley positioning was already automated, while hoisting/lowering remained manual.

This concept was further developed in the late 1980s, however TPS later installed ASCs at some terminals (Antwerp Gateway and Rotterdam World Gateway, both mainly DP World) by 2004. Regardless of the slightly higher investment, these terminals selected ASCs from TPS as they were characterised by their beam-guided spreaders and smart, camera-directed remote control for landside container delivery and pick-up.

This type of ASC proved to be a reliable stacking machine, quite similar to linear robots, widely spread in many industries. The precise, fast positioning (no fine-tuning at the selected slot) results in short ASC cycle times is attractive for ports facing heavy wind loads.

DEMANDS FROM PORTS AND SOCIETY

Another challenge for terminal automation has arrived in recent years via the demand from society and ports for more sustainable and environmentally friendly technologies. A change from diesel driven equipment towards an electric supply from the grid proved to be the most attractive. Obviously this is no problem for ASCs as they could benefit from the high speed data communication over fiber cores arranged in medium voltage supply cables. However, it is not that easy for automated transport vehicles, operating at the apron between STS and ASC. Here as well TPS could contribute with its experience and know-how of diesel-electric and hybrid drives and developed a battery-driven AGV in combination with a fully automated battery exchange and charging System (BES). TPS then integrated in terminal control systems.

For economic reasons and proven design batteries and charging models, today the lead-acid battery still offers the best feasible concept and at present there

Terex Gottwald Lift AGVs operating in a fully-automated terminal, here in an automated battery exchange station (BES) while an empty lead-acid battery is being exchanged for a full one, which takes only a few minutes

are more than 200 battery-supplied AGVs and Lift-AGVs operational; all of them with recyclable lead-acid batteries. To support a continuous terminal operation the developed BES proved to be a cost attractive concept with hardly any influence on terminal logistics.

Future battery and charging technologies triggered by the automotive industry may become attractive, however the availability of a required large energy capacity, a reliable operation and a long lifetime will determine the feasibility of such new technologies. At present AGVs and Lift-AGVs, provided with lead-acid batteries combined with a BES are proven in three major terminals and the electric supply from the grid allows a long-term cost control. They also allow the potential of applying green energy when power utilities purchase or generate renewable energy from solar, hydro or wind power stations. In that case automated terminal transport will be a real zero-emission system.

OPERATORS LOOKING AT COMPLETE SYSTEMS

The developments up until now have proven that the integration of automated equipment and all kinds of related sub-systems into one efficient, reliable terminal handling system is a real challenge. Various types of equipment must be efficiently controlled by means of equipment control systems integrated into the terminal's operations control system. On top of that, large amounts of data from RFID systems, container weighing systems, gate control systems, equipment status and condition monitoring, remote operations (such as STS crane operations, landside ASC operations, X-ray activities) must be processed, and process information must be made available for an operator's decisions (and manually controlled equipment) through standardised human interfaces and menu-driven graphical user interfaces.

At the dawn of terminal automation, operators themselves arranged the integration of all these various sub-systems. Recent terminal automation projects have emphasised the need for a well-structured, timely integration of all components and sub-systems. Extensive testing and training with emulation tools (such as those available from TBA) showed their benefit for a successful go-live of automated terminals.

This integration process of the growing numbers of features requires well defined interfaces and protocols and more and more an expert activity. Therefore terminal operators are increasingly interested in acquiring complete systems with guaranteed performances. For that reason system suppliers like TPS may offer a total automated terminal handling system, including the installation and commissioning of all components necessary for entire functionality.

During its 25 years of experience in the automation of container terminals, TPS has recognised the importance of interface engineering and systems integration. The future may bring new applications from the "Internet of Things", telematics, built-in standardised decision-making and automatic recovery procedures, and at that time, well-prepared systems integration will be even more important for the successful automation of terminals.

ABOUT THE AUTHOR

After finishing a Master's degree in mechanical engineering and a Doctor's Degree at the Technical University of Aachen, Dr Wieschemann joined Terex Port Solutions (TPS) in 2001 as a member of the systems group. Concerning the global activities of TPS, Dr Wieschemann is managing a team of engineers responsible for the planning and design of handling systems, the improvement of existing systems and the development of new technologies for terminals. Recent examples arethe Terex Gottwald Lift AGV andthe zero-emission Terex Gottwald Battery AGV with an automated battery exchange station.

ABOUT THE ORGANISATION

Terex Port Solutions (TPS) is part of the Material Handling & Port Solutions business segment of Terex Corporation that supplies customers in ports with a unique combination of machines, software and services under the Terex and Terex Gottwald brands. Whether it is ship-to-shore cranes, reach stackers or fully automated, integrated handling systems for containers and bulk, TPS provides reliable solutions for rapid, safe, efficient handling of all forms of cargo with low downtimes and excellent return on investment.

