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Crane Control System for Raw Material Yards

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A control system was developed for raw material yards of the works of a metal industry. It is devoted to the automatic operations of the raw material yards stackers, and to the improvement of the stacking method to stack granular coal uniformly. The system automatically controls the stacking operations without human intervention, and also prevents any collision between cranes, stackers, jibloaders and the level-roughing cranes.

1. Introduction

In steel industry, production process control has achieved a remarkable progress. And now, control and management of physical distribution is coming up to be the main subject of reasonalization or manpower saving. Particularly, computerization of yard control and material handling machine operation is demanded as a matter of course in a newly prepared raw material yard, or upgrading of management and control is demanded also in the existing facilities. The demand has its base in simplicity of both the shapes of handled materials and performance of the handling machines, and in need for both shortening anchoring days of ships and effective use of yard areas.

SEI delivered a control system in the raw material yard to a metal industry which aims at automatic operation of the stackers as well as improvement of stacking for uniformalization of coal granules. The keys for development of the system were adoption of the inductive radio system, of which SEI has many records in various sectors of industry, for accurate position detection for the stackers, installation technics of different detectors matching to the existing installations, and controlling softwares for cranes operating in the rather narrow yard of the existing facilities.

2. Outlines of the System

The objective coal yard was divided into two for the reason of location. In each of the two yards, controls were to be executed on automatic operation of stackers, and collision prevention between stackers, jibloaders and level-roughing cranes. The total number of the objective cranes was 21. Fig. 1 shows control equipment configuration in one of the two yards.

Loading of coal by automatic operation of the stacker is executed by program control, corresponding to the stacker's proper controlling device, according to operation procedures set on the monitor/control panel. Further, the system is adaptable also for perfect automatic operation by signals from the yard process computer in case of automation of the entire yards in the future. Prevention of collisions between stackers, jibloaders and level-roughing cranes is based on calculation of the minimum distance between cranes as they travel and their booms turn, and an indication either safe, attention or alarm is displayed depending on the calculated minimum distance. The signals for the indication are also used for stopping the stacker in automatic operation, warning to the operator of the jibloader or the level-roughing crane and displaying the monitoring indication on the luminous board on the ground.

Position detection for the automatic operation and collision prevention employs the absolute address detection system making use of inductive radio for position in travelling, and the selsyn giving digital outputs via an S/D converter for the boom that turns horizontally and vertically.

A data transmission system of 4,800BPS using transposed-pair-type inductive radio system transmits data to the control device on the ground on one hand and to the stackers, the jibloaders and the level-roughing crane on the other. In this system, a monitor/operation panel and a control device are provided

