INTEGRATED CRANE CONTROL

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Summary: This paper summarizes the most important features of the Crane Control System for automated container crane as a part of the port production and information system.

1. REQUIREMENTS OF MODERN CONTAINER TERMINALS

The competition between different container terminals and port is now growing rapidly due to the introduction of new container ships in the 6000-8000 TEU range and the forming of large groups of co-operating shipping lines. The importance of being able to attract main line calls and becoming the hub for trans shipment has increased tremendously.

To keep existing customers and attract new ones all container terminals big or small must provide:

- Fast and consistent turn around times of vessels.
- Low cost per container handled.
- Short time from between unload/load on large vessel to departure/arrival of feeder vessels, trains and trucks.
- On line information about container position and status to the customers.
- Flexibility to accept late changes in loads and to handle schedule changes of ships.
- Low numbers of misplaced or damaged containers.

These requirements result in demand for crane control and automation systems capable of handling loads fast, reliable connected to information systems continuously providing up-dated information about container moves and crane status.

2. THE HISTORY OF CRANE AUTOMATION

PLCs have been in use in container cranes for about 25 years. Neither the PLCs nor the digital DC drives introduced in the mid eighties did result in any significant improvement of functionality of the container cranes. The PLCs and drives could not solve any of the three key crane processes:

1. Measurement and control of load sway.
2. Communication between crane and terminal control.
3. Obstacle and target identification.

These technological obstacles did delay the introduction of automation and centralized control by decades compared with other industry applications. In the eighties tests were made to try to limit load sway using mechanical and/or hydraulic arrangements. The problems faced were:

- The space limitations when entering the cell guides of a container ship or working between high stacks in a stacking yard set the limit to hoist rope angles to be used.
- “Stiff” hoist rope arrangements can be designed using several extra hoist ropes, but this gets too complicated with lifting heights of more than 4 containers.
- Combinations of hoist ropes in angle and hydraulic dampening systems mounted on the trolley (machinery on trolley cranes) or acting on rope sheaves on the boom (rope trolley cranes) have been tested but result in considerable extra cost, weight and complexity.
It is very difficult to design any arrangement that can dampen sway in gantry and skew directions. All methods incorporating hoist ropes with significant angles result in creation of a rotation of the load, so called “secondary sway”, which can need considerable time to stabilize. As the mechanical/hydraulic systems are designed to dampen, time is need from that the trolley stops in the right position until the load sway has stopped.

The first break through, on load sway control, did come 1989 spearheaded by the ABB Container Positioning and Pendulum Control (CPC) handling load sway control and optimum path control. The key technologies used were:

- Powerful process controllers.
- Advanced control theory based on a software model of the sway process.
- Accurate optical load position sensor (LPS).

At about the same time the first cable drums with capability to transfer optical fibers did appear in the market, finally providing the crucial high speed connection between the crane and the terminal control. The last step in the process towards fully automated container cranes can now be taken using laser transducers as the eyes of the crane and using high speed communication networks for transmission of video signals. The development of automation for cranes is now faster than in other industry areas and the ports industry is quickly catching up with the paper, chemical and metals industries.

3. THE CONCEPT OF INTEGRATED CRANE CONTROL

The first Integrated Crane Control concept is now introduced by ABB [1]. It is designed for handling of the complete control and automation of a container crane. The total functions is built up of a number of distinct building blocks which can be installed from the beginning or added on after the delivery of the crane. Many of the building blocks are tightly connected to each other and requires as system deigned and built with the total functionality to achieve the right performance. Already the basic drive and control package has to be designed to handle the real time and communication requirements of the automation functions.

### 3.1. Drive and control

A number of features are needed in the basic drive and control package of the crane to enable the addition of automation and information system functions[2] [3]:

- Powerful process controller with advanced multitasking, capable of handling several time critical control loops simultaneously.
- High speed communication links between drives, transducers and controls.
- Accurate measurement and fast transmission of drive positions and speeds.
- Communication interfaces for all necessary drive, transducer, remote control and information system equipment.
- Centralized interface for diagnostics of the complete system.

### 3.2. Electronic load control

The concept of electronic load control is defined as the process of controlling the motion and path of a load hanging in suspended by ropes. The rope arrangement shall not have any significant mechanical dampening.

**Load Position Sensor (LPS).** To be able to control the load a fast and accurate measurement of the load position relative the trolley is necessary. The relative position in trolley, gantry and skew direction must be measured with an error not bigger than 2 mm within a range of 3 - 35 meters. So far the only transducer concept providing this accuracy is an image sensing systems with a defined target on the load as used in the ABB LPS system.

