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Automatic Scheduling of Charging and Pushing Sequence of Coke Ovens

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Abstract*: Most of the coke oven plants have the manual schedule for pushing and charging sequence of the coke ovens. The manual schedule gives rise to several problems which affect the process time and simultaneously affecting the production. This paper presents the full automatic system for coke oven scheduling using the process control system. Process control system uses plc logic based on the scheduling algorithm. Further, using this auto schedule battery machines can be made to work according to schedule leading to man-less operation of battery machines. This auto schedule system reduces all errors and all battery machines are made to work automatically using the schedule. This approach makes the system completely automatic in operation; which improves an overall efficiency of the plant and also reduces operator workload hence creating the comfortable working environment for plant operators.

Keywords: Battery machines, coke oven schedule, human machine interface, process control system, programmable logic controller.

I. INTRODUCTION

Coke oven battery includes battery machines along with group of coke ovens. Charging of coal into oven and discharging of coke from oven is done by charging machine car, pusher machine car and hot coke car which are collectively called as battery machines. The sequence in which ovens are discharged and charged again after discharging is scheduled by engineer, which is done manually in most of the coke making plants. Schedule is done on computer and printed slips are given to the operators. Though slips are given but later shuffling in sequence is conveyed through verbal communication only. This verbal communication creates many errors which lead to increase in process time simultaneously affecting the production. This paper proposes optimized automatic pushing and charging schedule for coke ovens. Further, development of full automation of battery machines can be done using auto schedule since most of the commands are given by operators for charging and discharging function though they are highly automated. The work in this project is divide in two categories:1) optimized auto schedule and 2) automation of battery machines using the schedule. Section II describes basic coke oven battery charging and discharging function using manual schedule. Section III describes detection of coke oven number by system using sensor. Section IV describes methodology, section V results and finally section VI covers conclusion.

II. BASIC COKE OVEN BATTERY SYSTEM

Coke oven battery involves carbonization process at high temperature in an oxygen deficient atmosphere over an extended period of time. Charging and discharging of coke is done by battery machines, which include charge car, pusher car and hot coke car. These machines are mobile and travel the length of the battery. Coal is loaded into the oven directly by charge car in powder form or in the form of coal cake which is made by compressing coal powder. Second method is more convenient since amount of coal powder loaded into the oven is more compare to then in the first one which results in higher production. Each car has programmable logic controller (PLC) and human machine interface (HMI) for control and monitoring purpose. Process control system is a master control which is a distributed control system (DCS). PCS is much more than a traditional distributed control system. Communication between PCS and coordinating PLC is via profinet. Further, coordinating PLC is connected via wireless system to all machine car PLCs. The wireless system is transparent radio system which behaves like normal Profibus cable. Master and slaves don't see the radio link. Since cars travel the entire battery on track cable communication is not feasible so radio solution is chosen in coke plants [1] [2]. Coke oven schedule is an order in which coke ovens are discharged at particular time and then charged again. When coal is charged into the oven, an oven takes approximately 47-48 hours to get ready. Industrial solution firms have developed a separate framework for automation which has different modules, out of which coke schedule is one of the module [4]. Further, using the schedule battery machines can be automated, which will function automatically the charging and pushing of the coke oven by

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providing interlocking between the machines [3] [5].