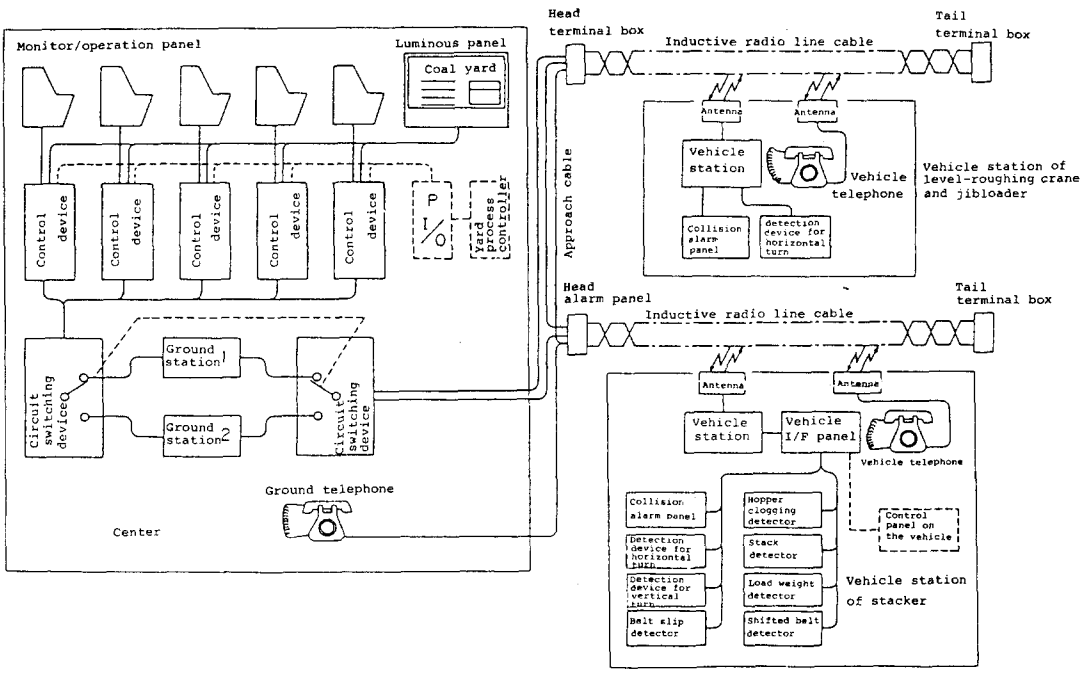

Fig. 1 Control System

independently for each stacker so that it can easily be involved, one-by-one individually, into future automatic operation system and, at the same time, in order to minimize effect on operation on occasions of failure of the control device. The control devices are collectively installed at the center for the reasons why the stacker does not require rapid response because of its slow performance and why this facilitates maintenance. A selected control device executes computation for collision prevention about all the cranes. With regard to data transmission equipment and position detection equipment, a device controls all the cranes collectively, and another device is provided as a backup to form a configuration preventing system failure due to connection change by the circuit switching device.

3. Stacker Operation

3.1 Operation mode

A stacker is loaded with coal by the procedures preset on the monitor/operation panel in normal cases, but is provided with the following four operation modes for future improvement, special work and backup for troubles:

(1) Remote automatic operation I

This mode executes automatic operation via the controller according to instruction from the process controller for yard control. The operator has nothing to do with the operation either at the raw material operation room or on the machine side, except for occasions of trouble. While not realized in this time installation because the process controller is yet to be installed, this mode is prepared for future upgrading of yard automation.

(2) Remote automatic operation II

This mode executes automatic operation via the controlling device according to the information set by the operator on the monitor/operation panel. That is, the operator plays a role equivalent to the instruction from the process controller for the yard in (1). He sets on the monitor/operation panel such information as a. area for loading and water spraying, b. loading patter, c. sort of work and d. stack height at the end of loading. His pressing "preparation" button and, then, "start" button after the setting lets the stacker implement automatic loading according to the program. His pressing "end" button stops the stacker finally. In this mode, the stacker lets the operator know of the end of each work (operation preparation, one-point stacking, etc.) by the buzzer to make him ascertain the stacker operation.

(3) Remote manual operation

This mode is only for travelling to a

designated position like evacuation of the stacker. The travelling is executed after moving the boom into the direction parallel to the rail by pressing "to the north," "to the south," high speed, low speed or stop switches on the monitor/ operation panel.

(4) Manual operation on the machine side

The operator executes manual operation of the stacker in the operation room.

3.2 Loading pattern

Selection of loading pattern is possible among the following three while an arbitrary pattern is available by programming on the controlling device.

(1) One-point stacking

One-point stacking stacks coal until it reaches the final height with the stacker boom fixed at the stacking point. Only elevation angle of the boom is changed according to the stack height. After the a stack has reached the final height, the stacker moves a predetermined distance (the pitch) in the travelling direction to make the similar stack there. This operation is repeated until end of stacking which is defined by the formation of the stack at the final place and by expiration of coal.

(2) Bag-like stacking

Bag-like stacking makes small stacks one after another in the yard moving the stacker with a small pitch. After the small stacks have been made over the whole area for stacking, new heaps are stacked upon the already-made. Thereby, stacking is done in accordance with the angle of repose on the periphery. The stacking is continued until the stacks reach the final height, and ends at coal expiration.

(3) Continuous stacking

Continuous stacking makes stack moving the stacker continuously at a constant speed. The stacker stacks the coal uniformly over the entire stacking area repeating travelling and turning. The stacking ends when the stack reaches the final height and coal expires. In case where the boom's horizontal/vertical angle is changed at a turn-back point, correction of tip end position of the boom is executed by inching the stacker in the travelling direction.

