An Operating Equipment Scheduling System Based on Multi-Rule Constraints

Duan Bin[1, a]

[1]Wuxi CAS Ubiquitous Information Technology R&D Center CO., LTD, Wuxi, JiangSu

[a]db19820409@163.com

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Abstract. Energy is devoted to building an operating equipment scheduling system based on multi-rule constraints as well as to describing system structure and functions of every model. Then it describes all the factors which impact the usage of operating equipment, and also abstracts from the factors to constraint rules, then, focus is placed on expounding the constraint rules and scheduling algorithm.

Introduction

As modern aluminum plant witnesses an increase in its production capacity, overhead travelling crane has evolved into the indispensable factor in production[1]. The reasonable and effective use of overhead travelling crane will have a direct influence on production efficiency and cost. Currently, some aluminum plant deals with task assignment of overhead travelling crane by means of artificial scheduling, whereas scheduling personnel may easily make mistakes due to the heavy task[2]. Additionally, the scheduling of overhead travelling crane mainly relies on broadcasting, as a result of which the schedulers on the ground will be unable to confirm where the overhead travelling crane is, and the overhead travelling crane operator will be incapable of predicting next task[3]. To address these problems, an overhead travelling crane scheduling system is designed.

System structure

As a sub-system of MES system, overhead travelling crane scheduling system includes server, PC terminal of electrolysis workshop, switch, wireless router, mobile terminal.

PC terminal of electrolysis workshop:

Each electrolysis workshop needs to be equipped with one PC terminal that connects with server via wired Ethernet;

Mobile terminals of overhead travelling crane:

Each overhead travelling crane is armed with one mobile terminal that connects with server and workshop PC terminal via wireless router[4];Network topological graph is Fig. 1:

System function

System functions are partially deployed in workshop PC terminal, including task management, task scheduling, and on-site scheduling, and partially deployed in mobile terminals, including task operation.

Task management. Task management involves task increase, task modification, task deletion, and task enquiry. The major function is to type tasks into module (partial tasks will be generated automatically when MES system is configured with task monitoring events; for instance, event monitoring service monitors the pole changing cycle table to generate pole changing tasks) to generate a task list and provide task source for subsequent scheduling.