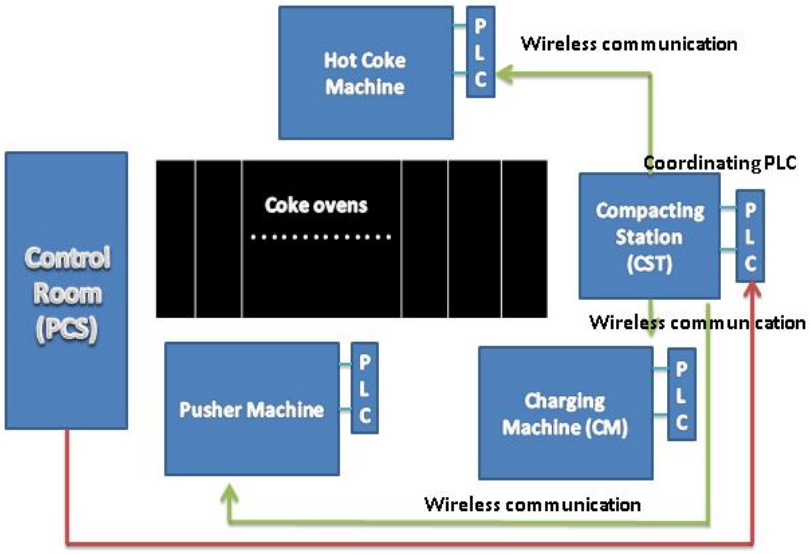


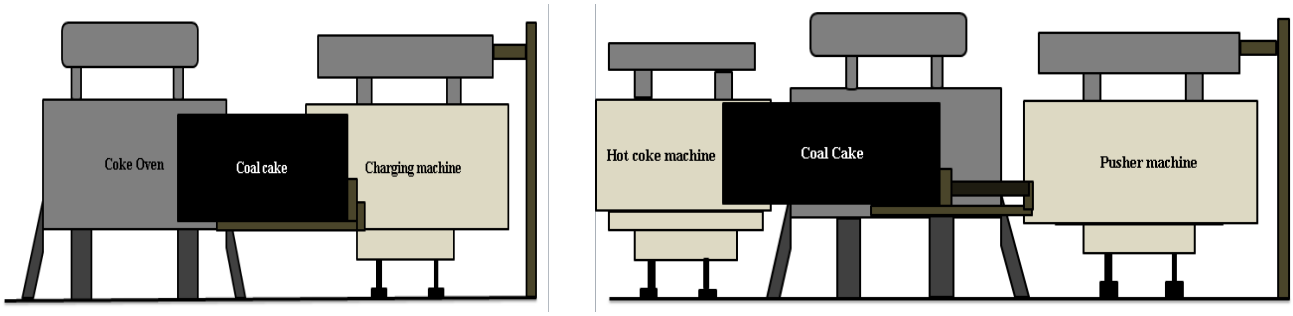
Figure 1: Basic Block diagram of Coke Oven Battery

A. Charging Function

Charging function is charging of coal powder in the form of coal cake or direct powder into the oven. Coal is carried to the oven by charging machine. The oven doors are opened and closed by pusher car.

B. Discharging Function

Discharging function is discharging of coke from oven. When coke is ready pusher car opens the oven door and pushes the entire ready coke into the hot coke car. Hot coke car is aligned at the same oven on the other side of the oven. It is ensured that hot coke car and pusher car are aligned properly at both side of the oven before discharging function to avoid spillage of coke and hazardous accidents.



(a) (b)

Figure 2: (a) Charging function and (b) Discharging function

III. AUTOMATIC POSITIONING AND DETECTION OF COKE OVENS

For the identification and positioning of coke oven sensors are used, which are called as Veroline® Positioning and Identification (PI) sensor. These sensors are pods (positioning Magnet) which are located on track close to oven. These pods have magnet and RFID tag inside which create magnetic field when Veroline® sensor passes near to pod. Veroline sensor is placed on the machine car. This has integrated reader which identifies coke oven number receiving 4-20 mA signals when car passes near pod. The increase and decrease in signal value also depicts the direction of car. When operator enters target Oven number in the car, car travels in the target oven direction with maximum speed. As the car reaches near target oven the speed of the car reduces. Finally, when car reaches at target oven speed becomes zero.

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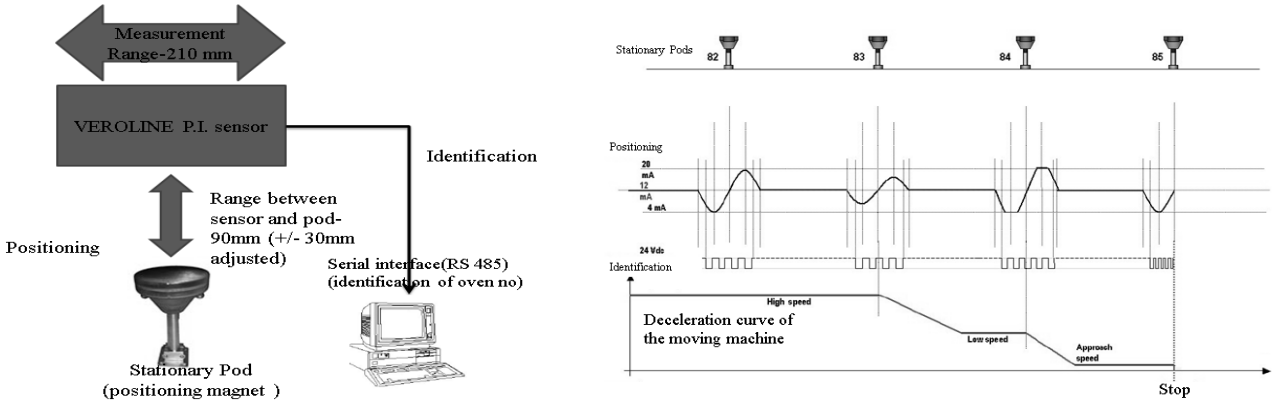