3.3 Collision prevention computation

Collision prevention computation is executed using commonly one of the controlling devices for the stackers' automatic operation. Data of travelling position and slewing angle of all the cranes in the yard are inputted into the controlling device for the computation, selected with the circuit switching device, via the ground station at every 0.5 sec or so (equal to the poling period of the data transmission). The controlling device executes collision prevention computation described below about all the combinations of cranes with possibility of collision--cranes on the same or adjacent rails--in the yard, and issues alarm to the relating cranes as well as displays indication on the luminous board.

(1) Two cranes on the same rail

Assuming the X-axis in the travelling direction, calculated is the distance Xc, shown in Fig. 2, between $X\alpha_1$ and $X\beta 1$, projections onto the X-axis of the parts approaching the nearest to the other among the booms, the counter-weights and the trippers of the relating cranes. And, it is judged "safe" when $Xc > 50m$, "caution" when $50m \geq Xc > 20m$ and "alarm" when $Xc \leq 20m$. And, alarm is issued to the relative cranes in the last case.

(2) Two cranes on the adjacent rails

Y-axis is assumed normal to the X-axis. Calculated are distance Xc', shown in Fig. 3, between $X\alpha$ and $X\beta$, projections onto the X-axis of the slewing centers of the relating cranes; Xc between $X\alpha_1$ and $X\beta$, projections of the parts approaching the nearest among the booms and the counterweights of the relating cranes; and Yc between $Y\alpha_2$ and $Y\beta_2$, the similar projections onto the Y-axis. And, it is judged "safe" when $Xc' > 50m$ or $Yc > 30m$, "caution" when $30m \geq Xc > 20m$ or when $Xc \leq 20m$ and $30m \geq Yc > 20m$, and "alarm" when $Xc \leq 20m$ and $Yc \leq 20m$. ANd, alarm is issued to the relating crane in the last case.

For jibloaders and level-roughing cranes, a signal indicating either the same or the adjacent rail is also sent to the operators besides those indicating "safe," "caution," or "alarm."

4. Equipment for Automatic Operation and Collision Prevention Computation

4.1 Controlling device

Two methods are available for automatic operation of stackers and computation of collision prevention among cranes:

a. Control by multiple microcomputers
b. Control by a microcomputer.

From concept putting weight on individuality of cranes mentioned previously, the former method was adopted. And, sequencers were employed as the microcomputer.

4.2 Data transmitting device

Strong to noise, "transposed-pair-type inductive radio system" transmits data between the cranes and the controlling devices installed on the ground. Data transmitting terminal devices from SEI's SUM-series, which have application records for overhead travelling cranes, serve the system. Designed especially for crane data transmission, SUM-series devices have the following features:

a. The terminal device of a proper function is contained in a standard unit making it possible to assemble an arbitrary data transmission system only by combining necessary units.

b. The unit is small in size and light in weight making it possible to replace the unit easily on occasion of trouble and to maintain the device with the least space.

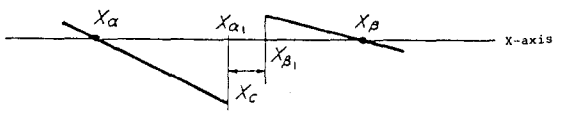

Fig. 2 Collision Computation on the Same Rail

c. The unit enables use of a mother board and a back panel in a wide range raising reliability of the device.

d. The device can be used even in an adverse noise environment since the bus line and external connections are isolated electrically.

e. The device generates only a little amount of heat during use since it adopts low power consumption elements.

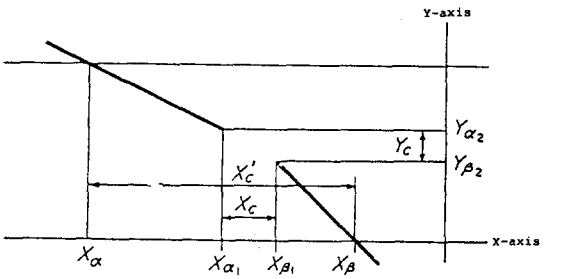

Fig. 3 Collision Computation across Adjacent Rails

Fig. 4 shows configuration of the data transmission device expressed mainly by units from SUM-series. Both the ground station and the vehicle station are composed around the CPU unit (SUM 080) and the memory unit (SUM 001) that use microprocessors.