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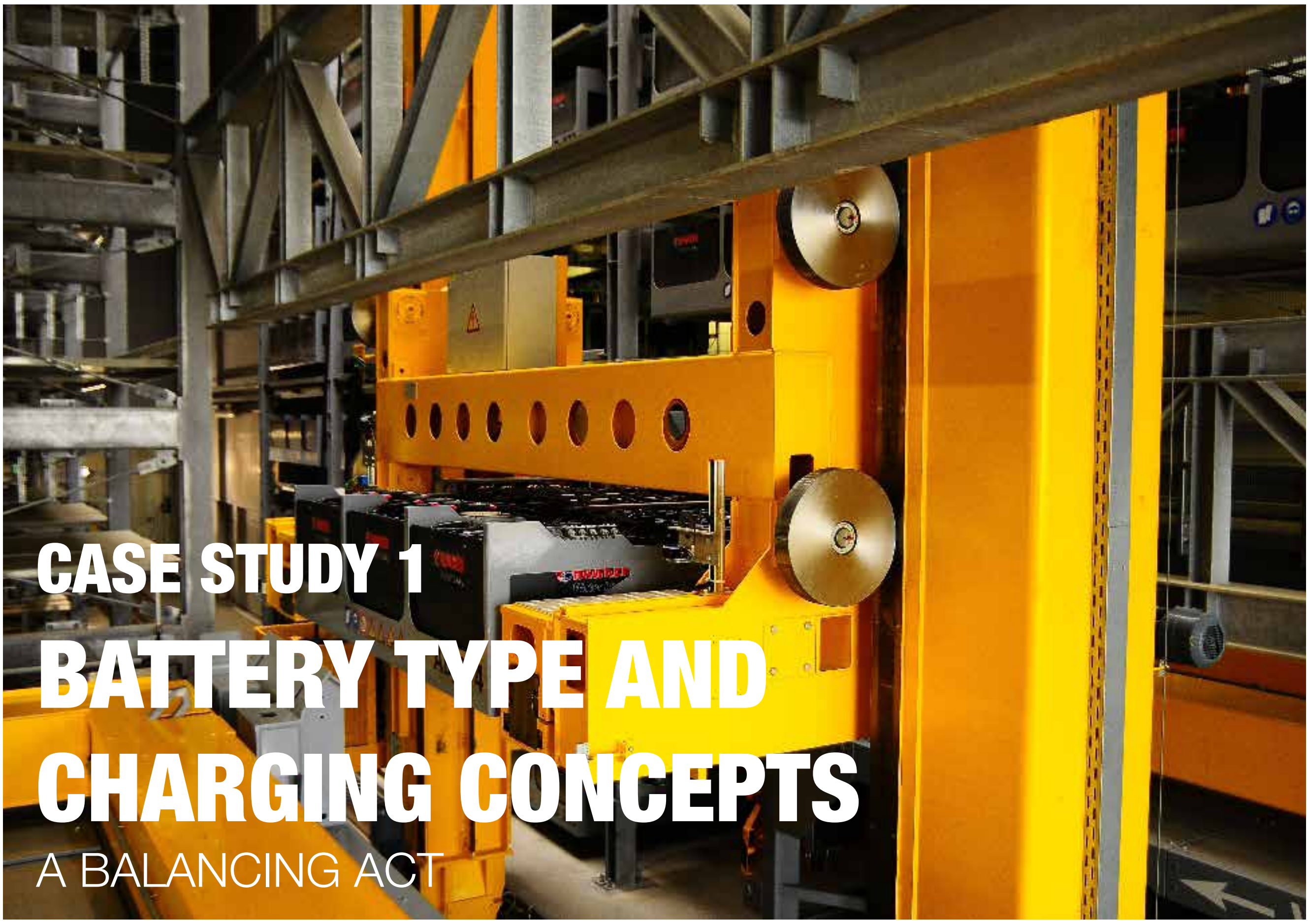

CASE STUDY 1

BATTERY TYPE AND CHARGING CONCEPTS

A BALANCING ACT

During the last decade various types of Li-Ion batteries have been developed for the automotive industry, both for hybrid and full-electric drive trains. Advantages such as a high energy density and the ability to store recuperated energy (fast recharging) are attractive for automotive applications. However, these types of batteries are more complex than the proven lead-acid batteries. For safe operations, most Li-Ion batteries need an additional cooling/heating system and a sophisticated battery management system.