Figure 3: Veroline sensor system

IV. METHODOLOGY

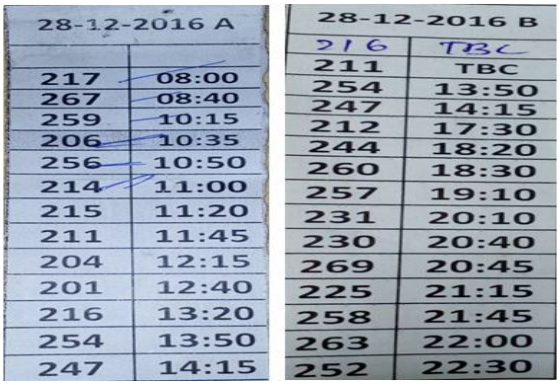
Most of the coke oven plant has manual scheduling which includes creation of schedule on computer and then printed slips are given to car operators. Though schedule slips are given, the shuffling of sequence is conveyed through verbal communication only which creates several errors.

Manual schedule creates following errors:

A. Wrong entry of oven number in the battery machine car by the operator. This can lead to pushing of wrong oven, which causes spillage of coke and wastage of time.

B. Hot coke car and pusher car alignment is different. If pusher car pushes the hot coke on the track it can cause hazardous accident if any person is on the track.

C. Pushing of same oven before oven gets ready. While making schedule if an engineer puts same oven in the list which has been already pushed in the morning shift, same oven can be pushed in the night shift. This causes spillage of coke and increase in process time.



28-12-2016 A

217	08:00
267	08:40
259	10:15
206	10:35
256	10:50
214	11:00
215	11:20
211	11:45
204	12:15
201	12:40
216	13:20
254	13:50
247	14:15

28-12-2016 B

216	TBC
211	TBC
254	13:50
247	14:15
212	17:30
244	18:20
260	18:30
257	19:10
231	20:10
230	20:40
269	20:45
225	21:15
258	21:45
263	22:00
252	22:30

Figure 4: Manual schedule

Above errors are removed by using automatic schedule. Auto schedule is schedule in which PCS system itself schedules the sequence of coke oven for pushing and charging of oven. For automatic schedule PLC logic is written which uses the data from battery machine car. For scheduling the most important data is date and time which include year, month, date, hour, minute, second and millisecond. Six data blocks are created in the PCS system. Data blocks are the memory location in PCS, which are accessed by functions in the logic. These data blocks hold the value of schedule date, schedule time, schedule delay, coke oven number, and coke oven tonnage. Fig.5 shows the scheduling algorithm which works on the charging bit.

When charge car charges the coke oven, the encoder produces a bit known as charging bit. When this charging bit is generated car PLC saves the time as charging time. This time is sent to PCS which saves it in the oven report. Since oven takes approximately 47-48 hours, scheduled delay added in the charging time is 48 hours. Addition of charging time and scheduled delay time gives the next pushing time of that particular oven. Now for the schedule which displays the coke oven numbers list in which oven which is due for pushing is first on the list followed by next pushing ovens, comparison of time of all ovens is done by the PCS system. PCS

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compares the time and date of the oven, two ovens at a time. This comparison is done for all ovens and the oven with latest time is placed on top of the list. Similarly for the charging, when oven is pushed that particular oven is sent to charge car for charging operation. For charging list the ovens which are charged latest are placed on top of the list followed by previously charged ovens. Feasibility to change schedule delay is provided so that engineer can change delay according to readiness of the oven. Though the standard time for oven to get ready is 47-48 hours but it can vary oven by oven depending on oven condition. That's why feasibility to change scheduled delay is provided into the system. Also provision to bypass oven from schedule is provided so that oven can be bypassed from schedule when oven is under repair. Maximum days an oven takes for repair is 23 days, so separate logic is written which removes oven number from schedule using repair command. After 23 days bypassed oven will come automatically back in the schedule as per the time but if the oven is repaired before 23 days it can be taken in the schedule using "in circuit" command.