4.3 Detecting Devices

(1) Travelling position detecting device

For detection of travelling positions of cranes, inductive radio system, which

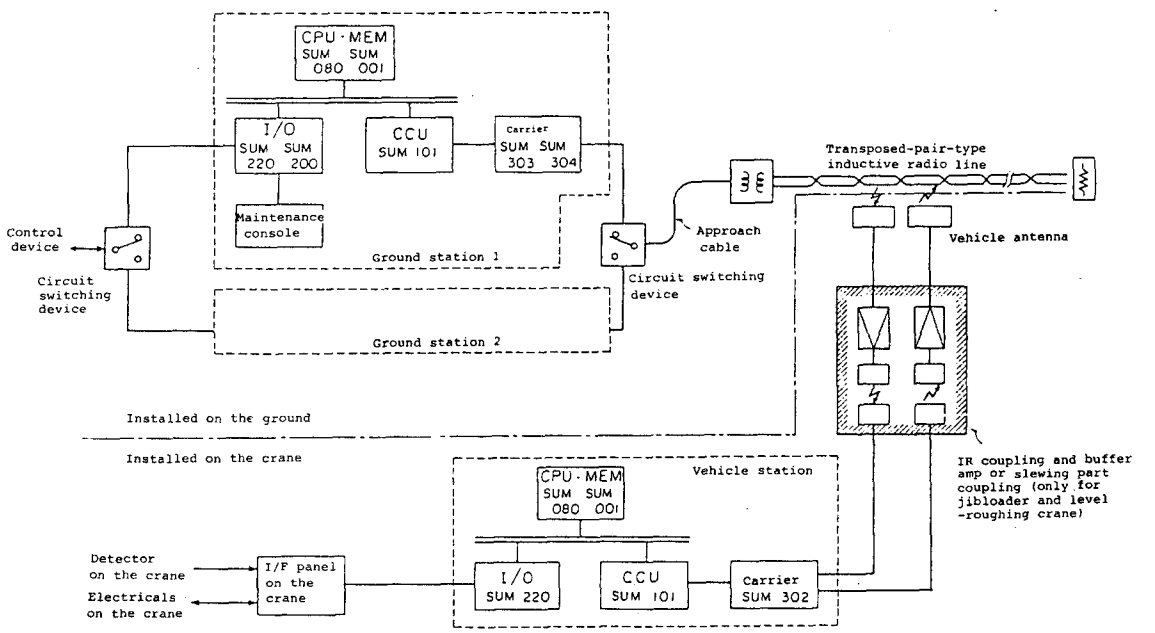

Fig. 4 Block Diagram of the Data Transmissing Device

has many application records for overhead travelling cranes and new traffic transportation systems, has been adopted. For the reasons why the controlling devices are installed on the ground and required indication accuracy of detected crane positions are as rough as the meter unit; level type, absolute address and on-the-ground detection system has been employed. The receiving devices for position detection are equipped in the data transmitting ground stations, transmission antennas on cranes used commonly with data transmission.

(2) Detectors on the cranes

Table 1 show summary of the detectors added specially in this system for automatic operation of the stackers and collision prevention computation between cranes.

4.4 Monitoring/Operating Devices

(1) Monitor/operation panel

The monitor/operation panel for each stacker is installed in the raw material yard operation room of each system. A stacker is operated automatically according to the setting made on the relevant monitor/operation panel. The push button switches for the setting are of self-illumination type, and lighted after signal check by the control device. As for setting values, value indication lamp is separately lighted to display the value checked by the control device in order to prevent setting error as well as maloperation of the stacker due to malfunction of relating switches. State of stacker operation and substances of various troubles are all displayed on the monitor/operation panel.

(2) Luminous panel

A relatively large luminous panel is provided for each system to make relative positions of cranes in the yard and state of collision alarm known at a glance. On this panel, graphically displayed are crane travelling positions in 25m step with indications showing presence or none of an alarm signal and a trouble in the position detecting device for each crane.

4.5 Crane Telephone

Crane telephone, using the inductive radio line commonly with data transmission and position detection, is installed. The telephone facilitates

a. Talking (mutual call) between the on-the ground operation room and an arbitrary crane cabin, and

b. Simultaneous call to all the cranes from the on-the-ground operation room.