A proper charge of Li-Ion batteries still requires 1 – 4 hours and in general, the longer the charging time (and lower amperage), the longer the battery lifetime, measured in load cycles. The outage for charging is acceptable for private cars and city buses, but for 24/7 continuous terminal operations these outages require either a surplus of equipment or a battery exchange facility. Quick charge provisions, as applied for the automotive industry, are under development but the impact of quick charging on battery lifetime is unknown. Moreover, it should be considered that AGVs require battery sizes up to 5 times larger than the largest car battery that is now applied in the Tesla S. This size influences battery design (hot spots) and charging control electronics.

CONS

It should be realised that a small Li-Ion battery may save investment, however for 24/7 terminal operations especially, small batteries will include disadvantages, such as:

- Reduced AGV utilisation due to relatively more travel time to charging stations
- Reduced battery life in years due to an increased number of charge cycles per day
- increased energy cost per handled container (due to more unproductive travelling)
- increased complexity for the logistic control system (less dual transport potential)

The complexity of charging procedures and provisions should not be underestimated. For instance, when a terminal has three 18,000 TEU vessels simultaneously operating, this will involve an 80 – 100 AGV fleet continuously operating for 48 hours. Regardless of battery type and charging method, the energy demand will be 1.5 – 2.5 MWh per hour with fluctuations in voltage and current.

THE FUTURE PICTURE

In the near future, Li-Ion batteries may become attractive due to their increased lifetime (in cycles), better energy transfer efficiency, better energy density, and low maintenance. However in the future their investment cost should be reduced, charging equipment must be standardised and there should be a solution to an environmentally acceptable disposal at the end of their life.

Li-Ion or other composite batteries will be further developed with a potential of short recharging times. Investment cost and lifetime must show their economics yet.

The investment cost for lithium batteries (now ranging from US$450 to 1,250 /kWh on system level) is still a major issue for mobile equipment with large capacities (e.g. above 200 kWh).

It is questionable whether planned large factories (e.g. Tesla-Panasonic) will substantially reduce Li-Ion battery cost, which is necessary to compete with the present large lead-acid batteries. The assessment for lead-acid or Li-Ion requires an in-depth TCO-analysis with an NPV (Net Present Value) approach and should cover the charging method and charging provisions, the planned outage algorithms, the installed transformer capacities and result in peak loads at the grid.

At present, lead-acid batteries with a guaranteed number of charge cycles offer a terrific value for money and are proven technology with many years of experience, both in port business and other industries. The future will show whether and when Li-Ion batteries will become an attractive alternative with long-term, better economics and reliability.

CASE STUDY 2

SYSTEMS APPROACH

DESIGNING AUTOMATED TERMINALS

In the design of an automated terminal a large variety of equipment such as control systems, data communication, priority rules and so forth has to be combined into one reliable handling system, capable of performing all handling functionalities, even under peak conditions. Right from the start of the conceptual design, a systems approach should be taken. This means that alternative solutions should be analysed and assessed on a multitude of topics. These include the potential to grow stepwise with the projected terminal throughput development or the requirements for sufficient stacking capacity and ample handling productivity simultaneously at the waterside and landside even under waterside peak conditions. This is especially true for a terminal with automated transportation at the apron and rail-mounted automated stacking cranes, as the balancing of stack capacity and handling capacity is of utmost importance. That requires a proper trade-off between infrastructural provisions, numbers and type of stacking cranes, numbers and type of transport vehicles (e.g. AGVs, Lift-AGVs or automated sprinter carriers) and interfacing (buffer) provisions around the quay cranes and at the stack ends.

A NEW PARADIGM

Growing performance demands from shipping lines must be met in the future and that issue requires a well-designed transport system that can follow the reversing logistics (push or pull when discharging or loading) from the quay cranes. For that reason, two Rotterdam terminals selected the Lift-AGV transport system offering a high productivity with manageable apron traffic and quay crane interfacing.

Obviously, in a systems approach, the characteristics of the many components must be known and well-determined. A successful automated terminal design can only be realised when the majority of applied components or systems has already a proven track record.

DEVELOPMENTAL STRATEGY

In the early stages of terminal development, the design team should already recognise the critical interfaces and should determine which type(s) of tests and commissioning efforts will be required to get a controlled integration. In that respect, the risk of unexpected problems can be reduced by opting for select suppliers and ensuring integration is managed under the responsibility of one system supplier, which has proven capabilities shown in earlier projects.

Instead of a completely new system design with all kinds of new (hardly tested) components, an evolution of existing (sub-) systems should be preferred because, in that case, the new design can benefit from improvements in earlier detected shortcomings. This evolution can be clearly recognised in the AGV/ASC systems subsequently installed at ECT, CTA, Euromax and RWG.

It is the same philosophy which should be in place during commissioning; operators and maintenance crew must be trained, not only in their day-to-day operations, but also in the handling of breakdowns and off-standard activities. These activities must be integrated in the commissioning and test phase and that ensure operations are easier to manage when only one or perhaps multiple suppliers have a stake in the implementation of an operation.