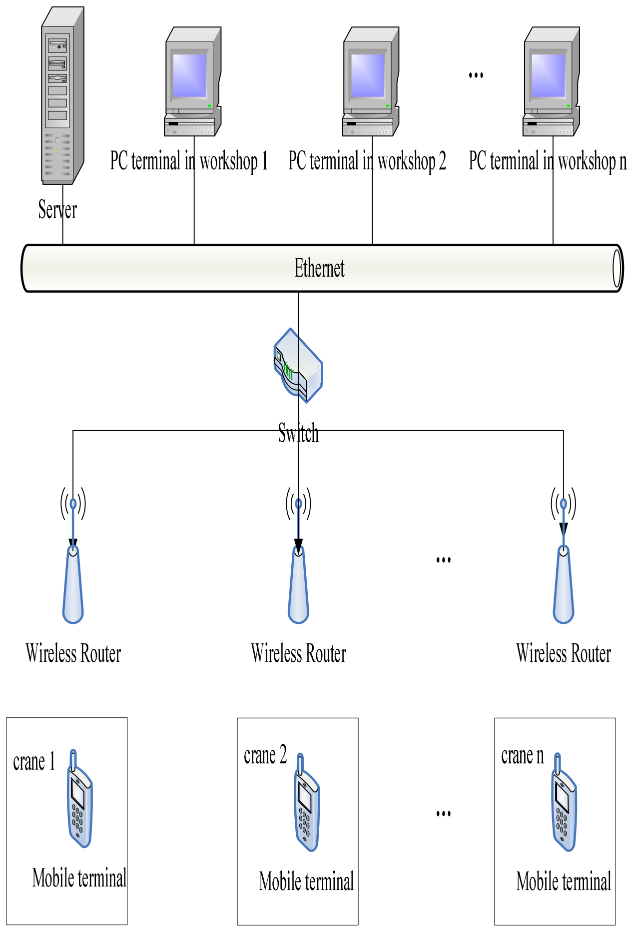

Fig .1. network topological graph

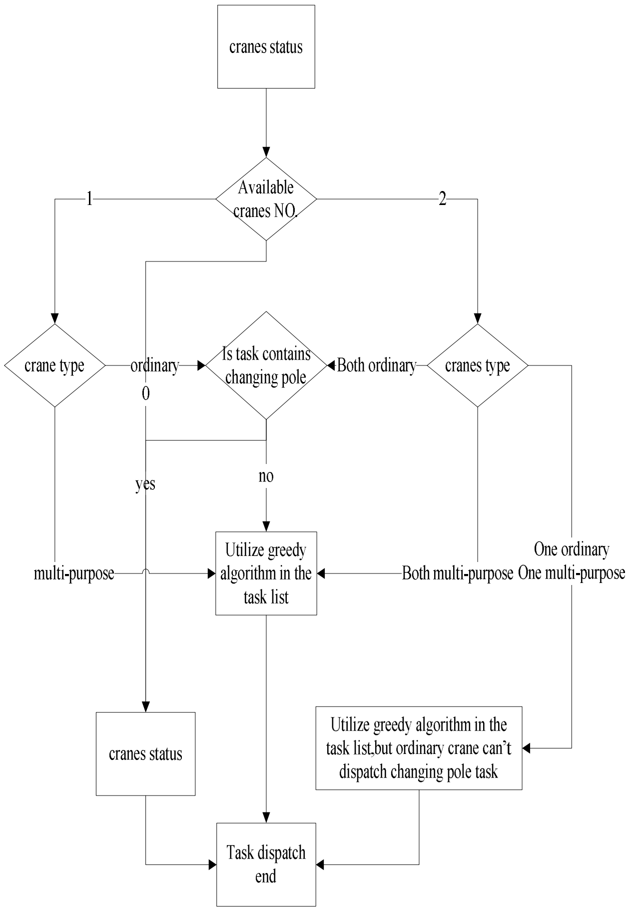

Fig.2. algorithm flow

Task scheduling. Task scheduling is the key function of scheduling module, which arranges tasks reasonably and makes them consistent with optimization requirements in the light of scheduling algorithm[5]. Below is the detailed introduction to scheduling algorithm (The aluminum plant consists of various work areas, each of which requires 3 shifts a day; given the basically identical production situation of every shift in each work area, a shift in a work area is hereby taken as an example).

Problem description:

1)In a work area, there are N electrolytic tanks in a row, and two overhead travelling cranes (overheard travelling cranes are either multi-purpose or ordinary, and their difference is that the multi-purpose one is able to accomplish all tasks, while the ordinary one is unable to process pole changing task), at least one of which should be multi-purpose overhead travelling crane. Since the two overhead travelling cranes share the same rail, their relative location will remain unchanged (that is, the two cranes move in an opposite direction, unable to pass over each other).

2) The overhead travelling crane needs to complete varieties of tasks, such as aluminum release, pole changing, bus lifting, fluoride salt adding, overlay adding, feeding of overhead travelling crane. Among these tasks, overlay adding and feeding are the associated tasks of pole changing. It is necessary to add overlay in the 40^{th} minute after the completion of pole changing task, and the overlay, stored in the stock bin of overhead travelling crane, will be completely consumed after being added for three times due to the limited space of overhead travelling crane[6]. Afterwards, overhead travelling cranes will have a need for feeding.

Scheduling model:

Scheduling algorithm is input as tList$\{T_1, T_2 \ldots T_n\}$. the total task list of the shifts on a day-via task management. Scheduling algorithm involves three major factors, namely, electrolytic tank, overhead travelling crane, and operation task. Electronic tank D [id, status, x, y] includes four attributes, respectively corresponding to id number ($1 \le id \le N$), status (status $\in$ {available, breakdown}), x-coordinate is $0 \le id \le (N-1)*P$, with P(meter) representing the clearance between two electrolytic tanks, and y-coordinate (constant). Overhead travelling crane C [id, status, x, y, type, stock] includes six attributes, respectively corresponding to id number ($1 \le id \le 2$), status (status $\in$ {available, breakdown}), x-coordinate is $0 \le id \le (N-1)*6$, y-coordinate (constant), crane type (type $\in$ {ordinary, multi-purpose}), and the remaining overlay in stock bin ($0 \le stock \le 3$). Operation task [type, prior, time, D (id)] includes four attributes, respectively corresponding to task type (type $\in$ {aluminum release, pole changing, bus lifting, overlay adding, fluoride salt adding, pole adjustment, electrolytic tank overhaul}), priority level ($0 \le prior < \infty$), standard completion time (constant), and electrolytic tank id number ($1 \le id \le N$). Additionally, scheduling algorithm also touches upon the information such as parking position of overhead travelling crane (two ends where the electrolytic tanks are placed linearly), feeding point of overhead travelling crane (the terminal end where electrolytic tanks are placed linearly and which is near the electrolytic tank with large id number), and the starting and ending time of a shift. All the information above can be acquired through the configuration of MES system. Since the electrolytic tanks are placed linearly (y-coordinates of all electrolytic tanks are the same), the distance between electrolytic tanks i and j is D(i).x-D(j).x, which is regarded as a known condition here.

Algorithm output:

Scheduling algorithm is output as CList which is {(T_1,$time_1$), (T_2,$time_2$),… (T_2,$time_2$)}, task list of overhead travelling crane, with $T_i \in$ tList, $time_i$ representing the starting time of T_i task.