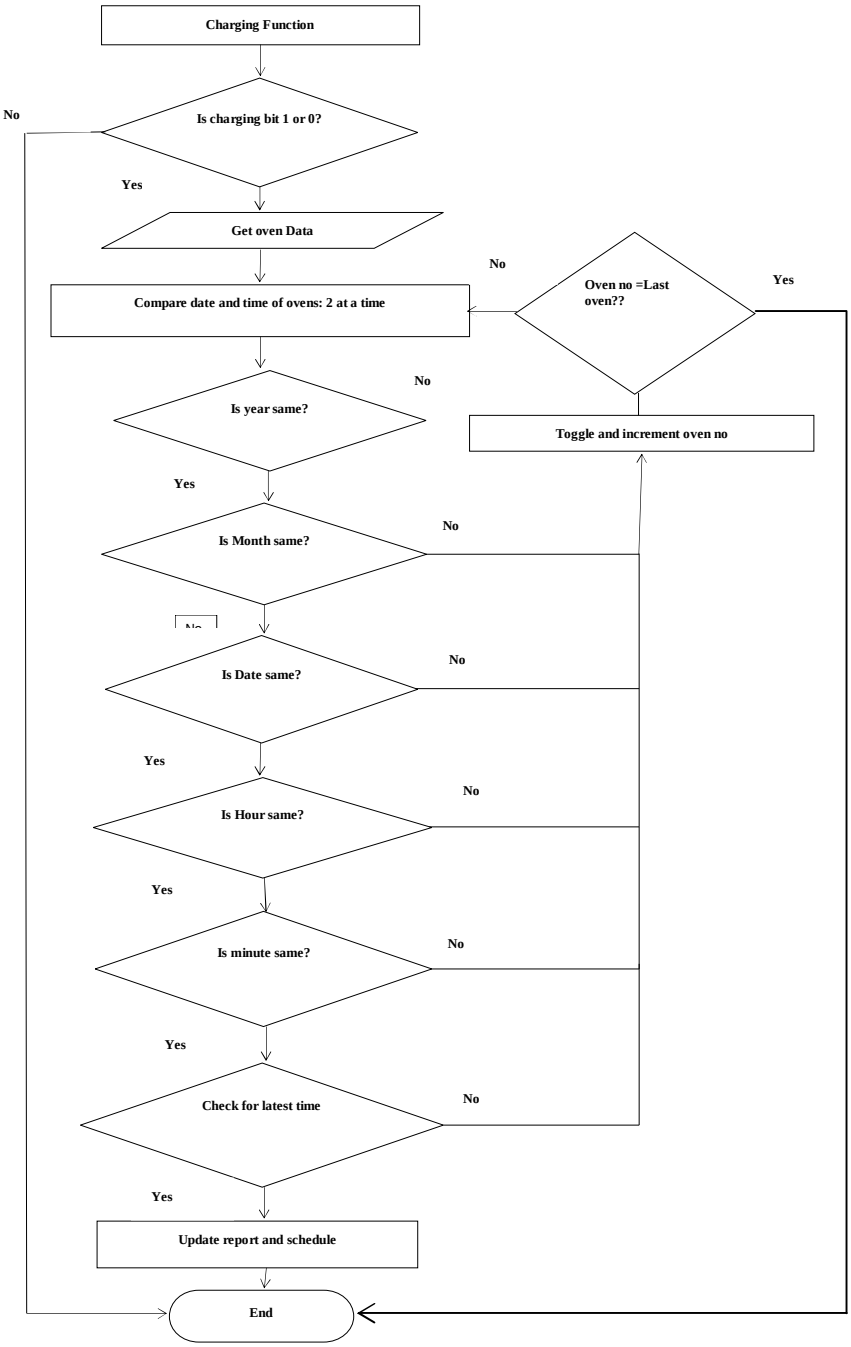

Figure 5: Scheduling Algorithm

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Using this schedule the battery machine cars are automated which operates without operators. PCS sends the schedule to all PLCs of battery machines car and displays on the HMI screen. When the oven is supposed to push, particular oven number is flashes in the target oven area and machine operates automatically pushing function. Similarly charge car operates when it gets oven number which is due for charging. Figure 6 shows the flow of data from battery machine to PCS and back for the schedule and also the control.