Operation frequency of the telephone uses 161kHz for communication from the ground to the crane and 84kHz for communication from the crane to the ground, separated from data transmission equipment and position detection equipment with a hybrid coil and a filter.

5. Disposals at a Trouble and Maintenance

5.1 Trouble detection

This system makes sure of all the signals and detects a trouble as described below in order to prevent stacker maloperation and runaway:

(1) Position detection signal

Signals detecting crane travelling position and boom slewing and elevation angles are compared with the preceding detection signals. And, "position detection trouble" is judged by a difference exceeding the predetermined.

(2) Stacker controlling signal

Checkup signal is returned from a stacker against a stacker controlling signal sent from the control device. Abnormal substance of the returned signal or no return of the checkup signal within the predetermined time after issuing the original controlling signal constitutes "checkup signal abnormality" judgment.

(3) Control device, ground station and vehicle station

Microcomputers in the devices are provided with self-diagnosis function to detect a trouble. With regard to data transmission, trouble is detected by transmission error detection and time-out check.

Table 1 Detectors on the Crane

Name	Detection system	Specification
Slewing angle detector	Selsyn S/D converter	Detection range 0°-360° Detection unit 1
Elevation angle detector	Selsyn S/D converter	Detection range 0°-36° Detection unit 1°
Belt slip detector	Speed switch	ON with a belt speed 30% lower than the rated
Belt shift detector	Limit switch	
Hopper clogging detector	Hung electrostatic type	
Load weight detector	Conveyor scale using a load cell	Measuring accurary (integral) 10% or less
Stack height detector	Limit switch	

Slewing angle detector only for jibloaders and level roughing cranes.

(4) Monitor/operation panel

All substances of settings and instructions except emergency stop can be checked up by indicator lamps and numeric displays. In case where operation is impossible due to wrong setting, "mis-setting" indicator lamp is lighted.

(5) Device/apparatus troubles

Different trouble detectors find out troubles of the device/apparatus troubles on the stackers.

5.2 Disposals at Troubles

With regard to troubles not continuing for more than a determined time or judged normal by re-checks among those detected by the detectors described in 5.1, their substances are only stored and automatic operation of the stacker is continued. When a trouble lasts longer than the determined time and automatic operation is judged impossible to continue, stacker operation is suspended issuing alarms. On such occasions, the operation is resumed after removing the cause of trouble by turning on the "re-start" switch except for a trouble of the control device.

5.3 Backups

All ground installations whose troubles may cause failure of the entire system are provided with backups, described below, in this system.

(1) Ground station

Each system has two ground stations, one for ordinary operation and the other for backup. And, switching from the one for ordinary operation to the one for backup is executed instantaneously by the circuit switching device. No information setting is required for this switching since no previous data storage is necessary in data transmission and position detection by the ground station.

(2) Control panel and monitor/operation panel

Control devices and monitor/operation panels are composed of the same hardwares and the same softwares. Consequently, if control device for an operating stacker fails, it can be replaced with control device and monitor/operation panel for a stacker in rest only by changing the connectors on the circuit switching device. In this replacement, operation procedure must be re-set on the monitor/operation panel only when the control device memory is found abnormal, re-starting being possible only by exchange of the memory unit or rewriting of the stored memory in other cases.

5.4 Maintenance

Besides the backups are provided as described in 5.3 for troubles, the following functions are prepared for easy maintenance:

(1) Ground station maintenance console

The console displays state of data transmission with each crane, and type and line of error occurrence together with CPU memory substance of an arbitrary address in the ground station.

(2) Maintenance program

By replacing the memory unit of the vehicle station or the ground station with the maintenance program, faulty parts can easily be separated.

(3) Oscillator for maintenance

The oscillator judges a trouble in the travelling position detection receptor.

(4) Loop test function

Loop test function enables folding tests for data transmission between devices.

6. Conclusion

Outlines of the raw material yard control system delivered to a metal industry has been described. Automation of the raw material yard operation and substantial benefit in quality control at the yard are expected by introduction of the system. Further development efforts are planned for the goal of automation of the entire yard including reclaimers besides stackers by future adoption of process controllers for yard control and development of various detectors.