Algorithm target:

The scheduling algorithm is targeted at the load balancing of overhead travelling algorithm; that is (refer with: Eq. 1) $CList_1$ stands for the task list of overhead travelling crane 1 and $T_b \in CList_2$, $CList_2$ stands for the task list of overhead travelling crane 2

$$\sum T_a.\text{time} = \sum T_b.\text{time}, \text{ with } T_a \in CList_1 \tag{1}$$

Scheduling algorithm constraint:

The SD standard for safe distance between overhead travelling cranes is (refer with: Eq. 2) and the ordinary overhead travelling crane is unable to accomplish pole changing task.

$$SD = | C_i.x - C_j.x | > 2P \tag{2}$$

Scheduling algorithm step:

the T_i.Status $\neq$ completed tasks are sequenced in accordance with T_i.prior, and the tasks at the same priority level are sequenced in the light of the id number of electrolytic tanks[7].

1) when C. status-the status of the two overhead travelling cranes is judged, step 2 should be followed if only one overhead travelling crane is available; step 3 should be followed if both the two overhead travelling cranes are available; users should be reminded of quitting from the scheduling process if neither overhead travelling crane is available;2) when the available type of overhead travelling cranes is judged, it is necessary to work out whether Clist in task list contains T. type = pole changing if T. type = ordinary overhead travelling crane; if T. type = pole changing is included, users should be reminded of quitting from the scheduling process because the ordinary overhead travelling crane is incapable of accomplishing the pole changing task; otherwise, there is a need proceed with this process; if T. type = multi-purpose overhead travelling crane, greedy algorithm should be utilized in the order of total task list: firstly, it is necessary to judge whether the total task list is non-null; if the total task list is null, the assignment will end; otherwise, the distance between every task and current overhead travelling crane should be calculated, and then the nearest task should be moved from total task list to task list of overhead travelling crane; also, there is a need to record the starting time = the starting time of previous task + standing completion time of task + constant G (setup time between tasks); these steps should not stop until the completion of task assignment;3) when the type of the two overhead travelling cranes is judged, step 4 should be followed if both of the overhead travelling cranes are multipurpose ones; provided one of the two overhead travelling cranes is ordinary one, step 5 should be followed; if the two overhead travelling cranes are ordinary ones, there is a need to judge whether task list involves pole changing task: if no, step 4 should be followed; otherwise, users should

be reminded of quitting from the scheduling process because of the inability to accomplish pole changing task;4) the tasks should be assigned to the two overhead travelling cranes alternately until the total task list is empty. There is a need to find out the task that is at highest priority level and closest to the overhead travelling crane with fewer tasks from the total task list. On this basis, the starting and ending time of the task should be calculated, and the task of another overhead travelling crane within this time period should be compared. If there is a task, it is necessary to calculate the distance between overhead travelling cranes, and if the distance exceeds the safe distance, it means that the task assignment is successful and the task should be added to task list of this overhead travelling crane; otherwise, it means that task assignment fails, and then next task should be found from total task list and assigned according to the aforementioned conditions repeatedly until the suitable task is found;5) assignment algorithm is basically identical to step 4, only differing in the judgment over the inability of overhead travelling crane to accomplish pole changing task; algorithm flow referens Fig.2

On-site scheduling:

In case of temporary or urgent tasks in production, on-site scheduling model will provide an interactive interface that allows the tasks to be included in current task list and trigger the function of task rearrangement[8]. To help overhead travelling crane operators understand current production situation and subsequent task arrangement timely, the system adds modules to mobile terminal, so that the operators will be able to check task arrangement and give feedbacks on task progress at any time. Then, overhead travelling crane will blend in with the system instead of becoming an information island;

Summary

With the help of overhead travelling crane scheduling system, production managers have emancipated themselves from the heavy and complicated scheduling tasks, devoting more time and energy to quality management. Meanwhile, task flow becomes more clear and foreseeable. What's more, production information management has shaped a closed loop, which has contributed to higher efficiency of aluminum's electrolytic production.

References

[1] Azza, L. El merouani, M. Medouri, A.: Logistics and Operations Management (GOL), pp.176-180, 2014 International Conference.

[2] Ma, H.L. , Chan, F.T.S. , Chung, S.H. ,Wong, C.S.: Quality and Reliability (ICQR), 2011 IEEE International Conference, pp.85-89.

[3] Cheng ji Liang, You fang Huang, Yang Yang: Automation and Logistics, 2008. ICAL 2008. IEEE International Conference, pp. 2131-2135.

[4] Jiao Zhao , Lixin Tang: Automation and Logistics, 2009. ICAL '09. IEEE International Conference, pp.270-272.

[5] Yang Gao, Xiao-qing Zeng, Wei zhou: Beijing: Tsinghua university press.2006.

[6] O'Connor J T: “Achieving integration on capital projects with enterprise resource planning systems[J]”. Automation in Construction,2000(9), pp.515 -524.

[7] Qingzhu Cui, Yuewen Fu, Fengxing Zou,” Automatic Control and Artificial Intelligence”. International Conference (ACAI 2012). pp. 1720 -1723.

[8] Tulluri, S, Baker R.C, “A Quantitative Framework for Designing Efficient Business Process Alliances”. Proceedings of the 1996 International Conference on Engineering Management and Control, pp. 656-660.