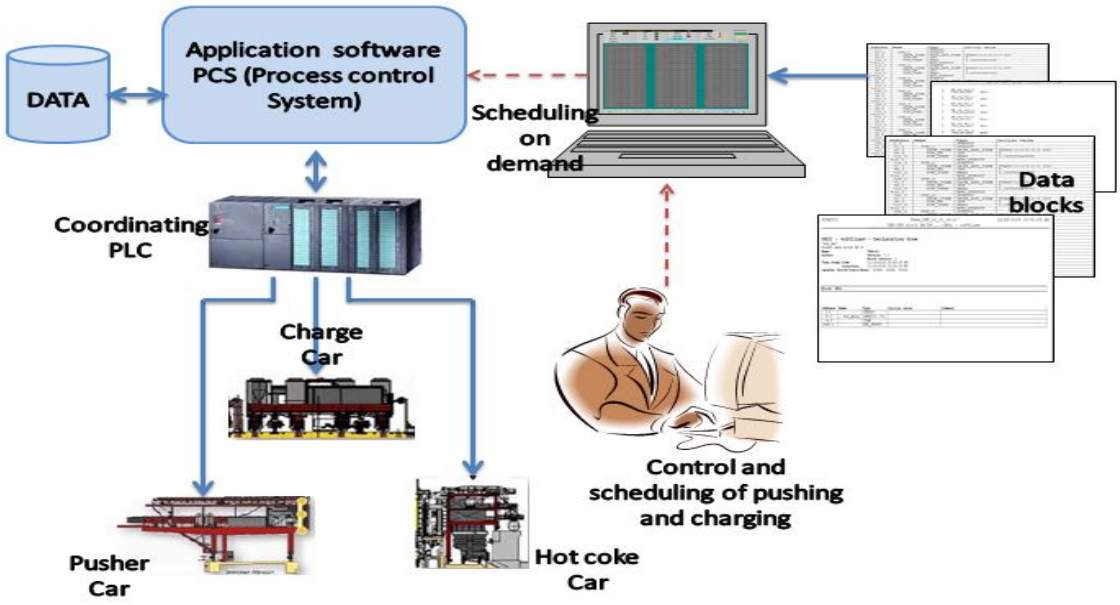
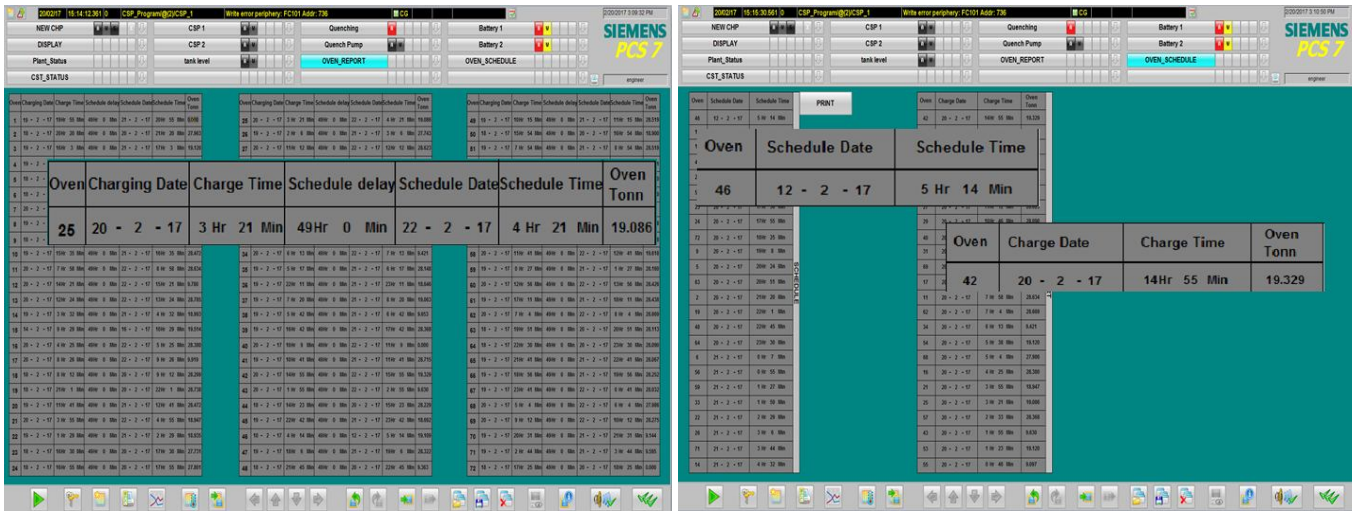