**Sway control.** Electronic sway control is available for trolley and gantry motions. The sway control transforms a load speed reference signal given by a driver or an automatic crane control software into a speed reference for the trolley or gantry drive of a crane. The regulator uses the feedback of load position from the LPS sensor system. The signal is filtered in such a way that the drive reference will as quickly as possible bring the load from the present state (speed, sway angle and sway speed) to the speed ordered and no sway. The technique used is very similar to what is used by an experienced crane driver. The trolley (gantry) is accelerated to bring the load in motion and is than slowing down for a moment before accelerating to final speed to be able to get the exact timing to “catch” the load when it has reached the right speed. The sway
control has to be a continuous control able to respond to any reference variations and to any disturbances like wind and initial sway. The control is adjustable to give comfortable working environment for the crane driver on the trolley.

**Skew control.** The skew control uses the LPS for feedback of the actual load skew position. The reference is either no skew or a skew angle ordered by the driver. The actuators can be screws powered by AC drives or hydraulic cylinders. The response has to be quite good as the skew motion has a short sway period.

**Position and Optimum Path Control.** The position and optimum path control as introduced by the ABB CPC system adds a trolley/gantry and hoist positioning function to the basic sway control. The optimum path function calculates the most efficient combination of horizontal and vertical motion to minimize the cycle time (fig 3).

### 3.3. Automated crane control (ACCS)

A crane with the electronic load control is well prepared for automatic, unmanned operation. To realize the unmanned operation the crane must be equipped with "eyes" to be able to identify obstacles and the position of targets like vehicles and stacks of containers [1].

**Target position Sensor (TPS).** The ABB Target Position Sensor is a high resolution laser distance meter capable of scanning in several directions to search for objects. The sensor is able to report the position of container with centimeter accuracy. The system can be operated for:

- Collision protection, scanning ahead of a motion to detect any unknown obstacles.
- Stack profile scanning, scanning the height of the containers in one bay on a ship or a row in the:
  1. stacking yard.
  2. Identification of vehicle position
  3. identification of container stack position.

**Automated Control Sequence.** The automated control sequence is the brain of the unmanned crane. The sequence control is built up to handle various types of motions with and without load and with different combinations of hoist, trolley and gantry motions. The control sequence provides the targets for the CPC positioning and path control and handles supervision of the whole motion to ensure that safe operation is guaranteed.

### 3.4. Remote control
Remote control provides a facility for real-time control of a crane from a location kilometers away from the actual crane. Remote control can be used for:

- Handling of special cases not part of the normal unmanned operation.
- Fault situations.
- Handling of loading/unloading of manually operated vehicles.

The function enables crane drivers to be placed in a good, office type, working environment, it eliminates traveling time in the terminal and it enables one driver to supervise a number of normally automatic cranes. The remote control package includes:

- Video cameras an microphones on the cranes.
- A fast communication network, normally ATM type.
- One or several remote consoles.
- Interface for remote reference to the crane control system.

3.5. Production control

All cranes are via a TCP/IP communication network and optical hubs connected to the Crane Information Management Server (CIMS_NT) which is the connection to the terminal control systems [4], [5], [6]. The production orders are sent from the terminal control via the CIMS server to the Checkers View (Ship To Shore Cranes) or Cabin View (stacking cranes) where the actual selection of the job to be passed to the automatic operation of the crane is done. When a movement of a container is completed the job is reported back with the actual location of the container, thereby closing the information loop in the terminal ensuring that no containers are misplaced and an immediate information of the location and status of the container. The CIMS server records and handles production statistics (fig.4).

3.6. Maintenance

The maintenance functionality on the crane is concentrated in the Crane Monitoring and Maintenance System (CMMS) in the electrical room [1]. The CMMS has the status, fault and diagnostic information about all electrical subsystems on the crane. Information customized for the crane driver is presented on the Cabin View and all information is also available on the remote CMMS normally located in the maintenance office. Several remote CMMS can be connected to the network and it is also possible to via the communication hub access information via telephone or computer networks from outside service people or ABB service center. Utilization, maintenance and fault statistics are available in the CIMS server.
3.7. Information

Computers connected to the terminal computer network can access information in the CIMS server to get updated information on crane status and production.

4. SUMMARY

With the Integrated Crane Control the container cranes the technological obstacles of automation of container cranes have been overcome and the level of full unmanned operation can be reached. The close integration of all necessary functions ensure optimum real time performance and efficiency. The cranes become large robots in a container terminal that is very similar to an automated warehouse and are fully integrated in the “warehouse” inventory and control system.

5. REFERENCES


[3] Slutej, A. "The new Multidrive concept for engineered drive application", Mipro, Rijeka pg. 2-1.2-51994