Figure 6: Scheduling sequence and control

V. EXPERIMENTAL RESULTS

Fig. 7 (a) shows the main oven report in which shows data of all ovens in an ascending order of oven number. The report shows charging time, oven number, schedule delay, charging date, pushing time and pushing date of all ovens. Feasibility to change the schedule delay is provided so that engineer can change schedule delay according to the readiness of the oven. Fig. 7 (b) shows schedule list and charging list. Schedule list displays the list of ovens which are ready for pushing along with the pushing time. Charging list shows list of ovens which are recently charged along with the charging time.



(a) (b)

Figure 7: Schedule and report (a) Oven report (b) Charging and pushing schedule

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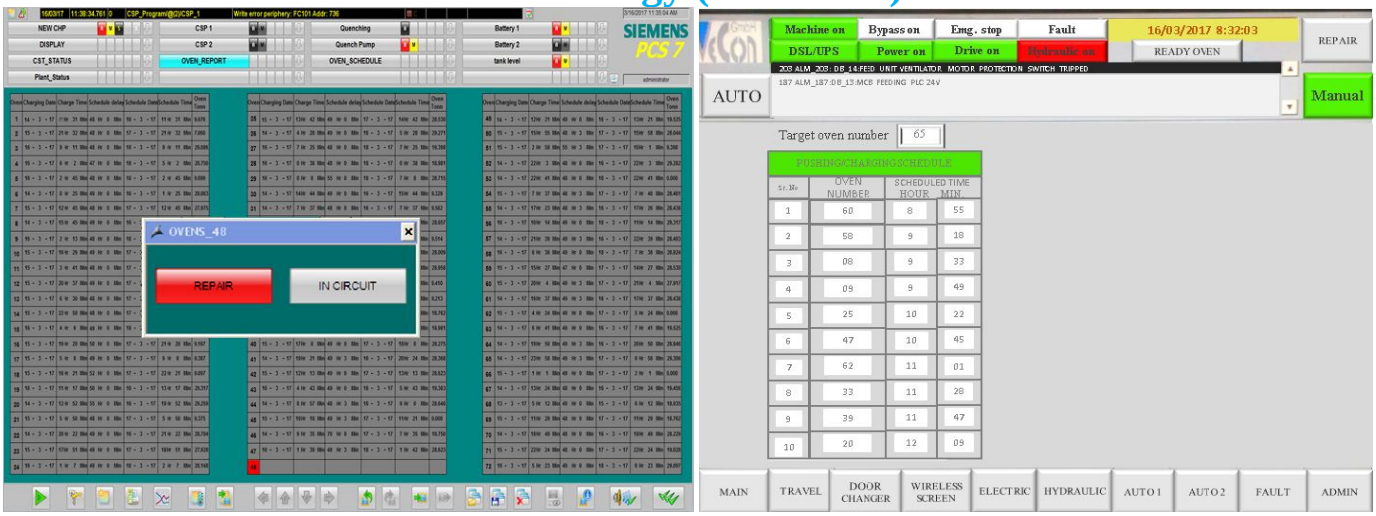

(a) (b)

Figure 8: (a) Oven repair option (b) Battery machine car HMI screen which displays Schedule

Figure 8 (a) shows provision provided for bypassing the oven from the schedule when oven is under repair. Once the oven is repaired it can be taken in the schedule again using "IN CIRCUIT" command. Fig. 8 (b) shows HMI screen of battery machine car which displays Pushing and charging schedule and automatically works according to schedule.

VI. CONCLUSION

Problems with the manual schedule are studied and new technique for development of automatic pushing and charging schedule is developed which reduces all the errors caused by manual schedule. Also using the schedule battery machines are automated completely for unmanned operation using the interlocking between the machines with coordinating PLC. The system makes plant fully automatic in nature. This system increases the plant efficiency by reducing operator workload and also creates comfortable working environment.

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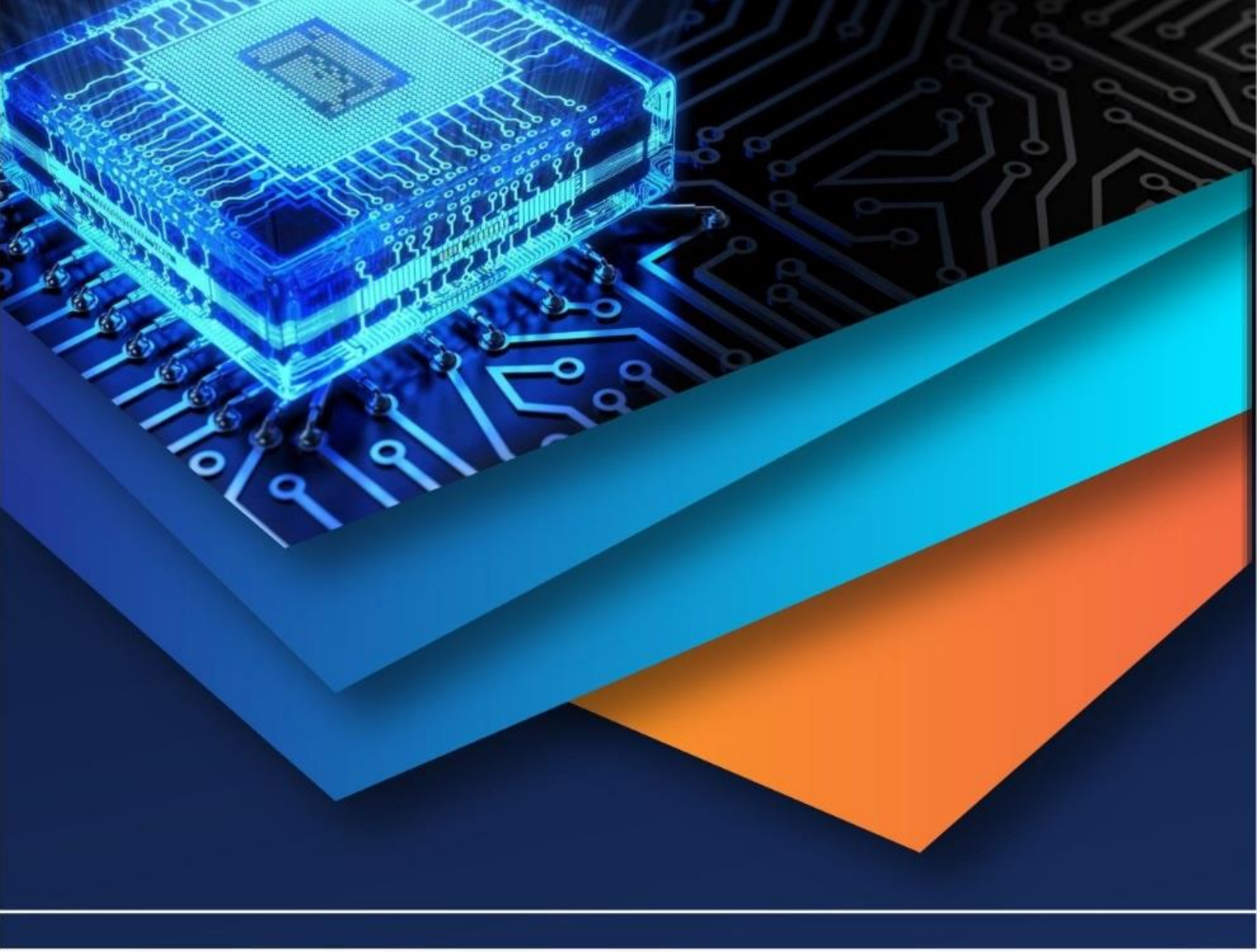

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